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HYDRO

FORMATION PRESSURE WORKSHEET

Well No. : 34/8-4A

Rig : Transocean 8

Date : 27-28.03.92

Pressure Units : Bars

RKB-MSL : 23.5 m

Witnessed by : Anderson / Giskeodegaard / Henderson

Run No. 2A	Depth (MD)	Depth TVD(RKB)	Initial Hydrostatic Press		Formation Pressure		Final Hydrostatic Press		Time		Remarks
			Strain	HP	Strain	HP	Strain	HP	Set	Retract	
1	2991.0	2867.6	468.00	468.62	450.27	449.90	468.63	468.29	19:22	19:25	76.8 deg C, 731 MD/cP
2	2997.0	2872.1	469.11	468.72	450.56	450.17	468.89	468.50	19:40	19:45	77.1 75.4
3	3008.0	2880.3	470.24	469.86	451.16	450.79	470.00	469.62	19:55	20:01	77.6 37.5
4	3012.0	2883.3	470.43	470.07	451.23	450.85	470.23	469.86	20:08	20:11	77.8 44.3
5	3019.0	2888.5	470.04	469.94	451.30	451.16	469.82	469.69	20:47	20:53	78.6 54.8
6	3061.5	2920.6	475.15	475.04	453.20	453.05	474.95	474.82	21:24	21:28	79.9 32.2
7	3066.0	2924.2	475.31	475.18	453.43	453.26	475.14	475.01	21:42	21:46	79.9 86.1
8	3077.3	2932.7	476.46	476.32	453.93	453.75	476.29	476.14	21:59	22:03	80.1 77.2
9	3086.0	2939.2	477.40	477.24	454.34	454.14	477.23	477.08	22:12	22:15	80.5 1124
10	3095.0	2946.2	478.42	478.27	454.75	454.56	478.25	478.10	22:22	22:26	80.8 19.9
11	3112.0	2959.0	480.64	480.49	455.53	455.34	480.47	480.32	22:34	22:37	81.2 278
12	3122.2	2966.8	481.84	481.71	456.03	455.86	481.65	481.51	22:43	22:47	81.4 23
13	3131.5	2974.2	482.84	482.71	456.42	456.24	482.66	482.51	22:54	22:48	81.6 44.9
14	3133.0	2975.1	482.80	482.64	456.53	456.33	482.66	482.50	23:05	23:08	81.7 65.2

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			Strain	HP	Strain	HP	Strain	HP	Set	Retract	
15	3136.2	2977.5	483.00	482.85	456.68	456.49	482.86	482.70	23:15	23:18	81.9 deg C, 63.5 MD/cP
16	3142.5	2982.4	483.69	483.53	457.01	456.79	483.54	483.38	23:24	23:28	82.3 41.7
17	3163.0	2997.9	486.39	486.23	457.91	457.73	486.20	486.05	23:36	23:39	83.0 4.9
18	3176.0	3007.4	487.87	487.71	458.52	458.31	487.68	487.53	23:46	23:50	83.6 56.4
19	3184.0	3013.7	488.71	488.56	458.87	458.67	488.55	488.39	23:55	23:58	84.0 44.0
20	3217.5	3039.0	493.25	493.08	462.10	461.91	492.99	492.84	00:06	00:10	84.5 4.6
21	3221.0	3041.7	493.38	493.21	462.19	461.98	493.21	493.05	00:16	00:19	84.9 20.5
22	3224.0	3044.0	493.57	493.41	462.48	462.33	493.36	493.21	00:24	00:27	85.1 3.4
23	3222.0	3042.5	492.94	492.77	462.29	462.09	492.73	492.58	00:36	00:42	85.3 6.6
24	3243.0	3058.5	495.56	495.41	462.71	462.51	495.37	495.21	00:52	00:57	86.1 21.2
25	3248.5	3062.8	496.01	495.84	462.94	462.73	495.81	495.65	01:03	01:07	86.5 44.5
26	3252.0	3065.5	496.16	496.00	463.11	462.89	496.05	495.89	01:19	01:21	86.7 37.4
27	3293.1	3096.6	501.90	501.75	464.35	464.16	501.70	501.56	01:33	01:36	86.8 90.1
28	3296.0	3099.0	501.92	501.77	464.46	464.26	501.76	501.63	01:44	01:47	86.8 59.2

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Well No. : 34/8-4A

Rig : Transocean 8

Date : 27-28.03.92

Pressure Units : Bars

RKB-MSL : 23.5m

Witnessed by : Anderson / Giskeodegaard / Henderson

Run No. 2A	Depth (MD)	Depth TVD (RKB)	Initial Hydrostatic Press		Formation Pressure		Final Hydrostatic Press		Time		Remarks
			Strain	HP	Strain	HP	Strain	HP	Set	Retract	
29	3298.5	3101.1	502.02	501.87	464.65	464.45	501.88	501.73	01:54	01:57	86.9deg C 18.4 MD/cp
30	3329.0	3124.2	506.09	505.91	467.59	467.38	505.91	505.74	02:10	02:14	87.4 18.6
31	3332.5	3127.0	506.37	506.20	467.79	467.56	506.23	506.06	02:20	02:23	87.9 105.5
32	3339.0	3131.8	507.14	506.96	468.10	467.86	506.99	506.82	02:28	02:31	88.3 246.9
33	3367.0	3153.1	510.86	510.66	-	-	-	-	02:47	-	No Seal
34	3367.5	3153.5	510.62	510.64	-	-	-	-	02:59	-	No Seal
35	3369.0	3154.5	510.70	510.51	-	-	-	-	03:08	-	No Seal
36	3367.0	3153.1	510.19	509.99	-	-	-	-	03:30	-	No Seal
37	3411.5	3187.5	516.27	516.04	-	-	-	-	04:50	-	Tight
38	3413.0	3188.6	516.38	516.17	-	-	-	-	05:03	-	No Seal

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FORMATION PRESSURE WORKSHEET

Well No. : 34/8-4A

Rig : Transocean 8

Date : 28.03.92

Pressure Units : Bars

RKB-MSL : 23.5

Witnessed by : Giskeodegaard / Waldum

Run No. 2B	Depth (MD)	Depth TVD (RKB)	Initial Hydrostatic Press		Formation Pressure		Final Hydrostatic Press		Time		Remarks	
			Strain	QG	Strain	QG	Strain	QG	Set	Retract		
1	3472.0	3235.6	548.95	548.74	480.75	480.28	547.93	547.53	02:12	02:20	78.9 C	0.4 mD/cP
2	3472.3	3235.8	547.71	547.22	-	-	-	-	02:31	02:34	Tight	
3	3476.0	3238.8	547.74	547.23	480.22	479.67	547.52	547.05	02:46	02:50	81.0 C	1.5 mD/cP
4	3515.5	3270.8	553.20	552.68	482.50	481.96	552.96	552.50	03:02	03:06	82.1 C	1.3 mD/cP
5	3519.8	3274.3	553.40	552.93	482.82	482.24	553.24	552.77	03:13	03:16	82.6 C	26 mD/cP
6	3524.0	3278.3	553.81	553.30	483.16	482.58	553.68	553.18	03:23	03:26	83.5 C	9.1 mD/cP
7	3448.5	3216.7	542.33	541.77	-	-	-	-	03:37	03:40	Tight	

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FORMATION FLUID SAMPLING

Well : 34/8-4A

Rig : Transocean 8

Pretest No. :		Sample Depth : 3294.5m		Witnesses : Waldum / Giskeodegaard	
Run No. :2B	Sample No. : 1	1st Chamber	2nd Chamber	3rd Chamber	
Chamber volume (gals)		2 3/4	1		
Chamber No.		MRSC DA11	MRSC BA15		
Filling time (mins.)		10	2		
Shut in press. (bar)/T deg C		463.63 / 83.9	463.75 / 84.0	/	
Chamber press. (surf bar)/T		173 / 10	/	/	
Gas volume (SCF)		25.7			
Oil volume (litres)		2.5			
Oil gravity (API/gm/cc)		46 / 0.79			
Water / Filtrate (litres)		5.5			
Water / Filtrate PPM CL-/K+		76000 / 45000			
Water filtrate pH/pF/Ca++		6.83/ 0 /1400	/ /	/ /	
Mud filtrate PPM CL-/K+		81000 / 66800			
Mud filtrate pH/pF/Ca++		8.0 / .20 / 420	/ /	/ /	
Gas composition % C1		826930			
C2		58424			
C3		29912			
IC4		3715			
NC4		7149			
H2S					
CO2					

Remarks : During sampling of the 2 3/4 gal chamber, resistivities rose from 0.02 to 20 ohmm, thereby indicating sampling of hydrocarbons.

