GEOCHEMICAL APPRAISAL OF BRIDGEWATER BAY-1, OTWAY BASIN

PROFESSIONAL OPINION

BY

Dianne S. EDWARDS

1997/008

23 May 1997

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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CONTENTS

1 Introduction

This report was written in response to a query from Tony Young, Cultus Petroleum N.L., who enquired about the validity of organic petrological and organic geochemical data acquired for Bridgewater Bay-1 in the Otway Basin, and whether the number of analyses were sufficient to appraise the hydrocarbon potential of the Late Cretaceous formations penetrated in this well.

2 Data Assessment

2.1 Vitrinite reflectance

Vitrinite reflectance (VR) data was acquired for Bridgewater Bay-1 by three laboratories (Phillips Australian Oil Company; ANALABS, Welshpool; and Geotechnical Services Pty. Ltd., Welshpool), the results of which are compiled in Table 1.

Phillips undertook vitrinite reflectance work on sidewall cores (SWCs). Vitrinite quality was deemed to be poor for only the deepest sample from 4175 m. Therefore, with the exception of the latter sample, *the vitrinite reflectance data obtained from SWCs are believed to be a reliable measure of thermal maturity for the section penetrated by this well.*

ANALABS and GEOTECH analysed ditch cuttings. ANALABS were able to carry out vitrinite reflectance on only two samples; at 2850 and 3200 m, due to insufficient vitrinite being present in the submitted ditch cuttings, and even in these samples vitrinite phytoclasts were rare. The vitrinite reflectance values are significantly lower than those data obtained from the SWCs (Fig. 1a), probably representing measurements made on cavings, hence these results have been discarded. In the well completion report (WCR), it was noted that overpressuring started at about 3050 m and heavy cavings in the mud returns indicated deterioration of the hole (Appendix A, WCR pp. 24-25).

In contrast, sufficient vitrinite phytoclasts for VR measurements were identified in the cuttings samples submitted to GEOTECH. Vitrinite reflectance measurements made on this sample set appear comparable with those measurements taken on the SWCs. The exceptions are two samples from 1400 m and 2050 m where lower VR values were recorded (Fig. 1a).

2.2 TOC and Rock-Eval pyrolysis

Total organic carbon (TOC) and Rock-Eval pyrolysis data were acquired for Bridgewater Bay-1 by four laboratories (Phillips, ANALABS, GEOTECH and Australian Geological Survey Organisation), the results of which are compiled in Table 1. Phillips ran these analyses on SWCs, whereas only ditch cuttings were available to the other laboratories. The TOC profile plotted for both the SWCs and ditch cuttings are similar (irrespective of the laboratory) to a depth of 3550 m (Fig. 1b). Below this depth, there is a marked difference between TOC data obtained from SWCs and ditch cuttings. These ditch cuttings have highly variable TOC contents, with some samples having TOCs greater than 10 %. Reasons for such a discrepancy occurring are;

a) Erroneous data. In this instance, it is believed that the laboratory analyses are *bona fide*. TOC contents decreases with increasing depth and maturity in the SWCs.

b) SWCs are not representative of the formation and were taken in organically leaner intervals. Gamma ray and resistivity logs indicate that between 2700 m and 4100 m the dominant lithologies are claystone and siltstone with no apparent fluctuations in the organic carbon content supporting the SWC TOC profile. With the exception of the SWC at 4175 m, which occurs in an interbedded sandstone and claystone sequence, it is unlikely that lithology changes are responsible for the differences in TOC values between the SWCs and ditch cuttings.

c) Ditch cuttings contain contaminants. The WCR shows that 'diesel oil' was added at 3550 m with a total of 200 barrels being used to complete the well (Appendix A, WCR pp. 27-28). Therefore, the anomalous TOC contents recorded in the ditch cuttings are most likely due to contamination.

In summary, TOC contents measured in the SWCs are representative of the formations with the TOC values for the ditch cuttings below 3550 m being anomalous due to contamination.

In the report by Phillips, Rock-Eval parameters (e.g. S_1, S_2, S_3 peaks) are documented for the SWCs but there is no record of Tmax values. Tmax is the temperature corresponding to the maximum amount of hydrocarbons generated from the cracking of kerogen (i.e. the S_2 peak). It is surprising that this value has not been reported and this incomplete data set should be viewed with some scepticism.

2.3 Organic geochemistry

GEOTECH carried out pyrolysis-gas chromatography (py-GC), gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analyses on a sample from 4120 m. These analyses are enclosed in Appendix B, with the permission of Mike Woollands, Minerals and Petroleum, Victoria.

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

AGSO NO	WELL	TOP (m)	BASE (m)	TYPE	ANALYST	SOURCE	CUSTOMER	WCR Stratigraphy	AGSO stratigraphy
54254	Bridgewater Bay 1	934	934	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Dilwyn Fm	Dilwyn Fm
54255	Bridgewater Bay 1	1185	1185	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Pember Mdst	Pember Mdst
54256	Bridgewater Bay 1	1318	1318	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Curdies Fm	Timboon Sst
74758	Bridgewater Bay 1	1400	1400	CUTT	Geotech	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Curdies Fm	Timboon Sst
54257	Bridgewater Bay 1	1522	1522	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Curdies Fm	Timboon Sst
54258	Bridgewater Bay 1	1870	1870	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Paaratte Fm	Paaratte
74759	Bridgewater Bay 1	2050	2050	CUTT	Geotech	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Paaratte Fm	Paaratte
54259	Bridgewater Bay 1	2215	2215	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Paaratte Fm	Paaratte
54260	Bridgewater Bay 1	2450	2450	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Paaratte Fm	Skull Creek Mdst
54261	Bridgewater Bay 1	2700	2700	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54262	Bridgewater Bay 1	2735	2735	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54263	Bridgewater Bay 1	2750	2750	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
74760	Bridgewater Bay 1	2800	2800	CUTT	Geotech	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Belfast Mdst	Belfast Mdst
54264	Bridgewater Bay 1	2800	2800	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54265	Bridgewater Bay 1	2850	2850	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54266	Bridgewater Bay 1	2900	2900	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54267	Bridgewater Bay 1	2945	2945	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54268	Bridgewater Bay 1	3000	3000	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54269	Bridgewater Bay 1	3015	3015	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54270	Bridgewater Bay 1	3050	3050	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Belfast Mdst
54271	Bridgewater Bay 1	3100	3100	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54272	Bridgewater Bay 1	3150	3150	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54273	Bridgewater Bay 1	3200	3200	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54274	Bridgewater Bay 1	3250	3250	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54275	Bridgewater Bay 1	3295	3295	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54276	Bridgewater Bay 1	3300	3300	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54277	Bridgewater Bay 1	3350	3350	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54278	Bridgewater Bay 1	3400	3400	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54279	Bridgewater Bay 1	3450	3450	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
74761	Bridgewater Bay 1	3500	3500	CUTT	Geotech	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Belfast Mdst	Morum Mdst
54280	Bridgewater Bay 1	3500	3500	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54281	Bridgewater Bay 1	3550	3550	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54282	Bridgewater Bay 1	3600	3600	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54283	Bridgewater Bay 1	3640	3640	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54284	Bridgewater Bay 1	3650	3650	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54285	Bridgewater Bay 1	3700	3700	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54286	Bridgewater Bay 1	3750	3750	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54287	Bridgewater Bay 1	3800	3800	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54288	Bridgewater Bay 1	3850	3850	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54289	Bridgewater Bay 1	3900	3900	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54290	Bridgewater Bay 1	3950	3950	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54297	Bridgewater Bay 1	3960	3960	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst
54291	Bridgewater Bay 1	4000	4000	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Morum Mdst

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

TOP (m)	TMAX	S1	S2	S3	TOC	PI	S2_S3	PC	HI	OI	TAI	SCI	CAI_MIN	CAI_MAX	REFLEC	MIN	MAX	NUMREF	STDEV
934		0.2	2.57		4.26	0.07		0.23	60		2-				0.49	0.4	0.57	50	0.04
1185		0.08	2.14		2.56	0.04		0.18	84		2				0.52	0.42	0.62	48	0.05
1318		0.06	0.68		1.59	0.08		0.06	43		2				0.54	0.45	0.63	50	0.04
1400	418	0.19	0.5	0.85	0.61	0.28	0.59		82	139					0.36	0.26	0.52	25	0.06
1522		0.12	0.77		1.35	0.13		0.07	57		2				0.56	0.46	0.66	50	0.05
1870		0.12	1.61		2.01	0.07		0.14	80		2				0.58	0.47	0.69	50	0.05
2050	427	0.09	0.77	4.71	1.36	0.10	0.16		57	346					0.43	0.32	0.62	26	0.08
2215		0.34	1.42		2.27	0.19		0.14	63		2				0.57	0.5	0.67	50	0.05
2450		0.18	1.24		1.5	0.13		0.12	83		2+				0.65	0.52	0.74	48	0.05
2700	421	0.66	1.76	1.23	1.18	0.27	1.43	0.2	149	104									
2735		12.49	2.63		1.95	0.83		1.24	135		2+				0.64	0.54	0.77	50	0.06
2750	483	0.13	0.63	0.24	1.12	0.17	2.63	0.06	56	21									
2800	478	0.21	0.4	1.11	0.82	0.34	0.36		49	135					0.62	0.46	0.77	11	0.09
2800	530	0.13	0.67	0.27	0.94	0.16	2.48	0.07	71	29									
2850	428	0.13	0.3	0.2	1.06	0.3	1.5	0.04	28	19					0.55	0.54	0.57	2	
2900	501	0.17	1.46	0.64	1.31	0.1	2.28	0.13	111	49									
2945	536	0.22	2.66	0.63	1.26	0.08	4.22	0.24	211	50									
3000	502	0.21	1.03	0.62	1.36	0.17	1.66	0.1	76	46									
3015		0.37	0.98		1.31	0.27		0.11	75		2+				0.67	0.57	0.77	40	0.06
3050	505	0.25	1.71	0.7	1.31	0.13	2.44	0.16	131	53									
3100	474	0.21	0.86	0.46	1.26	0.2	1.87	0.09	68	37									
3150	433	0.19	0.66	0.61	1.46	0.22	1.08	0.07	45	42									
3200	508	0.26	1.39	0.86	1.19	0.16	1.62	0.14	117	72					0.53	0.5	0.56	3	
3250	435	0.18	0.68	0.58	1.29	0.21	1.17	0.07	53	45									
3295		0.31	0.72		0.55	0.3		0.08	131		2+				0.7	0.58	0.82	51	0.06
3300	436	0.3	1.06	0.57	2.93	0.22	1.86	0.11	36	19									
3350	454	0.24	1.02	0.53	1.86	0.19	1.92	0.1	55	28									
3400	435	0.25	0.68	0.44	1.19	0.27	1.55	0.08	57	37									
3450	436	0.33	0.73	0.61	1.23	0.31	1.2	0.09	59	50									
3500	428	0.19	0.26	0.67	0.82	0.42	0.39		32	82					0.8	0.6	1.08	28	0.13
3500	428	0.3	0.38	0.35	0.88	0.44	1.09	0.06	43	40									
3550	434	2.72	1.4	0.75	1.55	0.66	1.87	0.34	90	48									
3600	429	2.64	8.58	1.58	3.57	0.24	5.43	0.92	240	44									
3640		0.28	0.76		0.9	0.27		0.09	84		3-				0.8	0.71	1	77	0.07
3650	431	2.45	1.42	1.1	1.13	0.63	1.29	0.32	126	97									
3700	427	0.63	0.71	0.59	0.97	0.47	1.2	0.11	73	61									
3750	430	3.76	77.34	5.46	11.82	0.05	14.16	6.65	654	46									
3800	429	1.6	21.86	2.5	4.22	0.07	8.74	1.92	518	59									
3850	431	2.77	45.11	4.94	7.01	0.06	9.13	3.93	644	70									
3900	432	0.69	1.82	0.67	1.24	0.27	2.72	0.21	147	54									
3950	429	1.41	12.33	1.16	2.57	0.1	10.63	1.13	480	45									
3960		0.26	0.83		0.71	0.24		0.09	117		3-				1.07	0.92	1.2	57	0.07
4000	429	0.94	5.4	1.06	1.73	0.15	5.09	0.52	312	61									

