

36" and 26" Hole Sections

<u>PRODUCT</u>	<u>QUANTITY AND UNIT</u>	<u>COST PER UNIT</u>	<u>TOTAL COST</u>
Barite	23 M.T	USD 78,50	USD 1805,50
Bentonite	39 M.T	USD 190,00	USD 7410,00
Caustic Soda	39 (25 kg)	USD 7,90	USD 308,10
			SECTION TOTAL: USD 9,523.60
MUD VOLUME BUILT	3188 bbls		
MUD VOLUME USED	3188 bbls		

17 ½" Hole Section

<u>PRODUCT</u>	<u>QUANTITY AND UNIT</u>	<u>COST PER UNIT</u>	<u>TOTAL COST</u>
Barite	730 MT	USD 78.50	USD 57,305.00
Caustic Soda	54 (25 kg)	USD 7.90	USD 426.60
XC - Polymer	41 (25 kg)	USD 198.60	USD 8,142.60
Drispac Reg	90 (50 lbs)	USD 69.10	USD 6,219.00
Polylo	538 (50 kg)	USD 14.55	USD 7,827.90
KCl	3283 (50 kg)	USD 9.45	USD 31,024.35
Polycap	81 (25 ltr)	USD 53.10	USD 4,301.10
Antibac	18 (25 ltr)	USD 57.60	USD 1,036.80
Stayflo XL	56 (25 kg)	USD 78.07	USD 4,371.92
Stayflo Reg	14 (25 kg)	USD 78.07	USD 1,092.98
Drispac SL	58 (50 lbs)	USD 69.10	USD 4,007.80
			SECTION TOTAL: <u>USD 125,756.05</u>

Volume Built on Rig:	4390 bbls
Dilution:	923 bbls
Sub Total:	5313 bbls
Surface Losses:	1141 bbls
Sub Surface Losses:	200 bbls
Other Losses Dumped:	2283 bbls
Total Losses:	3624 bbls
Volume Left at End of Section:	1689 bbls
Net Volume of Mud Used:	5313 bbls

<u>PRODUCT</u>	<u>QUANTITY AND UNIT</u>	<u>COST PER UNIT</u>	<u>TOTAL COST</u>
Barite	593 MT	USD 78.50	USD 46,550.50
Caustic Soda	187 (25 kg)	USD 7.90	USD 1,477.30
XC - Polymer	76 (25 kg)	USD 198.60	USD 15,093.60
Drispac Reg	157 (50 lbs)	USD 69.10	USD 10,848.70
Drispac SL	194 (50 lbs)	USD 14.55	USD 13,405.40
KCl	3442 (50 kg)	USD 9.45	USD 32,526.90
Polylo	553 (25 kg)	USD 14.55	USD 8,046.15
Polycap	80 (25 ltr)	USD 53.10	USD 4,248.00
Antibac	20 (25 ltr)	USD 57.60	USD 1,145.00
Stayflo Reg	14 (25 kg)	USD 78.07	USD 1,092.98
Sodium Bicarbonate	20 (50 kg)	USD 12.00	USD 240.00
Soda Ash	25 (50 kg)	USD 8.80	USD 220.00
D - Terg	2 (200 ltr)	USD 388.50	USD 777.00
Desco	14 (50 lbs)	USD 28.00	USD 392.00
W300 (Defoamer)	2 (25 ltr)	USD 45.00	USD 90.00

SECTION TOTAL: USD 136,160.53

Initial Volume of Mud on Rig:	1689 bbls
Volume Built on Rig:	1160 bbls
Dilution:	3942 bbls
Sub Total:	5120 bbls
Surface Losses:	1243 bbls
Sub Surface Losses:	200 bbls
Other Losses Dumped:	3343 bbls
Total Losses:	4786 bbls
Volume Left at End of Section:	2365 bbls
Net Volume of Mud Used:	5102 bbls

<u>PRODUCT</u>	<u>QUANTITY AND UNIT</u>	<u>COST PER UNIT</u>	<u>TOTAL COST</u>
Barite	430 MT	USD 78.50	USD 33,755.00
Caustic Soda	91 (25 kg)	USD 7.90	USD 718.90
Drispac SL	76 (50 lbs)	USD 69.10	USD 5,251.60
Drispac Reg	5 (50 lbs)	USD 69.10	USD 345.50
Stayflo Reg	11 (25 kg)	USD 78.07	USD 78.07
Antibac	7 (25 ltr)	USD 57.60	USD 403.20
Sodium Biacarbonate	8 (50 kg)	USD 12.00	USD 96.00
W300	1 (25 ltr)	USD 45.00	USD 45.00
EZ - Spot	5 (200 ltr)	USD 725.75	USD 3,628.75
EZ - Spot	4 (200 ltr)	USD 777.60	USD 3,110.40
SFT	55 (25 kg)	USD 54.26	USD 2,984.30
Soltex	154 (50 lbs)	USD 68.93	USD 10,615.22
Lime	14 (50 kg)	USD 7.00	USD 98.00
Lignosulfonate	185 (25 kg)	USD 9.35	USD 1,729.75
Lignite	115 (25 kg)	USD 88.90	USD 11,023.50
Polylo	3 (25 kg)	USD 14.55	USD 43.65
Stayflo XL	1 (25 kg)	USD 78.07	USD 78.07
XC - Polymer	2 (25 lbs)	USD 198.60	USD 397.20

SECTION TOTAL: USD 64,402.11

Volume Built on Rig:	185 bbls
Dilution Volume:	998 bbls
Sub Total:	1183 bbls
Surface Losses:	1258 bbls
Sub Surface Losses:	115 bbls
Other Losses Dumped:	2215 bbls
Total Losses:	3588 bbls

<u>PRODUCT</u>	<u>QUANTITY AND UNIT</u>	<u>COST PER UNIT</u>	<u>TOTAL COST</u>
Barite	1776 MT	USD 78.50	USD 139,416.00
Bentonite	39 MT	USD 190.00	USD 7,410.00
Caustic Soda	371 MT	USD 7.90	USD 2,930.90
Drispac SL	328 MT	USD 69.10	USD 22,664.80
Drispac Reg	252 (50 lbs)	USD 69.10	USD 17,413.20
Stayflo XL	57 (25 kg)	USD 78.07	USD 4,449.99
Stayflo Reg	29 (25 kg)	USD 78.07	USD 2,264.03
Polylo	1094 (25 kg)	USD 14.55	USD 15,917.70
XC - Polymer	119 (25 kg)	USD 198.60	USD 23,633.40
Polycap	161 (25 ltr)	USD 53.10	USD 8,549.10
KCl	6725 (50 kg)	USD 9.45	USD 63,551.25
Antibac	45 (25 ltr)	USD 57.60	USD 2,592.00
Sodium Bicarbonate	28 (50 kg)	USD 12.00	USD 336.00
Soda Ash	25 (50 kg)	USD 8.80	USD 220.00
D - Terg	2 (200 ltr)	USD 388.50	USD 777.00
Desco	14 (50 lbs)	USD 28.00	USD 392.00
Lignite	115 (25 kg)	USD 8.90	USD 1,023.50
Lignosulfonate	185 (25 kg)	USD 9.35	USD 1,729.75
Soltex	154 (59 lbs)	USD 68.93	USD 10,615.22
W300 (Defoamer)	3 (25 ltr)	USD 45.00	USD 135.00
Lime	14 (50 kg)	USD 7.00	USD 98.00
EZ - Spot	5 (200 ltr)	USD 725.75	USD 3,628.75
EZ - Spot	4 (200 ltr)	USD 777.60	USD 3,110.40
SFT	55 (25 kg)	USD 54.26	USD 2,984.30

