

**ESSO NORGE A/S
10/7-1 WELL**

**A Petroleum Geochemical Analysis of
the Interval 810m to 1890m**

Report No. 7212/Ic

Project No. Ic/21355

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**For:
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ESSO NORGE A/S 10/7-1 WELL

Chapter 2**INTRODUCTION**

This report presents the results of a petroleum geochemical evaluation of the interval 810m to 1890mTD in the 10/7-1 well, drilled offshore Norway, carried out on behalf of Esso Norge A/S.

Geochemical analyses have been performed in accordance with Proposal No. 92/Ic/029, dated 16 June 1992, which was prepared in response to Esso Norge's invitation to bid conveyed by telex on 10 June 1992. This work was carried out under authority of Esso Norge's Service Order No. 3-1-2-84320-00.

Sealed, canned drill cuttings samples composited at 30m intervals arrived at Simon Petroleum Technology's North Wales laboratories on 5 August 1992. Five sidewall core samples arrived on 4 August 1992. All samples were submitted for airspace and occluded gaseous hydrocarbon analyses. A smaller number, mainly those for which higher airspace gaseous hydrocarbon yields were obtained, were submitted for gasoline range (C₄ - C₇) hydrocarbon analysis. All the samples submitted for light hydrocarbon analysis were subsequently washed, in order to remove drilling fluid contaminants, prior to selection for organic carbon (TOC) analysis.

Preliminary analytical data have been forwarded to the client at regular intervals, on 10 September 1992 (light hydrocarbon and TOC data), 21 September 1992 (Rock-Eval pyrolysis and occluded gaseous hydrocarbon data) and 6 October 1992 (vitrinite reflectance data).

Client contacts throughout the course of the study were Mr R Millen and Mr R Lyons at Esso Norge A/S, Stavanger.

Simon Petroleum Technology personnel involved in this study were as follows:

Project initiation	- C Darlington
Interpretation/Report preparation	- R Harding
Microscopy studies	- R Harding, M A Bastow
Chemical analysis	- Supervised by M Wadsworth

The total numbers of geochemical analyses carried out during the course of the study were as follows:

Airspace gaseous (C ₁ - C ₆₊) hydrocarbons	: 37
Occluded gaseous (C ₁ - C ₆₊) hydrocarbons	: 37
Gasoline range (C ₄ - C ₇) hydrocarbons	: 6
Sample preparation (including lithology description)	: 42
Picking of individual lithologies	: 13
Total organic carbon	: 48
Rock-Eval pyrolysis	: 22
Solvent extraction	: 8
Extraction fractionation	: 5
Alkane gas chromatography	: 5
Kerogen preparation for microscopy studies	: 17
Spore colouration and kerogen description	: 17
Vitrinite reflectance	: 20

GENERAL DATA		AIRSPACE GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH Metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
810	Ctgs	0.34	98.1	0.9	0.1	-	-	-	-	0.9	1130	99.1	99.1	1.0	0.01	-
840	Ctgs	0.23	98.4	0.9	0.3	-	0.1	-	-	0.3	892	99.7	99.7	1.3	0.01	-
870	Ctgs	0.35	96.0	1.0	0.5	-	-	-	-	2.4	742	97.6	97.6	1.5	0.02	-
900	Ctgs	0.16	96.8	1.2	0.2	-	-	-	-	1.8	597	98.2	98.2	1.4	0.01	-
930	Ctgs	0.13	94.1	1.4	0.2	0.2	-	-	-	4.2	699	95.8	95.8	1.7	0.02	-
960	Ctgs	0.09	92.1	1.2	0.4	0.2	0.1	-	-	6.0	224	94.0	94.0	1.9	0.02	1.52
990	Ctgs	0.10	86.9	1.7	0.3	-	-	-	-	11.1	295	88.9	88.9	2.0	0.02	-
1020	Ctgs	0.11	78.3	1.8	0.6	0.5	0.4	-	-	18.4	85	81.6	81.6	3.2	0.04	1.42
1050	Ctgs	0.86	93.1	0.8	0.5	0.2	0.2	-	-	5.2	521	94.8	94.8	1.7	0.02	1.47
1080	Ctgs	1.07	96.0	1.5	1.1	0.4	0.3	0.2	0.1	0.5	4371	99.5	99.2	3.2	0.03	1.39
1110	Ctgs	0.91	93.8	1.3	1.3	0.8	0.6	0.6	0.3	1.4	1905	98.6	97.7	3.9	0.04	1.31
1140	Ctgs	0.92	89.6	1.8	2.1	1.2	1.1	1.0	0.6	2.6	1027	97.4	95.8	6.2	0.07	1.16
1170	Ctgs	0.91	82.0	3.4	2.4	1.4	1.5	1.0	0.8	7.5	254	92.5	90.7	8.7	0.10	0.93
1200	Ctgs	0.86	83.6	2.9	2.6	1.4	1.4	1.0	0.7	6.4	274	93.6	91.9	8.3	0.09	1.02
1230	Ctgs	0.89	80.6	3.1	3.0	1.9	2.0	1.7	1.0	6.8	290	93.2	90.6	9.9	0.11	0.98
1260	Ctgs	0.72	93.0	1.9	1.2	0.5	0.5	0.2	-	2.7	382	97.3	97.0	4.1	0.04	0.95
1290	Ctgs	0.65	30.3	6.5	4.8	4.8	5.3	5.8	4.2	38.4	41	61.6	51.7	21.4	0.41	0.91
1320	Ctgs	0.69	19.6	72.6	2.1	0.3	2.3	-	-	3.0	598	97.0	97.0	77.4	0.80	0.14
1350	Ctgs	0.82	62.9	5.2	5.3	3.4	3.5	2.4	1.4	15.7	164	84.3	80.4	17.5	0.22	0.98
1380	Ctgs	0.97	71.9	7.9	5.9	2.6	2.0	1.5	0.8	7.3	189	92.7	90.3	18.4	0.20	1.33
1410	Ctgs	0.88	68.7	7.6	8.2	4.5	3.1	2.6	1.1	4.3	584	95.7	92.0	23.4	0.25	1.45
1440	Ctgs	0.77	77.9	6.5	5.9	2.6	1.7	1.4	0.7	3.4	585	96.6	94.6	16.6	0.18	1.55
1470	Ctgs	0.83	80.4	6.4	5.6	2.1	1.6	1.0	0.5	2.4	706	97.6	96.1	15.7	0.16	1.30
1500	Ctgs	1.00	85.4	7.6	4.6	0.9	0.6	0.3	-	0.6	2460	99.4	99.1	13.7	0.14	1.63
1530	Ctgs	1.81	79.9	9.1	7.2	1.5	1.0	0.4	0.2	0.7	4635	99.3	98.7	18.8	0.19	1.51
1560	Ctgs	1.72	59.3	15.1	16.3	3.6	2.4	1.1	0.5	1.7	2326	98.3	96.7	37.4	0.39	1.46
1590	Ctgs	1.36	82.9	8.4	5.4	1.0	0.7	0.3	0.2	1.1	6847	98.9	98.4	15.5	0.16	1.45
1620	Ctgs	-	79.1	9.0	6.8	1.4	1.0	0.6	0.3	1.7	3260	98.3	97.4	18.3	0.19	1.42
1650	Ctgs	1.29	81.0	9.0	6.7	1.3	0.8	0.3	0.1	0.8	870	99.2	98.7	17.8	0.18	1.57
1680	Ctgs	44.20	87.7	7.7	3.4	0.6	0.3	-	-	0.3	17815	99.7	99.7	12.0	0.12	2.04
1710	Ctgs	18.40	85.2	8.9	4.3	0.8	0.4	0.1	-	0.4	17396	99.6	99.5	14.3	0.14	2.12
1740	Ctgs	-	82.9	8.0	5.4	1.1	0.7	0.3	-	1.6	2818	98.4	98.1	15.2	0.15	1.66
1770	Ctgs	-	85.4	8.5	4.4	0.8	0.4	0.2	-	0.4	20488	99.6	99.5	14.1	0.14	1.88
1800	Ctgs	-	87.0	7.9	3.9	0.6	0.3	-	-	0.3	19107	99.7	99.7	12.7	0.13	1.91
1830	Ctgs	-	93.2	4.7	1.5	0.2	0.1	-	-	0.2	25394	99.8	99.8	6.6	0.07	2.13

AIRSPACE GASEOUS HYDROCARBON DATA
TABLE 1A

COMPANY: ESSO NORGE

WELL: 10/7-1

LOCATION: OFFSHORE NORWAY

GENERAL DATA		AIRSPACE GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH Metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
1860	Ctgs	0.68	65.0	10.7	9.2	1.9	1.3	0.9	0.3	10.7	562	89.3	88.1	23.1	0.26	1.46
1890	Ctgs	0.41	52.4	7.0	10.4	3.3	4.4	2.3	1.7	18.6	316	81.4	77.5	25.1	0.32	0.74