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

TOP (m)	ALG	VIT	EX	INERT	OTHER	COMMENTS
934	55	40	3	2		
1185	80	15	2	3		
1318	12	35	10	43		
1400	0.00	17.39	4.35	78.26		
1522	65	15	5	15		
1870	50	20	5	25		
2050	0.00	13.79	17.24	68.97		
2215	10	30	5	55		
2450	55	20	5	20		
2700						
2735	60	15	5	20		
2750						
2800	0.00	0.00	0.00	100.00		
2800						
2850						Ditch cuttings, VR unreliable due to low abundance of vitrinite in this sample.
2900						
2945						
3000						
3015	10	15	5	70		
3050						
3100						
3150						
3200						Ditch cuttings, VR unreliable due to low abundance of vitrinite in this sample.
3250						
3295	20	30	10	40		
3300						
3350						
3400						
3450						
3500	0.00	0.00	0.00	100.00		
3500						
3550						
3600						
3640	65	15	5	15		
3650						
3700						
3750						
3800						
3850						
3900						
3950						
3960	20	30	5	45		
4000						

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

AGSO NO	WELL	TOP (m)	BASE (m)	TYPE	ANALYST	SOURCE	CUSTOMER	WCR Stratigraphy	AGSO stratigraphy
54292	Bridgewater Bay 1	4045	4045	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Flaxman Fm equiv
54293	Bridgewater Bay 1	4100	4100	CUTT	Analabs	WCR	Phillips Aust Oil Co	Belfast Mdst	Flaxman Fm equiv
74762	Bridgewater Bay 1	4120	4120	CUTT	Geotech	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9308	Bridgewater Bay 1	4130	4135	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9309	Bridgewater Bay 1	4140	4145	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9310	Bridgewater Bay 1	4150	4155	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
54294	Bridgewater Bay 1	4150	4150	CUTT	Analabs	WCR	Phillips Aust Oil Co	Waarre Fm	Flaxman Fm equiv
9311	Bridgewater Bay 1	4160	4165	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9312	Bridgewater Bay 1	4170	4175	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
54295	Bridgewater Bay 1	4175	4175	SWC	Phillips Aust Oil Co	WCR	Phillips Aust Oil Co	Waarre Fm	Flaxman Fm equiv
9313	Bridgewater Bay 1	4180	4185	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9314	Bridgewater Bay 1	4195	4195	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
9315	Bridgewater Bay 1	4200	4200	CUTT	AGSO	Energy and Minerals, Victoria	Energy and Minerals, Victoria	Waarre Fm	Flaxman Fm equiv
54296	Bridgewater Bay 1	4200	4200	CUTT	Analabs	WCR	Phillips Aust Oil Co	Waarre Fm	Flaxman Fm equiv

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

TOP (m)	TMAX	S1	S2	S3	TOC	PI	S2_S3	PC	HI	OI	TAI	SCI	CAI_MIN	CAI_MAX	REFLEC	MIN	MAX	NUMREF	STDEV
4045	427	1.14	9.38	1.91	2.26	0.11	4.91	0.86	415	85									
4100	428	3.13	21.08	3	4.78	0.13	7.03	1.99	441	63									
4120	422	4.33	49.7	1.54	10.3	0.08	32.27		483	15					1.1	0.79	1.22	8	0.14
4130	427	3	53.28	2.7	10.8	0.05	19.73		493	25									
4140	429	0.65	11.5	2.54	2.33	0.05	4.53		494	109									
4150	425	0.64	6.74	1.93	1.67	0.09	3.49		404	116									
4150	426	0.71	3.36	1.1	0.98	0.17	3.05	0.33	343	112									
4160	427	4.55	58.88	5	11.4	0.07	11.78		516	44									
4170	427	5.65	78	3.6	15.7	0.07	21.67		497	23									
4175		0.38	0.72		0.81	0.35		0.09	89						1.29	1.16	1.4	52	0.06
4180	429	1.35	8.38	5.26	2.71	0.14	1.59		309	194									
4195	424	1.02	13.3	2.06	2.76	0.07	6.46		482	75									
4200	430	3.31	58.56	4.32	11.41	0.05	13.56		513	38									
4200	431	3.82	51.6	5.14	9.55	0.07	10.04	4.54	540	54									

Table 1 TOC, Rock-Eval pyrolysis and vitrinite reflectance data, Bridgewater Bay-1

TOP (m)	ALG	VIT	EX	INERT	OTHER	COMMENTS
4045						
4100						
4120						
4130						
4140						
4150						
4150						
4160						
4170						
4175	15	40	5	40		Vitrinite quality is poor, low confidence in VR data
4180						
4195						
4200						
4200						

3. Interpretation of Results

3.1 Vitrinite reflectance

The Timboon Sandstone and Paaratte Formation have low thermal maturities (Fig. 1a), whereas the Skull Creek Formation, Nullawarre Greensand and Belfast Mudstone lie within the top of the conventional oil window (VR = 0.65 % at 2450 m). Peak oil generation is assumed to occur over the vitrinite reflectance range 0.8-1.2 %. Hence, the Morum and Flaxman Formations are presently at optimum maturity for hydrocarbon generation.

3.2 TOC and Rock-Eval pyrolysis data

The data set between 1240-2710 m shows that the Late Cretaceous Timboon Sandstone, Paaratte Formation, Skull Creek Formation and Nullawarre Greensand have little hydrocarbon potential. Although the organic richness of these formations is fair to very good (range TOC = 0.6-2.3 %), their potential yields are consistently poor ($S_1+S_2 < 3$ kg hydrocarbons/tonne). The hydrogen indices are low (HI < 82 mg hydrocarbons/gTOC) indicating the presence of poor quality Type III-IV kerogen. These data are consistent with those found elsewhere in the Otway Basin for the Timboon Sandstone and Paaratte Formation.

The Belfast Mudstone (2710-3100 m) and uppermost Morum Formation (3100-3350 m) contain a large proportion of oxidised organic matter (inertinite), as indicated by the high Tmax values (Fig. 1c). The vitrinite reflectance profile increases regularly over this depth range which suggests that the high Tmax values are due to oxidation of the organic matter during sedimentation rather than an influx of 'eroded' kerogen. Only one sample from the Belfast Mudstone (2945 m) has a significantly high hydrogen index (HI = 211). For for an organic-rich sediment to have any liquid hydrocarbon potential, hydrogen indices in excess of 150 mg hydrocarbon/gTOC are necessary, and typically an oil-prone source rock has a HI greater than 300 mg hydrocarbon/gTOC. Analyses from other wells *e.g.* Argonaut-1, Breaksea Reef-1 and Triton-1 (Fig. 2) indicate that the Belfast Mudstone was deposited under oxidising conditions.

Petrological examination revealed that inertinite is the dominant maceral type with lamalginite being rare (Appendix B; Table 2.1).

The presence of free hydrocarbons in the sidewall core at 2735 m is indicated by a high S_1 peak (S_1 = 12.5 kg hydrocarbon/tonne; Fig. 1d), and high production index (PI = 0.8). From these analyses alone, it is impossible to determine whether this is an indigenous oil or a contaminant introduced during coring.

Figure 1 Plots of vitrinite reflectance, TOC and Rock-Eval pyrolysis parameters versus depth, Bridgewater Bay-1