TOTAL: USD 335,842.29

Volume Built on Rig: 8923 bbls  
 Dilution (Drillwater): 6263 bbls  
 Sub Total: 15186 bbls

Surface Losses: 3642 bbls  
 Sub Surface Losses: 3703 bbls  
 Other Losses Dumped: 7841 bbls  
 Total Losses: 15186 bbls

Net Volume of Mud Used: 15186 bbls

WELL NO. 7/8-4

RIG NORTRYM

DATE (19) 84	DEPTH XX m	WT (ppg)	RHEOLOGY				FILTRATION RATE			FILTRATE ANALYSIS				RETORT					Sand (% by Vol)	Methy- Blue ml/ml mud	ph	Finess Time				
			Funnel Viscosity (sec/gt)	Plastic Viscosity (cp)	Yield Point (lb/100ft)	Gels (lb/100ft) 0/10	ml (30 min.)			Cake (32nd in)	Calcium (ppm)	Chloride (ppm)	Total Hardness (ppm)	PI/MI	F R	O/W Ratio	W.P.R PPM	Oil (% by Vol)					Water (% by Vol)	Solids (% by Vol)		
							API	HT-HP	*F																	
10/12/85		8.9	120+																							
11/12/85	175	8.9	120+																							
12/12/85	205	9.8	120+																							
13/12/85	208	8.8	100+																							
14/12/84	619	9.4	31				49					18.000														
15/12/85	619	8.9	100+																							
16/12/84	619	8.9	100+																							
17/12/84	619	9.1	48	17	22	3/5	9.0	-	-	1/4	42	56.000	160	-	-	-	-	0	93	1	0	-	-	8.9	-	
18/12/84	831	10.0	49	20	24	3/5	8.1	-	-	1	43	58.000	120	-	-	-	-	0	90	5	3/4	-	-	9.0	-	
19/12/84	1245	11.6	58	25	24	6/22	9.5	-	-	1	44	78.000	600	-	-	-	-	0	83	12	1	-	-	8.5	-	
20/12/84	1534	12.5	55	27	21	10/29	10.6	-	-	2	45	74.000	600	-	-	-	-	0	80	15	1	-	-	8.5	-	
21/12/84	1694	12.5	65	30	20	8/31	9.9	-	-	2	45	72.000	560	-	-	-	-	0	79	16	1	-	-	8.5	-	
22/12/84	1914	12.5	131	32	63	61/65	14.6	-	-	2	44	68.000	520	-	-	-	-	0	81	16	1	37.5	-	8.6	-	
23/12/84	1963	13.1	55	23	23	9/32	8.0	-	-	1	44	68.000	520	-	-	-	-	0	76	21	1	27.5	-	8.5	-	
24/12/84	1963	13.4	49	27	20	9/30	8.2	-	-	1	43	67.000	480	-	-	-	-	0	75	22	1	25	-	8.5	-	
25/12/84	1963	13.3	62	26	22	11/31	8.0	-	-	1	43	66.000	480	-	-	-	-	0	76	21	1	25	-	8.5	-	
26/12/84	1963	13.2+	56	25	20	9/29	14.8	-	-	2	44	68.000	520	-	-	-	-	0	76	21	1	25	-	8.0	-	
27/12/84	1971	13.3	46	23	20	4/25	10.5	-	-	2	40	65.000	1100	-	-	-	-	0	75	22	1	20	10.5	-	-	
28/12/84	2074	13.3	56	34	22	5/33	7.8	-	-	2	43	68.500	1200	-	-	-	-	0	78	22	1	20	9.8	-	-	
29/12/84	2118	12.8	49	28	17	4/23	5.8	-	-	2	46	89.000	1200	-	-	-	-	0	81	19	TR	22.5	9.7	-	-	
30/12/84	2195	12.3	67	30	18	6/31	5.4	-	-	2	44	82.000	1000	-	-	-	-	0	81	19	TR	27.5	9.4	Lowere	-	
31/12/84	2298	12.3	56	30	20	10/33	5.4	-	-	2	45	84.000	360	-	-	-	-	0	81	19	TR	27.5	9.5	Treat.	-	

WELL NO. 7/8-4

RIG...NORTRYM

DATE (1985)	DEPTH (ft.)	WT (ppg)	RHEOLOGY				FILTRATION RATE				FILTRATE ANALYSIS			RETORT										
			Funnel Viscosity (sec/gt)	Plastic Viscosity (cp)	Yield Point (lb/100ft)	Gels (lb/100ft) 0/10	ml (30 min.)			Cake (32nd in)	Calcium (ppm)	Chloride (ppm)	Total Hardness (ppm)	PI/MI	F.S.	O/W Ratio	W.P.S. PPM	Oil (% by Vol)	Water (% by Vol)	Solids (% by Vol)	Sand (% by Vol)	Methy- Blue me/ml mud	ph	Excess Lime
							API	HT-HP	%F															
1/1/85	2354	12.3	64	34	22	12/42	7.8	-	-	2	44	82.000	600	-	-	-	-	-	80	20	TR	37.5	9.8	
2/1/85	2592	12.3	60	29	19	10/41	7.2	-	-	2	45	87.000	520	-	-	-	-	-	79	21	TR	32.5	9.3	
3/1/85	2642	12.3	78	33	22	7/36	8.8	-	-	2	49	80.000	520	-	-	-	-	-	82	18	TR	40.0	9.2	
4/1/85	2909	12.3	55	24	20	7/42	8.4	-	-	2	58	84.000	400	-	-	-	-	-	82	18	1.0	35.0	9.3	
5/1/85	2992	12.3	52	22	23	9/38	9.5	-	-	2	42	68.000	400	-	-	-	-	-	84	16	1/2	32.5	9.1	
6/1/85	3103	12.3	58	21	21	8/40	7.4	-	-	2	47	77.000	380	-	-	-	-	-	85	15	3/4	28	9.0	
7/1/85	3128	12.2+	65	26	28	8/38	6.3	-	-	1 1/2	44	80.000	300	-	-	-	-	-	84	16	1/2	28	9.6	
8/1/85	3196	12.3	53	26	23	7/32	5.7	-	-	1 1/2	55	89.000	280	-	-	-	-	-	84	16	1/4	34	9.3	
9/1/85	3254	12.3	58	24	27	9/32	6.0	-	-	1	55	94.000	200	-	-	-	-	-	85	15	TR	32.5	9.1	
10/1/85	3330	12.3	49	25	24	6/31	5.5	-	-	1	58	87.000	200	-	-	-	-	-	84	16	TR	32.5	8.9	
11/1/85	3421	12.3	48	22	25	7/35	5.6	-	-	1	56	83.000	200	-	-	-	-	-	84	16	TR	32.5	9.0	
12/1/85	3438	12.3	50	23	23	6/31	5.2	-	-	1	56	75.000	200	-	-	-	-	-	84	16	TR	30	8.9	
13/1/85	3453	12.3	46	22	27	8/35	5.9	-	-	1	50	68.000	200	-	-	-	-	-	84	16	TR	30	8.9	
14/1/85	3559	12.3	53	22	25	8/34	5.2	-	-	1	53	72.000	160	-	-	-	-	-	84	16	TR	25	9.1	
15/1/85	3572	12.8	51	27	23	7/31	5.0	-	-	1	52	77.000	140	-	-	-	-	-	82	18	TR	25	8.8	
16/1/85	3613	12.8	50	27	25	8/33	4.8	-	-	1	56	72.000	120	-	-	-	-	-	82	18	TR	25	9.3	
17/1/85	3661	12.8	48	27	25	8/34	5.0	-	-	1	51	70.000	120	-	-	-	-	-	82	18	TR	25	9.2	
18/1/85	3685	12.8	47	25	26	10/34	5.2	-	-	1	51	69.000	120	-	-	-	-	-	82	18	TR	27.5	9.0	
19/1/85	3728	12.8	46	25	23	7/30	5.0	-	-	1	54	72.000	120	-	-	-	-	-	82	18	TR	25	9.2	
20/1/85	3771	12.8	47	27	22	7/31	4.9	-	-	1	54	73.000	120	-	-	-	-	-	82	18	TR	27.5	9.0	
21/1/85	3808	12.8	51	29	24	7/35	4.9	-	-	1	53	72.000	120	-	-	-	-	-	82	18	TR	22.5	9.1	
22/1/85	3808	12.8	58	31	27	7/35	4.7	-	-	1	53	72.000	120	-	-	-	-	-	82	18	TR	25	9.1	
23/1/85	3808	12.8	59	35	28	7/33	4.7	-	-	1	53	72.000	120	-	-	-	-	-	82	18	TR	25	9.1	