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FORMATION FLUID SAMPLING

Well : 34/8-4A

Rig : Transocean 8

Pretest No. :		Sample Depth : 3326.5m		Witnesses : Waldum / Giskeodegaard	
Run No. : 2B	Sample No. : 2	1st Chamber		2nd Chamber	3rd Chamber
Chamber volume (gals/litres)		2 3/4		1	
Chamber No.		MRSC DA13		MRSC BA13	
Filling time (mins.)		12min		3min	
Shut in press. (bar)/T deg C		467.18 / 85.4		466.85 / 85.4	/
Chamber press. (surf bar)/T		152 / 10		/	/
Gas volume (SCF)		21.5			
Oil volume (litres)		3.5			
Oil gravity (API/gm/cc)		42 / 0.81			
Water / Filtrate (litres)		5.0			
Water / Filtrate PPM CL-/K+		72000 / 45000			
Water filtrate pH/pF/Ca++		7.09/ 0 /1200		/ /	/ /
Mud filtrate PPM CL-/K+		81000 / 66800			
Mud filtrate pH/pF/Ca++		8.0 / .20 /420		/ /	/ /
Gas composition % C1		608355			
C2		155100			
C3		120310			
IC4		16473			
NC4		38943			
H2S					
CO2					

Remarks : No increase in resistivity was observed even though the 2 3/4 gal chamber turned out to contain 3.5 litres of oil.

TEST NO.	1	2	3
PERFORATED INTERVAL	3322.9-3340.9	3214.0-3228.0	3160.6-3184.6
CHOKE SIZE (mm)	14.29	12.70	19.05
OIL/COND. FLOW RATE /Sm ³ /D)	936	35	821
GAS FLOW RATE (Sm ³ /D)	212000	15700	171000
GOR (Sm ³ /Sm ³)	226	448	208
OIL/COND. GRAVITY (g/cc) @ 15°C	0.815	0.802	0.820
GAS GRAVITY (air=1)	0.77	0.81	0.74
FWHP (bar)	231.3	12.0	110.0
WHT (deg C)	85.6	17.3	79.4
BHT (deg C)	118.3	105.1	113.6
BHFP (bar)	431.5	77.4	267.6
BHSIP (bar)	448.9	275.4 (tight)	451.5
BS&W (%)	0	0	0
CO2 (%) (Max)	1.4	1.2	1.2
H2S (ppm) (Max)	<0.1	<0.1	0
Gauge: Geoservices TQ	3279.8	3172.2	3121.0
Halliburton HMR	3274.7	3166.8	3115.7
DEPTH OF BH MEASUREMENTS	m MD RKB	m MD RKB	m MD RKB

TEST NO.	4	5	
PERFORATED INTERVAL	3056.0-3108.0	2988.5-3019.5	
CHOKE SIZE (mm)	12.70	14.29	
OIL/COND. FLOW RATE /Sm ³ /D)	831	992	
GAS FLOW RATE (Sm ³ /D)	181000	225000	
GOR (Sm ³ /Sm ³)	218	227	
OIL/COND. GRAVITY (g/cc) @ 15°C	0.821	0.820	
GAS GRAVITY (air=1)	0.74	0.74	
FWHP (bar)	264.8	257.6	
WHT (deg C)	81.4	86.0	
BHT (deg C)	110.5	109.2	
BHFP (bar)	448.3	437.8	
BHSIP (bar)	450.0	445.4	
BS&W (%)	0	0	
CO2 (%) (Max)	1.2	1.2	
H2S (ppm) (Max)	0.5	0.5	
Gauge: Geoservices TQ Halliburton HMR	3014.8 3009.5	2948.8 2943.5	
DEPTH OF BH MEASUREMENTS	m MD RKB	m MD RKB	m MD RKB

Daily mud properties															Date																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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Date	Mid. depth	Mud : m,MD (SG)	PV : cp	YP : Pa	GEL : Pa	GEL : Pa	100 : psi	HP/HT : C1 : inn/out	Alkalinity : Pf	CaCl : mg/l	Oil : Sol : H2O : %	V.G. meter at 115 gr. F. : 600:300:200:100: 6: 3:Mud																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

Daily mud properties																								Date
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: Mid.: Mud.: PV: YP: GEL: GEL.: 100: HP/HT: Cl-: Alkalinity: : CaCl: : Oil: Sol: H2O: : V.G. meter at 115 gr. F: :																								
: depth: Dens.: : 0: 10: : psi: : inn/out: :																								



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RESERVOIR GEOCHEMISTRY
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WELL: 34/8-4A.

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RESEARCH REPORT

OLJEDIREKTORATET

Summary/Conclusion/Recommendation

Keywords

Petroleum Geochemistry, Reservoir Geochemistry,
Gas and oil correlations.

Pages-appendix 20	Amendment no.	Revision no.	Revision date
Quadrant/Block-well 34/8-4A	Project no. 22379-1-1	Licens no. PL120	Date 29.09.92
Department	Petroleum Geochemistry		
Section	Geosection		
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1. INTRODUCTION.

A list of samples analysed in this study is given in Table 1.2.

Gas analyses were performed by Institute for energiteknikk, Kjeller, Norway. Stable carbon isotope measurements on the fractions of the oils was undertaken by Geolab Nor, Trondheim, Norway. All other analytical work, together with the interpretation of data and the compilation of this report was done at Norsk Hydro Research Centre, Bergen , Norway.

All depths in this report are in mRKB MD.

Table 1.2 List of samples analysed.

HYLAB results SUMMARY : Summary of results in the database

Starting at Result Data for Well 34/8-4A

Page 1

C	Well	Licence	Type	St.Depth	En.Depth	R-Ev	Extr	MPLC	Iatr	SatGC	PyGC	Isot	Biom	Vitr	Visk	Sample
NOR	34/8-4A	PL 120	COCH	2994.50	2994.50	1										-979970531
NOR	34/8-4A	PL 120	COCH	2998.50	2998.50	1	1	1	1	1						-979970432
NOR	34/8-4A	PL 120	COCH	3002.50	3002.50	1										-979970529
NOR	34/8-4A	PL 120	COCH	3003.50	3003.50	1	1		1							-979970528
NOR	34/8-4A	PL 120	COCH	3005.50	3005.50	1										-979970430
NOR	34/8-4A	PL 120	COCH	2988.50	3019.50		1	1	1	1		1				-979972299
NOR	34/8-4A	PL 120	OIL	3065.50	3065.50	1	1	1	1	1						-979970526
NOR	34/8-4A	PL 120	COCH	3070.25	3070.25	1	1	1	1	1						-979970525
NOR	34/8-4A	PL 120	COCH	3071.25	3071.25	1	1	1	1	1						-979970524
NOR	34/8-4A	PL 120	COCH	3077.50	3077.50	1	1	1	1	1						-979970523
NOR	34/8-4A	PL 120	COCH	3081.50	3081.50	1	1	1	1	1						-979970522
NOR	34/8-4A	PL 120	COCH	3088.50	3088.50	1	1	1	1	1						-979970521
NOR	34/8-4A	PL 120	COCH	3091.50	3091.50	1	1	1	1	1						-979970520
NOR	34/8-4A	PL 120	COCH	3097.50	3097.50	1	1	1	1	1						-979970519
NOR	34/8-4A	PL 120	COCH	3104.50	3104.50	1	1	1	1	1						-979970518
NOR	34/8-4A	PL 120	COCH	3108.00	3108.00		1	1	1	1						-979972625
NOR	34/8-4A	PL 120	OIL	3110.75	3110.75	1	1	1	1	1						-979970517
NOR	34/8-4A	PL 120	COCH	3111.50	3111.50	1	1	1	1	1						-979970516
NOR	34/8-4A	PL 120	COCH	3114.25	3114.25	1	1	1	1	1						-979970515
NOR	34/8-4A	PL 120	COCH	3121.25	3121.25	1	1	1	1	1						-979970514
NOR	34/8-4A	PL 120	COCH	3123.50	3123.50	1	1	1	1	1						-979970513
NOR	34/8-4A	PL 120	COCH	3126.50	3126.50	1	1	1	1	1						-979970512
NOR	34/8-4A	PL 120	COCH	3128.00	3128.00	1	1	1	1	1						-979970511
NOR	34/8-4A	PL 120	COCH	3129.50	3129.50	1	1	1	1	1						-979970510
NOR	34/8-4A	PL 120	COCH	3131.25	3131.25	1	1	1	1	1						-979970509
NOR	34/8-4A	PL 120	COCH	3132.50	3132.50	1	1	1	1	1						-979970508
NOR	34/8-4A	PL 120	COCH	3134.50	3134.50	1	1	1	1	1						-979970507
NOR	34/8-4A	PL 120	COCH	3135.25	3135.25	1	1	1	1	1						-979970506
NOR	34/8-4A	PL 120	COCH	3137.25	3137.25	1	1	1	1	1						-979970505
NOR	34/8-4A	PL 120	COCH	3140.50	3140.50	1	1	1	1	1						-979970504
NOR	34/8-4A	PL 120	COCH	3143.50	3143.50	1	1	1	1	1						-979970503
NOR	34/8-4A	PL 120	COCH	3144.50	3144.50	1	1	1	1	1						-979970502
NOR	34/8-4A	PL 120	COCH	3147.75	3147.75	1	1	1	1	1						-979970501
NOR	34/8-4A	PL 120	COCH	3159.25	3159.25	1	1	1	1	1						-979970500
NOR	34/8-4A	PL 120	COCH	3172.50	3172.50	1	1	1	1	1						-979970499
NOR	34/8-4A	PL 120	COCH	3175.50	3175.50	1	1	1	1	1						-979970498
NOR	34/8-4A	PL 120	COCH	3178.50	3178.50	1	1	1	1	1						-979970497
NOR	34/8-4A	PL 120	COCH	3181.50	3181.50	1	1	1	1	1						-979970496
NOR	34/8-4A	PL 120	OIL	3161.00	3185.00		1	1	1	1						-979972300
NOR	34/8-4A	PL 120	COCH	3185.50	3185.50	1	1	1	1	1						-979970495
NOR	34/8-4A	PL 120	COCH	3187.50	3187.50	1	1	1	1	1						-979970494
NOR	34/8-4A	PL 120	COCH	3189.50	3189.50	1	1	1	1	1						-979970493
NOR	34/8-4A	PL 120	COCH	3193.50	3193.50	1	1	1	1	1						-979970492
NOR	34/8-4A	PL 120	COCH	3197.50	3197.50	1	1	1	1	1						-979970491
NOR	34/8-4A	PL 120	COCH	3199.50	3199.50	1	1	1	1	1						-979970490
NOR	34/8-4A	PL 120	COCH	3201.50	3201.50	1	1	1	1	1						-979970489