AIRSPACE GASEOUS HYDROCARBON DATA
TABLE 1B

GENERAL DATA		OCCLUDED GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
810	Ctgs	0.34	83.3	3.8	2.7	-	1.5	-	-	8.7	593	91.3	91.3	8.0	0.09	-
840	Ctgs	0.23	19.6	10.3	10.4	1.3	8.0	0.6	1.1	48.8	645	51.2	49.5	29.9	0.60	0.16
870	Ctgs	0.35	52.5	1.5	1.0	-	-	-	-	44.9	622	55.1	55.1	2.5	0.05	-
900	Ctgs	0.16	40.3	5.4	2.3	1.0	2.0	1.2	2.6	45.4	188	54.6	50.9	10.6	0.21	0.50
930	Ctgs	0.13	47.2	4.5	1.0	-	-	-	-	47.3	105	52.7	52.7	5.5	0.10	-
960	Ctgs	0.09	61.8	-	-	-	-	-	-	38.2	59	61.8	61.8	0.0	0.00	-
990	Ctgs	0.10	35.9	12.4	6.3	-	-	-	-	45.5	157	54.5	54.5	18.7	0.34	-
1020	Ctgs	0.11	42.2	6.7	1.3	0.4	-	-	-	49.4	80	50.6	50.6	8.4	0.17	-
1050	Ctgs	0.86	42.6	-	-	-	-	-	-	57.4	31	42.6	42.6	0.0	0.00	-
1080	Ctgs	1.07	22.1	6.0	5.3	-	-	-	-	66.7	136	33.3	33.3	11.2	0.34	-
1110	Ctgs	0.91	33.7	3.5	-	-	-	-	-	62.8	64	37.2	37.2	3.5	0.09	-
1140	Ctgs	0.92	37.1	-	-	-	-	-	-	62.9	76	37.1	37.1	0.0	0.00	-
1170	Ctgs	0.91	22.6	2.0	3.1	2.0	2.6	2.7	2.7	62.4	80	37.6	32.2	9.6	0.30	0.79
1200	Ctgs	0.86	67.7	-	-	-	-	-	-	32.3	12	67.7	67.7	0.0	0.00	-
1230	Ctgs	0.89	41.4	-	-	-	-	-	-	58.6	53	41.4	41.4	0.0	0.00	-
1260	Ctgs	0.72	35.7	-	-	-	-	-	-	64.3	31	35.7	35.7	0.0	0.00	-
1290	Ctgs	0.65	24.9	6.9	3.7	-	-	-	-	64.5	170	35.5	35.5	10.6	0.30	-
1320	Ctgs	0.69	18.1	8.8	6.2	-	3.8	1.1	1.9	60.3	206	39.7	36.8	18.7	0.51	-
1350	Ctgs	0.82	34.4	-	-	2.6	5.6	5.4	5.1	46.9	43	53.1	42.6	8.2	0.19	0.47
1380	Ctgs	0.97	25.5	-	6.1	5.6	4.6	6.9	5.9	45.3	75	54.7	41.8	16.4	0.39	1.21
1410	Ctgs	0.88	19.9	3.2	2.0	1.6	2.6	4.2	3.3	63.2	185	36.8	29.4	9.4	0.32	0.62
1440	Ctgs	0.77	32.7	-	4.1	4.6	5.3	7.5	4.8	41.1	68	58.9	46.7	14.0	0.30	0.86
1470	Ctgs	0.83	18.1	2.5	7.6	6.6	6.6	7.2	3.2	48.2	279	51.8	41.4	23.3	0.56	1.01
1500	Ctgs	1.00	9.6	3.5	17.7	10.2	8.9	9.3	5.9	34.9	877	65.1	49.9	40.3	0.81	1.14
1530	Ctgs	1.81	23.8	4.1	14.9	9.3	10.2	4.6	4.8	28.2	56	71.8	62.4	38.5	0.62	0.92
1560	Ctgs	1.72	8.4	2.7	20.5	11.2	10.7	7.5	4.2	34.9	337	65.1	53.4	45.0	0.84	1.05
1590	Ctgs	1.36	4.5	4.6	21.2	9.8	8.9	6.6	3.8	40.6	1582	59.4	49.0	44.5	0.91	1.10
1620	Ctgs	-	3.3	3.7	22.6	10.8	10.1	7.6	4.4	37.6	1640	62.4	50.4	47.1	0.93	1.07
1650	Ctgs	1.29	6.0	4.4	28.6	12.5	11.7	7.8	4.1	25.0	1744	75.0	63.1	57.1	0.91	1.07
1680	Ctgs	44.20	35.4	26.9	25.5	4.6	3.1	1.3	0.3	2.8	21548	97.2	95.5	60.2	0.63	1.47
1710	Ctgs	18.40	9.6	21.5	38.6	9.3	7.0	3.3	0.9	9.8	15637	90.2	86.0	76.5	0.89	1.33
1740	Ctgs	-	40.1	-	8.8	6.3	5.9	5.9	3.2	29.9	38	70.1	61.1	21.0	0.34	1.08
1770	Ctgs	-	10.5	13.9	37.8	10.0	8.1	3.7	1.4	14.4	3997	85.6	80.4	69.9	0.87	1.23
1800	Ctgs	-	31.5	16.8	28.4	6.3	5.1	2.3	0.7	8.8	5417	91.2	88.1	56.6	0.64	1.24
1830	Ctgs	-	15.9	28.7	34.0	6.3	4.4	2.0	0.6	8.1	1789	91.9	89.3	73.4	0.82	1.42

OCCLUDED GASEOUS HYDROCARBON DATA
TABLE 2A

GENERAL DATA		OCCLUDED GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
1860	Ctgs	0.68	25.3	3.9	14.8	5.9	5.5	4.2	1.7	38.7	832	61.3	55.4	30.1	0.54	1.07
1890	Ctgs	0.41	21.6	3.7	13.8	6.5	9.2	5.2	5.3	34.8	230	65.2	54.7	33.1	0.61	0.70

OCCLUDED GASEOUS HYDROCARBON DATA
TABLE 2B

GENERAL DATA		AIRSPACE PLUS OCCLUDED GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
810	Ctgs	0.34	93.0	1.9	1.0	-	0.5	-	-	3.6	1723	96.4	96.4	3.4	0.04	-
840	Ctgs	0.23	65.3	4.8	4.5	0.5	3.4	0.3	0.5	20.6	1537	79.4	78.7	13.3	0.17	0.16
870	Ctgs	0.35	76.2	1.3	0.7	-	-	-	-	21.8	1364	78.2	78.2	2.0	0.03	-
900	Ctgs	0.16	83.3	2.2	0.7	0.2	0.5	0.3	0.6	12.2	785	87.8	86.9	3.6	0.04	0.50
930	Ctgs	0.13	88.0	1.8	0.3	0.1	-	-	-	9.8	804	90.2	90.2	2.2	0.02	-
960	Ctgs	0.09	85.7	0.9	0.3	0.2	0.1	-	-	12.8	283	87.2	87.2	1.5	0.02	1.52
990	Ctgs	0.10	69.2	5.4	2.4	-	-	-	-	23.0	452	77.0	77.0	7.8	0.10	-
1020	Ctgs	0.11	60.8	4.2	0.9	0.4	0.2	-	-	33.5	165	66.5	66.5	5.7	0.09	2.39
1050	Ctgs	0.86	90.3	0.8	0.5	0.2	0.2	-	-	8.1	552	91.9	91.9	1.6	0.02	1.47
1080	Ctgs	1.07	93.7	1.7	1.2	0.4	0.3	0.2	0.1	2.5	4507	97.5	97.2	3.5	0.04	1.39
1110	Ctgs	0.91	91.8	1.4	1.3	0.7	0.6	0.6	0.3	3.4	1969	96.6	95.7	3.9	0.04	1.31
1140	Ctgs	0.92	86.0	1.7	2.0	1.1	1.0	0.9	0.5	6.8	1103	93.2	91.8	5.8	0.06	1.16
1170	Ctgs	0.91	67.8	3.1	2.6	1.6	1.8	1.4	1.2	20.6	334	79.4	76.8	9.0	0.12	0.88
1200	Ctgs	0.86	82.9	2.8	2.5	1.3	1.3	1.0	0.7	7.5	286	92.5	90.8	8.0	0.09	1.02
1230	Ctgs	0.89	74.5	2.6	2.5	1.6	1.7	1.4	0.8	14.8	344	85.2	82.9	8.4	0.10	0.98
1260	Ctgs	0.72	88.6	1.7	1.1	0.5	0.5	0.2	-	7.4	413	92.6	92.4	3.8	0.04	0.95
1290	Ctgs	0.65	26.0	6.8	4.0	0.9	1.0	1.1	0.8	59.4	211	40.6	38.7	12.7	0.33	0.91
1320	Ctgs	0.69	19.2	56.3	3.1	0.2	2.7	0.3	0.5	17.7	804	82.3	81.5	62.3	0.76	0.09
1350	Ctgs	0.82	57.0	4.1	4.2	3.3	3.9	3.0	2.2	22.3	207	77.7	72.5	15.5	0.21	0.83
1380	Ctgs	0.97	58.7	5.7	6.0	3.5	2.7	3.1	2.3	18.1	264	81.9	76.6	17.8	0.23	1.27
1410	Ctgs	0.88	56.9	6.5	6.7	3.8	3.0	3.0	1.6	18.4	769	81.6	77.0	20.0	0.26	1.27
1440	Ctgs	0.77	73.3	5.8	5.7	2.8	2.1	2.0	1.1	7.3	653	92.7	89.6	16.3	0.18	1.36
1470	Ctgs	0.83	62.8	5.3	6.1	3.4	3.0	2.8	1.3	15.4	985	84.6	80.6	17.8	0.22	1.12
1500	Ctgs	1.00	65.5	6.5	8.1	3.4	2.8	2.7	1.6	9.6	3337	90.4	86.2	20.7	0.24	1.22
1530	Ctgs	1.81	79.2	9.0	7.3	1.5	1.1	0.5	0.2	1.1	4691	98.9	98.2	19.0	0.19	1.45
1560	Ctgs	1.72	52.8	13.5	16.9	4.5	3.5	1.9	1.0	5.9	2663	94.1	91.2	38.4	0.42	1.30
1590	Ctgs	1.36	68.2	7.7	8.4	2.7	2.2	1.5	0.8	8.5	8429	91.5	89.1	20.9	0.23	1.19
1620	Ctgs	-	53.7	7.2	12.1	4.6	4.0	2.9	1.6	13.7	4900	86.3	81.7	28.0	0.34	1.13
1650	Ctgs	1.29	30.9	5.9	21.3	8.8	8.1	5.3	2.8	17.0	2614	83.0	74.9	44.0	0.59	1.08
1680	Ctgs	44.20	59.0	18.2	15.5	2.8	1.8	0.7	0.2	1.7	39363	98.3	97.4	38.4	0.39	1.51
1710	Ctgs	18.40	49.4	14.9	20.5	4.8	3.5	1.6	0.4	4.8	33033	95.2	93.2	43.8	0.47	1.37
1740	Ctgs	-	82.3	7.9	5.4	1.2	0.7	0.4	0.0	2.0	2856	98.0	97.6	15.3	0.16	1.60
1770	Ctgs	-	73.2	9.4	9.8	2.3	1.7	0.7	0.2	2.7	24485	97.3	96.3	23.2	0.24	1.36
1800	Ctgs	-	74.7	9.8	9.3	1.9	1.4	0.5	0.2	2.2	24524	97.8	97.1	22.4	0.23	1.35
1830	Ctgs	-	88.2	6.3	3.7	0.6	0.4	0.1	0.0	0.7	27183	99.3	99.1	11.0	0.11	1.59