WELL NO. 7/8-4

RIG NORTRYM

DATE (1985)	DEPTH (ft.)	WT (ppg)	RHEOLOGY				FILTRATION RATE			FILTRATE ANALYSIS			RETORT				Sand (% by Vol)	Methy- Blue me/ml mud	ph	Excess Time				
			Funnel Viscosity (sec/gt)	Plastic Viscosity (cp)	Yield Point (lb/100ft) O/10	Gels (lb/100ft) O/10	ml (30 min.)			Calcium (ppm)	Chloride (ppm)	Total Hardness (ppm)	PI/MI	F.S.	O/W Ratio	W.P.S PPM					Oil (% by Vol)	Water (% by Vol)	Solids (% by Vol)	
							API	HT-HP	°F															Cake (32nd in)
24/1/85	3808	12.8	6.0	36	28	8/35	4.7	-	-	1	53	72.000	120	-	-	-	-	-	82	18	TR	25	9.1	-
25/1/85	3825	14.5	56	38	30	7/35	4.6	-	-	1	53	74.000	130	-	-	-	-	-	77	23	TR	27.5	-	-
26/1/85	3832	14.5	60	38	30	8/38	4.1	-	-	1	50	75.000	150	-	-	-	-	-	78	23	TR	25	10.0	-
27/1/85	3857	14.5	53	33	24	8/38	4.9	-	-	1	49	73.000	160	-	-	-	-	-	78	22	TR	25	9.9	-
28/1/85	3857	14.5	54	34	26	9/39	4.8	-	-	1	49	73.000	160	-	-	-	-	-	78	22	.25	25	9.8	-
29/1/85	3912	14.5	55	26	31	10/44	5.9	-	-	1½	43	69.000	80	-	-	-	-	-	80	20	.6	25	9.5	-
30/1/85	3943	14.5	48	38	24	7/29	4.8	-	-	1½	37	70.000	80	-	-	-	-	-	80	20	1	22.5	9.5	-
31/1/85	4090	14.5	55	36	23	6/38	4.1	-	-	1	39	69.000	60	-	-	-	-	-	76	24	.5	20	10.0	-
1/2/85	4192	14.5+	56	31	21	5/32	5.4	-	-	1½	30	64.000	TR	-	-	-	-	-	74	26	.5	20	10.0	-
2/2/85	4192	14.0	56	30	23	8/36	5.3	-	-	1½	30	60.000	60	-	-	-	-	-	74	26	.5	20	9.4	-
3/2/85	4348	14.0	50	31	17	4/25	5.3	22	-	1	22	53.000	TR	-	-	-	-	-	77	23	.25	17.5	9.7	-
4/2/84	4400	13.9	47	28	14	3/22	5.2	22	-	1	23	50.000	TR	-	-	-	-	-	77	23	.85	17.5	9.4	-
5/2/85	4400	13.9	47	28	10	3/15	5.1	21	-	1	20	47.000	20	-	-	-	-	3	73	24	.25	15	8.9	-
6/2/85	4400	14.1	53	28	12	3/17	4.0	-	-	1	20	49.000	120	-	-	-	-	4	68	28	TR	15	10.2	-
7/2/85	4400	14.2	50	31	13	3/20	4.0	19	-	1	18	44.000	120	-	-	-	-	5	67	28	TR	15	10.2	-
8/2/85	4400	14.3	53	33	16	3/21	4.1	19.3	-	1	19	47.000	120	-	-	-	-	5	67	28	TR	15	10.2	-
9/2/85	4400	14.2	50	32	14	3/21	4.1	19.4	-	1	19	47.000	120	-	-	-	-	5	67	28	TR	15	10.2	-
10/2/85	4400	14.3	50	33	15	3/22	4.2	19.8	-	1	20	49.000	120	-	-	-	-	5	67	28	TR	15	10.1	-
11/2/85	4140	14.2	49	32	15	3/22	4.5	20.0	-	1	20	46.000	320	-	-	-	-	6	67	27	1/4	12.5	10.6	-
12/2/85	4166	14.2	47	34	16	3/24	4.4	19.2	-	1	18	48.000	320	-	-	-	-	6	67	27	½	12.5	10.5	-
13/2/85	4255	14.2	57	38	20	4/26	4.1	17.8	-	1	18	44.000	320	-	-	-	-	6	67	27	1/4	12.5	10.2	-
14/2/85	4334	14.2	57	39	21	3/25	3.2	17.4	-	1	18	40.000	320	-	-	-	-	6	67	27	1/4	12.5	10.3	-
15/2/85	4400	14.2	52	38	18	3/20	3.6	17.3	-	1	18	37.000	280	-	-	-	-	5	68	27	1/4	10	10.1	-





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**Title**

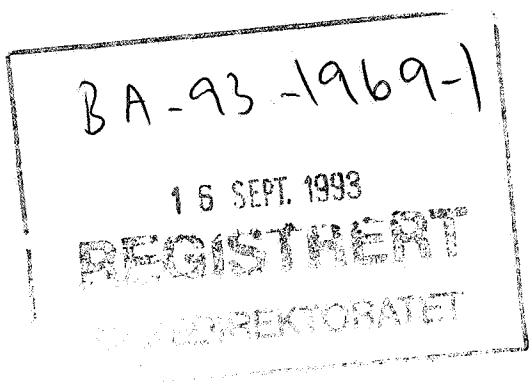
GEOCHEMICAL DATA REPORT FOR WELL 7/8-4

**Authors(s)**

NIGEL MILLS

**Abstract**


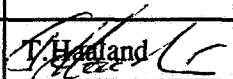
Five samples from the cored interval in well 7/8-4 have been analysed by Iatroscan (TLC-FID).  
 NOT INCLUDED IN WELL TRADE.