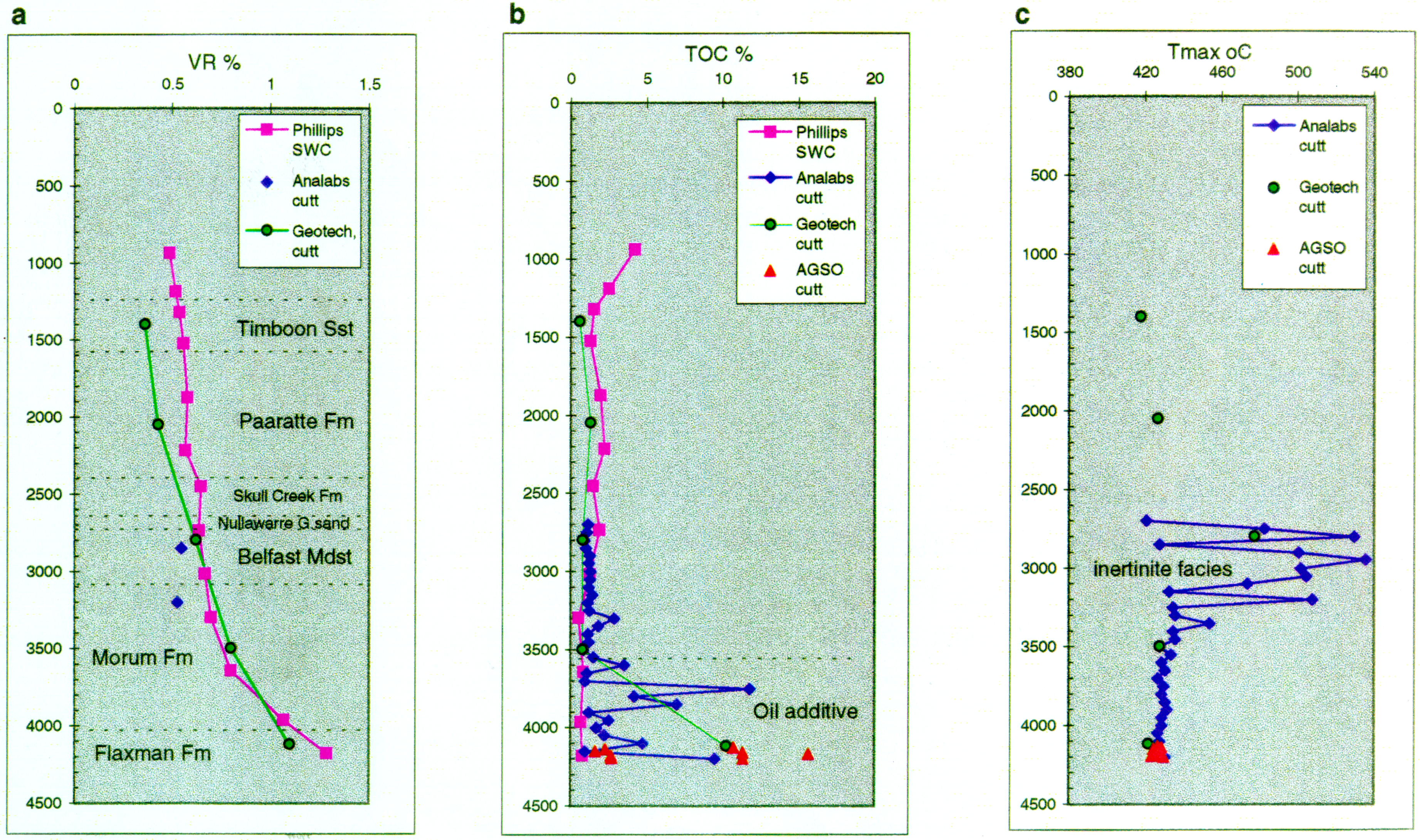


Figure 1 Plots of vitrinite reflectance, TOC and Rock-Eval pyrolysis parameters versus depth, Bridgewater Bay-1

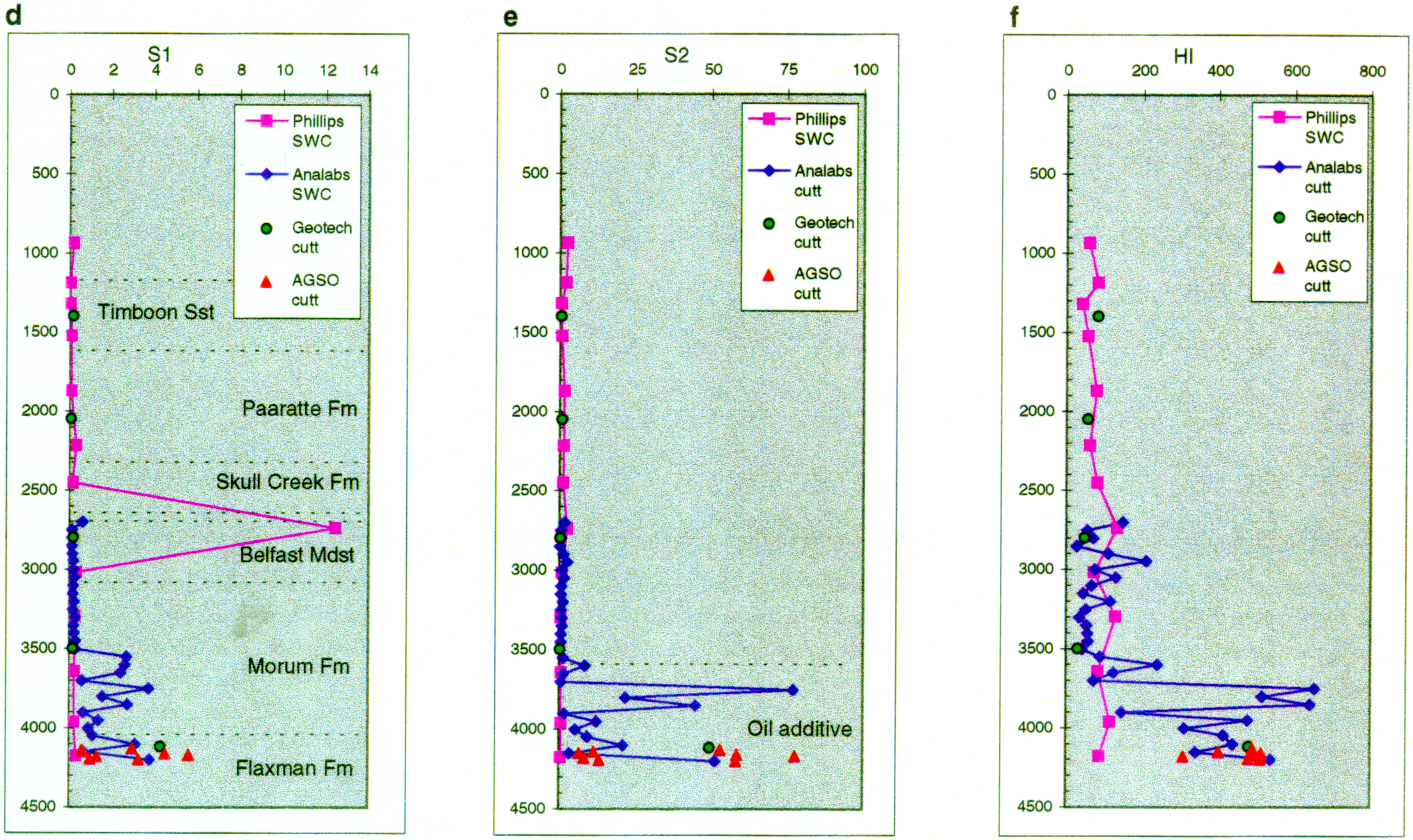
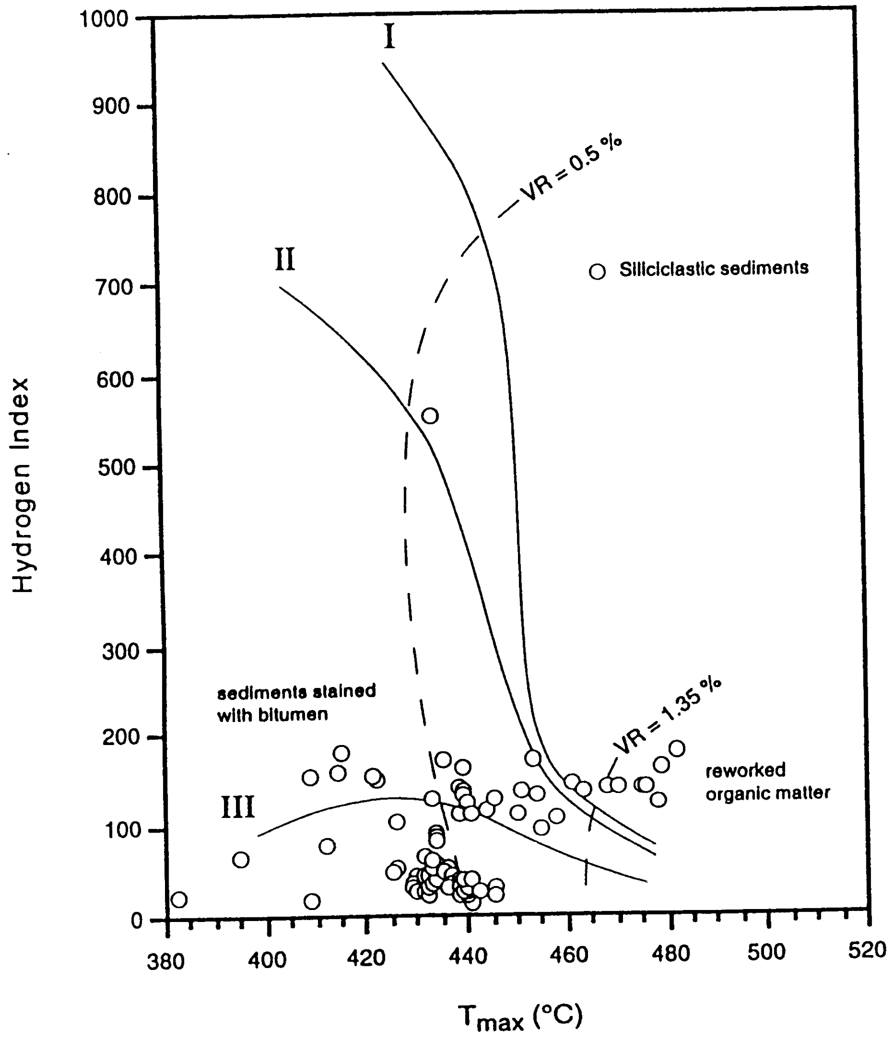
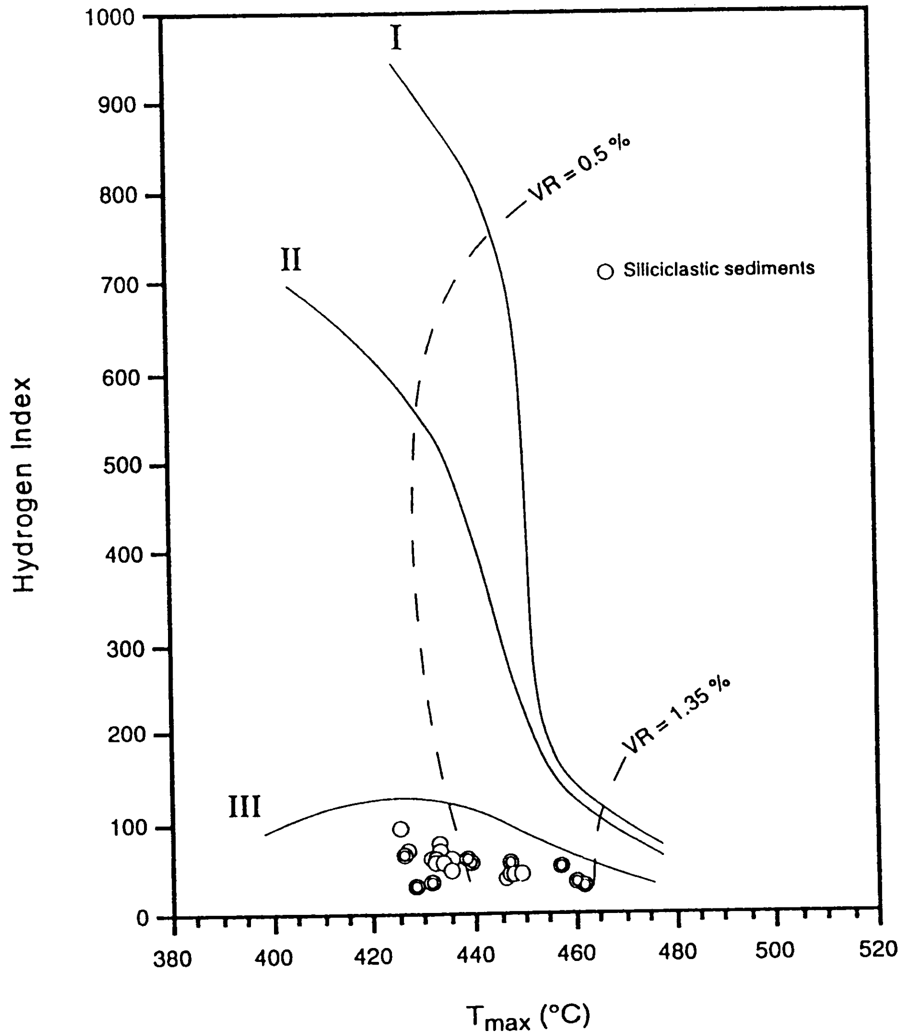


Figure 2a Rock-Eval pyrolysis data for the Belfast Mudstone, western Otway Basin. (Padley, 1995)



Data compiled from Argonaut-1 and Breaksea Reef-1.