COMBINED AIRSPACE AND OCCLUDED GASEOUS HYDROCARBON DATA
TABLE 3A

GENERAL DATA		AIRSPACE PLUS OCCLUDED GASEOUS HYDROCARBON DATA														
SAMPLE DEPTH metres	SAMPLE TYPE	TOC % OF ROCK	GAS ABUNDANCE, %								TOTAL ABUNDANCE (ppm)	SUM, %			RATIOS	
			C1	C2	C3	iC4	nC4	iC5	nC5	C6+		C1-C5	C1-C4	C2-C4	C2-C4/ C1-C4	i-C4/ n-C4
1860	Ctgs	0.68	41.3	6.6	12.5	4.3	3.8	2.8	1.2	27.4	1394	72.6	68.6	27.3	0.40	1.13
1890	Ctgs	0.41	39.4	5.6	11.8	4.6	6.5	3.5	3.2	25.4	546	74.6	67.9	28.5	0.42	0.72

COMBINED AIRSPACE AND OCCLUDED GASEOUS HYDROCARBON DATA
TABLE 3B

SAMPLE DATA						
SAMPLE DEPTH (Mtrs)	1530	1680	1710	1770	1800	1830
SAMPLE TYPE	Ctgs	Ctgs	Ctgs	Ctgs	Ctgs	Ctgs

COMPONENTS	GASOLINE RANGE COMPONENT ABUNDANCE (%)					
	1530	1680	1710	1770	1800	1830
i-C4	24.114	40.297	37.399	28.774	29.238	32.768
n-C4	21.576	27.797	26.763	23.732	23.752	24.264
i-C5	13.286	10.117	9.117	10.012	9.020	10.553
n-C5	9.350	2.983	2.515	4.429	3.596	3.986
2,2,dmb	.047	.023	.033	.089	.058	.026
cp	1.283	1.119	1.134	1.359	1.395	1.302
2,3,dmb	.709	.426	.476	.480	.480	.509
2,mp	5.002	1.292	1.338	1.922	2.020	2.100
3,mp	1.310	.694	.700	1.066	.995	.913
n-C6	3.321	.247	.353	.840	1.103	.822
mcp+2,2,dmp	6.263	4.624	4.604	5.781	4.718	4.756
2,4,dmp	.331	.035	.062	.074	.072	.063
benz	1.703	2.097	2.670	4.207	4.657	4.178
3,3,dmp	.013	.005	.006	.016	.032	.009
ch	.787	.562	.440	1.168	1.259	1.195
2,mh	1.076	.197	.195	.405	.424	.321
1,1,dmcp	.012	.012	.005	.036	.022	.011
3,mh	.610	.088	.094	.282	.253	.183
cis,1,3,dmcp	.687	.528	.488	.643	.469	.460
trans,1,3,dmcp	.539	.481	.445	.570	.412	.401
trans,1,2,dmcp+3,ep	.920	1.331	1.414	1.540	.952	1.153
n-C7	1.756	.040	.091	.310	.532	.295
mch+cis,1,2,dmcp	2.716	2.552	2.384	4.930	6.322	2.941
ecp	.599	.411	.387	.755	.430	.371
tol	1.992	2.043	6.890	6.579	7.788	6.418

GENERAL DATA												
Total Abundance(ppb)	485		3840		4435		3815		1015		2275	
TOC (% of Rock)	1.81		44.20		18.40		*		*		*	
Abundance at 1% TOC	268		87		241		*		*		*	
Alkane Composition	37	48	14	32	55	12	33	55	12	33	49	18
C7Alkane Composition	11	12	77	0	3	97	1	3	96	2	5	93
Aromatic Composition	3.70		4.14		9.56		10.79		12.44		10.60	

RATIOS						
i/n-C4	1.12	1.45	1.40	1.21	1.23	1.35
i/n-C5	1.42	3.39	3.63	2.26	2.51	2.65
cp / 2,3,dmb	1.81	2.63	2.38	2.83	2.91	2.56
n-C7 / mch	.65	.02	.04	.06	.08	.10
2,mp / 3,mp	3.82	1.86	1.91	1.80	2.03	2.30
n-C6 / mcp +2,2,dmp	.53	.05	.08	.15	.23	.17
mch / tol	1.36	1.25	.35	.75	.81	.46
Late Mature Index	.63	.82	1.12	.85	.74	1.42
Aromaticity Index	1.13	51.08	75.71	21.22	14.64	21.76
Heptane Index	18.97	.70	1.63	3.24	5.36	4.75
Isoheptane Index	.78	.12	.12	.25	.36	.25
Kerogen Type Index	19.15				3.73	3.02

LEGEND					
i - iso	c - cyclo	m - methyl	b - butane	h - hexane	tol - toluene
n - normal	d - di	e - ethyl	p - pentane	benz - benzene	
Alkane Composition - % composition of normal, iso and cyclo alkanes					
C7 Alkane Composition - % composition of C7 normal, iso and cyclo alkanes					
Aromatic Composition - % composition of Benzene + Toluene					
For definition of indices - Late Mature, Aromaticity, Heptane, Isoheptane & Kerogen Type - see following page					

GASOLINE RANGE HYDROCARBON DATA

TABLE : 4

Gasoline ratios - definition of indices

Late Mature Index - Benzene/methyl cyclohexane

Aromaticity Index - Toluene/*n*-heptane

Heptane Index - *n*-Heptane/all C₇ compounds (%)

Iso-heptane Index - Methyl hexanes (non-cyclic)/dimethyl cyclopentanes

Kerogen Type Index - Heptane Index -4/Iso-heptane Index

GENERAL DATA			MATURITY DATA		KEROGEN COMPOSITION DATA						
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	SPORE COLOUR INDEX	VITR. REFL. R oil av %	% (Visual, from microscopy)			% (Calculated)			
					INERTINITE	VITRINITE	SAPROPEL	INERT	VIT	ALG SAP	WXY SAP
870	Ctgs	CMT+ 10% LST, wht+ mnr CHT	2.5	.31(6) .51(9)R .95(3)R	10	65	25				
960	Ctgs	LST, wht+ 10% LST, bl-wht+ 10% MDST, med gy, calc+ mnr CHT	3.0	.35(6) .46(1)R 1.07(6)R 1.67(1)R	20	35	45				
1050	Ctgs	MDST, ol-gy, calc+ 30% LST, wht+ 10% MDST, pal red-brn, calc+ mnr MDST, gy-blk, carb	3.0	.60(1)R 1.09(9)R 1.79(2)R	5	95	Prt				
1110	Ctgs	MDST, med gy, calc+ tr LST, wht	3.0	.38(17) .49(9)R .74(14)R 1.02(10)R	15	60	25				
1170	Ctgs	MDST, med-dk gy, calc+ tr LST, wht+ tr MDST, mod red-brn calc	3.5	.41(20) .50(13)R .68(13)R .86(7)R	20	70	10				
1230	Ctgs	MDST, med-dk gy+ mnr LST, lt gy+ tr LST, wht	3.5	.40(27) .50(11)R .88(10)R	40	45	15				
1290	Ctgs	MDST, med-dk gy+ 10% CMT	3.5	.37(44) .48(7)R .63(2)R	15	10	75				
1350	Ctgs	MDST, med-lt gy, calc+ mnr MDST, yel-gy, calc+ mnr LST, wht	3.5	.38(47) .71(3)R	30	5	65				
1410	Ctgs	MDST, dk gy+ tr LST, lt gy+ tr MDST, yel-gy, calc	3.5	.38(32) .50(7)R .74(1)R 1.15(3)R	40	15	45				
1470	Ctgs	MDST, med gy+ tr LST lt gy	3.5	.41(37) .51(9)R .64(7)R	25	45	30				
1512.0	Swc	MDST, dk gy	3.5	.38(34) .52(7)R .83(9)R	15	70	15				
1530	Ctgs	MDST, med-dk gy+ tr MDST, lt ol-gy, calc	3.5	.39(7) .54(26)R .69(11)R 1.05(5)R	30	30	40				
1590	Ctgs	MDST, med-dk gy+ 10% SST, lt gy+ tr LST, wht	3.0	.40(15) .64(25)R .85(4)R 1.22(1)R	40	10	50				
1680	Ctgs	COAL+ tr LST, wht									
	P	COAL		.42(37)							
1688.0	Swc	MDST, dk gy, mic	3.0	.44(55)	55	35	10				

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 5A

GENERAL DATA			MATURITY DATA		KEROGEN COMPOSITION DATA							
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	SPORE COLOUR INDEX	VITR. REFL. R oil av %	% (Visual, from microscopy)			% (Calculated)				
					INERTINITE	VITRINITE	SAPROPEL	INERT	VIT	ALG SAP	WXY SAP	
1688.0	P	MDST, dk gy, mic		.41(16)								
1710	Ctgs	COAL+ 30% MDST, med gy+ mnr ANH	3.5	.42(43)	30	25	45					
1800	Ctgs	QTZ+ 30% COAL+ 10% MDST, ol-gy+ mnr ANH + mnr pyr	3.5	.41(51)	30	55	15					
1830	Ctgs	QTZ+ 20% COAL+ 20% LST, wht+ 10% MDST, ol-gy										
	P	COAL		.45(22) .57(11)R								
1890	Ctgs	MDST, med gy+ 20% MDST, lt gy, calc+ 10% LST, yel-gy+ 10% LST, wht	3.5	.44(37) .61(16)R .88(2)R	25	15	60					