**Key Words**

7/8-4, geochemistry, Iatroscan

Classification:  Free  Saga and partners  Internal  Confidential  Strictly confidential

Org. Unit	EUG				
Reviewed	I. Horstad 				
Accepted					
Approved	T. Hoiland 				

**Hovedkontor/Head Office Oslo:**

Adresse/Address: Kjarboveien 18, Postboks 480, N-1301 SANDVIKA  
 Telefon/Telephone: Nasjonalt 87 12 68 00, Intern. +47 67 12 68 00

Teleks/Telex: 78862 Saga n  
 Telefax: Nasjonalt 87 126666, Intern. +47 67 126666

**Driftdivisjon/Operations Division Stavanger:**

Adresse/Address: Godesetdalen 8, Postboks 117, N-4003 FORUS  
 Telefon/Telephone: Nasjonalt 04 57 40 00, Intern. +47 4 57 40 00

Teleks/Telex: 33244 sagap n  
 Telefax: Nasjonalt 04 570281, Intern. +47 4 570281

## **1 Objectives**

The objective of this study was to characterise the extractable hydrocarbons in five core samples from well 7/8-4.

## **2 General well information**

The well was drilled by Conoco as operator of licence 069 from 11.12.84 to 20.2.85 and reached a total depth of 4400 mRKB. The KB of the rig was 25 metres and the water depth was 82 metres.

## **3 Samples and analytical scheme**

Five samples were picked from the cored interval in the well on the 6th of August 1992. All samples were analysed by Iatroscan (TLC-FID).

## **4 Vitrinite reflectance**

No samples were analysed.

## **5 TOC and Rock Eval**

No samples were analysed.

## **6 Iatroscan (TLC-FID)**

Five samples were analysed, and the results are tabulated in Table 1.

## **7 GC-FID**

No samples were analysed.

## **8 GC/MS**

No samples were analysed.

## **9 Stable carbon isotopes**

No samples were analysed.

**Tab. 1**

SAGLAB RESULTS MANAGEMENT : EXTRACTION ANALYSIS RESULTS in mg/g Rock

Data for Well 7/8-4

Page 1

Type	St.Depth	En.Depth	Weight (g)	EOM mg/g Rock	EOM mg/g TOC	Sat (mg/g)	Aro (mg/g)	NSO (mg/g)	Asph (mg/g)	Polars (mg/g)	TOC (%)	M/I
CCP	3826.10	3826.10	2.86	0.09		0.00	0.00			0.09		I
CCP	3828.10	3828.10	2.49	0.11		0.00	0.00			0.11		I
CCP	3830.10	3830.10	2.06	0.17		0.00	0.00			0.17		I
CCP	3832.00	3832.00	2.37	0.17		0.00	0.00			0.17		I
CCP	3834.00	3834.00	2.08	0.08		0.00	0.00			0.08		I
Averages this Well:				0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.00	
Averages all Wells:				0.12	0.00	0.00	0.00	0.00	0.00	0.12	0.00	

5 RESULT(s) selected ..., from the following search criteria:

Nat: NOR, Well: 7/8-4, Type: CCP,

Depth between: 0.000 and 99999.990

m



U-446

3

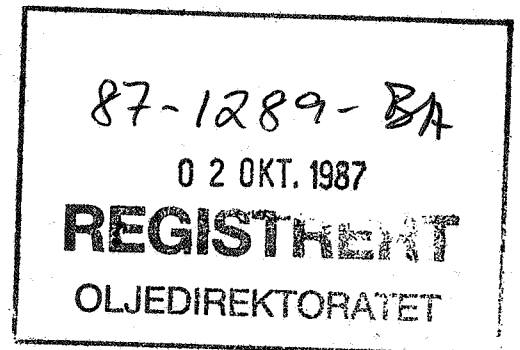
ROBERTSON RESEARCH INTERNATIONAL LIMITED

REPORT NO. 6157/Ic

VITRINITE REFLECTIVITY STUDIES OF THE  
INTERVAL 3463m TO 3762.8m OF THE 7/8-3 WELL  
AND THE INTERVAL 3746m TO 3824m OF THE 7/8-4 WELL,  
DRILLED IN THE NORWEGIAN NORTH SEA

by

F. JAMES



PROJECT NO. RRPS/878/Ic/25559

Prepared by:  
Robertson Research International Ltd.  
Llandudno  
Gwynedd LL30 1SA  
United Kingdom

Prepared for:  
Conoco Norway Inc.  
P.O. Box 488  
Finnestadveien 28  
4001 Stavanger  
Norway

JULY 1987



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1 Abbreviations used in Analytical Data Sheets
2 Analytical Procedures and Techniques
3 Histograms, Data and Statistics for Vitrinite Reflectivity

## 1 SUMMARY

Vitrinite reflectivity studies of the interval 3463m to 3762.8m of the 7/8-3 well and of the interval 3746m to 3824m of the 7/8-4 well, drilled in the Norwegian North Sea, have been carried out for Conoco Norway Inc. The report is in 'data-only' format, and includes tabulated data, depth plots and vitrinite reflectivity histograms for each well plus brief notes on the organic matter observed.



## 2 INTRODUCTION

This report presents vitrinite reflectivity data for the interval 3463m to 3762.8m of the 7/8-3 well and for the interval 3746m to 3824m of the 7/8-4 well.

The study was initiated by Conoco Norway Inc. by telex of 27th May 1987, and the samples were received at Robertson Research International Ltd. laboratories on 26th June 1987. The samples comprised 6 ditch cuttings samples for 7/8-4, and 3 ditch cuttings samples and 5 samples of conventional core for 7/8-3. The 7/8-4 samples were of poor quality and quantity, whilst the quality and quantity of the 7/8-3 samples were variable but were generally fair. Analytical procedures and techniques are given in Appendix 2 of this report.

The number of analyses carried out are as follows:

Sample preparation	:	14
Kerogen preparation	:	13
Vitrinite reflectivity	:	14

Preliminary geochemical data were transmitted to Mr. Lou of Conoco Norway Inc. by telex of 7th July and by letter dated 13th July 1987. This report is in 'data-only' format and no reference has been made to logs, stratigraphic or other geological data.

Robertson Research personnel involved in this study are:

Project co-ordination	:	P.C. Barnard
Report preparation	:	F. James
Microscopy	:	F. James
Kerogen preparation	:	supervised by M. Jones

### 3 RESULTS

#### 3.1 7/8-3 Well

##### 3.1.1 Vitrinite reflectivity data (Table 1, Figure 1, Appendix 3.1 and 3.2)

The amount of organic matter present is sparse and is dominated by humic kerogens, mainly degraded humic amorphous matter with infrequent vitrinite and inertinite particles. Measurable vitrinite particles are sparse to moderately frequent and the quality of the data is fair to poor. At 3463m, a minor amount of ?coal is present and this was picked out and mounted as a whole rock preparation. On examination, this material appeared to be lignite with a mean reflectance of  $R_o$  0.25%, and is possibly derived from drilling additives.