HYLAB results SUMMARY : Summary of results in the database

Starting at Result Data for Well 34/8-4A

Page 2

C	Well	Licence	Type	St.Depth	En.Depth	R-Ev	Extr	MPLC	Iatr	SatGC	PyGC	Isot	Biom	Vitr	VisK	Sample
NOR	34/8-4A	PL 120	OIL	3214.00	3228.00		1	1	1	1		1				-979972684
NOR	34/8-4A	PL 120	COCH	3248.50	3248.50	1	1	1	1	1						-979970488
NOR	34/8-4A	PL 120	COCH	3252.25	3252.25	1	1	1	1	1						-979970487
NOR	34/8-4A	PL 120	COCH	3255.25	3255.25	1	1	1	1	1						-979970486
NOR	34/8-4A	PL 120	COCH	3329.25	3329.25	1	1	1	1	1						-979970485
NOR	34/8-4A	PL 120	COCH	3337.50	3337.50	1	1	1	1	1						-979970484
NOR	34/8-4A	PL 120	COCH	3340.75	3340.75	1	1	1	1	1						-979970482
NOR	34/8-4A	PL 120	OIL	3324.00	3342.00		1	1	1	1		1				-979972890
NOR	34/8-4A	PL 120	COCH	3342.25	3342.25	1	1		1							-979970481

TABLE: 2.1

RockEval results, reservoir section.

Depth (m)	Lithology	Type	Tmax DegC	S1 kg/t	S2 kg/t	TOC %	HI	PI	Analysing Company
2994.50		COCH		0.	0.	0.	20		F-BERGEN
2998.50		COCH	421	9.	1.	1.	10	0.9	F-BERGEN
3002.50		COCH		0.	0.	0.			F-BERGEN
3003.50		COCH	418	7.	0.	0.	8	0.9	F-BERGEN
3005.50		COCH		0.	0.	0.			F-BERGEN
3065.50		COCH	422	17.	1.	1.	10	0.9	F-BERGEN
3070.25		COCH	418	12.	1.	1.	8	0.9	F-BERGEN
3071.25		COCH		3.	0.	0.	6	0.9	F-BERGEN
3077.50		COCH	418	14.	1.	1.	10	0.9	F-BERGEN
3081.50		COCH	426	13.	0.	1.	7	0.9	F-BERGEN
3088.50		COCH	414	10.	1.	1.	11	0.8	F-BERGEN
3091.50		COCH	423	5.	0.	0.	11	0.9	F-BERGEN
3097.50		COCH	424	9.	1.	1.	12	0.8	F-BERGEN
3104.50		COCH	417	8.	1.	0.	16	0.8	F-BERGEN
3110.75		COCH	408	10.	1.	1.	12	0.8	F-BERGEN
3111.50		COCH	412	14.	1.	1.	11	0.9	F-BERGEN
3114.25		COCH	414	7.	1.	0.	12	0.8	F-BERGEN
3121.25		COCH		0.	0.	0.	72	0.1	F-BERGEN
3123.50		COCH		6.	0.	0.	10	0.9	F-BERGEN
3126.50		COCH		0.	0.	0.	48	0.4	F-BERGEN
3128.00		COCH	418	10.	1.	1.	12	0.8	F-BERGEN
3129.50		COCH	421	2.	0.	0.	22	0.7	F-BERGEN
3131.25		COCH	416	7.	0.	0.	9	0.9	F-BERGEN
3132.50		COCH	423	6.	0.	0.	11	0.8	F-BERGEN
3134.50		COCH	423	7.	1.	0.	15	0.8	F-BERGEN
3135.25		COCH		5.	1.	0.	18	0.8	F-BERGEN
3137.25		COCH	418	4.	0.	0.	11	0.8	F-BERGEN
3140.50		COCH	423	4.	0.	0.	16	0.8	F-BERGEN
3143.50		COCH	420	7.	1.	0.	14	0.8	F-BERGEN
3144.50		COCH	420	12.	1.	1.	15	0.8	F-BERGEN
3147.75		COCH	419	4.	0.	0.	10	0.9	F-BERGEN
3159.25		COCH	414	3.	0.	0.	17	0.8	F-BERGEN
3172.50		COCH	423	6.	0.	0.	13	0.8	F-BERGEN

RockEval results, reservoir section.

TABLE: 2.1

(cont'd)

Depth (m)	Group/Fm.	Lithology	Type	Tmax DegC	S1 kg/t	S2 kg/t	TOC %	HI	PI	Analysing Company
3175.50			COCH	423	8.	1.	0.	13	0.8	F-BERGEN
3178.50			COCH	415	8.	1.	0.	12	0.8	F-BERGEN
3181.50			COCH	420	5.	0.	0.	13	0.8	F-BERGEN
3185.50			COCH	418	3.	0.	0.	7	0.9	F-BERGEN
3187.50			COCH		0.	0.	0.	32	0.2	F-BERGEN
3189.50			COCH		0.	0.	0.	22	0.8	F-BERGEN
3193.50			COCH	422	2.	0.	0.			F-BERGEN
3197.50			COCH		0.	0.	0.	110	0.2	F-BERGEN
3199.50			COCH		0.	0.	0.	120	0.1	F-BERGEN
3201.50			COCH		0.	0.	0.	20		F-BERGEN
3248.50			COCH		0.	0.	0.	3	0.9	F-BERGEN
			COCH		1.	0.	0.			
3252.25			COCH	427	8.	0.	0.	9	0.9	F-BERGEN
3255.25			COCH		1.	0.	0.	6	0.9	F-BERGEN
3329.25			COCH	422	9.	0.	0.	9	0.9	F-BERGEN
3337.50			COCH	416	12.	1.	1.	11	0.9	F-BERGEN
3340.75			COCH	419	1.	0.	0.	6	0.9	F-BERGEN
3342.25			COCH	422	2.	0.	0.	5	0.9	F-BERGEN

DEPTH m	POR	Shre
2994,5	8,1	#VALUE!
2998,5	31,8	8,41
3002,5	6,2	0,00
3003,5	28,1	7,42
3005,5	6,2	0,05
3065,5	26,9	17,79
3070,25	24	15,28
3071,25	9,3	12,28
3077,5	24,9	16,50
3081,5	27,6	13,64
3088,5	26,8	10,77
3091,5	18,9	8,31
3097,5	24,6	11,34
3104,5	24,4	10,20
3110,75	25	12,59
3111,5	28,6	14,03
3114,25	26,6	8,35
3121,25	14,3	0,83
3123,5	19,3	10,19
3126,5	17	0,75
3128	23,1	13,02
3129,5	17,5	5,60
3131,25	20,8	10,14
3132,5		#DIV/0!
3134,5		#DIV/0!
3135,25	23,9	7,39
3137,25	25,3	5,51
3140,5	18,9	8,32
3143,5	23,2	10,08
3144,5	25,2	14,88
3147,75	15	9,78
3159,25	15,2	8,04
3172,5	21,3	9,03
3175,5	21,7	12,56
3178,5	20,2	12,88
3181,5	14,4	11,62
3185,5	12,7	8,32
3187,5	12,1	0,47
3189,5	16,1	6,04
3193,5	2,7	0,00
3197,5	10,7	0,38
3199,5	7,1	0,59
3201,5	8,9	0,13
3248,5	10,6	3,85
3252,25	23,7	10,34
3255,25	8	5,09
3329,25	27,1	9,40
3337,5	26,4	13,49
3340,75	9,3	5,78
3342,25	8,6	10,58

Table 2.2 Porosity and hydrocarbon saturation data.

Table 2.3 Bulk separation data.