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 5B

ESSO NORGE A/S 10/7-1 WELL

Table 6

DETAILED KEROGEN COMPOSITION DATA

Depth (m)	SCI	Kerogen Type				
		Inertinite	Vitrinite (struct.)	Amorphous (non-fluor.)	Amorphous (fluor.)	Liptinite (struct.)
870	2.5	10	Mnr	65	20W	5 Di, Sp
960	3.0	20	Mnr	35	35W	10 Di, Sp
1050	3.0	5	5	90	0	Tr Di, Sp
1110	3.0	15	Mnr	60	20W	5 Di, Sp
1170	3.5	20	Tr	70	10W	Tr Di, Sp
1230	3.5	40	5	40	10W	5 Di, Sp
1290	3.5	15	Mnr	10	70W	5 Di, Sp
1350	3.5	30	5	0	35W	30 Di, Sp
1410	3.5	40	5	10	15W	30 Di, Sp
1470	3.5	25	5	40	0	30 Di, Sp
1512	3.5	15	5	65	5	10 Di, Sp
1530	3.5	30	Mnr	30	25	15 Di, Sp
1590	3.0	40	Mnr	10	40	10 Di, Sp
1688	3.0	55	5	30	Mnr	10 Sp, Di
1710	3.5	30	25	0	30	15 Sp
1800	3.5	30	15	40	Mnr	15 Sp
1890	3.5	25	5	10	50W	10 Sp

Di - dinoflagellates

Sp - spores

W - fluorescence response relatively weak

GENERAL DATA			CHEMICAL ANALYSIS DATA										
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	PYROLYSIS					SOLVENT EXTRACTION/FRACTIONATION				
				Tmax °C	HI	OI	PI	POT.YLD. (ppm)	EXTR. (ppm)	HC (ppm)	EXTR. % OC	HC	
					%OC	%EX							
810	Ctgs	LST, v lt gy+ 30% CMT+ mnr CHT	.34										
840	Ctgs	LST, wht+ 30% CMT+ mnr CHT	.23										
870	Ctgs	CMT+ 10% LST, wht+ mnr CHT	.35										
900	Ctgs	LST, wht+ 20% CMT+ 10% MDST, lt ol-gy, calc+ mnr CHT	.16										
930	Ctgs	LST, wht+ 20% MDST, lt ol-gy, calc+ mnr CHT	.13										
960	Ctgs	LST, wht+ 10% LST, bl-wht+ 10% MDST, med gy calc+ mnr CHT	.09										
990	Ctgs	LST, wht+ 10% LST, lt bl-gy+ 10% MDST, ol-gy, calc+ mnr CHT	.10										
1020	Ctgs	LST, wht+ 20% LST, med gy+ mnr CHT	.11										
1050	Ctgs	MDST, ol-gy, calc+ 30% LST, wht+ 10% MDST, pal red-brn, calc+ mnr MDST, gy-blk, carb	.86										
	P	MDST, ol-gy, calc	1.06	*	7	186	.36	70					
1080	Ctgs	MDST, med gy, calc+ 20% LST, wht	1.07										
	P	MDST, med gy, calc	1.64	424	63	87	.11	1030					
1110	Ctgs	MDST, med gy, calc+ tr LST, wht	.91										
1140	Ctgs	MDST, med-dk gy, calc+ tr foss+ tr MDST, mod red-brn, calc	.92	414	17	68	.06	160					
1170	Ctgs	MDST, med-dk gy, calc+ tr LST, wht+ tr MDST, mod red-brn, calc	.91										
1200	Ctgs	MDST, med-dk gy+ tr LST, lt gy	.86										
1230	Ctgs	MDST, med-dk gy+ mnr LST lt gy+ tr LST, wht	.89	417	30	73	.07	270					
1260	Ctgs	MDST, med-lt gy, calc+ 20% CMT	.72										
1290	Ctgs	MDST, med-dk gy+ 10% CMT	.65										
1320	Ctgs	MDST, med-lt gy, calc+ mnr MDST, yel-gy, calc+ tr LST, wht	.69										

SUMMARY OF CHEMICAL ANALYSIS DATA

TABLE : 7A

GENERAL DATA			CHEMICAL ANALYSIS DATA													
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	PYROLYSIS					SOLVENT EXTRACTION/FRACTIONATION							
				Tmax °C	HI	OI	PI	POT.YLD. (ppm)	EXTR. (ppm)	HC (ppm)	EXTR. % OC	HC %OC	HC %EX	ALK. %HC		
1350	Ctgs	MDST, med-lt gy, calc+ mnr MDST, yel-gy, calc+ mnr LST, wht	.82													
1380	Ctgs	MDST, med gy+ tr LST, v lt gy	.97	421	69	66	.03	670								
1410	Ctgs	MDST, dk gy+ tr LST, lt gy+ tr MDST, yel-gy, calc	.88													
1440	Ctgs	MDST, med gy+ tr LST, lt gy	.77													
1470	Ctgs	MDST, med gy+ tr LST, lt gy	.83	419	40	53	.06	330								
1500	Ctgs	MDST, med gy+ tr foss	1.00													
1500.0	Swc	MDST, dk gy	3.19	424	224	26	.02	7140	600	210	1.9	7	35	57		
1512.0	Swc	MDST, dk gy	1.26	422	79	56	.03	1000								
1530	Ctgs	MDST, med-dk gy+ tr MDST lt ol-gy, calc	1.81	423	116	39	.02	2100								
1560	Ctgs	MDST, med gy+ 10% CMT+ 10% SST, v lt gy	1.72													
	P	MDST, med gy	2.17	428	147	40	.01	3200	750		3.5					
1590	Ctgs	MDST, med-dk gy+ 10% SST lt gy+ tr LST, wht	1.36													
1620	Ctgs	MDST, med-dk gy+ 10% SST v lt gy+ 10% LIG+ mnr LST, wht	-													
	P	MDST, med-dk gy	2.38	425	223	29	.02	5310	945	185	4.0	8	20	57		
1650	Ctgs	MDST, med-dk gy+ 30% SST ol-gy+ 10% SST, v lt gy	1.29													
	P	MDST, med-dk gy	2.20	425	202	27	.01	4450	650		3.0					
1680	Ctgs	COAL+ tr LST, wht	44.20	423	154	10	.03	67950	10785	4615	2.4	10	43	22		
1688.0	Swc	MDST, dk gy, mic	6.14	420	118	17	.06	7250	1555	655	2.5	11	42	36		
1710	Ctgs	COAL+ 30% MDST, med gy+ mnr ANH	18.40													
	P	COAL	34.30	423	157	8	.05	53870	10350	3500	3.0	10	34	19		
	P	MDST, med gy	1.64	425	159	67	.05	2610	910		5.5					
1740	Ctgs	QTZ+ 10% MDST, med gy+ 10% COAL	-													
	P	MDST, med gy	1.74	426	175	51	.03	3040								
	P	COAL	30.80	420	165	7	.05	50920								
1770	Ctgs	MDST, med gy+ 20% QTZ+ 20% COAL+ 10% SST, wht	-													

SUMMARY OF CHEMICAL ANALYSIS DATA

TABLE : 7B

GENERAL DATA			CHEMICAL ANALYSIS DATA											
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	PYROLYSIS					SOLVENT EXTRACTION/FRACTIONATION					
				Tmax °C	HI	OI	PI	POT.YLD. (ppm)	EXTR. (ppm)	HC (ppm)	EXTR. % OC	HC %OC	EX %EX	ALK. %HC
1770	P	MDST, med gy	1.13	423	79	47	.03	890						
1800	Ctgs	QTZ+ 30% COAL+ 10% MDST, ol-gy+ mnr ANH+ mnr pyr	-											
	P	COAL	41.70	409	233	5	.03	97290						
	P	MDST, ol-gy	2.15	426	256	20	.01	5500						
1830	Ctgs	QTZ+ 20% COAL+ 20% LST, wht+ 10% MDST, ol-gy	-											
	P	COAL	38.30	415	129	5	.03	49390						
1860	Ctgs	LST, wht+ 10% MDST, dk gy+ mnr MDST, lt ol-gy, calc+ mnr QTZ	.68											
1870.0	Swc	MDST, dk gy	-											
1877.0	Swc	MDST, dk gy	-											
1890	Ctgs	MDST, med gy+ 20% MDST, lt gy, calc+ 10% LST, yel-gy+ 10% LST, wht	.41											

SUMMARY OF CHEMICAL ANALYSIS DATA

TABLE : 7C

GENERAL DATA			CHEMICAL ANALYSIS DATA									
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	P Y R O L Y S I S								
				S1 (ppm)	S2 (ppm)	S3 (ppm)	HI	OI	PI	Tmax °C	S2/S3	
810	Ctgs	LST, v lt gy+ 30% CMT+ mnr CHT	.34									
840	Ctgs	LST, wht+ 30% CMT+ mnr CHT	.23									
870	Ctgs	CMT+ 10% LST, wht+ mnr CHT	.35									
900	Ctgs	LST, wht+ 20% CMT+ 10% MDST, lt ol-gy, calc+ mnr CHT	.16									
930	Ctgs	LST, wht+ 20% MDST, lt ol-gy, calc+ mnr CHT	.13									
960	Ctgs	LST, wht+ 10% LST, bl-wht+ 10% MDST, med gy, calc+ mnr CHT	.09									
990	Ctgs	LST, wht+ 10% LST, lt bl-gy+ 10% MDST, ol-gy, calc+ mnr CHT	.10									
1020	Ctgs	LST, wht+ 20% LST, med gy+ mnr CHT	.11									
1050	Ctgs	MDST, ol-gy, calc+ 30% LST, wht+ 10% MDST, pal red-brn, calc+ mnr MDST, gy-blk, carb	.86									
	P	MDST, ol-gy, calc	1.06	40	70	1970	7	186	.36	*		.04
1080	Ctgs	MDST, med gy, calc+ 20% LST, wht	1.07									
	P	MDST, med gy, calc	1.64	130	1030	1420	63	87	.11	424		.73
1110	Ctgs	MDST, med gy, calc+ tr LST, wht	.91									
1140	Ctgs	MDST, med-dk gy, calc+ tr foss + tr MDST, mod red-brn, calc	.92	10	160	630	17	68	.06	414		.25
1170	Ctgs	MDST, med-dk gy, calc+ tr LST, wht+ tr MDST, mod red-brn, calc	.91									
1200	Ctgs	MDST, med-dk gy+ tr LST, lt gy	.86									
1230	Ctgs	MDST, med-dk gy+ mnr LST, lt gy+ tr LST, wht	.89	20	270	650	30	73	.07	417		.42
1260	Ctgs	MDST, med-lt gy, calc+ 20% CMT	.72									
1290	Ctgs	MDST, med-dk gy+ 10% CMT	.65									
1320	Ctgs	MDST, med-lt gy, calc+ mnr MDST, yel-gy, calc+ tr LST, wht	.69									
1350	Ctgs	MDST, med-lt gy, calc+ mnr MDST, yel-gy, calc+ mnr LST, wht	.82									
1380	Ctgs	MDST, med gy+ tr LST, v lt gy	.97	20	670	640	69	66	.03	421		1.05
1410	Ctgs	MDST, dk gy+ tr LST, lt gy+ tr MDST, yel-gy, calc	.88									
1440	Ctgs	MDST, med gy+ tr LST, lt gy	.77									