##### 3.1.2 Ultra-violet/blue light examination

Under ultra-violet/blue light, rare palynomorphs with yellow or orange fluorescence were observed, and confirm the level of maturity indicated by the vitrinite reflectivity data.

#### 3.2 7/8-4 Well

##### 3.2.1 Vitrinite reflectivity data (Table 2, Figure 2, Appendix 3.3)

The amount of organic matter present in the samples 3746m to 3809m is sparse and no measurements were possible. At 3821m and 3824m, the organic matter is mainly amorphous with moderately frequent vitrinite particles.

##### 3.2.2 Ultra-violet/blue light examination

Under ultra-violet/blue light, palynomorphs including bisaccate pollen with moderate orange or yellow-orange fluorescence were observed, and confirm the level of maturity indicated by the vitrinite reflectance data.

SAMPLE DEPTH (METRES)	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1 · 10)	VITRINITE REFLECTIVITY R oil av %	KEROGEN COMPOSITION (%) (by microscopic examination)			KEROGEN COMPOSITION (%) (by calculation from pyrolysis data)				
					INERTINITE	VITRINITE	SAPROPEL	INERTINITE	VITRINITE	ALGAL SAPROPEL	WAXY SAPROPEL	
3463	Ctgs	ADD+ 30% LST, v pal orng+ mnr COAL+ tr SST, lt gy										
	"	COAL		.25(12)L								
3547	"	SH, dk gy+ 10% LST, v pal orng + tr SLTST, gy-red		*								
3607	"	SH, dk gy+ mnr SST, lt brn-gy		.47( 2)								
3731	"	SST, lt gy, glc		*								
3739	"	SH, dk gy		.43(12)								
3754	"	SH, dk gy		.53( 6)								
3760	Core	SST, lt gy		.55(16)								
3762.8	"	SST, lt gy, carb		.51( 3)								

Maturity and Kerogen Composition Data

TABLE 1

SAMPLE DEPTH (METRES)	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1 - 10)	VITRINITE REFLECTIVITY R <sub>oil av</sub> %	KEROGEN COMPOSITION (%) (by microscopic examination)			KEROGEN COMPOSITION (%) (by calculation from pyrolysis data)				
					INERTINITE	VITRINITE	SAPROPEL	INERTINITE	VITRINITE	ALGAL SAPROPEL	WAXY SAPROPEL	
3746	Ctgs	LST, lt gy+ 20% SLTST, gy-red+ 10% LST, gy-blk		*								
3770	"	SLTST, brn-gy, calc+ tr LST, lt gy+ tr SLTST, pal red-brn		*								
3773	"	LST, gy-pnk+ 10% SLTST, brn-gy, calc+ tr LST, gy-blk		*								
3809	"	SLTST, gy-red		*								
3821	"	SST, lt gy, glc + 10% SH, dk gy + tr LST, gy-blk + tr SLTST, gy-red		.55(21)								
3824	"	SLTST, gy-red+ 20% SH, dk gy+ 10% LST, lt gy		.54(20)								