Depth (m)	% Lithology	Type	EOM(mg)	EOM(%)	Hydrocarbons			Non Hydrocarbons		
					SAT(%)	ARO(%)	TOTAL(%)	NSO(%)	ASPH(%)	TOTAL(%)
2998.50		COCH	141.8	1.36	74.62	15.28	89.90	9.89	0.21	10.10
3003.50		COCH	99.9	1.00	57.50	33.00	90.50	6.50	1.70	8.20
3065.50		COCH	220.2	1.94	69.52	17.80	87.33	10.17	2.50	12.67
3070.25		COCH	65.9	0.64	60.50	30.50	91.00	6.50	2.50	9.00
3071.25		COCH	55.9	0.56	69.80	17.98	87.78	8.46	3.76	12.22
3077.50		COCH	176.5	1.61	61.50	28.00	89.50	7.00	3.50	10.50
3081.50		COCH	172.9	1.64	70.67	17.32	87.99	9.70	2.31	12.01
3088.50		COCH	104.9	0.89	60.50	24.50	85.00	9.50	5.50	15.00
3091.50		COCH	73.6	0.71	66.69	19.76	86.45	9.88	3.67	13.55
3097.50		COCH	106.9	0.95	58.50	28.00	86.50	8.00	5.50	13.50
3104.50		COCH	104.3	1.04	70.87	14.50	85.37	11.28	3.36	14.63
3110.75		COCH	116.8	1.33	58.00	30.50	88.50	8.00	3.50	11.50
3111.50		COCH	180.0	1.67	68.74	15.78	84.52	14.65	0.83	15.48
3114.25		COCH	113.6	1.03	57.50	26.50	84.00	11.50	4.50	16.00
3123.50		COCH	71.1	0.72	68.32	19.37	87.69	10.20	2.11	12.31
3128.00		COCH	126.2	1.21	59.50	27.50	87.00	11.00	2.00	13.00
3129.50		COCH	40.6	0.39	59.00	31.50	90.50	7.50	2.00	9.50
3131.25		COCH	93.2	0.97	67.31	18.93	86.24	9.47	4.29	13.76

Table 2.3

(cont'd)

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HYDRO

Depth (m)	Group/Fm.	% Lithology	Type	EOM(mg)	EOM(%)	Hydrocarbons			Non Hydrocarbons		
						SAT(%)	ARO(%)	TOTAL(%)	NSO(%)	ASPH(%)	TOTAL(%)
3132.50			COCH	93.4	0.81	58.50	31.50	90.00	8.00	2.00	10.00
3134.50			COCH	85.0	0.88	59.50	30.00	89.50	8.00	2.50	10.50
3135.25			COCH	86.1	0.77	61.00	29.50	90.50	7.00	2.50	9.50
3137.25			COCH	64.6	0.61	58.00	31.00	89.00	8.00	3.00	11.00
3140.50			COCH	80.4	0.69	66.24	19.77	86.01	9.89	4.10	13.99
3143.50			COCH	111.3	0.97	58.00	31.50	89.50	6.50	4.00	10.50
3144.50			COCH	134.9	1.41	59.50	32.00	91.50	6.50	2.00	8.50
3147.75			COCH	68.9	0.63	70.62	17.65	88.27	8.83	2.90	11.73
3159.25			COCH	56.2	0.54	67.78	19.72	87.50	12.32	0.18	12.50
3172.50			COCH	78.0	0.81	65.79	19.30	85.09	9.65	5.26	14.91
3175.50			COCH	108.6	1.03	63.50	24.50	88.00	7.50	4.50	12.00
3178.50			COCH	99.4	0.93	59.50	33.50	93.00	5.00	2.00	7.00
3181.50			COCH	82.3	0.77	61.49	22.04	83.53	13.92	2.55	16.47
3185.50			COCH	46.2	0.46	58.00	33.50	91.50	6.00	2.50	8.50
3189.50			COCH	48.8	0.42	68.19	18.13	86.32	11.22	2.46	13.68
3248.50			COCH	26.7	0.25	71.85	16.77	88.62	8.38	3.00	11.38
3252.25			COCH	86.5	0.82	60.50	33.50	94.00	4.00	2.00	6.00
3255.25			COCH	20.1	0.20	72.81	17.13	89.94	8.57	1.49	10.06
3329.25			COCH	104.5	0.97	68.89	22.96	91.86	7.95	0.19	8.14

Table 2.3

(cont'd)

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Research Centre Bergen

HYDRO

Depth (m)	Group/Fm.	% Lithology	Type	EOM(mg)	EOM(%)	Hydrocarbons			Non Hydrocarbons		
						SAT(%)	ARO(%)	TOTAL(%)	NSO(%)	ASPH(%)	TOTAL(%)
3337.50			COCH	159.0	1.46	61.50	28.50	90.00	7.50	2.50	10.00
3340.75			COCH	29.0	0.27	70.64	17.40	88.04	10.24	1.72	11.96
3342.25			COCH	40.8	0.40	60.50	31.50	92.00	6.00	2.00	.8.00

Table 2.4 Molecular data, saturated hydrocarbons.

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Depth	Group/Fm.	% Lithology	Type	Pristane ----- nC17	Pristane ----- Phytane	CPI-I	CPI-II	nC15+ ----- Total	nC20 ----- nC25
2998.50			COCH	0.71	1.55	1.05	0.99		
3065.50			COCH	0.71	1.54	1.05	0.97		
3071.25			COCH	0.71	1.54	1.06	0.97		
3081.50			COCH	0.71	1.53	1.03	0.95		
3091.50			COCH	0.72	1.41	1.04	0.99		
3104.50			COCH	0.71	1.52	1.05	0.96		
3111.50			COCH	0.72	1.67	1.06	0.99		
3123.50			COCH	0.71	1.55	1.02	0.97		
3131.25			COCH	0.71	1.57	1.07	1.01		
3140.50			COCH	0.72	1.47	1.05	0.99		
3147.75			COCH	0.72	1.64	1.05	0.98		
3159.25			COCH	0.73	1.49	1.02	0.98		
3172.50			COCH	0.72	1.52	1.04	0.95		
3181.50			COCH	0.72	1.56	1.04	0.97		
3189.50			COCH	0.72	1.53	1.06	1.01		
3248.50			COCH	0.69	1.50	1.03	0.96		
3255.25			COCH	0.69	1.40	1.05	0.98		
3329.25			COCH	0.71	1.51	1.06	0.99		

Table 2.4

(cont'd)

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Depth	%	Lithology	Type	Pristane	Pristane	CPI-I	CPI-II	nC15+	nC20
				----- nC17	----- Phytane			----- Total	----- nC25
3340.75			COCH	0.71	1.44	1.03	0.93		

Table 2.5 Biomarker ratios.

WELL	DEPTH	%20S	%abb	Ts/Tm	BNH/C30	25-NOR/C30	DIA/C30
34/8-4A	2998.50	58	58	2.4	0.18	0.05	0.20
34/8-4A	3065.50	54	59	2.2	0.16	0.05	0.21
34/8-4A	3071.25	59	61	2.1	0.18	0.05	0.21
34/8-4A	3081.50	54	59	2.4	0.17	0.05	0.20
34/8-4A	3091.50	58	58	2.1	0.19	0.06	0.22
34/8-4A	3104.50	57	57	2.3	0.19	0.05	0.22
34/8-4A	3111.50	55	58	2.0	0.19	0.05	0.22
34/8-4A	3123.50	56	60	2.4	0.20	0.04	0.24
34/8-4A	3131.25	53	58	2.0	0.19	0.04	0.19
34/8-4A	3140.50	60	57	2.1	0.19	0.05	0.20
34/8-4A	3147.75	58	58	2.3	0.18	0.05	0.21
34/8-4A	3159.25	59	60	2.0	0.22	0.06	0.23
34/8-4A	3172.50	48	56	2.1	0.20	0.05	0.22
34/8-4A	3181.50	58	58	2.2	0.19	0.04	0.21
34/8-4A	3189.50	49	57	2.3	0.18	0.05	0.20
34/8-4A	3248.50	57	59	2.1	0.15	0.04	0.21
34/8-4A	3255.25	54	59	2.0	0.14	0.04	0.23
34/8-4A	3329.25	58	58	2.1	0.19	0.05	0.21
34/8-4A	3340.75	55	56	2.1	0.16	0.06	0.20

Table 3.1 Volume composition, 34/8-4A gases.

Sample	IFE no	C ₁ %	C ₂ %	C ₃ %	iC ₄ %	nC ₄ %	iC ₅ %	nC ₅ %	CO ₂ %	ΣC ₁ -C ₅	Wet- ness	iC ₄ / nC ₄ /
DST 1; 3324-3342 md/RKB	10605	82.5	8.5	5.3	0.60	1.25	0.20	0.23	1.4	98.6	0.16	0.48
DST 2; 3214-3228 md/RKB	10606	77.6	9.4	7.5	0.88	2.48	0.45	0.57	1.2	98.8	0.21	0.36
DST 4; 3056.0 - 3108.0 md/RKB	10687	81.5	9.1	5.5	0.67	1.47	0.03	0.03	1.7	98.3	0.17	0.46
DST 3; 3161 - 3185 md/RKB	10688	80.8	9.5	5.6	-0.69	1.48	0.03	0.04	1.9	98.1	0.18	0.47
DST 5; 2988.5. - 3019.5 md/RKB	10689	81.6	9.3	5.5	0.63	1.38	0.02	0.03	1.5	98.5	0.17	0.46

Table 3.2 Stable isotopes, 34/8-4A gases.

Sample	IFE no	C ₁	C ₁	C ₂	C ₃	iC ₄	nC ₄	CO ₂	CO ₂
		δ ¹³ C	δ D ‰	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹⁸ O
		‰ PDB	SMOW	‰ PDB	‰ PDB	‰ PDB	‰ PDB	‰ PDB	‰ PDB
DST 1; 3324-3342 md/RKB	10605	-43.3	-181	-30.8	-28.7	-25.6	-29.0	-15.6	-12.6
DST 2; 3214-3228 md/RKB	10606	-42.9	-183	-31.1	-29.1	-25.9	-28.4	-16.6	-14.7
DST 4; 3056.0 - 3108.0 md/RKB	10687	-42.6	-180	-31.1	-29.0	-25.3	-28.9	-15.2	-6.5
DST 3; 3161 - 3185 md/RKB	10688	-42.7	-183	-31.1	-29.1	-25.2	-28.9	-18.2	-12.8
DST 5; 2988.5. - 3019.5 md/RKB	10689	-42.6	-171	-31.0	-29.0	-25.8	-29.0	-15.1	-13.5



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Table 3.3 Volume composition, Visund gases.