Figure 2b Rock-Eval pyrolysis data for the Belfast Mudstone at Triton-1, eastern offshore Otway Basin. (Padley, 1995).



Ditch cuttings analysed from the underlying Morum (below 3350 m) and Flaxman Formations show a marked increase in organic richness (mean TOC = 4.6 %), abundant free hydrocarbons (mean S_1 = 2 kg hydrocarbons/tonne) and the presence of oil-prone kerogen (mean S_2 = 22 kg hydrocarbons/tonne; mean HI = 334 mg hydrocarbons/gTOC; Figs. 1b, 1d, 1e and 1f). As stated above, the Morum and Flaxman Formations are presently at peak oil generation. Although the production index does not appear unduly high (PI < 0.4), the Tmax values appear suppressed (Fig. 3) suggesting the presence of free hydrocarbons. Since 'diesel oil' was added from 3550 m and data for the SWCs do not indicate the presence of oil-prone organic facies, it is probable that the apparent increase in hydrocarbon potential of the ditch cuttings is due to contamination.

The petrological description of a ditch cuttings sample from 4120 m describes the presence of bitumen which exhibits a weak brown fluorescence under UV light and bright green yellow fluorescence is observed throughout the mineral matrix (Appendix B, Table 2.1). Diesel may account for the pervasive bright green fluorescence; however, the origin of the bitumen is more problematic.

3.3 Organic geochemistry.

The saturates chromatogram of the ditch cuttings sample from 4120 m (Appendix B) has a narrow range of *n*-alkane homologues (C_{16}-C_{26}) with a maximum at C_{20}, high pristane/phytane ratio (pr/ph = 3.6) and high abundance of pristane to *n*-heptadecane (pr/nC_{17} = 1.13). In these respects this chromatogram resembles a fractionated oil, whereas in a typical land-plant-derived crude oil the high pristane/phytane ratio is accompanied by an abundance of long chain *n*-alkanes (up to C_{35}). The latter alkane distribution is exhibited by some Otway Basin oils such as Lindon-1, Windermere-1 and Campbell-4 (Fig. 4) in the Port Campbell Embayment which were generated from the Early Cretaceous Eumeralla Formation.

GC-MS analyses show a full complement of hopane and sterane biomarker compounds that do not appear to be markedly different to those observed in other land-plant-derived Otway oils and source rocks. For example, the sterane distribution is dominated by the land-plant-derived C_{29} homologues. Exotic biomarker compounds, such as oleanane and bicadinane are not observed. Therefore, it is impossible to determine whether the biomarker assemblage is indigenous to the Flaxman Formation or originated from the introduced 'diesel oil'. Having said this, the maturity-dependent saturated hydrocarbon ratios appear to indicate a lower maturity level than interpreted from the VR measurements, implying that the free hydrocarbons were not generated *in situ*.

Figure 3 Rock-Eval pyrolysis data for Bridgewater Bay-1

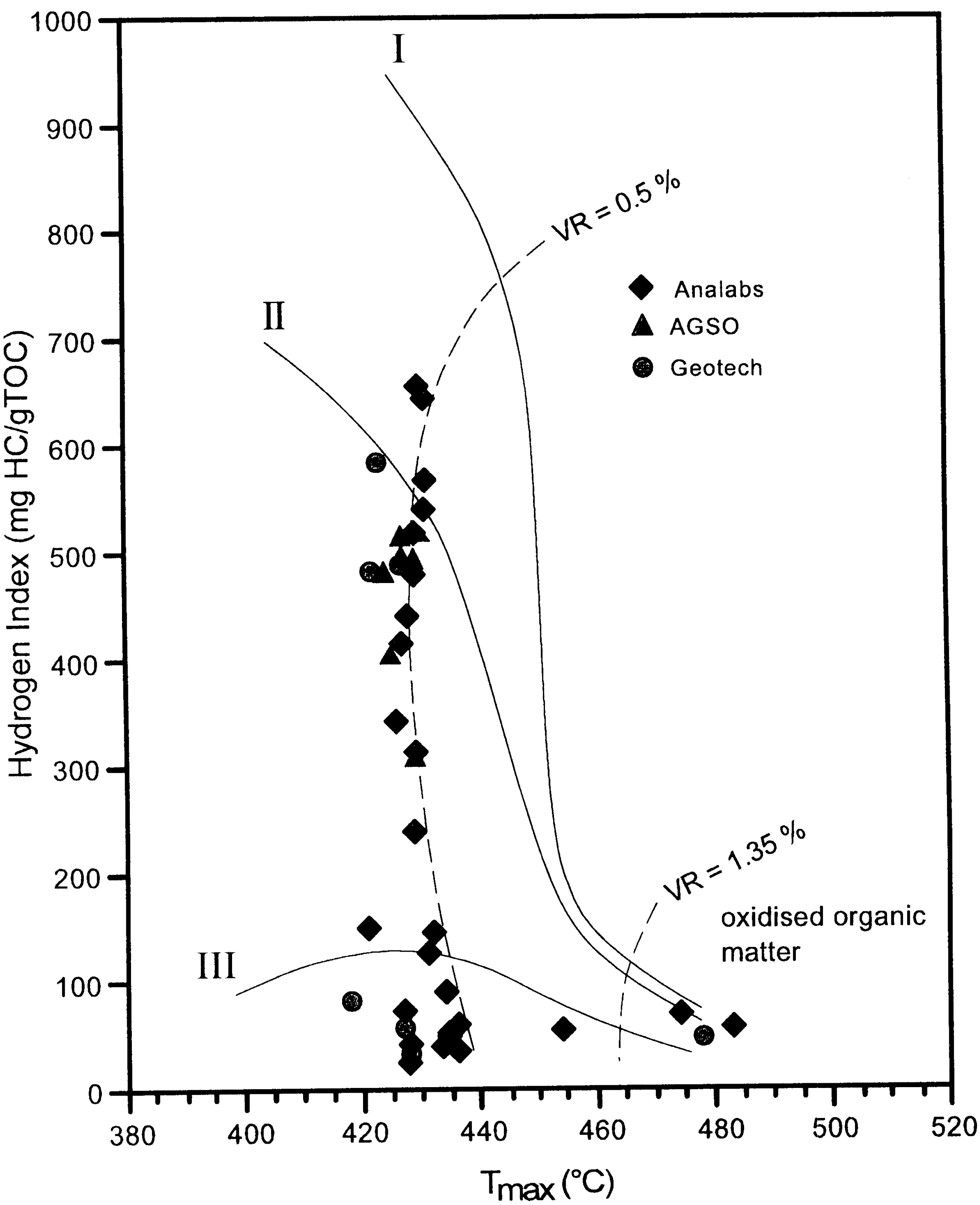
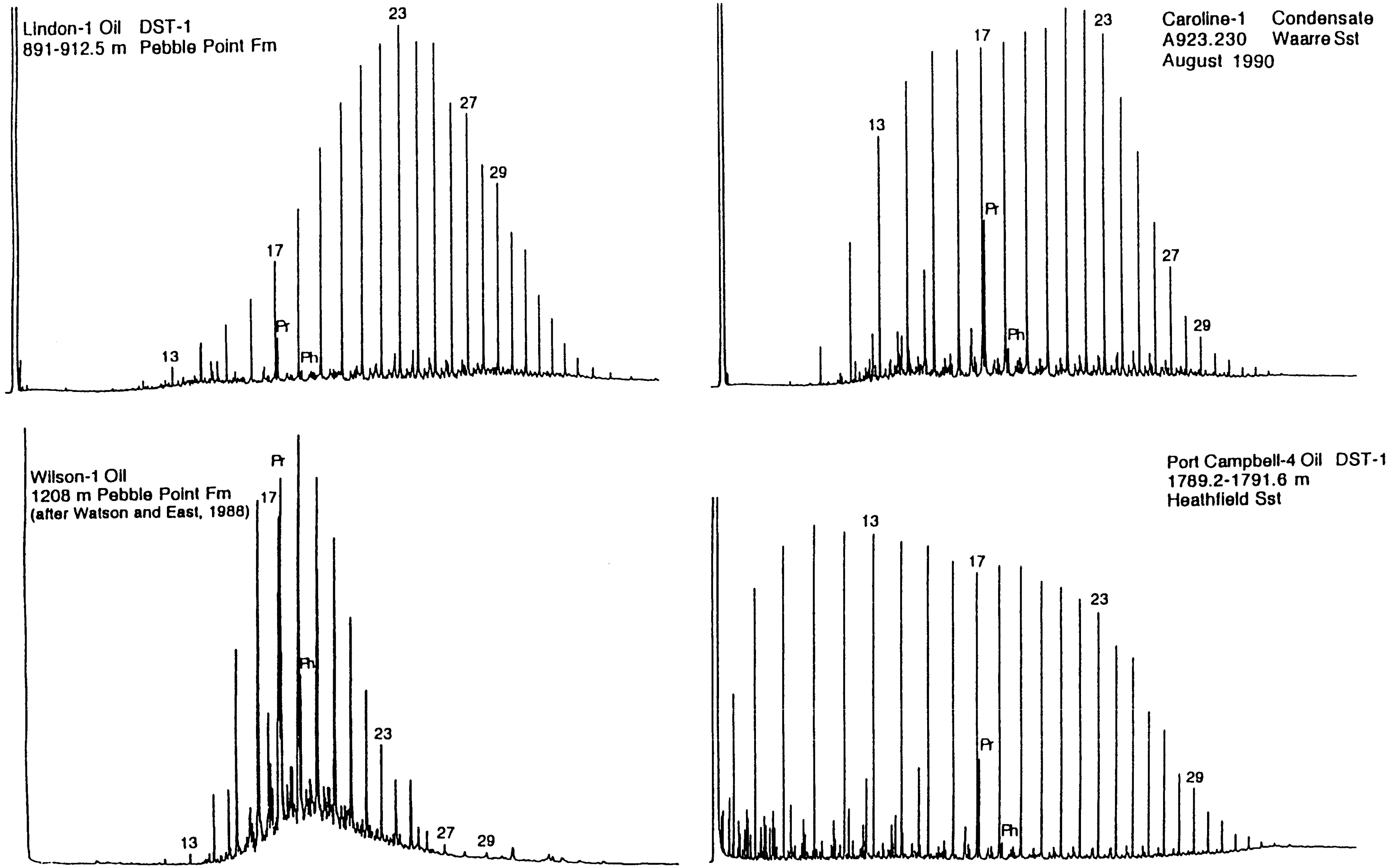
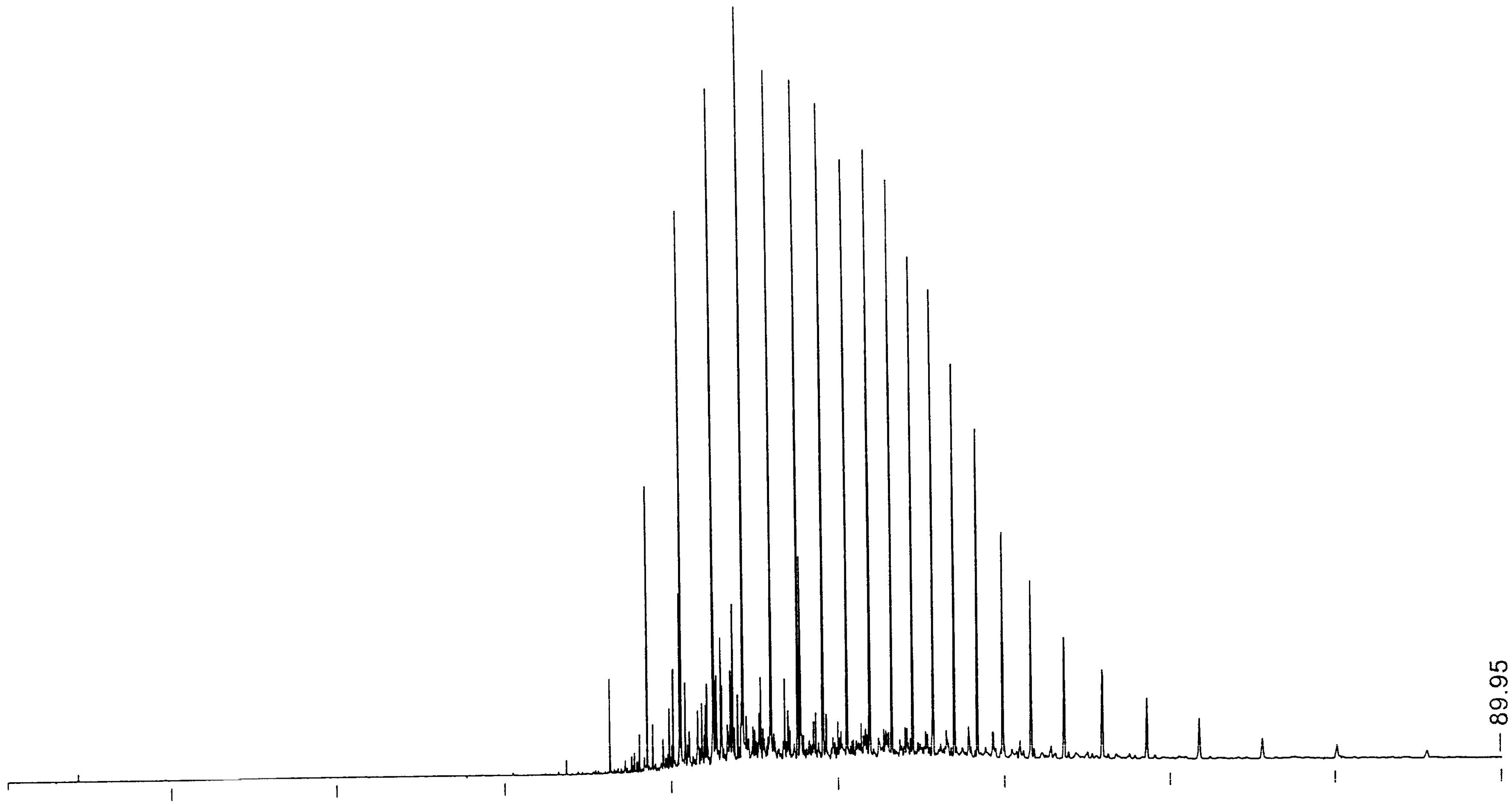