Maturity and Kerogen Composition Data

TABLE 2

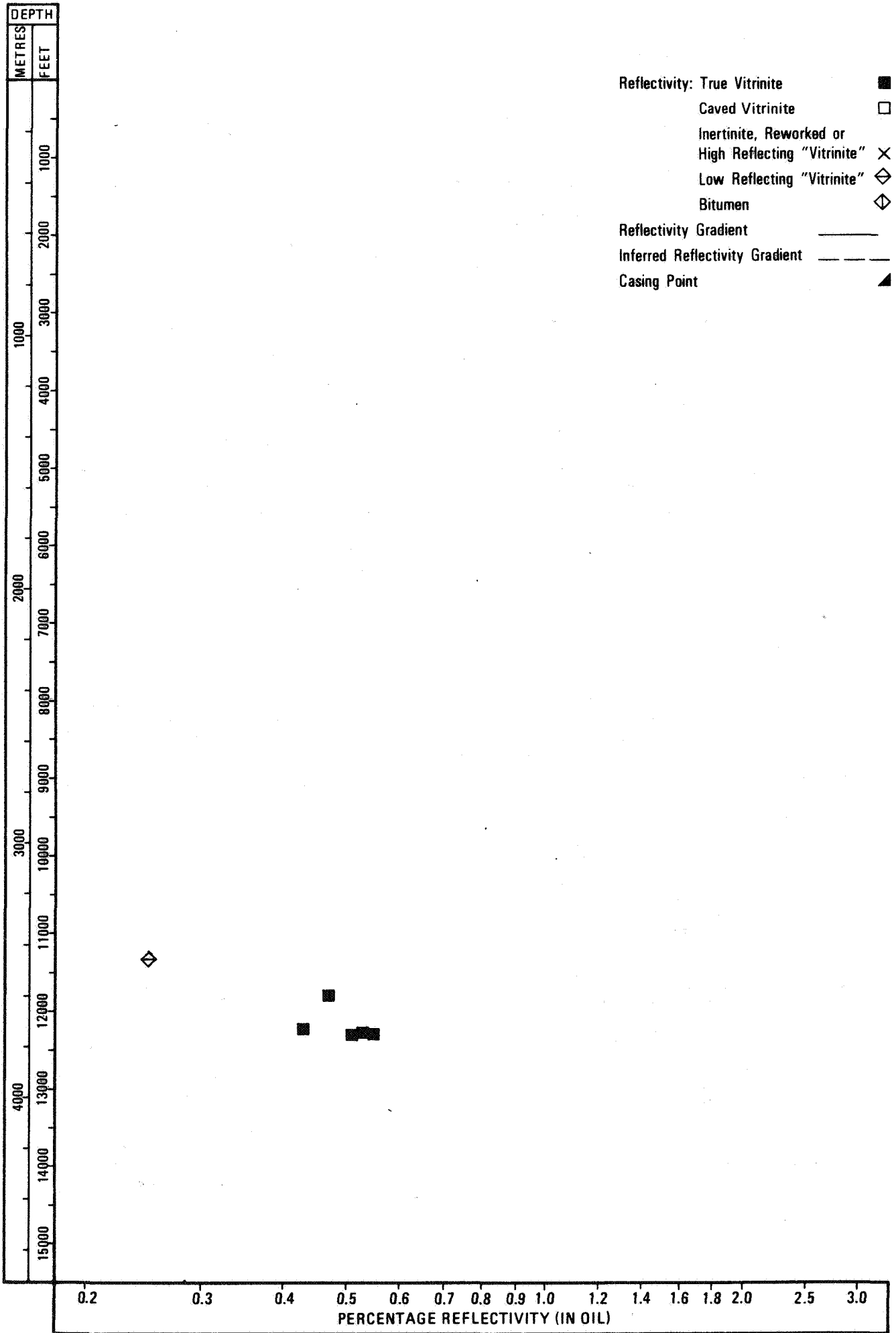


FIGURE 1 Vitrinite Reflectivity against Depth

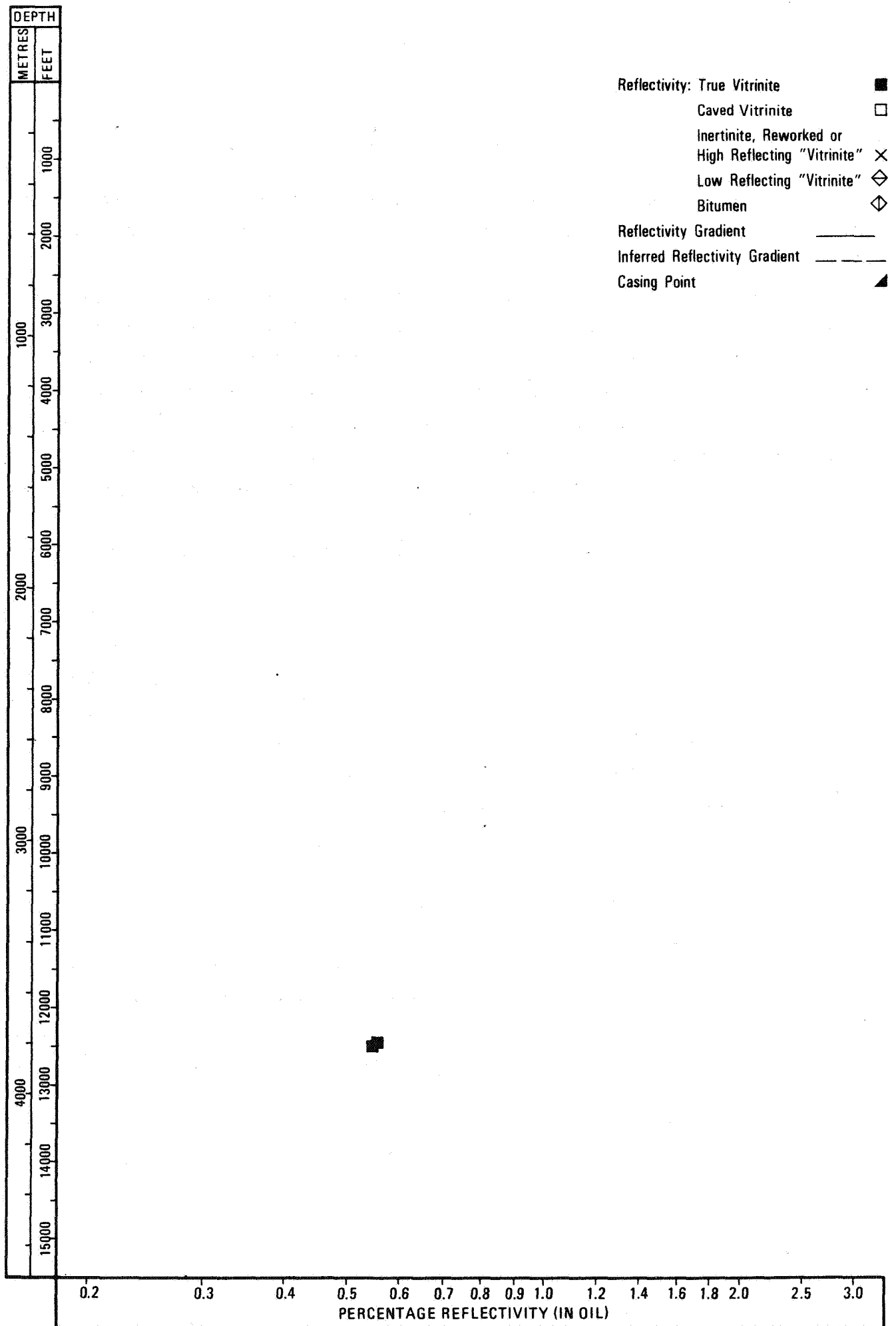


FIGURE 2 Vitrinite Reflectivity against Depth

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	orang	-	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
CLYST	-	claystone	pp	-	purple
CMT	-	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	slty	-	silty
foss	-	fossils/fossiliferous	SND	-	sand
fr	-	friable	sndy	-	sandy
frac	-	fracture	Sp	-	spores
frags	-	fragments	SST	-	sandstone
Fu	-	fusinite	st	-	stained
GLC/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		-	no analysis carried out
lns	-	lens(es)	*	-	analysed but no data obtained
L(RV)	-	low reflecting vitrinite	gy-gn	-	greyish green
LST	-	limestone	gy/gn	-	grey-green (gradation)
lt	-	light	gn-gy	-	greenish grey
mass	-	massive			

Note: (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.



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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 PreparationGeneral

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 T<sub>max</sub>, and hydrocarbon analysis including gas chromatography and gas chromatography-mass spectrometry.

Spore Colouration

Sporomorph colour is assessed using a >20 $\mu$  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 $\mu$  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 IFF-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 $\mu$  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<sub>15</sub>) 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 Latroscan 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 C<sub>15+</sub> fraction.

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

#### 5. Gas Analysis

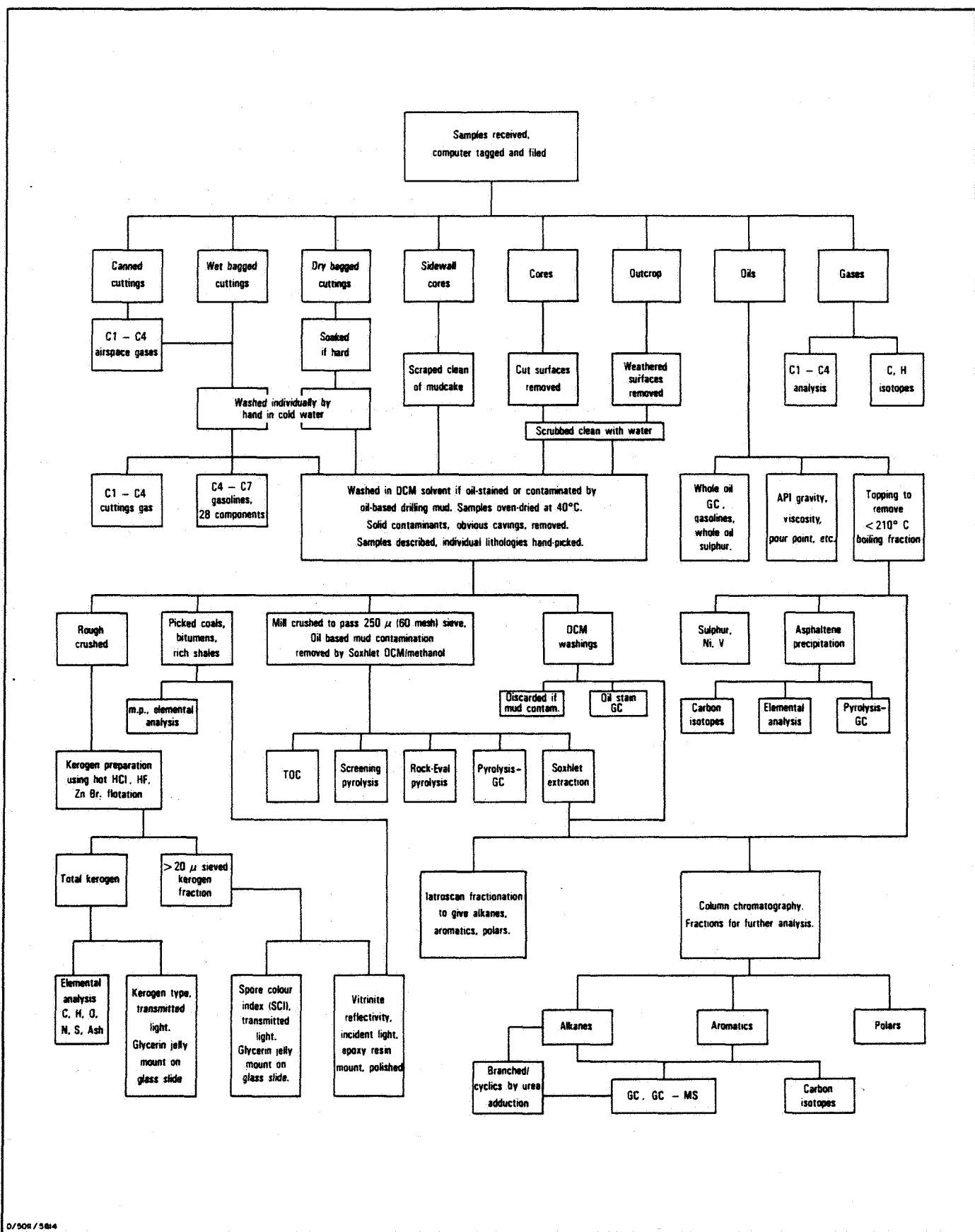
The hydrocarbon gases, C<sub>1</sub> to C<sub>4</sub>, may be collected from the airspace of sealed canned samples or may be received from well-site tests in a special sealed gas cylinder (gas mouse). Chromatographic separation of the C<sub>1</sub> to C<sub>4</sub> gases is effected as described under 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