Sample	Depth		Methane	Ethane	Propane	Butane		$C_2 + 100 - C_1$	$\frac{iC_4}{nC_4}$	$\frac{C_1}{C_{2+}}$	$\Sigma C_1 - C_4$	Wet-ness	$CO_2 \%$
			$C_1 \%$	$C_2 \%$	$C_3 \%$	$iC_4 \%$	$nC_4 \%$		nC_4	C_{2+}			
34/8-1, #2	2854.1-57.1		88.4	5.8	2.9	0.45	0.95	11.6	0.47	8.75	98.2	0.10	1.4
34/8-1, #3	2767.9-2806.9		89.4	5.3	2.7	0.40	0.95	10.6	0.42	9.56	98.7	0.09	1.3
34/8-3, #1	2935.0-47.05		85.7	7.9	2.7	0.41	0.89	14.3	0.46	7.20	98.0	0.12	2.0
34/8-3, #2	2905.0-21.0		89.0	5.5	2.5	0.41	0.93	11.0	0.44	9.52	98.8	0.10	1.2
34/8-3, #3	2868.0-80.0		87.1	6.8	2.4	0.38	0.89	12.9	0.43	8.32	98.0	0.11	2.0
34/8-4S, #1	3219-41		78.1	9.7	6.6	0.94	2.0	21.9	0.46	3.58	97.4	0.21	1.6
34/8-4S, #3	3001-18		74.6	10.8	7.9	1.2	2.6	25.4	0.45	2.94	97.1	0.24	1.7
34/8-4S, #4	2903-17		83.2	7.2	4.6	0.72	1.6	16.8	0.44	4.95	97.3	0.15	1.8

Sample	Depth		Methane	Ethane	Propane	Butane		$C_2 + 100 - C_1$	$\frac{iC_4}{nC_4}$	$\frac{C_1}{C_{2+}}$	$\Sigma C_1 - C_4$	Wet-ness	$CO_2 \%$
			$C_1 \%$	$C_2 \%$	$C_3 \%$	$iC_4 \%$	$nC_4 \%$		nC_4	C_{2+}			
34/8-4A #1	3324 - 3342		82.5	8.5	5.3	0.60	1.25	17.5	0.48	4.71	98.2	0.16	1.4
34/8-4A #2	3214 - 3228		77.6	9.4	7.5	0.88	2.48	22.4	0.36	3.46	97.3	0.21	1.2
34/8-4A #3	3161 - 3185		80.8	9.5	5.6	0.69	1.48	19.2	0.47	4.21	98.1	0.18	1.9
34/8-4A #4	3056 - 3108		81.5	9.1	5.5	0.67	1.47	18.5	0.46	4.41	98.2	0.17	1.7
34/8-4A #5	2988.5-3019.5		81.6	9.3	5.5	0.63	1.38	18.4	0.46	4.43	98.4	0.17	1.5

Table 3.4 Stable isotopes, Visund gases.

Sample	Depth		Methane $\delta o/oo$	Ethane $\delta o/oo$	Propane $\delta o/oo$	Butane		D $\delta o/oo$	CO ₂	
						$\delta o/oo$ iC ₄	$\delta o/oo$ nC ₄		$\delta o/oo$ ¹³ C	$\delta o/oo$ ¹⁸ O
34/8-1, #2	2854.1-57.1		-39.2	-30.5	-29.0	-29.1	-29.2	-170	-14.0	-12.7
34/8-1, #3	2767.9-2806.9		-41.5	-30.7	-29.4	-29.1	-29.2	-160	-14.8	-13.9
34/8-3, #1	2935.0-47.0		-39.4	-30.3	-28.0	-22.9	-25.6	-158	- 9.4	- 9.8
34/8-3, #2	2905.0-21.0		-39.5	-30.1	-28.0	-25.9	-25.8	-169	-14.9	-10.8
34/8-3, #3	2868.0-80.0		-39.5	-30.2	-28.3	-24.6	-26.2	-167	- 8.2	-12.0
34/8-4S, #1	3219 - 41		-43.2	-29.0	-24.3	-28.4	-27.8	-177	-18.8	- 4.7
34/8-4S, #3	3001 - 18		-43.4	-30.7	-27.9	-28.4	-26.4	-175	-16.6	- 9.7
34/8-4S, #4	2903 - 17		-40.9	-31.0	-28.5	-28.4	-29.4	-164	-16.1	-10.3
34/8-4A #1	3324 - 3342		-43.3	-30.8	-28.7	-25.6	-29.0	-181	-15.6	-12.6
34/8-4A #2	3214 - 3228		-42.9	-31.1	-29.1	-25.9	-28.4	-183	-16.6	-14.7
34/8-4A #3	3161 - 3185		-42.7	-31.1	-29.1	-25.2	-28.9	-183	-18.2	-12.8
34/8-4A #4	3056 - 3108		-42.6	-31.1	-29.0	-25.3	-28.9	-180	-15.2	- 6.5
34/8-4A #5	2988.5-3019.5		-42.6	-31.0	-29.0	-25.8	-29.0	-171	-15.1	-13.5

Table 4.1 Bulk composition data, 34/8-4A oils.

Depth (m)	Group/Fm.	% Lithology	Type	EOM(mg)	EOM(%)	Hydrocarbons			Non Hydrocarbons		
						SAT(%)	ARO(%)	TOTAL(%)	NSO(%)	ASPH(%)	TOTAL(%)
3019.50			OIL			62.40	26.50	88.90	6.60	4.50	11.10
3108.00			OIL			62.50	27.30	89.80	5.50	4.70	10.20
3185.00			OIL			62.60	29.60	92.20	3.50	4.30	7.80
3228.00			OIL			65.50	27.00	92.50	3.70	3.80	7.50
3342.00			OIL			60.40	29.00	89.40	5.60	5.00	10.60

Table 4.2 Molecular ratios, 34/8-4A oils.

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HYDRO

Depth	Group/Fm.	% Lithology	Type	<u>Pristane</u> ----- nC17	<u>Pristane</u> ----- Phytane	CPI-I	CPI-II	<u>nC15+</u> ----- Total	<u>nC20</u> ----- nC25
3019.50			OIL	0.74	1.69	1.07	0.92		
3108.00			OIL	0.75	1.63	1.14	1.07		
3185.00			OIL	0.75	1.59	1.06	1.02		
3228.00			OIL	0.73	1.61	1.05	0.96		
3342.00			OIL	0.74	1.60	1.08	0.98		

Table 4.3 Biomarker ratios, 34/8-4A oils.

	TEST	%20S	%abb	Ts/Tm	BNH/C30	25-NOR/C30	DIA/C30
34/8-4A	DST5	0.58	0.58	1.7	0.18	0.04	0.21
34/8-4A	DST4	0.60	0.58	1.8	0.17	0.03	0.21
34/8-4A	DST3	0.53	0.56	2.0	0.18	0.04	0.20
34/8-4A	DST2	0.59	0.61	1.7	0.15	0.04	0.23
34/8-4A	DST1	0.56	0.58	1.7	0.16	0.04	0.22

Table 4.4 Stable carbon isotope data, 34/8-4A oils.

Well	Type	St.Depth	En.Depth	Oil	Extr	Sat	Aro	NSO	Asph
34/8-4A	OIL	2988.50	3019.50			-29.70	-28.38	-27.79	
34/8-4A	OIL	3056.00	3108.00			-29.69	-28.23	-27.99	
34/8-4A	OIL	3161.00	3185.00			-29.40	-28.04	-27.78	
34/8-4A	OIL	3214.00	3228.00			-29.54	-28.23	-28.18	
34/8-4A	OIL	3324.00	3342.00			-29.59	-28.45	-28.29	

Table 4.5 SATURATED FRACTION MOLECULAR RATIOS WELL 34/8-1

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HYDRO

Depth	%	Lithology	Type	<u>Pristane</u> nC17	<u>Pristane</u> Phytane	CPI-I	CPI-II	<u>nC15+</u> Total	<u>nC20</u> nC25
2806.90		2749.8-2788.	OIL	0.70	1.74	1.10	0.95		
2857.11		2834.1-2857.	OIL	0.64	1.64	1.10	0.95		

Table 4.5 SATURATED FRACTION MOLECULAR RATIOS WELL 34/8-3

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Depth	% Lithology	Type	<u>Pristane</u> ----- nC17	<u>Pristane</u> ----- Phytane	CPI-I	CPI-II	<u>nC15+</u> ----- Total	<u>nC20</u> ----- nC25
2880.00		OIL	0.59	1.82	1.05	0.91		
2921.00		OIL	0.58	1.80	1.03	0.92		
2936.00		OIL	0.55	1.46	1.08	0.94		
2947.00		OIL	0.56	1.54	1.13	0.98		