Figure 4a Saturates chromatograms of selected crude oils from the Otway Basin. (Padley, 1995).



Whole oil chromatogram, Flaxman-1 oil, AGSO No. 498



It is interesting to note that an oil shows with similar gas chromatograms to the Bridgewater Bay-1 extract were recovered from Flaxman-1 and in the Pebble Point Formation at Wilson-1. These oils are, to my knowledge, some of the few Otway Basin oils believed to be derived from a Late Cretaceous source (Fig. 4). In summary, geochemical analyses are inconclusive in determining the origin of the free hydrocarbons found in the Bridgewater Bay-1 extract.

4. Recommendations for further work.

1. To appraise the hydrocarbon potential of the Late Cretaceous Paaratte and Skull Creek Formations it is suggested that TOC and Rock-Eval pyrolysis analyses are repeated on SWCs or, if unavailable, additional ditch cuttings between 1240 and 2620 m. It must be stated that source rocks have not been identified within the Paaratte Formation elsewhere in the Otway Basin. Analyses from other wells that penetrate this formation and the underlying Belfast Mudstone indicate that the organic matter preserved in these sediments is oxidised, being at best gas-prone.

2. Detailed palynological and maceral analyses are recommended to be carried out on Bridgewater Bay-1, particularly below 3550 m. Determining organic facies and maceral associations would allow the depositional environment to be interpreted. In addition to the type of organic matter, its state of preservation may indicate the oxicity of the water column and amount of reworking sustained during deposition, and hence determine the likelihood of accumulating oil-prone source rocks. Such analyses may also determine whether the high TOC contents and HI values in this section are due to the presence of hydrocarbon-enriched organic facies in addition to the oil-based drilling mud.

3. Once the integrity of the ditch cuttings below 3550 m has been established the following geochemical analyses may be used to determine the source potential and timing of hydrocarbon generation from a source rock:

- Bulk kinetics;
- Compositional kinetics;
- Biomarker (GC, GC-MS) analyses; and
- Stable carbon isotopic determinations.

Reference

Padley, D. (1995) Petroleum geochemistry of the Otway Basin and the significance of coastal bitumen strandings on adjacent southern Australian beaches. Ph.D. Thesis, Dept. Geology and Geophysics, University of Adelaide, S.A.

Appendix A

WELL COMPLETION REPORT

Bridgewater Bay No. 1

Phillips Australian Oil Company

June, 1984

CONTENTS

*Interpretative and Confidential Data

LIST OF FIGURES

LIST OF TABLES

*Interpretative and Confidential data

LIST OF ENCLOSURES

LIST OF APPENDICES

LIST OF ADDENDA

*Interpretative and Confidential Data

b) General Data

Well Name	: Bridgewater Bay No. 1
Name and Address of Operator	: Phillips Australian Oil Company 23rd floor, St. Martins Tower 44 St. George's Terrace PERTH. W.A. 6000. (G.P.O. Box 2066W PERTH. W.A. 6001.)
Co-venturer Parties' Names and Addresses	: Gas & Fuel Exploration N.L., 151 Flinders Street, MELBOURNE, Vic. 3000 Mount Isa Mines Limited 15th floor, 160 Ann Street BRISBANE, QLD. 4000.
Exploration Permit	: VIC/P14
District	: Otway Basin, Victoria
Location	: Lat. 38 degrees 32 min 25.9698 sec South Long. 141 degrees 21 min 47.9468 sec East
Elevations	: Water depth 109 metres RKB to seabed 131 metres
Total Depth	: 4200 metres RKB
Status	: Plugged and Abandoned

h) Drilling Fluids

The hole was spudded and the 36-inch and 26-inch holes were drilled using seawater, periodically flushing with high viscosity slugs of Aquagel flocculated with caustic soda.

The 17-1/2 inch hole was drilled with a seawater, gel, polymer mud system. The mud was prepared by blending seawater with prehydrated bentonite and treating with Drispac to maintain an API filtrate of less than 10 cc/30 min. Pills of seawater, Desco and walnut hulls along with 4 ppg of Soltex were added to alleviate suspected bit balling from 884 to 1372 metres.

The 12-1/4 inch hole was drilled with a potassium chloride - polymer mud system. The hole was drilled to 3548 metres with a KCL content of 10-12% by weight with the API filtrate maintained between 7.0 and 8.5 cc/30 min. After reaching this depth 70 hours were lost due to weather. While running in the hole after the weather abated, hole problems (high torque, swelling clays, caving hole) were encountered below 3358 metres. The following steps were taken to overcome these problems:

1. Added Drispac and Drispac Superlo to reduce API filtrate to 5 cc or less.
2. Raised KCL content to 16-17% by weight.
3. Progressively raised mud weight from 9.9 ppg to 12.5 ppg.
4. Added 4 ppb Soltex to mud.
5. Added Torque Trim.
6. Added 10% by volume of diesel oil. (Temporary step only)

Raising the mud weight and adding diesel oil seemed to be the most effective measures in stabilizing the hole to the present total depth before running electric logs. Electric logs were unable to go deeper than 3534 metres. They indicated formation overpressuring started at approximately 3050 metres, increasing with depth.

During the subsequent clean-out trip, heavy cavings in the mud returns indicated deterioration of the hole condition.

The cementation of the 9-5/8 inch casing at 3519 metres was preceded by cavings and mud losses. The KCL - polymer mud system continued to be used for the 8-1/2 inch hole. Upon drilling out of the 9-5/8 inch casing shoe, hole problems (high torque, hole packing off, swelling clay) were encountered. The mud weight was raised from 12.5 ppg to 15.0 ppg, thereby stabilizing the formation. When turbodrilling ahead was resumed, the KCL content was thereafter increased from 16% to 25-26% by weight and Drispac Superlo was added to maintain an API filtrate around 5cc. Also Desco and dilution were used to maintain the rheological mud properties at acceptable levels and Soltex was added to combat torque problems. While making a wiper trip with the turbodrill at 4041 metres, some overpulls of 140,000 lbs were experienced. Some high torques were also occasionally occurring while drilling. It was therefore decided to increase the mud weight to 15.5 ppg, but before that mud was halfway up the annulus, with the bit drilling in a sand at 4052 metres there was a loss of circulation to the formation. Mud weight was reduced to 15.2 ppg, normal circulation was regained, and drilling proceeded to 4101 metres, when circulation was again lost. The mud weight was cut back to 15.0 ppg and a 30 bbl mica pill was pumped in the hole. Full circulation was regained. (The loss of circulation was most likely due to the combination of the high mud weight and high circulation rates used to operate the turbodrill. This combination caused a high pressure loss across the turbo which was capable of fracturing the formation). The hole was drilled on to 4200 metres with a conventional drilling bit and slick drillcollars with 15.0 ppg mud without problems. The well was logged, plugged and abandoned.