ORGANIC CARBON AND ROCK-EVAL PYROLYSIS DATA

TABLE : 8A

GENERAL DATA			CHEMICAL ANALYSIS DATA								
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	P Y R O L Y S I S							
				S1 (ppm)	S2 (ppm)	S3 (ppm)	H1	O1	PI	Tmax °C	S2/S3
1470	Ctgs	MDST, med gy+ tr LST, lt gy	.83	20	330	440	40	53	.06	419	.75
1500	Ctgs	MDST, med gy+ tr foss	1.00								
1500.0	Swc	MDST, dk gy	3.19	150	7140	840	224	26	.02	424	8.50
1512.0	Swc	MDST, dk gy	1.26	30	1000	700	79	56	.03	422	1.43
1530	Ctgs	MDST, med-dk gy+ tr MDST, lt ol-gy, calc	1.81	50	2100	700	116	39	.02	423	3.00
1560	Ctgs	MDST, med gy+ 10% CMT+ 10% SST v lt gy	1.72								
	P	MDST, med gy	2.17	40	3200	870	147	40	.01	428	3.68
1590	Ctgs	MDST, med-dk gy+ 10% SST, lt gy+ tr LST, wht	1.36								
1620	Ctgs	MDST, med-dk gy+ 10% SST, v lt gy+ 10% LIG+ mnr LST, wht									
	P	MDST, med-dk gy	2.38	100	5310	700	223	29	.02	425	7.59
1650	Ctgs	MDST, med-dk gy+ 30% SST, ol-gy+ 10% SST, v lt gy	1.29								
	P	MDST, med-dk gy	2.20	60	4450	600	202	27	.01	425	7.42
1680	Ctgs	COAL+ tr LST, wht	44.20	2440	67950	4280	154	10	.03	423	15.88
1688.0	Swc	MDST, dk gy, mic	6.14	470	7250	1030	118	17	.06	420	7.04
1710	Ctgs	COAL+ 30% MDST, med gy+ mnr ANH	18.40								
	P	COAL	34.30	3060	53870	2900	157	8	.05	423	18.58
	P	MDST, med gy	1.64	130	2610	1100	159	67	.05	425	2.37
1740	Ctgs	QTZ+ 10% MDST, med gy+ 10% COAL									
	P	MDST, med gy	1.74	80	3040	890	175	51	.03	426	3.42
	P	COAL	30.80	2630	50920	2100	165	7	.05	420	24.25
1770	Ctgs	MDST, med gy+ 20% QTZ+ 20% COAL+ 10% SST, wht									
	P	MDST, med gy	1.13	30	890	530	79	47	.03	423	1.68
1800	Ctgs	QTZ+ 30% COAL+ 10% MDST, ol-gy + mnr ANH+ mnr pyr									
	P	COAL	41.70	2910	97290	2080	233	5	.03	409	46.77
	P	MDST, ol-gy	2.15	60	5500	440	256	20	.01	426	12.50
1830	Ctgs	QTZ+ 20% COAL+ 20% LST, wht+ 10% MDST, ol-gy									
	P	COAL	38.30	1510	49390	1960	129	5	.03	415	25.20
1860	Ctgs	LST, wht+ 10% MDST, dk gy+ mnr MDST, lt ol-gy, calc+ mnr QTZ	.68								

ORGANIC CARBON AND ROCK-EVAL PYROLYSIS DATA

TABLE : 8B

GENERAL DATA			CHEMICAL ANALYSIS DATA									
SAMPLE DEPTH (Metres)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	P Y R O L Y S I S								
				S1 (ppm)	S2 (ppm)	S3 (ppm)	HI	OI	PI	Tmax °C	S2/S3	
1890	Ctgs	MDST, med gy+ 20% MDST, lt gy, calc+ 10% LST, yel-gy+ 10% LST wht	.41									

ORGANIC CARBON AND ROCK-EVAL PYROLYSIS DATA
TABLE : 8C

ESSO NORGE A/S 10/7-1 WELL

Table 9

ROCK-EVAL PYROLYSIS STANDARD DATA

Analysis Number	Tmax	S1	S2	S3	HI	OI
1	434	0.64	6.65	0.35	665	35
2	435	0.61	6.54	0.34	654	34
3	433	0.62	6.57	0.34	657	34
4	434	0.60	6.11	0.29	611	29
5	434	0.62	6.58	0.31	658	31
6	434	0.62	6.83	0.33	683	33
7	433	0.61	6.67	0.32	667	32
8	433	0.60	6.45	0.29	645	29
9	432	0.63	6.77	0.32	677	32
mean	433.6	0.6167	6.574	0.3211	657.4	32.1
sd	0.882	0.0132	0.209	0.0215	20.941	2.147

Analysis of pyrolysis standard carried out at regular intervals during analysis of samples from the 10/7-1 well. S1, S2 and S3 pyrolysis yields given as g/gTOC. Hydrogen and oxygen indices calculated at 1% organic carbon (TOC).

Key:

sd = standard deviation

GENERAL DATA				SOLVENT EXTRACTION AND IATROSCAN DATA								
SAMPLE DEPTH Metres	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	EXTR. ppm	EXTR. % OF ORG. CARB. (EPOC)	ALKS. % OF EXTR.	AROMS. % OF EXTR.	POLARS % OF EXTR.	HYDROCARBONS			ALKS. % OF HC
									ppm	% OF ORG. CARB.	% OF EXTR.	
1500.0	Swc	MDST, dk gy	3.19	600	1.9	20	15	65	210	7	35	57
1620	Ctgs	MDST, med-dk gy+ 10% SST, v lt gy+ 10% LIG+ mnr LST, wht	-									
	P	MDST, med-dk gy	2.38	945	4.0	11	8	80	185	8	20	57
1680	Ctgs	COAL+ tr LST, wht	44.20	10785	2.4	9	33	57	4615	10	43	22
1688.0	Swc	MDST, dk gy, mic	6.14	1555	2.5	15	27	58	655	11	42	36
1710	Ctgs	COAL+ 30% MDST, med gy+ mnr ANH	18.40									
	P	COAL	34.30	10350	3.0	6	27	66	3500	10	34	19

SOLVENT EXTRACTION AND IATROSCAN FRACTIONATION DATA

TABLE: 10

SAMPLE DATA						
SAMPLE DEPTH (Mtrs)	1500.0	1620	1680	1688.0	1710	
SAMPLE TYPE	Swc	Ctgs (P)	Ctgs	Swc	Ctgs (P)	

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
	1500.0 Swc	1620 Ctgs (P)	1680 Ctgs	1688.0 Swc	1710 Ctgs (P)	
n-C10						
n-C11						
n-C12						
n-C13				.58		.27
n-C14				1.28		1.46
n-C15	.12			1.55	.33	4.99
n-C16	.58			2.76	.76	.62
n-C17	2.81	.32		2.52	1.80	2.34
n-C18	3.30	1.51		6.61	6.42	2.99
n-C19	5.25	3.83		2.11	2.98	2.93
n-C20	4.75	5.22		5.27	6.77	2.36
n-C21	6.17	7.62		2.64	2.00	2.76
n-C22	4.57	5.56		2.92	4.33	2.90
n-C23	6.93	9.90		8.93	4.05	8.97
n-C24	4.16	3.98		4.45	10.11	4.08
n-C25	7.65	9.74		14.22	5.80	14.28
n-C26	9.92	9.78		5.27	4.48	3.45
n-C27	6.26	10.73		4.72	5.36	5.87
n-C28	4.48	4.34		1.11	3.46	2.57
n-C29	5.49	7.22		2.34	3.95	4.94
n-C30	2.16	2.23		.02	1.72	1.57
n-C31	2.22	3.99		.82	1.78	4.95
n-C32	1.40	2.05		.66	1.40	1.22
n-C33	1.03	1.56		1.49	1.44	1.19
n-C34	2.69	4.10		1.26	2.09	.77
n-C35	.65	.50		.04	.48	1.27
n-C36	.89	.67		.41	.98	.05
i-C15 (Farnesane)				1.21		1.79
i-C16	.01			3.78	.54	.79
i-C18 (Norpristane)	1.06	.00		1.00	.66	1.40
i-C19 (Pristane)	6.24	.84		19.46	23.93	13.71
i-C20 (Phytane)	9.19	4.31		.21	2.38	3.50

GENERAL DATA						
Total Abundance(%)	100	100	100	100	100	
TOC (% of Rock)	3.19	2.38	44.20	6.14	34.30	
Extract (ppm)	600	945	10785	1555	10350	
Hydrocarbons (ppm)	210	185	4615	655	3500	
Hydrocarbon(mg/gTOC)	7	8	10	11	10	
Alks(% Hydrocarbons)	57	57	22	36	19	
Rock-Eval HI	224	223	154	118	157	
Rock-Eval PI	.02	.02	.03	.06	.05	

RATIOS						
CPI-1	1.06	1.48	2.44	1.13	2.84	
CPI-2	1.12	1.64	2.58	1.19	2.99	
CPI-3	.87	1.52	1.48	1.35	1.95	
Bias	.53	.37	.56	.58	.32	
i-C19 / n-C17	2.22	2.63	7.73	13.28	5.86	
i-C20 / n-C18	2.79	2.85	.03	.37	1.17	
i-C19 / i-C20	.68	.19	92.67	10.04	3.92	

LEGEND	
i - isoprenoid	n - normal
For definition of Ratios CPI-1,-2,-3 and Bias - see following page	

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 11

Alkane gas chromatography data - definition of ratios

CPI 1 (Bray and Evans):

$$\frac{1}{2} \times \left[\frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{24} + C_{26} + C_{28} + C_{30} + C_{32}} + \frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{26} + C_{28} + C_{30} + C_{32} + C_{34}} \right]$$

CPI 2 (Radke and Statoil):

$$\frac{1}{2} \times \left[\frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{24} + C_{26} + C_{28} + C_{30}} + \frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{26} + C_{28} + C_{30} + C_{32}} \right]$$

CPI 3 (Statoil and Philippi):

$$\frac{2 \times C_{27}}{C_{26} + C_{28}}$$

Bias:

$$\frac{C_{16} + C_{17} + C_{18} + C_{19} + C_{20} + C_{21} + C_{22}}{C_{23} + C_{24} + C_{25} + C_{26} + C_{27} + C_{28} + C_{29} + C_{30} + C_{31} + C_{32} + C_{33}}$$

Gasoline ratios - definition of indices

- Late mature index - Benzene/methyl cyclohexane
- Aromaticity index - Toluene/*n*-heptane
- Heptane index - *n*-Heptane/all C₇ compounds (%)
- Iso*-heptane index - Methyl hexanes (non-cyclic)/dimethyl cyclopentanes
- Kerogen type index - Heptane index-4/*Iso*-heptane index

SIMON LABORATORIES

Analysis Name : 5 S92J0004R1, 1, 1.