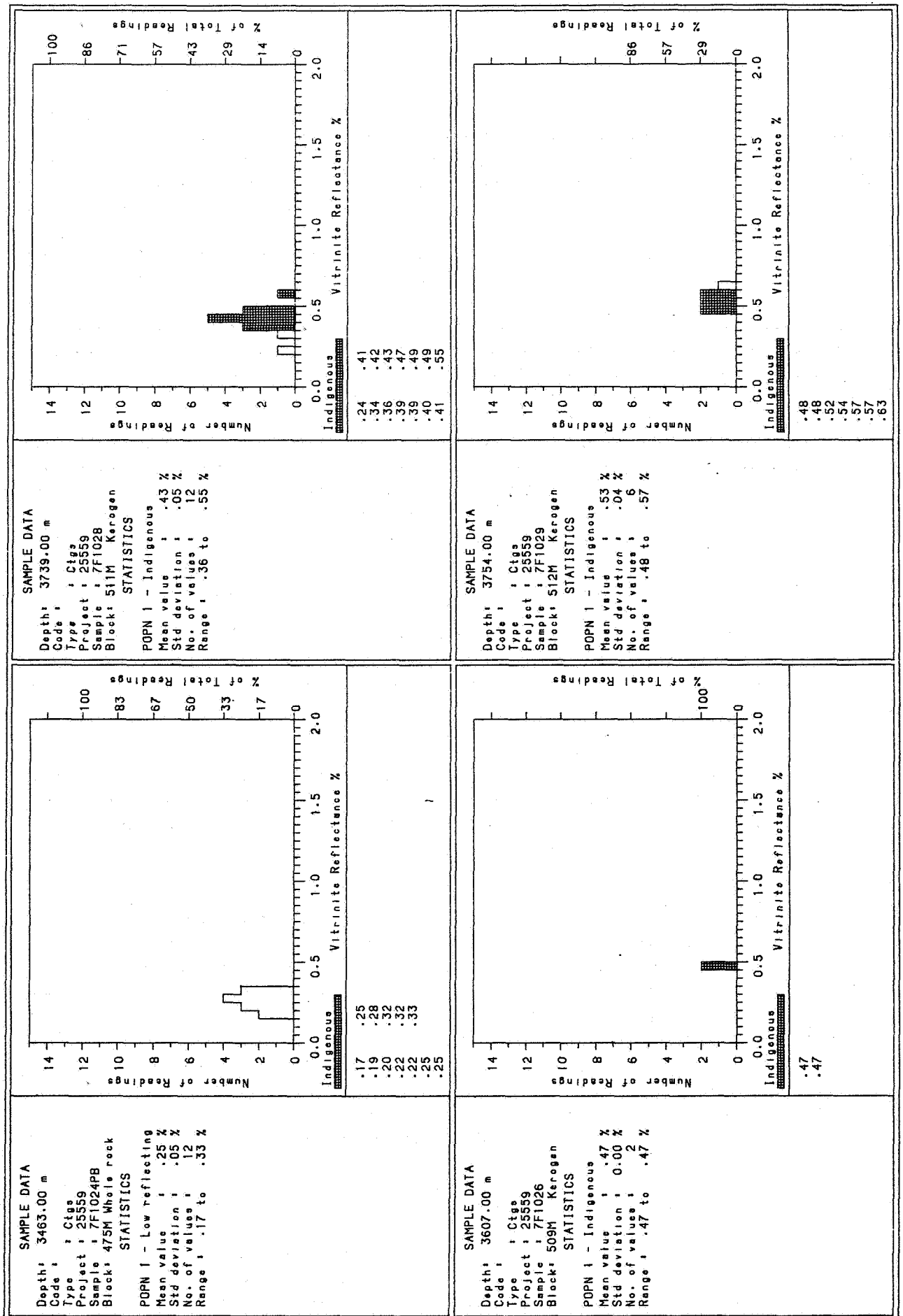
In some oil fields, problems are encountered where bitumen developments form continuous or patchy layers within reservoirs, dividing the pay zones and acting as barriers to natural fluid movement or inhibiting enhanced oil recovery techniques. Integrated geochemical and sedimentological studies aim to 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.