Mud properties, materials and costs are given in Tables 5, 6, and 7.

Table 5

Bridgewater Bay No. 1

Mud Properties

Depth (m)	Hole Size (inches)	Weight (ppg)	Chloride (PPM)	KCL (%WT.)	OIL (%)	Water Loss (API)	Viscosity (sec)	PV	YP	PH
180	36	8.5	-	-	-	-	200+	-	-	-
256	26	8.5	-	-	-	-	200+	-	-	
504	26	8.5	-	-	-	-	200+	-	-	
842	17-1/2	9.3	12,000	-	-	13.0	35	6	6	10.0
988	17-1/2	9.2	13,000	-	-	10.0	38	10	10	10.0
1120	17-1/2	9.1	15,000	-	-	12.0	37	6	7	9.4
1188	17-1/2	9.2	15,000	-	-	12.5	36	7	7	9.9
1514	17-1/2	9.1	15,000	-	-	12.0	36	7	7	9.4
1603	17-1/2	9.1	15,000	-	-	10.0	43	7	10	9.6
1664	12-1/4	9.2	75,000	-	-	10.0	39	9	15	9.5
1832	12-1/4	9.4	73,000	-	-	9.8	38	10	14	9.5
2113	12-1/4	9.4	75,000	-	-	9.8	36	9	14	9.3
2094	12-1/4	9.4	75,000	10.0	-	9.8	36	9	14	9.3
2221	12-1/4	9.6	63,000	9.5	-	9.8	35	9	9	8.4
2344	12-1/4	9.5	59,000	7.0	-	8.0	38	12	12	9.5
2434	12-1/4	9.5	59,000	9.0	-	8.0	38	13	14	9.5
2469	12-1/4	9.5	57,500	9.0	-	8.4	36	9	10	10.0
2470	12-1/4	9.5	57,000	9.0	-	8.8	37	10	9	10.5
2499	12-1/4	9.5	56,500	10.0	-	7.4	37	10	10	10.0
2693	12-1/4	9.6	60,000	10.0	-	8.7	36	9	9	10.0
2745	12-1/4	9.6	60,000	10.0	-	7.8	36	10	11	9.5
2861	12-1/4	9.7	61,500	11.5	-	8.2	37	10	11	9.0
2979	12-1/4	9.7	60,000	11.0	-	7.8	37	12	11	9.0
3073	12-1/4	9.7	61,500	12.0	-	7.2	39	14	13	9.5
3121	12-1/4	9.7	62,000	12.0	-	6.9	39	12	11	9.5
3257	12-1/4	9.7	61,000	12.0	-	7.4	36	10	10	9.5

Table 5 (continued)

Mud Properties

Depth (m)	Hole Size (inches)	Weight (ppg)	Chloride (PPM)	KCL (%WT.)	OIL (%)	Water Loss (API)	Viscosity (sec)	PV	YP	PH
3385	12-1/4	9.8	59,500	10.0	-	8.4	36	9	9	9.5
3476	12-1/4	9.9	60,500	10.0	-	8.9	36	9	7	9.0
3550	12-1/4	9.9	60,000	10.0	-	8.6	37	10	9	9.5
3550	12-1/4	11.2	77,000	15.0	9	7.0	44	15	20	9.5
3550	12-1/4	12.5	86,000	16.0	8	4.2	61	30	26	9.0
3550	8-1/2	14.0	86,000	16.0	7	5.6	58	38	22	11.5
3551	8-1/2	14.9	87,500	14.0	6	6.2	68	47	20	10.0
3559	8-1/2	14.9	95,000	14.5	6	4.6	73	50	23	10.5
3604	8-1/2	15.0	144,000	26.0	5	5.8	63	43	20	10.0
3623	8-1/2	15.1	142,000	25.0	5	5.5	63	40	27	9.5
3655	8-1/2	15.0	144,000	26.0	4	4.8	64	41	19	10.0
3725	8-1/2	14.9	149,000	22.0	3	6.2	66	37	21	10.0
3790	8-1/2	15.0	147,000	23.0	2	7.4	65	30	15	9.5
3868	8-1/2	15.0	147,500	24.0	1	5.6	54	33	17	10.5
3937	8-1/2	15.0	146,500	25.0	1	5.6	54	32	16	10.0
4023	8-1/2	15.0	145,000	24.0	1	5.2	53	34	19	10.0
4056	8-1/2	15.2	151,000	26.0	1	5.1	48	31	14	10.0
4059	8-1/2	15.1	148,000	26.0	1	5.8	48	31	14	10.0
4101	8-1/2	14.9	134,000	25.5	1	5.8	49	33	14	10.0
4102	8-1/2	15.0	134,500	24.5	1	6.1	49	33	14	9.5
4147	8-1/2	14.9	141,000	26.0	1	4.8	54	36	18	10.0
4180	8-1/2	15.0	143,000	26.0	1	5.1	50	36	15	10.5
4200	8-1/2	15.0	143,000	26.0	1	5.0	48	33	15	10.0

Table 6

Bridgewater Bay No. 1

Mud Materials

Type	Unit	Quantity
Al. Stearate	25 kg	6
Aquagel (bulk)	100 lbs	2,430
Aquagel (sack)	100 lbs	42
Baradefoam	55 gal	6
Caustic Soda	70 kg	167
Desco	25 lbs	356
Drispac	50 lbs	435
Drispac Superlo	50 lbs	307
Lime	25 kg	6
Mica	40 lbs	30
Potassium Chloride	50 kg	6,694
Soda ash	40 kg	95
Soltex	50 lbs	454
Torque Trim II	55 gal	12
Walnut	50 lbs	47
XL Polymer	50 lbs	136
Baroid (bulk)	100 lbs	17,620
Diesel Oil	bbl	200
Mud chemicals	bbl	1,300
Reserve mud	bbl	250
Barite	bbl	1,178
Fresh water	bbl	14,238
Sea water	bbl	6,960
Total mud made	bbl	24,126

g) Relevance to the Occurrence of Hydrocarbons

Hydrocarbon Indicators

A continuous record of gas levels was maintained by Geoservices after drilling out of the 20-inch casing shoe at 493.11 metres in Bridgewater Bay No. 1 (Addendum 2 , Enclosure 2). Total gas determinations and chromatographic analyses were conducted using a Geoservices gas chromatograph and a Flame Ionization Detector (FID). No hydrocarbon indications were noted from cuttings or sidewall cores examined. However, the extreme sensitivity of the Flame Ionization Detector allowed for the recording of trace amounts of C_2 and C_3, which otherwise would have gone undetected using the conventional chromatograph.

From the first sample returns at 513 metres to a depth of 2500 metres, only trace amounts of C_1 gas were recorded. The C_1 content ranged from a trace amount to a maximum of 4 percent between 2500 metres and 3480 metres with trace amounts of C_2 and C_3 present. In the Belfast Formation between 3480 metres and 4050 metres, C_1 ranged from trace amounts to a maximum of 0.12 percent with trace amounts of C_2 and C_3 being logged in only a few of the sample intervals. From 4050 metres to 4053 metres a C_1 maximum of 13 percent was recorded, and after circulating at 4052 metres, 0.12 percent C_2 was also detected. This C_1 peak was related to overpressure/lost circulation problems which were encountered at this zone. Trace amounts of C_1 were recorded from 4055 metres to the total depth of the well at 4200 metres.

Porosity and Permeability

Potential reservoir sections in Bridgewater Bay No. 1 comprise the Lower Tertiary Dilwyn and Pebble Point Formations and the Mid to Late Cretaceous Curdies, Paaratte, and Waarre Formations.

The Dilwyn Formation extends from 901 metres to 1168 metres and is comprised of lower delta plain sandstones with interbedded claystone and siltstone. Coal beds ranging in thicknesses of one-to-two metres occur in the top portion of this section. Sandstone beds range from two-to-nine metres in thickness with reservoir quality deteriorating with depth. In the uppermost 49 metres of the Dilwyn Formation the sandstones are quartzose, fine-to-medium grained, with occasional coarse

The Waarre Formation was penetrated between 4102 metres and 4200 metres (Total Depth) and is comprised of interbedded sandstone and claystone with minor siltstone. The Waarre Formation sequence was deposited in a transgressive shallow marine environment. The sandstone is white to light grey, very fine-to-fine grained, angular to subangular, with fair sorting, low-to-moderate sphericity, very clayey, very silty, siliceous cement, carbonaceous, with very poor-to-no visual porosity. The Waarre Formation was the principal drilling objective of the Bridgewater Bay No. 1 well. The CPI log indicates log-derived porosities of less than 2 percent throughout the section. Although the complete Waarre Formation was not penetrated, it must generally be regarded as having very poor reservoir quality in this portion of the basin.

Source Rock Potential

The hydrocarbon source rock potential of the sedimentary section encountered in Bridgewater Bay No. 1 was evaluated using geochemical analysis, palynological and vitrinite reflectance data, incorporated with borehole temperature measurements.

Organic geochemical analyses were performed by Analabs on thirty-one 50-metre composite drill cuttings samples taken over the interval 2700 - 4200 metres. The samples were analysed for Total Organic Carbon (TOC) content and by gas chromotography and pyrolysis (Appendix 7). Additional TOC determinations and pyrolysis, vitrinite reflectance, kerogen and spore coloration studies were also performed on thirteen sidewall cores by the Exploration Projects Section of Phillips Petroleum Company (Appendix 8).

Light hydrocarbons (C_1 and C_7) gas chromatography (headspace analysis; Appendix 7) was also performed by Analabs on cuttings samples over the interval 1130 - 4200 metres. These results indicate that sands within the interval are lean in gas and condensate, and consequently are considered to be non-prospective for any significant quantitites of indigenously-generated hydrocarbons.

Vitrinite reflectance measurements were performed on four cuttings samples at 2800 metres, 3200 metres, 3600 metres and 4200 metres. However, only two samples, those at 2800 metres and 3200 metres, contained measurable vitrinite. Both of these samples gave marginally mature reflectances (0.55% Ro and 0.53% Ro) placing these rocks in the initial stages of petroleum generation.

Tmax-pyrolysis temperatures were obtained from the thirty-one cuttings samples. The temperatures in the primary zone of interest were found to be contaminated by a petroleum-based mud additive and were therefore interpreted as being unreliable below 3600 metres. The temperatures were found to vary greatly in the overlying uncontaminated section and were found to be devoid of any recognizable maturity trend. Computer-generated results illustrate very erratic S_2 peaks, for Tmax analysis, which are interpreted to be due to the poor quality organic matter and reworked inertinite present in those samples.