Table 4.5 SATURATED FRACTION MOLECULAR RATIOS WELL 34/8-3A

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HYDRO

Depth	Group/Fm.	%	Lithology	Type	<u>Pristane</u> nC17	<u>Pristane</u> Phytane	CPI-I	CPI-II	<u>nC15+</u> Total	<u>nC20</u> nC25
3093.00				OIL	0.55	1.41	1.17	0.96		
3093.00		-3078.6-3081		OIL	0.53	1.54	1.02	0.95		

Table 4.5 SATURATED FRACTION MOLECULAR RATIOS WELL 34/8-4A

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Depth	% Lithology	Type	Pristane	Pristane	CPI-I	CPI-II	nC15+	nC20
			----- nC17	----- Phytane			----- Total	----- nC25
3019.50		OIL	0.74	1.69	1.07	0.92		
3108.00		OIL	0.75	1.63	1.14	1.07		
3185.00		OIL	0.75	1.59	1.06	1.02		
3228.00		OIL	0.73	1.61	1.05	0.96		
3342.00		OIL	0.74	1.60	1.08	0.98		

Table 4.5 SATURATED FRACTION MOLECULAR RATIOS WELL 34/8-4S

Petroleum Geochemistry Group
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HYDRO

Depth	% Lithology	Type	Pristane ----- nC17	Pristane ----- Phytane	CPI-I	CPI-II	nC15+ ----- Total	nC20 ----- nC25
2917.00		OIL	0.73	1.63	1.05	0.95		
3017.00		OIL	0.70	1.68	1.05	0.94		
3142.00		OIL	0.67	1.82	1.07	0.97		
3242.00		OIL	0.65	1.67	1.05	0.95		

Table 4.6 Biomarker ratios, Visund oils.

	TEST	%20S	%abb	Ts/Tm	BNH/C30	25-NOR/C30	DIA/C30
34/8-4A	DST5	0.58	0.58	1.7	0.18	0.04	0.21
34/8-4A	DST4	0.60	0.58	1.8	0.17	0.03	0.21
34/8-4A	DST3	0.53	0.56	2.0	0.18	0.04	0.20
34/8-4A	DST2	0.59	0.61	1.7	0.15	0.04	0.23
34/8-4A	DST1	0.56	0.58	1.7	0.16	0.04	0.22
34/8-4S	DST3	0.51	0.64	2.5	0.16	0.06	0.32
34/8-3	RFT2	0.45	0.64	2.4	0.09	0.04	0.24
34/8-3A	DST1A	0.45	0.65	2.3	0.07	0.05	0.25
34/8-1	DST2	0.47	0.63	2.7	0.11	0.06	0.23

Well	Type	St.Depth	En.Depth	Oil	Extr	Sat	Aro	NSO	Asph
34/8-1	OIL	2767.90	2806.90	-29.53		-28.35	-27.53	-29.30	
34/8-1	OIL	2854.10	2857.11	-29.30		-29.69	-28.73	-28.73	-28.28
34/8-3	OIL	2935.00	2947.00	-29.12		-29.50	-28.65	-28.14	-28.74
34/8-3A	OIL	3087.00	3093.00	-28.75		-29.13	-28.06	-27.13	-27.04
34/8-4A	OIL	2988.50	3019.50			-29.70	-28.38	-27.79	
34/8-4A	OIL	3056.00	3108.00			-29.69	-28.23	-27.99	
34/8-4A	OIL	3161.00	3185.00			-29.40	-28.04	-27.78	
34/8-4A	OIL	3214.00	3228.00			-29.54	-28.23	-28.18	
34/8-4A	OIL	3324.00	3342.00			-29.59	-28.45	-28.29	
34/8-4S	OIL	2903.00	2917.00	-28.69		-28.89	-26.83		
34/8-4S	OIL	3000.00	3017.00	-29.08		-29.34	-27.96		
34/8-4S	OIL	3132.00	3142.00	-28.96		-29.26	-27.86		
34/8-4S	OIL	3220.00	3242.00	-28.73		-29.27	-27.75		

Table 4.7 Stable carbon isotope data, Visund oils.

APPENDIX IV

Report on stable isotopes ($\delta^{13}\text{C}$, δD)
on gas samples from well 34/8-4A.

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	REPORT TITLE REPORT ON STABLE ISOTOPES ($\delta^{13}\text{C}$, δD) ON GAS SAMPLES FROM WELL 34/8-4A.		DATE OF LAST REV.	
			REV. NO.	
	CLIENT Norsk Hydro a.s.		NUMBER OF PAGES 7	
	CLIENT REF. Bestilling nr. F 11371/F 11373, Best. no. 32217		NUMBER OF ISSUES 15	
SUMMARY The gas components C_1 - C_5 and CO_2 have been separated from five gas samples from well 34/8-4A; DST 1, 3324 - 3342 md/RKB; DST 2, 3214 - 3228 md/RKB; DST 4, 3056.0 - 3108.0 md/RKB; DST 3, 3161 - 3185 md/RKB; DST 5, 2988.5 - 3019.5 md/RKB. The $\delta^{13}\text{C}$ values of methane, ethane, propane, the butanes and CO_2 have been determined. The hydrogen isotopic composition of methane has also been determined.			DISTRIBUTION Norsk Hydro a.s. (10) Andresen, B. Råheim, A. Throndsen, T. File (2)	
KEYWORDS				
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1 INTRODUCTION

Five gas samples from well 34/8 - 4A; DST 1, 3324 - 3342 md/RKB; DST 2, 3214 - 3228 md/RKB; DST 4, 3056.0 - 3108.0 md/RKB; DST 3, 3161 - 3185 md/RKB; DST 5, 2988.5 - 3019.5 md/RKB, were received and analysed May/June 1992.

On the samples C_1 - C_5 and CO_2 are quantified. The $\delta^{13}C$ value is measured on methane, ethane, propane, the butanes and CO_2 . In addition the δD value is measured on methane.

2 ANALYTICAL PROCEDURE

The natural gas samples have been quantified and separated into the different gas components by a Carlo Erba 4200 gas chromatograph.

The hydrocarbon gas components were oxidised in separate CuO-ovens in order to prevent cross contamination. The combustion products CO_2 and H_2O were frozen into collection vessels and separated.

The combustion water was reduced with zinc metal in a sealed quartz tube to prepare hydrogen for isotopic analysis. The isotopic measurements were performed on a Finnigan MAT 251 and Finnigan Delta mass spectrometer.

IFEs value on NBS 22 is $29.77 \pm .06\text{‰}$ PDB.

3 RESULTS

The volume composition of the gas samples is given in Table 1. The results have been normalised to 100%. The stable isotope results are given in Table 2.

The uncertainty on the $\delta^{13}C$ value is estimated to be $\pm 0.3\text{‰}$ PDB and includes all the different analytical steps. The uncertainty in the δD value is likewise estimated to be $\pm 5\text{‰}$.

Table 1: Volume composition of gas samples from well 34/8-4A.

Sample	IFE no	C ₁ %	C ₂ %	C ₃ %	iC ₄ %	nC ₄ %	iC ₅ %	nC ₅ %	CO ₂ %	ΣC ₁ -C ₅	Wet- ness	iC ₄ / nC ₄ /
DST 1; 3324-3342 md/RKB	10605	82.5	8.5	5.3	0.60	1.25	0.20	0.23	1.4	98.6	0.16	0.48
DST 2; 3214-3228 md/RKB	10606	77.6	9.4	7.5	0.88	2.48	0.45	0.57	1.2	98.8	0.21	0.36
DST 4; 3056.0 - 3108.0 md/RKB	10687	81.5	9.1	5.5	0.67	1.47	0.03	0.03	1.7	98.3	0.17	0.46
DST 3; 3161 - 3185 md/RKB	10688	80.8	9.5	5.6	0.69	1.48	0.03	0.04	1.9	98.1	0.18	0.47
DST 5; 2988.5. - 3019.5 md/RKB	10689	81.6	9.3	5.5	0.63	1.38	0.02	0.03	1.5	98.5	0.17	0.46

Table 2: Isotopic composition of gas samples from well 34/8-4A.

Sample	IFE no	C ₁	C ₁	C ₂	C ₃	iC ₄	nC ₄	CO ₂	CO ₂
		δ ¹³ C	δ D ‰	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹³ C	δ ¹⁸ O
		‰ PDB	SMOW	‰ PDB	‰ PDB	‰ PDB	‰ PDB	‰ PDB	‰ PDB
DST 1; 3324-3342 md/RKB	10605	-43.3	-181	-30.8	-28.7	-25.6	-29.0	-15.6	-12.6
DST 2; 3214-3228 md/RKB	10606	-42.9	-183	-31.1	-29.1	-25.9	-28.4	-16.6	-14.7
DST 4; 3056.0 - 3108.0 md/RKB	10687	-42.6	-180	-31.1	-29.0	-25.3	-28.9	-15.2	-6.5
DST 3; 3161 - 3185 md/RKB	10688	-42.7	-183	-31.1	-29.1	-25.2	-28.9	-18.2	-12.8
DST 5; 2988.5. - 3019.5 md/RKB	10689	-42.6	-171	-31.0	-29.0	-25.8	-29.0	-15.1	-13.5

APPENDIX IX

Data report.

Isotope analysis for well 34/8-4A.