FLOW CHART FOR GEOCHEMICAL ANALYSIS



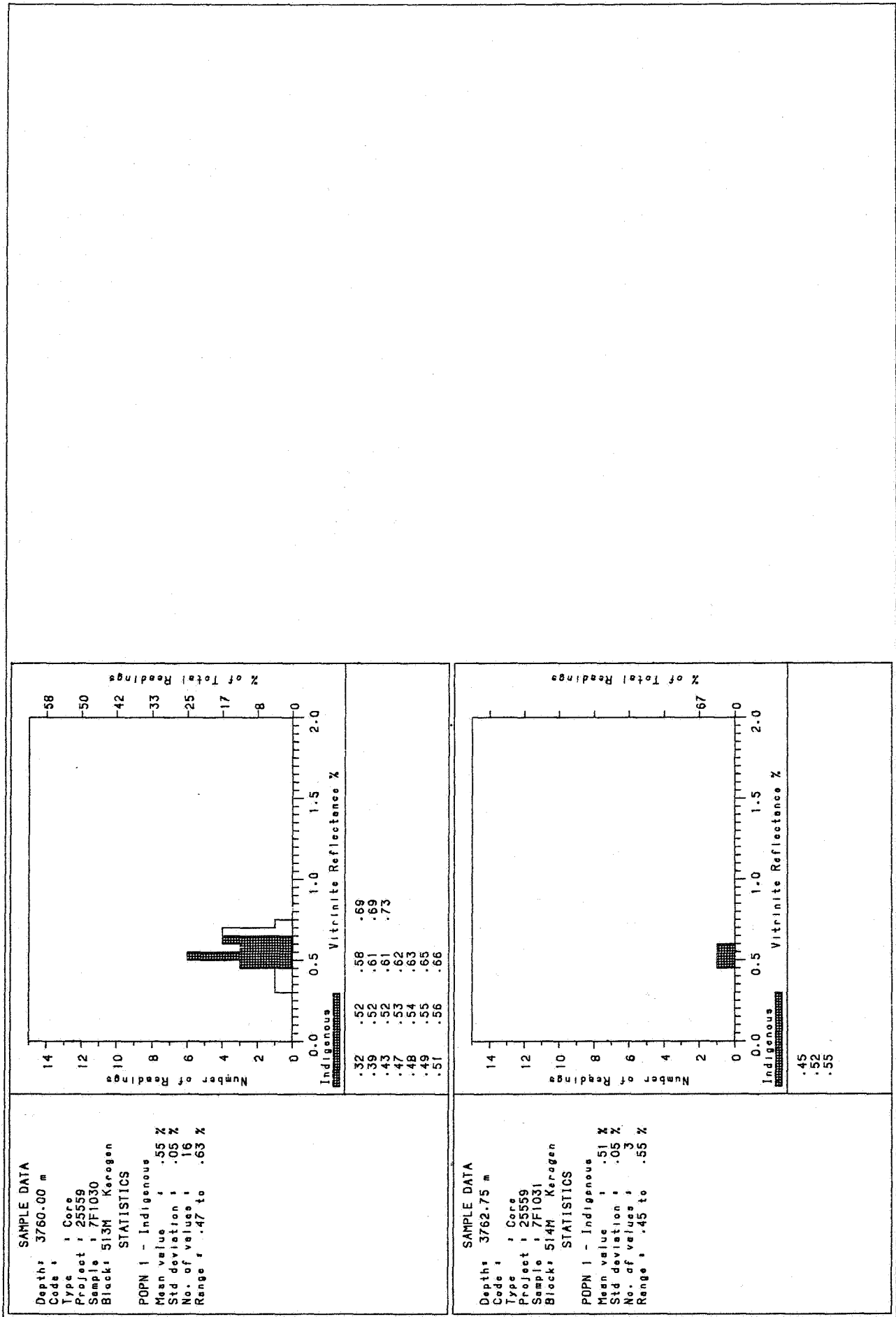
APPENDIX FIGURE 1



COMPANY : CONOCO NORWAY  
 WELL : 7/8-3  
 LOCATION : NORWEGIAN NORTH SEA

HISTOGRAMS, DATA AND STATISTICS  
 FOR VITRINITE REFLECTIVITY

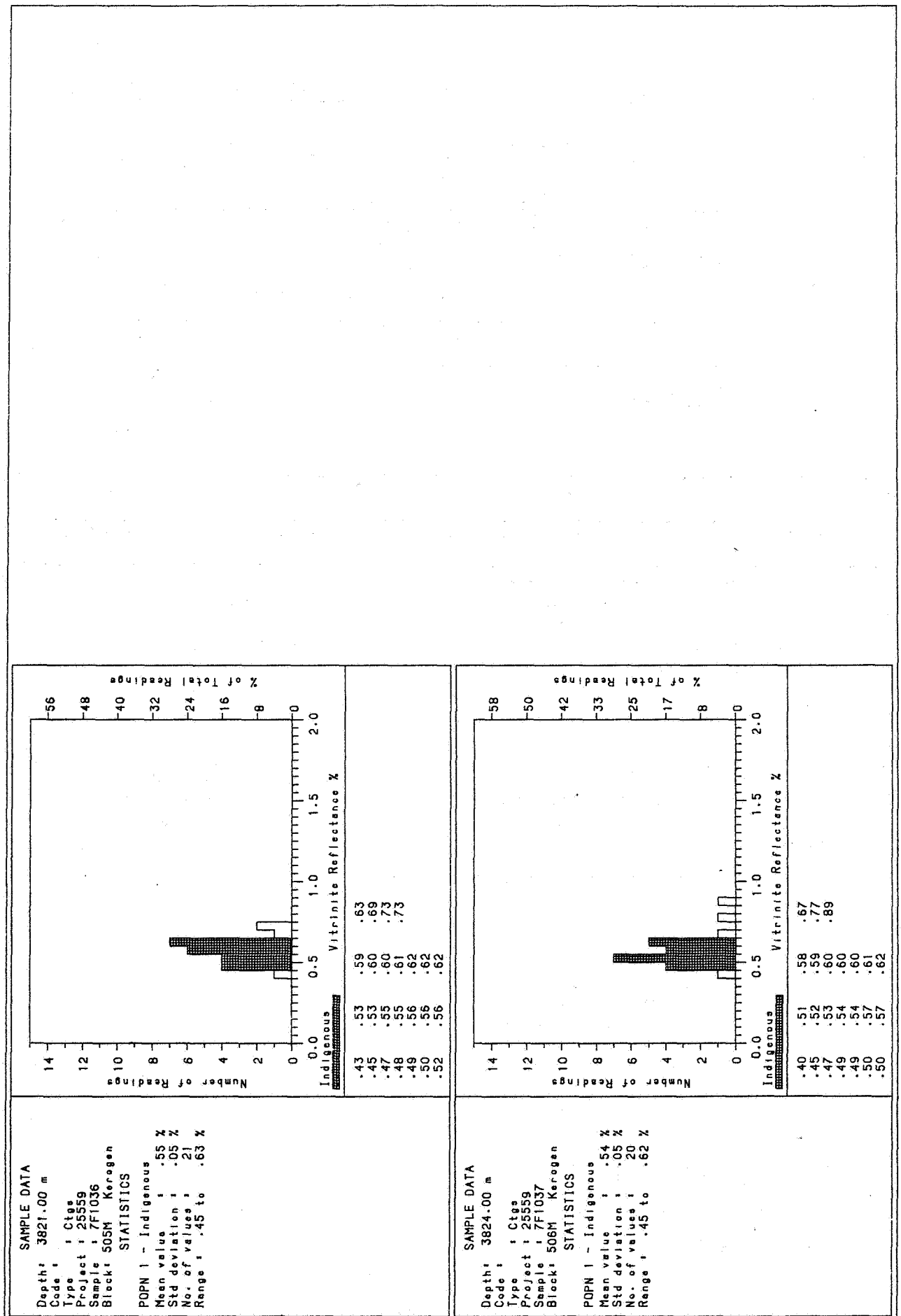




COMPANY : CONOCO NORWAY  
 WELL : 7/8-3  
 LOCATION : NORWEGIAN NORTH SEA

HISTOGRAMS, DATA AND STATISTICS  
 FOR VITRINITE REFLECTIVITY





COMPANY : CONOCO NORWAY  
 WELL : 7/8-4  
 LOCATION : NORWEGIAN NORTH SEA

HISTOGRAMS, DATA AND STATISTICS  
 FOR VITRINITE REFLECTIVITY