92J 4 ESSO NORGE 10/7-1 Amount : 1.000

SATURATES G.C. C15+ BY METHOD OLS/016

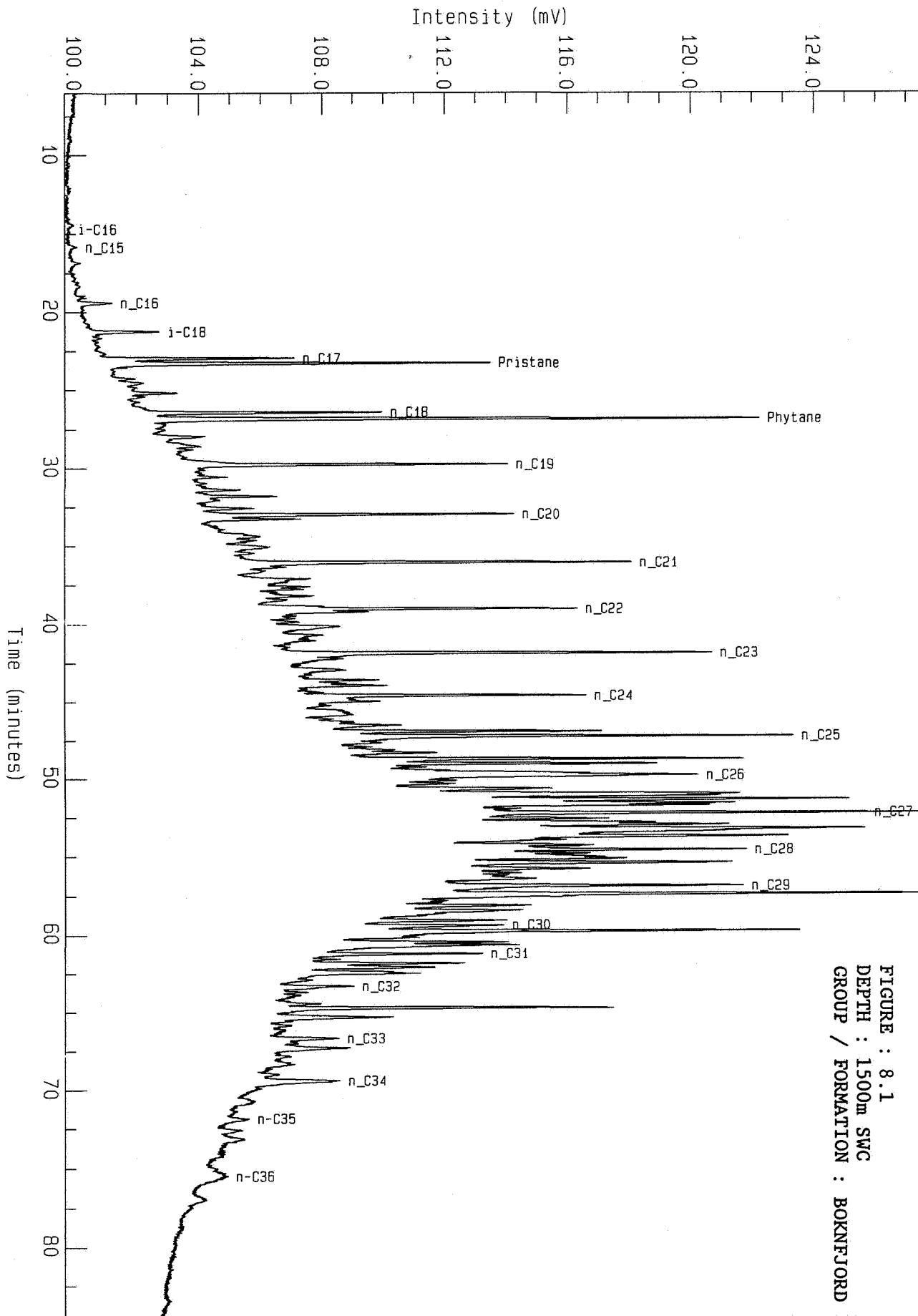


FIGURE : 8.1
DEPTH : 1500m SWC
GROUP / FORMATION : BOKNFJORD

ESSO NORGE A/S 10/7-1 WELL

Appendix 2

ANALYTICAL PROCEDURES AND TECHNIQUES

ANALYTICAL PROCEDURES AND TECHNIQUES

This appendix summarises the main steps in the analyses carried out in the Robertson Research International Ltd. petroleum geochemistry laboratories. Analytical pathways are shown on the flow chart (Appendix Figure 1) and details of laboratory procedures and techniques are given in the text. These may in certain circumstances be adapted to suit particular samples or conditions. Interpretation guidelines are also defined.

1. Sample Preparation

General

Samples are received into the laboratories in the forms of well-site canned ditch cuttings, bagged ditch cuttings in various stages of preparation from wet, unwashed to dried, washed; sidewall cores, conventional cores, outcrop samples, crude oil samples and gas samples. Each sample is assigned a number which is entered into a computer system to monitor sample selection and progress. Preparation techniques are directed towards obtaining clean samples, free of drilling mud and mud additives, obvious caving contamination and indeterminate fine material. Washing with cold water is standard but further washing with solvent (dichloromethane, DCM) is carried out if oil-based mud is present, after which samples are dried, described and individual lithologies hand-picked where practicable. Samples are rough crushed to approximately pea-sized fragments for kerogen preparation or finely milled for chemical analysis.

Kerogen Preparation

Kerogen concentrates for microscopic examination and elemental analysis are prepared using standard palynological procedures but omitting oxidation or acetolysis. Acid maceration involves the use of hot hydrochloric acid (HCl) to remove carbonates and hot 60% hydrofluoric acid (HF) to remove or break down silicates. Mineral residues are separated from the kerogen by a combination of ultrasonic vibration and zinc bromide flotation. Kerogen samples for spore colour and kerogen typing are mounted on glass slides in glycerin jelly, those for vitrinite reflectivity are dried and mounted in epoxy resin. Kerogen residues are stored in methanol.

2. Maturity Evaluation

The techniques employed for interpreting maturity and thermal history in these laboratories are based mainly on spore colouration and vitrinite reflectivity measurement, supplemented by data obtained from airspace gas and gasoline analysis, pyrolysis Tmax, and hydrocarbon analysis including gas chromatography and gas chromatography-mass spectrometry.

Spore Colouration

Sporomorph colour is assessed using a >20 μ sieved kerogen fraction viewed in transmitted light on a standard palynological microscope. Unusual hues are checked using incident blue/UV light fluorescence. Measurement is made by eye against reference sets of single grain spore mounts and trained operators achieve a high degree of accuracy and reproducibility. The 1 to 10 Spore Colour Index (SCI) scale was designed for linearity with increasing depth and temperature and correlates approximately with the following zones of oil generation: 1.0 to 3.5, immature; 3.5 to 5.0, early mature, generation of low gravity oils (28 to 35 °API); 5.0 to 7.0, middle mature, generation of medium gravity oils (35 to 42°API); 7.0 to 8.5, late mature, generation of light oils (>42°API) and condensates; 8.5 to 10, post mature, generation of condensate, wet gas and, ultimately, dry gas. Linearity of scale is of great value in prediction, by extrapolation, of the depth to any part of the oil generation sequence. The value of SCI measurement lies in the objective selection of measured grains, so minimising problems of caving and reworking, and in its more direct correlation against oil generation than vitrinite reflectivity measurement. Limitations in its use concern the difficulty of correlation against other colour scales and the insensitivity of the scale in the late to post mature region. Anomalous colours may result from bleaching or staining during deposition and diagenesis. The correlation of SCI against Thermal Alteration Index (TAI) given on the SCI versus depth plot in the reports was made by direct comparison of Staplin's standard slides with SCI standard slides.

Vitrinite Reflectivity

The majority of preparations examined under reflected light in these laboratories are made using >20 μ sieved kerogen, mounted in resin blocks and polished with carborundum and alumina although total kerogen may be used when sample size is

limited. Picked coals, organic-rich shales or limestones containing solid bitumen are mounted directly in resin blocks and polished in the usual way. Measurement is made on a Leitz Orthoplan microscope fitted with an MPV Compact photometer which feeds values direct to a desk top computer for data processing from each sample. The system is calibrated against glass standards and reflectance values are expressed as arithmetic means of measurements taken in oil immersion (R_o or $R_{m \text{ oil}}$). R_{max} and R_{min} may be measured and quoted in certain circumstances but the difference is insignificant below about R_o 1.0%. Some operator selection of particles during measurement is essential and obvious contaminants or non-vitrinitic material are noted but not necessarily quoted. The value quoted on data tables is that which is interpreted as most appropriate, but other possibilities may also be given. Plotted figures assume a logarithmic increase of reflectance with depth. R_o 0.5% is a widely accepted threshold value for the onset of oil generation, although as the kinetics of oil generation may not be identical to those of vitrinite reflectivity development this must be seen only as a general guide. The floor for oil generation is characterised by a reflectance value of about 1.3%. Wet gas generation peaks at a value of about 1% and ceases at the 2% level. Dry gas generation peaks at a reflectance of about 1.5% and ceases at the 3% to 4% level. Correlation of reflectance values with other maturity parameters may not be universal because of time-temperature factors and is best made on a local basis.