(Geolab Nor)

REPORT:

DATA REPORT
Isotope Analysis for Well 34/8-7
and 34/8-4A

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**RESPONSIBLE
SCIENTIST:**

Rita P. Moe

**RESPONSIBLE
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Trine Øyås

DATE: 10/9-92

GEOLAB PROJECT: 526263

CLIENTS REF.: FB25552/FB25551

EXPERIMENTAL

Isotope Ratio Mass Spectrometry

The isotope analysis were performed on a dual inlet VG SIRA 10 instrument. The combustion of the samples were done by a Carlo Erba EA 1108 element analyser directly connected to the inlet system of the mass spectrometer.

The combustion temperature was 1020°C and the carries gas used was Helium. After the combustion H₂O and CO₂ were trapped in different cool traps. The CO₂ gas was then heated up before it was admitted to the mass spectrometer. The whole operation was controlled by a IBM PC50 computer system.

δ-values

The isotope ratios are given as δ-values in ‰ versus the PDB-standard:

$$\delta^{13}\text{C} = (R_{\text{sample}} - R_{\text{standard}} / R_{\text{standard}}) * 1000$$

$$R = {}^{13}\text{C} / {}^{12}\text{C}$$

The PDB standard (a marine chalk of the Pee Dee-formation, USA) was created by Craig 1957. All results of ${}^{13}\text{C} / {}^{12}\text{C}$ - analysis of organic matter today are calculated (Craig correction) against this international standard.

Reproduceability

The presision of the combustion system and the mass spectrometer is controlled by determinations of an international calibrated standard, NBS22 oil and a house standard of carbon.

Double analysis on samples are also done.

Table 2A: Tabulation of carbon isotope data for EOM/EOM - fractions for well NOCS 34/8-4A

Page: 1

<u>Sample</u>	<u>EOM</u>	<u>Saturated</u>	<u>Aromatic</u>	<u>NSO</u>	<u>Asphaltenes</u>	<u>Kerogen</u>	<u>Sample</u>
DST 1	-	-29.59	-28.45	-28.29	-	-	0006-0
DST 2	-	-29.54	-28.23	-28.18	-	-	0007-0
DST 3	-	-29.40	-28.04	-27.78	-	-	0008-0
DST 4	-	-29.69	-28.23	-27.99	-	-	0009-0
DST 5	-	-29.70	-28.38	-27.79	-	-	0010-0

Table 2B: Tabulation of cv values from carbon isotope data for well NOCS 34/8-4A

<u>Sample</u>	<u>Saturated</u>	<u>Aromatic</u>	<u>cv value</u>	<u>Sample</u>
DST 1	-29.59	-28.45	0.05	0006-0
DST 2	-29.54	-28.23	0.42	0007-0
DST 3	-29.40	-28.04	0.48	0008-0
DST 4	-29.69	-28.23	0.80	0009-0
DST 5	-29 70	-28.38	0.49	0010-0



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1. INTRODUCTION

Vitrinite Reflectance measurements were performed by GeoOptics, Newcastle, UK, and Spore Colouration Index, and kerogen typing undertaken by Simon-Robertson, Llandudno, UK, with their own report enclosed (see App. II).

Interpretation of data and compilation of this report was done by Norsk Hydro Research Centre, Bergen, Norway.

2. THERMAL MATURITY

The thermal maturity of Well 34/8-4A has been established using Vitrinite Reflectance ($\%R_o$) and Spore Colouration Index (SCI) in drill-cuttings.

The analysed range is from Upper Cretaceous (2894m) down to TD (3567m) in Triassic.

The results of the average vitrinite reflectance measurements are listed in Table 2.1. Figure 2.1 is showing these values plotted against depth. The individual readings are shown in App. I.

Table 2.1 VITRINITE REFLECTANCE DATA WELL 34/8-4A
Average values

Petroleum Geochemistry Group
Research Centre Bergen



Depth	Group/Fm.	%	Lithology	Type	Population I	Population II	Population III	SCI
2190.00		100	CMT	DC				
2240.00		100	SH	DC	0.48 (2)			
2290.00		100	SH	DC	0.52 (6)			
2340.00		100	SH	DC	0.49 (2)			
2390.00		100	SH	DC	0.48 (3)			
2440.00		100	SH	DC	0.50 (3)			
2500.00		100	SLTY.SH	DC	0.55 (10)			
2550.00		100	SH	DC	0.51 (6)			
2600.00		100	SLTY.SH	DC	0.55 (20)			
2650.00		100	SLTY.SH	DC	0.49 (14)			
2700.00		100	SH	DC	0.52 (4)			
2750.00		100	SH	DC	0.49 (2)			
2800.00		100	SH	DC	0.57 (5)			
2850.00		100	SH	DC	0.58 (5)			
2900.00		60	SH	DC	0.57 (11)			
2950.00		100	SH	DC	0.54 (20)			
2995.00		100	SLST	DC	0.49 (10)			
3050.00		90	SST	DC	0.49 (14)			

Table 2.1 VITRINITE REFLECTANCE DATA WELL 34/8-4A (cont'd)
Average values

Depth	Group/Fm.	%	Lithology	Type	Population I	Population II	Population III	SCI
3097.00		90	SST	DC	0.47 (20)			
3157.00		100	SST	DC	0.51 (13)			
3202.00		90	SST	DC	0.53 (5)			
3250.00		80	SST	DC	0.49 (4)			
3300.00		100	SLTY.SH	DC				
3350.00		70	SST	DC	0.52 (7)			
3400.00		100	SLTY.SH	DC				
3450.00		90	SH	DC	0.47 (1)	0.63 (4)		
3500.00		100	SH	DC				
3567.00		100	SH	DC				

TABLE 2.2

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

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
2190	Ctgs	No liths available	2.5 5.0 R		15	20	65				
2240	Ctgs	No liths available	3.0 6.0 R		15	65	20				
2290	Ctgs	No liths available	3.0 5.5 R		5	90	5				
2340	Ctgs	No liths available	3.5 6.0 R		5	95	Mnr				
2390	Ctgs	No liths available	4.0 6.5 R		20	75	5				
2440	Ctgs	No liths available	4.5 7.0 R		10	85	5				
2500	Ctgs	No liths available	4.0 6.0 R		20	75	5				
2550	Ctgs	No liths available	4.0 6.0 R		10	80	10				
2600	Ctgs	No liths available	3.5 6.5 R		10	85	5				
2650	Ctgs	No liths available	4.5 R		5	75	20				
2700	Ctgs	No liths available	5.0 7.0 R		5	95	Mnr				
2750	Ctgs	No liths available	4.0 6.5 R		5	90	5				
2800	Ctgs	No liths available	4.5		5	90	5				
2850	Ctgs	No liths available	4.0 7.0 R		5	95	Mnr				
2900	Ctgs	No liths available	4.0 6.5 R		10	85	5				
2950	Ctgs	No liths available	4.0 6.5 R		5	70	25				
2995	Ctgs	No liths available	4.0		10	70	20				
3050	Ctgs	No liths available	4.0		10	65	25				
3097	Ctgs	No liths available	4.0 6.0 R		10	50	40				
3157	Ctgs	No liths available	4.0 6.0 R		10	80	10				
3202	Ctgs	No liths available	4.5		25	45	30				
3250	Ctgs	No liths available	4.0		10	70	20				
3300	Ctgs	No liths available	4.0		15	80	5				
3350	Ctgs	No liths available	4.5 6.5 R		15	75	10				

MATURITY AND KEROGEN COMPOSITION DATA

TABLE 2.2

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

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
3400	Ctgs	No liths available	4.5 7.0 R		5	60	35				
3450	Ctgs	No liths available	5.0		5	80	15				
3500	Ctgs	No liths available	4.5 2.5 C 6.5 R		10	70	20				
3567	Ctgs	No liths available	5.0 3.5 C 7.0 R		35	25	40				

MATURITY AND KEROGEN COMPOSITION DATA

A P P E N D I X I I

SIMON-ROBERTSON

REPORT NO. 7136/Ic

SPORE COLOURATION AND KEROGEN TYPING STUDY OF THE NORSK HYDRO 34/8-4A WELL, INTERVAL 2190m TO 3567m, NORWEGIAN SECTOR, NORTH SEA

by

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JUNE 1992

2 INTRODUCTION

This report presents the results of spore colouration and visual kerogen typing studies carried out on 28 well cuttings samples from the interval 2190m to 3567m in the 34/8-4A well, Norwegian North-Sea.

Clean and dried cuttings samples from Norsk Hydro arrived at Simon-Robertson's North Wales laboratories on 30 March 1992. In accordance with Norsk Hydro's request for a three week turnaround, preliminary results were sent by facsimile message to Lotte Aakvaag, our contact at Norsk Hydro for this project, on 21 April 1992. The work programme followed for this study was detailed in Simon-Robertson's proposal number Ic/91/058 of 18 November 1991, and the study was carried out under the authority of Norsk Hydro's purchase order number NHO 577984 of 27 March 1992.

Simon-Robertson personnel involved in this study were:

C Darlington, A G Collins	-	Project advice		
R Harding	-	Microscopy,	interpretation	and report
		preparation		
K Oakley	-	Supervision of kerogen preparation.		