The samples in the uncontaminated section contained good amounts of organic matter (>1.0 percent TOC) but the quality appeared to be low due to the overall low hydrogen index values. This resulted in the potential yields being lower, giving those sediments an overall poor hydrocarbon source character. However, the samples at 2700 metres, 2945 metres, and 3050 metres, have moderate hydrogen index values, with marginal-to-moderate potential yields.

The overall summary presented by Analabs' analysis indicates the sedimentary section penetrated in the Bridgewater Bay No. 1 well to have experienced a low degree of thermal maturation. This is based on the marginally mature Ro values obtained at 2800 metres and 3200 metres. The sediments below 3200 metres are not considered by Analabs to have obtained levels much higher than marginally to moderately mature. This would then place them within the top to middle portions of the oil window. This conclusion is not confirmed by maturation results obtained independently by Phillips Petroleum Company (Figure 14), and appear to be invalid. Pyrolysis analysis performed by Phillips

Although Analabs would be considered to have a high level of expertise Australia wide and specifically in the Otway Basin, they were provided with sample cuttings which in all liklihood had been contaminated by sloughing. This contamination material would have been the result of the drilling difficulties encountered in the overpressure zone beginning at 3050 metres. Phillips Petroleum Company, on the other hand, were provided with sidewall cores taken from 934 metres to 4175 metres. These sidewall cores would be the most representative samples of the formation at the sample points. Therefore, the resulting analytical data would be the most valid.

The present day geothermal gradient at Bridgewater Bay No. 1 is 2.87°C/100 metres as calculated from the bottom hole temperature at each logging run extrapolated to static equilibrium temperature (Figure 15).