Reflectivity measurement is a widely used and versatile tool which may be readily calibrated against easily obtained standards. It is applicable over a wide range of maturity stages from immature to post mature (0.2% to 5% R_o). High surface intercepts on plotted figures and discordances at faults and unconformities can give realistic estimates of the amount of section missing. It is of limited value in Early Palaeozoic sections where land plant material is absent, although a general guide to maturity may be obtained from chitinous organic matter. Even a skilled operator may have difficulty in distinguishing indigenous vitrinite from some forms of inertinite, anomalously reflecting "pseudovitrinite", cavings and reworked fragments.

Airspace Gas Analysis

Wet cuttings are collected at the well site and sealed in partly full cans containing bactericide. In the laboratory, the airspace (headspace) gas is extracted using a can piercer fitted with a septum and analysed by gas chromatography. The proportions of methane, ethane, propane, iso- and n-butane are calculated from integrated peak areas by comparison with a standard mixture of these gases. Methane is the dominant gas in immature and post mature sediments, comprising 90-100% of total gas, falling to 30-70% in mature sediments. The onset of maturity for oil generation (SCI 3.5) is characteristically marked by an increase in wet gas (C_2-C_4) to between 10 and 20% with further increases in maturity indicated by a decrease in the ratio of iso- to n-butane. Ratios of >1.0 are typical for immature sediments and <0.5 are usual in mature sediments. Departures from composition versus depth trends may be useful in indicating migrant gas at faults, unconformities or reservoir rocks but limit the method as a reliable maturity indicator. Airspace gas analysis is an inexpensive and rapidly executed method of screening samples for further maturity and hydrocarbon content determinations.

Gasoline Analysis and Cuttings Gas Analysis

Cuttings samples received wet, preferably in sealed containers, are suitable for gasoline and cuttings gas analysis. A portion of the washed cuttings sample is retained wet, pulverised in a sealed shaker and warmed to expel the C_1 to C_7 hydrocarbon components into the shaker airspace. A sample of this airspace gas is then removed and analysed by gas chromatography either for cuttings gas (C_1 to C_4) or gasolines (C_4 to C_7). Up to 28 hydrocarbon components are identified in the C_4 to C_7 range and their relative proportions calculated from integrated peak areas with reference to standard mixtures. Immature source rocks yield low total abundances and limited numbers of components whereas mature source rocks usually contain a full complement of identified hydrocarbons with the onset of maturity indicated by a rapid rise in total gasoline abundances with depth. Anomalous amounts of gasolines may mark the presence of oil stain. Gasolines may be used in oil to oil or oil to source rock correlations but the concentration of some of the measured components is not only a function of source but also depends on maturity, migration and alteration in the reservoir. Using the most stable compounds, pairs with similar chemical structure and boiling points are reduced to pair ratios and compared with the same pair ratios in other oils or possible source rocks. Gasoline analysis is a valuable tool in that it measures directly the hydrocarbons being generated from a sediment but its sensitivity in detecting traces of oil places constraints on its use as a maturity indicator.

Rock-Eval Pyrolysis, Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) in Maturity Analysis

These three analytical processes measure parameters which are functions of both maturity and kerogen type. Data from them may give a general guide to maturity but if the kerogen types are known, more specific conclusions may be drawn. From Rock-Eval data, the temperature of maximum rate of pyrolysis, T_{max} , is the most useful datum; gas chromatograms of alkanes, separated from source rock extracts or oils, yield carbon preference indices (CPI) and isoprenoid ratios; GC-MS quantitative fragmentograms provide abundance ratios for specific compounds which are particularly useful in assessing the level of maturity at which source rock hydrocarbons or oils have been generated. All these supplementary data may be used to confirm results from visual analysis or supplant them if poor or unavailable.

3. Source Rock Evaluation

Total Organic Carbon Content (TOC)

Organic carbon values are obtained by treating 0.1g of crushed rock sample with hot, concentrated HCl to remove carbonates. The washed residue is filtered on to a glass fibre pad and ignited in a Leco carbon analyser. For screening purposes, samples are analysed singly but where further analyses, such as pyrolysis or solvent extraction are anticipated, a duplicate sample is run. Blanks and standards are run as routine and where values from duplicated samples do not concur within strict accuracy limits, they are rerun. Where samples are heavily stained with oil, either from natural deposits or drilling mud, TOC is repeated on the dried, solvent extracted sample.

TOC measurement is fundamental in assessing source rock quality since when combined with kerogen type and maturity, a full description of the potential to generate oil may be given. It is found in practice that sediments containing less than 0.3% TOC are unlikely to have any source potential, those containing between 0.3% and 1% may be marginal sources but the better quality sources contain in excess of 1% TOC. Screening by TOC is therefore an inexpensive and rapid method of selection of samples for further analysis in source potential evaluation.

Rock-Eval Pyrolysis

Pyrolysis data are obtained using the IFP-Fina Rock-Eval apparatus. 100 mg of crushed, whole rock either from bulk sample or picked lithology is weighed accurately into a crucible and introduced into a furnace at 250°C. Free hydrocarbons (roughly equivalent to solvent extractable hydrocarbons) are volatilised and quantified by flame ionisation detector (FID) to give Peak 1 (S_1 , ppm). The furnace temperature is increased to 550°C at 25°C/minute and within this range, kerogens crack to give hydrocarbons, measured by FID to give Peak 2 (S_2 , ppm) and carbon dioxide, measured by thermal conductivity detector (TCD) to give Peak 3 (S_3 , ppm). The temperature at the maximum rate of evolution of cracked volatiles (T_{max}) is measured automatically but can also be monitored visually. The instrument is calibrated daily using standards both at the beginning of the work period and at regular intervals thereafter and crucible blanks are run as routine. The tabulated data in reports comprise the following parameters:

- T_{max} °C - temperature of maximum rate of Peak 2 hydrocarbon evolution.
- Hydrogen Index (HI) - S_2/TOC (mg/g) or ratio of released hydrocarbon to organic carbon content. This is a measure of the hydrocarbon generating potential remaining in the kerogen as opposed to that of the whole rock.
- Oxygen Index (OI) - S_3/TOC (mg/g) or ratio of released carbon dioxide to organic carbon content.
- Production Index (PI) - S_1/S_1+S_2 , or ratio of the amount of hydrocarbons released in the first stage of heating to the total amount of hydrocarbons released and cracked during pyrolysis.
- Potential Yield (PY) - S_2 (ppm) or total of hydrocarbons released during cracking of kerogen compared to original weight of rock.

T_{max} , hydrogen index and oxygen index are each functions of both maturity and kerogen type. Using published and empirical data, it has been possible to assemble a model to show the relationships of these factors to maturity as measured by spore colouration and vitrinite reflectivity for a selection of pure kerogen types. The kerogen types used are algal sapropel (type I), waxy sapropel (type II), vitrinite (type IIIA) and inertinite (type IIIB) and a computer program has been devised by which the amounts of these components may be calculated from the HI, OI, T_{max} and maturity

data for any sample. These are the values expressed in the "kerogen composition by calculation" columns tabulated in the reports.

The hydrogen index is a measure of the hydrocarbon generating potential of the kerogen and is analogous to the atomic H/C ratio. Immature, organically rich source rocks and oil shales give values above 500, mature oil source rocks give values between 200 and 550. For a given kerogen type, these values progressively diminish with increasing maturity.

The temperature of maximum rate of pyrolysis depends partly on the kerogen type but the transition from immature to mature organic matter is marked by temperatures between 415° and 435°C. The maturity transition from oil and wet gas generation to dry gas generation is marked by temperatures between 455° and 460°C. In practice, greater variation than these ideal temperature ranges may be seen, but they are nevertheless useful as general guides to the level of maturity attained by the sediment.

The production index increases with maturity from values near zero for immature organic matter to maximum values of 0.15 during the late stages of oil generation. Anomalously high values indicate the presence of oil or contaminants. The potential yield is an indication of the predicted yield of hydrocarbons from the source rock at optimum maturity and is a measure of the quality of the source rock. For immature sediments, values of 0 to 2000 ppm of hydrocarbon characterise a poor source rock, 2000 to 6000 ppm fair, 6000 to 20 000 ppm good and above 20 000 ppm very good.

Pyrolysis techniques have in recent years provided a major advance in the assessment of source rock quality and generating potential. Hydrocarbon yields from immature source beds examined on-structure may be translated into actual oil productivity from the same beds in mature basinal, off-structure situations. Models relating maturity and kerogen type may be used to define original source rock quality grades which are of great value in mapping organic facies. Amorphous kerogen types, indistinguishable in microscopic preparations over a wide range of chemical properties, may be readily differentiated by pyrolysis. The problem of analysing bulk samples containing mixed kerogens has been largely overcome by the kerogen type/maturity model and anomalous results arising from the presence of caving contamination and drilling mud additives can usually be explained by inspection. High oxygen indices sometimes occur as a result of the presence of metastable carbonates and in such cases the sample is acid decarbonated and re-run.

Visual Examination of Kerogen Concentrates

All palynological preparations on which SCI determinations are made are also examined for kerogen type. Visual estimations of the relative abundance of the broad groups vitrinite, inertinite and sapropel are made on the total kerogen slide mount but reference is also made to the >20 μ sieved fraction to assist in identification. The scheme of identification is shown in Appendix Table 1. Full use is made of incident blue or UV light in distinguishing immature or early mature oil-prone kerogen from gas-prone kerogen.

Extract Analysis

The soluble organic materials present in rocks can be extracted with organic solvents, fractionated and analysed. The type and amount of material extracted depends largely upon the nature of the contained kerogen and its maturity, although the presence of migrant oil or drilling contamination may be the determining factors.

A maximum of 40g of crushed sample is extracted for a minimum of 12 hours in a Soxhlet apparatus using laboratory redistilled DCM. The solvent and the more volatile components (approximately up to $n-C_{15}$) are lost by evaporation in an air flow and the resulting total extract is weighed, dissolved in hexane and separated into alkane (saturate) hydrocarbon, aromatic hydrocarbon, resene and asphaltene (polar) fractions by silica adsorption chromatography in the Iatroscan process.