The numbers of analyses performed were as follows:

Kerogen isolation and slide preparation	:	28
Spore colouration	:	28
Kerogen typing	:	28

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

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
2190	Ctgs	No liths available	2.5 5.0 R		15	20	65				
2240	Ctgs	No liths available	3.0 6.0 R		15	65	20				
2290	Ctgs	No liths available	3.0 5.5 R		5	90	5				
2340	Ctgs	No liths available	3.5 6.0 R		5	95	Mnr				
2390	Ctgs	No liths available	4.0 6.5 R		20	75	5				
2440	Ctgs	No liths available	4.5 R 7.0 R		10	85	5				
2500	Ctgs	No liths available	4.0 6.0 R		20	75	5				
2550	Ctgs	No liths available	4.0 6.0 R		10	80	10				
2600	Ctgs	No liths available	3.5 6.5 R		10	85	5				
2650	Ctgs	No liths available	4.5 R		5	75	20				
2700	Ctgs	No liths available	5.0 R 7.0 R		5	95	Mnr				
2750	Ctgs	No liths available	4.0 6.5 R		5	90	5				
2800	Ctgs	No liths available	4.5		5	90	5				
2850	Ctgs	No liths available	4.0 7.0 R		5	95	Mnr				
2900	Ctgs	No liths available	4.0 6.5 R		10	85	5				
2950	Ctgs	No liths available	4.0 6.5 R		5	70	25				
2995	Ctgs	No liths available	4.0		10	70	20				
3050	Ctgs	No liths available	4.0		10	65	25				
3097	Ctgs	No liths available	4.0 6.0 R		10	50	40				
3157	Ctgs	No liths available	4.0 6.0 R		10	80	10				
3202	Ctgs	No liths available	4.5		25	45	30				
3250	Ctgs	No liths available	4.0		10	70	20				
3300	Ctgs	No liths available	4.0		15	80	5				
3350	Ctgs	No liths available	4.5 6.5 R		15	75	10				

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 1A

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

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
3400	Ctgs	No liths available	4.5 7.0 R		5	60	35				
3450	Ctgs	No liths available	5.0		5	80	15				
3500	Ctgs	No liths available	4.5 2.5 C 6.5 R		10	70	20				
3567	Ctgs	No liths available	5.0 3.5 C 7.0 R		35	25	40				

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 1B

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

DEPTH (m)	SCI	KEROGEN TYPE				
		INERTINITE	VITRINITE (STRUCT.)	AMORPHOUS (NON-FLUOR.)	AMORPHOUS (FLUOR.)	LIPTINITE (STRUCT.)
2190	2.5 5.0R	15	10	10	30	35Di, Sp
2240	3.0 6.0R	15	10	55	10	10Di, Sp
2290	3.0 5.5R	5	10	80	5	trDi, Sp
2340	3.5 6.0R	5	20	75	0	Mnr Di, Sp
2390	4.0R 6.5R	20	20	55	0	5Di, Sp
2440	4.5R 7.0R	20	20	55	0	5Di, Sp
2500	4.0 6.0R	10	20	65	0	5Di, Sp
2550	4.0 6.0R	10	10	70	10	MnrDi, Sp
2600	3.5 6.5R	10	10	75	5	MnrDi, Sp
2650	4.5R	5	10	65	15	5Di, Sp
2700	5.0R 7.0R	5	10	85	0	Mnr, Di, Sp
2750	4.0 6.5R	5	10	80	Mnr	5Di, Sp
2800	4.5	5	10	80	Tr.	5Di, Sp

Di - dinoflagellates
 Sp - spores and pollen
 Al - algal debris
 Rs - resin or drilling contaminant

DETAILED KEROGEN TYPING DATA

TABLE 2A

COMPANY: NORSK HYDRO

WELL: 34/8-4A

LOCATION: NORWEGIAN NORTH SEA

DEPTH (m)	SCI	KEROGEN TYPE				
		INERTINITE	VITRINITE (STRUCT.)	AMORPHOUS (NON-FLUOR.)	AMORPHOUS (FLUOR.)	LIPTINITE (STRUCT.)
2850	4.0 7.0R	5	5	90	0	Mnr Di, Sp
2900	4.0 6.5R	10	5	80	5	Mnr Di, Sp
2950	4.0 6.5R	5	10	60	20	5 Di, Sp
2995	4.0	10	10	60	10	10 Sp, Di
3050	4.0	10	20	45	10	15 Sp, Di
3097	4.0 6.0R	10	10	40	30	10 Sp, Di
3157	4.0 6.0R	10	5	75	0	10 Sp, Di
3202	4.5	25	10	35	15	15 Sp, Di
3250	4.0	10	10	60	5	15 Sp, Di
3300	4.0	5	Mnr	80	10	5 Sp, Di
3350	4.5 6.5R	15	10	65	Mnr	10 Sp, Di
3400	4.5 7.0R	5	10	50	20	15 Sp, Di
3450	5.0	5	5	75	10	5 Sp, Di
3500	4.5 2.5C 6.5R	10	5	65	10	10 Sp, Di
3567	5.0 3.5C 7.0R	35	15	10	0	40Rs, Sp, Di

Di - dinoflagellates
 Sp - spores and pollen
 Al - algal debris
 Rs - resin or drilling contaminant

DETAILED KEROGEN TYPING DATA

TABLE 2B

APPENDIX 1
ABBREVIATIONS USED IN ANALYTICAL DATA SHEETS

a/a	-	as above	MDST	-	mudstone
Ac	-	acritarchs	med	-	medium
ADD	-	mud additive	MET	-	metamorphic rocks
Al	-	algae	mic	-	mica/micaceous
Am	-	amorphous	micr	-	micritic
ang	-	angular	min	-	mineral
ANH	-	anhydrite	mnr	-	minor
aren	-	arenaceous	mod	-	moderate
arg	-	argillaceous	mtl	-	mottled
BAS	-	basalt	n-	-	normal
bd	-	bedded/bedding	NA	-	not available
B(IT)	-	bitumen/bituminous	nod	-	nodule/nodular
bl	-	blue	NS	-	no sample
bld	-	bleached	occ	-	occasional
blk	-	black	ol	-	olive
bri	-	brilliant	ool	-	oolitic
brn	-	brown	orng	-	orange
calc	-	calcareous	OS	-	oil stain
CALT	-	calcite	P	-	picked lithology
carb	-	carbonaceous	pal	-	pale
CGL	-	conglomerate	Ph	-	phytane
CHK	-	chalk	pnk	-	pink
CHT	-	chert	por	-	porous/porosity
CLST	-	claystone	pp	-	purple
cmnt	-	cement	Pr	-	pristane
Comp	-	composite	pred	-	predominantly
crs	-	coarse	Prt	-	present
CSG	-	casing point/shoe	PYR/pyr	-	pyrite/pyritic
Ctgs	-	ditch cuttings	QTZ(T)	-	quartz(ite)
Cu	-	cuticle	Re	-	resin
C(vd)	-	caved	R(ew)	-	reworked
decarb	-	decarbonated	rnd	-	round(ed)
Di	-	dinocysts	Sap	-	sapropel
dk	-	dark	sbng	-	subangular
DLT	-	dolerite	sbrd	-	subrounded
DOL/dol	-	dolomite/dolomitic	SCI	-	spore colour index
dsk	-	dusky	Sf	-	semifusinite
Ex	-	exinite	sft	-	soft
Exs	-	exsudatinite	SH	-	shale
extr	-	extracted	shly	-	shaly
f	-	fine	sil	-	siliceous
fel	-	feldspathic	sks	-	slickenside surface
fer	-	ferruginous	SLA	-	slate
flu	-	fluorescence	SLT(ST)	-	silt(stone)
fm	-	formation	silty	-	silty
foss	-	fossils/fossiliferous	SND	-	sand
fr	-	friable	sndy	-	sandy
frac	-	fracture	Sp	-	spores
frags	-	fragments	SST	-	sandstone
f	-	fusinite	st	-	stained
glc	-	glauconite/glauconitic	stks	-	streaks
gn	-	green	suc	-	sucrosic
grd	-	graded/grading to	surf	-	surface
grns	-	grains	SWC	-	side wall core
gy	-	grey	TD	-	total depth
GYP	-	gypsum	TOC	-	total organic carbon
HAL	-	halite	tr	-	trace(s)
hd	-	hard	trns	-	transparent
hor	-	horizontal	v	-	very
H(RV)	-	high reflecting vitrinite	vgt	-	variegated
i-	-	iso-	Vit	-	vitrinite
i/b	-	inter-bedded	vn	-	vein
IGN	-	igneous rocks	VOLC	-	volcanic rocks
inc	-	including	VR	-	vitrinite reflectivity
Inert	-	inertinite	wht	-	white
lam	-	laminae/laminated	xln	-	crystalline
LCM	-	lost circulation material	yel	-	yellow
LIG/Lig	-	lignite/lignitic		-	
lns	-	lens(es)		-	no analysis carried out
L(RV)	-	low reflecting vitrinite	*	-	analysed but no data obtained
LST	-	limestone	gy-gn	-	greyish green
lt	-	light	gy/gn	-	grey-green (gradation)
mass	-	massive	gn-gy	-	greenish grey

(Maturity data tables only). Number in brackets refers to number of reflectivity values averaged to give quoted result. Preferred values for indigenous phytoclasts are listed first.

APPENDIX 2

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

Spore 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 $n\text{-C}_{15}$) 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 $n\text{-C}_{15+}$, 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: $n\text{-C}_{17}$ 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 $n\text{-C}_{26}$ to $n\text{-C}_{35}$ 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 ($^{13}\text{C}/^{12}\text{C}$) 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 $^{13}\text{C}/^{12}\text{C}$ 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

Oil 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.