Larger fractions, suitable for further analysis, are obtained by column chromatography. The extract is run through a short glass column packed with silica and alumina and eluted with hexane (to give the saturate fraction), (3:1 hexane: toluene mixture (to give the aromatic fraction) and methanol (to give the polar, or resene and asphaltene, fraction). A small proportion of non-eluted polar compounds usually remains on the column.

The data tabulated in reports comprise the following parameters:

Total extract - soluble organic matter, heavier than about $n-C_{15+}$, expressed as ppm of weight of rock.

Hydrocarbons - sum of alkane and aromatic hydrocarbons, expressed as ppm of weight of rock.

Extract % of organic carbon (EPOC) - $\frac{\text{total extract ppm}}{\text{TOC} \times 100}$; the extractability.

Hydrocarbons mg/g of organic carbon - total hydrocarbons normalised to 1g of organic carbon.

Hydrocarbons % extract - total hydrocarbons as a proportion of total extract.

Alkanes % hydrocarbons - the proportion of alkanes (saturates) in the total hydrocarbons. The proportion of aromatics is (100 minus this value) expressed as a percentage.

The extractability of oil-prone sapropelic organic matter increases rapidly in the oil generation zone and diminishes to very low values in post mature sediments. Overall the extractability of sapropelic organic matter is greater than that of gas-prone humic organic matter for similar levels of maturity. Samples with extractabilities of greater than 20% generally contain migrant oil or are contaminated with mud additives.

As maturation proceeds in the oil generation zone the proportion of hydrocarbons in the total extract increases from less than 20% to a maximum in the most productive horizons of around 60%. This trend is reversed as the oil-condensate zone is entered. The relative proportions of alkanes to aromatics can be used as a check for low levels of contamination. Fractions of the extract, separated by column chromatography are retained for further analysis by gas chromatography or for stable carbon isotope determination.

Capillary Gas Chromatography of C_{15+} Alkanes

A portion of the Soxhlet extract is eluted with hexane through a short silica column to yield the saturate hydrocarbon fraction. This fraction is evaporated in a stream of dry nitrogen at room temperature. A small portion of the fraction is then taken up in hexane and introduced into a 25 metre, wall-coated, open tubular glass capillary column coated with OV-1, or equivalent, mounted in a Carlo Erba gas chromatograph which is temperature programmed from 70°C to 270°C at 3°C/minute.

C_{15+} chromatograms are inspected for the distributions of n -alkanes, and the presence and abundance of isoprenoids (particularly pristane and phytane), steranes and triterpanes and unresolved envelopes of naphthenic compounds. The ratios pristane:phytane and pristane: $n-C_{17}$ are calculated. Carbon Preference Index (CPI) values quoted are those as defined by Philippi as the ratio $2C_{29}$ to $(C_{28}+C_{30})$ unless otherwise stated. Chromatography may reveal information about the kerogen type of the source rock, its maturity and condition of deposition and, if migrant oil is present, whether this has been water-flushed or biodegraded. Contaminant drilling mud additives may be identified.

Capillary Gas Chromatography of Aromatic and Branched/Cyclic Alkanes

The aromatic portion of the Soxhlet extract is eluted from a short silica/alumina column by a hexane/toluene mixture. The dried fraction is taken up in DCM and introduced into a 25 metre, wall-coated, open tubular glass capillary column coated with OV-1, or equivalent, mounted in a Carlo Erba gas chromatograph which is temperature programmed from 70°C to 270°C at 3°C/ minute.

Branched chain alkanes are separated from normal alkanes by urea adduction and treated as for total alkanes.

Gas Chromatography-Mass Spectrometry

Mass spectrometry is a technique in which molecules are bombarded with high energy electrons causing ionisation and fragmentation of the molecules into ions of varying mass(m) and charge(z). The way in which a molecule fragments into ions of various m/z value is known as its fragmentation pattern, or mass spectrum and is unique. When linked to a gas chromatograph the mass spectrometer can be used in two different modes:

1. Full Scan Mode: A mass spectrum is obtained of each peak eluting from the gas chromatograph and a structural identification of the compound producing that peak can be made.
2. Multiple or Single Ion Monitoring Mode: The mass spectrometer is tuned to certain m/z values to detect whether a compound, eluting from the gas chromatograph, fragments to give an ion at that value. Certain fragmentations are indicative of specific compound types and the most commonly monitored fragment ions used in petroleum geochemistry are those with m/z values of 191, 217 and 259 which are the principal fragment ions obtained from groups of alkanes known as triterpanes, regular steranes and rearranged steranes respectively. These are compounds containing 27 to 35 carbon atoms arranged in a polycyclic, normally 4 or 5 ring, structure, occurring in the $n-C_{26}$ to $n-C_{35}$ region of a gas chromatogram. The basic molecular skeletons of these compounds are very similar to those of the original organic matter deposited in the sediment and so these 191, 217 and 259 distribution plots, known as mass fragmentograms or mass chromatograms, form a pattern characteristic of the source material. This technique of "fingerprinting" is also one of the more exact methods of correlating an oil to its source, or to another oil.

Carbon Isotope ($^{13}C/^{12}C$) Ratio Analysis

Carbon has two stable isotopes, the more abundant ^{12}C isotope and the heavier ^{13}C isotope, which in nature forms about 1% of carbon. Deviations from the $^{13}C/^{12}C$ ratio are extremely small and carbon isotope ratios, as measured by mass spectrometry, are expressed as deviations from a standard, the Pee Dee Belemnite carbonate (PDB standard) in parts per thousand (parts per mil; ‰). Positive deviations indicate ^{13}C enrichment and conversely, negative deviations indicate ^{13}C impoverishment.

While the carbon isotope ratios of oils and rock extracts can range from -20 to -32 ‰ depending on the source organic matter type, the difference between a specific oil and its source is small. Measurements are usually made on the C_{15+} alkane and aromatic hydrocarbon fractions separately and there should be no more than 1 ‰ difference between the oil and its source for either fraction. If there is any doubt that the source rock extracts are not indigenous to the source rock kerogen, the carbon isotope ratio of the extracted source rock kerogen can be measured.

Pyrolysis-Gas Chromatography

The hydrocarbon pyrolysate derived from thermal, anhydrous cracking of kerogen is analysed by capillary gas chromatography. A few mg of rock, kerogen or asphaltene is heated to 600°C for 20 seconds in the injector of a gas chromatograph. The chromatograph oven is kept at -30°C during pyrolysis and then raised to 300°C at a programmed rate of 7.5°C/minute. Chromatograms produced this way are often very different from those of source rock extracts or oils in that branched and cyclic isomers are generated freely giving numerous, closely spaced peaks, along with unsaturated, alkene (olefin) hydrocarbons. The "doublet" peaks often observed in these chromatograms comprise alkene-alkane pairs, the first eluting, and usually smaller peak, being the alkene. The chromatograms range from C_1 to C_{30} or above and although variable, are broadly characteristic of source rock type. Gas-prone kerogen cracks to give a more limited molecular weight range of products, concentrated towards the light ends, whereas oil-prone kerogen gives more prominent alkene-alkane doublets in the C_{12} to C_{30} region. The largest peak from both types is usually methane.

Elemental Analysis

Total (unsieved) kerogen is prepared as described in Section 1. The dried material is combusted in oxygen in an elemental analyser and the oxides of carbon, hydrogen, nitrogen and sulphur are measured. The unburnt residue is the ash content. Oxygen is usually calculated by difference but can be determined separately if required. Results are quoted as percentage weights of C, H, O, N, S and Ash with the atomic ratio H/C and O/C calculated and plotted on the standard van Krevelen diagram. The relative amounts of C, H and O present in organic matter are dependent on both source and maturity. At known maturity levels, some measure of source quality may be determined. Limitations of the method in source rock assessment involve the difficulty of obtaining pure kerogen (in particular, free from pyrite) and the lack of a simple, direct determination of oxygen content.

4. Oil Analysis

RRI laboratories offer a wide range of oil analyses both for geochemical purposes and industrial use. Physical property determinations are based mainly on IP methods and are available for lubricating oils, fuels and greases as well as crudes. Frequently measured properties of crude oils presented in geochemistry reports include: API gravity, pour point, viscosity and contents of water, sulphur, wax, asphaltene, nickel, vanadium and other metals. Chemical analysis of oils involves the following:

Whole oil gas chromatography - using split syringe injection and a temperature programme from -20°C or -30°C up to 270°C at 4°C/minute.

Associated gas - if oil has high gas/oil ratio.

Gasoline analysis - as for gasolines in rock samples but a weighed quantity of oil is used.

Topping of the oil - this is equivalent to the removal of the fraction boiling below about 210°C and gives a more standardised product for comparison of gas chromatograms of the C₁₅₊ fraction.

Column chromatography and gas chromatography - as for solvent extracts. Analysis is carried out on topped oil.

5. Gas Analysis

The hydrocarbon gases, C₁ to C₄, may be collected from the airspace of sealed canned samples or may be received from well-site tests in a special sealed gas cylinder (gas mouse). Chromatographic separation of the C₁ to C₄ gases is effected as described under airspace gas analysis. In addition, the separated gas components may be analysed for stable carbon and hydrogen isotope composition which may provide valuable clues to the origin of the gas.

6. Solid Bitumen Analysis

In some oil fields, problems are encountered where bitumen developments form continuous or patchy layers within reservoirs, dividing the pay zones and acting as barriers to natural fluid movement or inhibiting enhanced oil recovery techniques. Integrated geochemical and sedimentological studies aim to produce geological models capable of predicting the occurrence of bitumen layers and their likely thickness and ability to act as permeability barriers. Of further concern are the past or present relationships between the bitumen and reservoir oil, their source rocks and the timing of bitumen formation.

Analysis schemes involve screening of samples by assessing the amount of bitumen in polished core pieces using reflected light microscopy, followed by solvent extraction of control samples to estimate the proportion of solvent soluble bitumen. Different phases of bitumen formation are differentiated by reflectance measurement as described for vitrinite reflectance measurement. Soluble extracts are fractionated to give alkane, aromatics, asphaltene and resene components. Separated bitumens may be subjected to elemental analysis.