SANDSTONE POROSITY Vs DEPTH
BRIDGEWATER BAY - 1

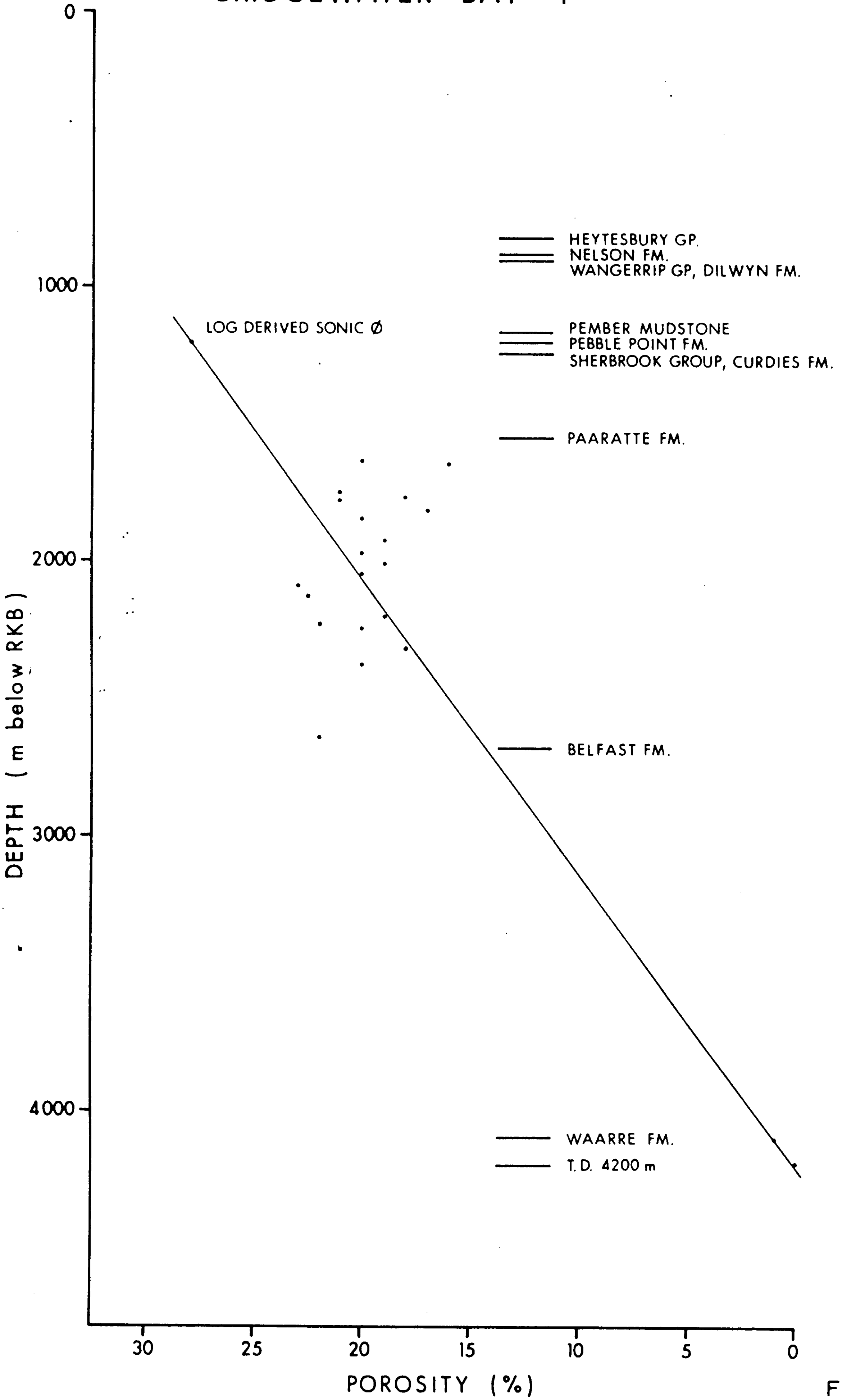


FIGURE 13
A-6150

VITRINITE REFLECTANCE Vs DEPTH
BRIDGEWATER BAY - 1

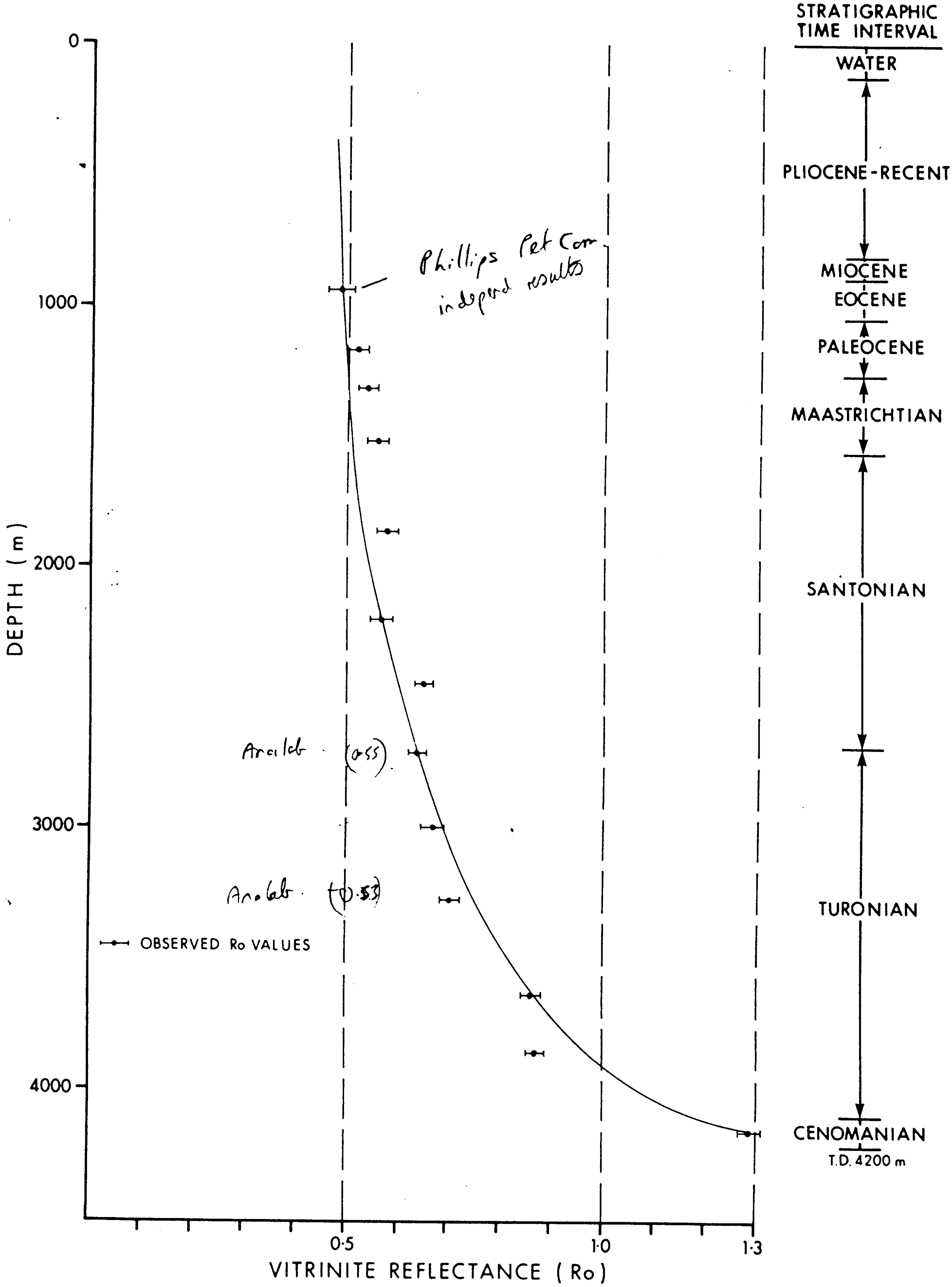


FIGURE 14

A-6151

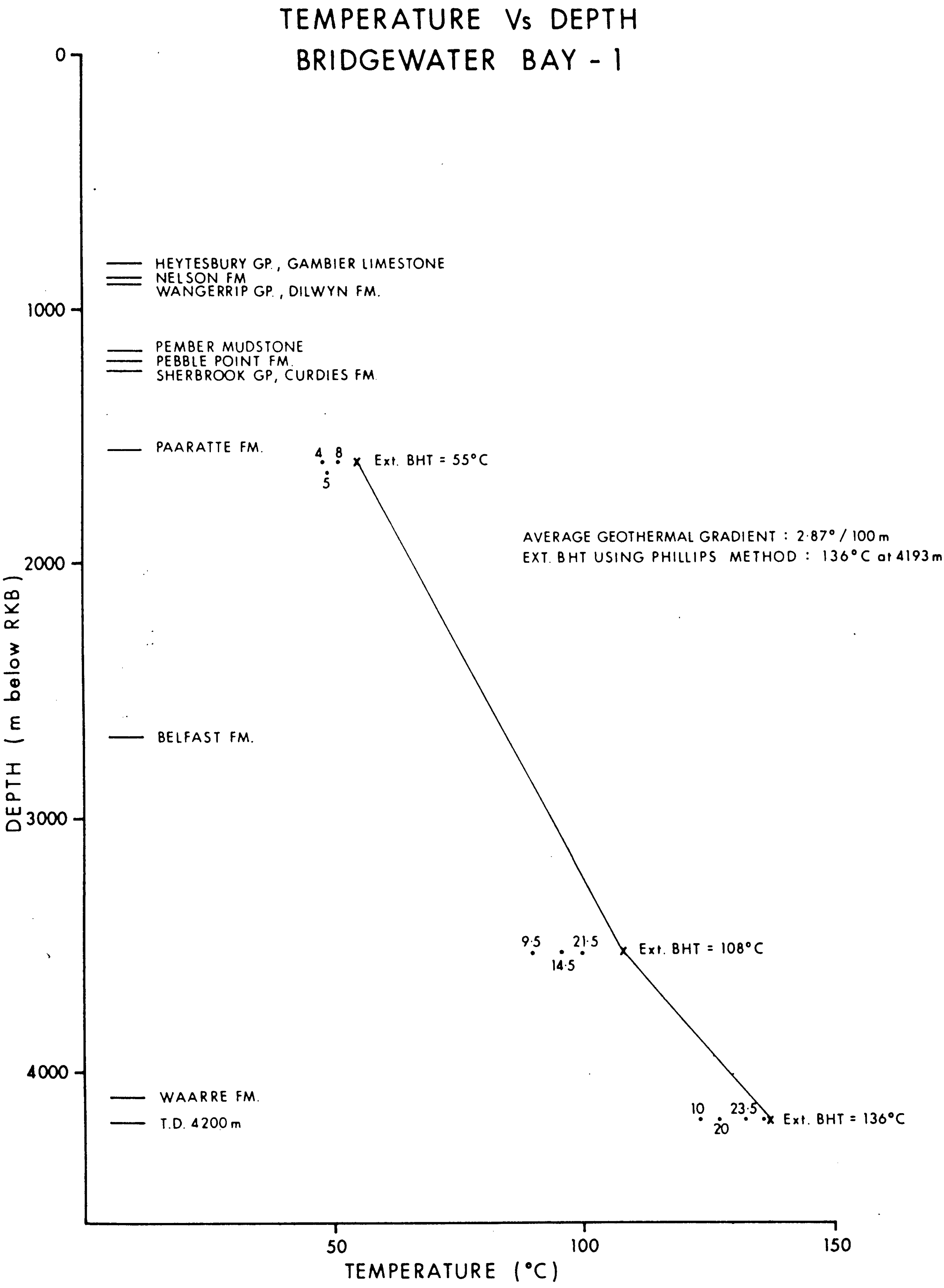


FIGURE 15

A- 6149

Summary of Hydrocarbon Significance

1. The lack of significant accumulations of hydrocarbons at Bridgewater Bay No. 1 can be attributed to the following parameters:

a) The Bridgewater Bay No. 1 well penetrated the basal Paaratte Formation/Top Belfast Formation contact 482 metres lower than anticipated. The mapped faulted anticlinal closure is considered to be valid because of the conformability of the mid-Sherbrook sediments. However, the lack of hydrocarbon shows indicates either that the bounding fault does not seal or that hydrocarbons have not migrated into the structure. The latter consideration is favoured because of the demonstrated poor source potential of the underlying Belfast Formation.

Minor sandstone beds were developed at the top of the Belfast Formation. However, they were only one to three metres thick and due to a very silty and clay choked matrix displayed very poor porosity development.

b) In excess of 100 metres of vertical closure was predicted for a faulted anticlinal structure developed at the Waarre Formation level. Because of seismic miscorrelation, the sandstones of the Waarre Formation were penetrated some 1100 metres lower than anticipated and were found to have log-derived porosities of less than two percent with very possibly nil permeability. Although there was no structural closure developed at the deeper level, the poor reservoir quality would have prohibited the trapping of significant hydrocarbons.

c) Excellent reservoir sections exist within the Pebble Point, Curdies and basal Paaratte Formations. The 39 metres of the Pebble Point Formation contain log-derived sonic porosities of between 26 percent and 44 percent and the overlying Pember Mudstone provides an excellent seal for any structural development. The sandstones of the Curdies Formation display fair-to-excellent visual porosity but lack top and intra-formational sealing mechanisms. Good quality reservoir sections are also developed within the sandstones of the Paaratte Formation, the average porosity of selected sand units being 17 percent. Log-derived porosities in the sandstones of the basal Paaratte Formation were between 10 percent and 22 percent.

d) Good quality source rocks were not penetrated at Bridgewater Bay No. 1. TOC values varied from fair-to-excellent and the majority of the samples analyzed were dominated by liquid-prone amorphous kerogen. However, the combination of low hydrogen index and lack of fluorescence indicates poor liquid hydrocarbon potential through oxidation. Thermal maturity, however, was attained below approximately 3295 metres on the basis of vitrinite reflection analysis of sidewall core material.

2. In that thermal maturity was attained below approximately 3295 metres, and a majority of samples analyzed were dominated by liquid-prone amorphous kerogen, it has been concluded that anerobic conditions which would enhance the source rock potential of the Belfast Formation could be developed in a more basinward position. The potential of Upper Sherbrook and Lower Tertiary plays may therefore be enhanced basinward of the Bridgewater Bay No. 1 location.

3. Conversely to item 4 above, Waarre Formation plays are more prospective in a landward direction, where higher energy conditions would have winnowed out the finer material and where shallower buried depths would have lessened the effects of sediment compaction. The thermal maturity of Otway Group source rocks would also be less with shallower buried depths landward.

APPENDIX NO. 7

BASIC HYDROCARBON SOURCE ROCK POTENTIAL ANALYSIS OF BRIDGEWATER BAY No. 1 SIDEWALL CORE SAMPLES*

PETROLEUM GEOCHEMISTRY

HYDROCARBON SOURCE ROCK

EVALUATION STUDY

BRIDGEWATER BAY NO. 1

Prepared for

PHILLIPS AUSTRALIAN OIL COMPANY

MARCH, 1984.

ANALABS
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HYDROCARBON SOURCE ROCK

EVALUATION STUDY

BRIDGEWATER BAY NO. 1

SUMMARY

Organic geochemical analyses performed on well cutting samples between 1130m to 4200m in the Phillips Australian Oil Company, Bridgewater Bay No. 1 well drilled in Vic-P-14 offshore Victoria, Australia in the Otway Basin have indicated:

- The rocks from 2800m to 3200m are marginally mature and considered to be in the initial stages of petroleum generation. Reliable maturity data is unavailable for the remaining intervals penetrated by this well, however, we suspect that the maturity at the bottom of the well does not exceed oil generating maturation levels.

- The rocks between 2700m to 3550m have an overall poor oil and gas source character with marginal to moderate hydrocarbon source potential at 2700m, 2945m and 3050m.

- The rocks below 3550m are contaminated with an oil base mud additive, which has affected the total organic carbon and pyrolysis results. The C_1-C_7 light hydrocarbon results appear to be unaffected, however the values are low and indicate these rocks have poor oil and gas generating capabilities.

PAUL TYBOR

INTRODUCTION

Organic geochemical analyses have been performed on well cutting samples between 1130m to 4200m in the Phillips Australian Oil Company's Bridgewater Bay No. 1 well, drilled in Vic-P-14 offshore Victoria, Australia in the Otway Basin (38° 32'26"S; 141° 21'48"E).

The purpose of this study has been to evaluate the hydrocarbon source quality (oil vs gas), richness and state of thermal maturity (pre oil, oil-generative, post oil-generative) of the rocks analysed from this well.

Analytical

The samples from this well were assigned the Analabs Job Number 31840. A total of two hundred and seventy-seven (277) wet canned well cuttings were submitted to C_1-C_7 light hydrocarbon head space gas chromatography. Another thirty-one (31) samples, which were picked and high graded by Phillips personnel, were analysed by % total organic carbon and Rock-Eval pyrolysis analysis. Four (4) samples were chosen for vitrinite reflectance, and these were sent to David Marchioni and Associates for assessment.

The results of these analyses are presented in the following:

Type of Analysis	Figure	Table
C_1-C_7 light hydrocarbon head space gas chromatography	1	1
% total organic carbon determination	2	2
Pyrolysis analysis	2	2
Vitrinite reflectance and coal maceral description	1,2,3	

RESULTS AND INTERPRETATIONS

A. Thermal Maturity of Sediments

The maturity data available for samples from this well are limited due to apparent poor quality organic matter, within the sediments, and contamination added to the drilling mud.

Vitrinite reflectance was performed on four samples at 2800m, 3200m, 3600m and 4200m, with only the two samples at 2800m and 3200m containing measurable vitrinite. Both samples gave marginally mature reflectances (0.55 % Ro and 0.53 % Ro; Figures 1, 2 and 3), which places these rocks in the initial stages of petroleum generation.

Tmax pyrolysis temperatures were obtained from thirty-one (31) picked cuttings samples. The temperatures in the contaminated zone below 3600m are interpreted to be unreliable due to this contamination. In the overlying uncontaminated section the temperatures vary greatly, without any recognisable maturity trend present. The pyrograms illustrate very erratic S_2 peaks, the peak at which Tmax is recorded, which we interpret to be due to the poor quality organic matter present in these samples (ie. reworked, inertinite).

In summary, the sedimentary section penetrated by this well, has probably experienced a low degree of thermal maturation, based on the marginally mature % Ro values obtained at 2800m and 3200m. Below these depths we can only speculate on the maturity of the rocks, however, we feel that the sediments do not obtain levels much higher than marginally/ moderately mature, and would be within the top to middle portions of the oil window.

B. Hydrocarbon Source Characterisation

Due to the drilling mud contamination present in the samples below 3600m, it is difficult to determine the hydrocarbon source rock character of these sediments. However, the C_1-C_7 light hydrocarbon headspace gas chromatography data does not appear to have affected, as has the % T.O.C. and pyrolysis data. This gas data is low (Figure 1; Table 1), and consequently we interpret these sediments have poor hydrocarbon source rock characteristics.

The samples in the uncontaminated section contain good amounts of organic matter (>1.0% T.O.C.; Figures 1 and 2; Table 2), but the quality appears to be low due to the overall low hydrogen index values observed (Figure 2; Table 2). As a result, the potential yields are low (S_1+S_2; Figure 2; Table 2), which gives these sediments an overall poor hydrocarbon source character. The samples at 2700m, 2945m and 3050m, have moderate hydrogen index values, with marginal to moderate potential yields.

In summation, the sediments between 2700m to 3600m have overall poor oil and gas source potential, with thin zones at 2700m, 2945m and 3050m having marginal to moderate oil and gas potential at higher levels of thermal maturity.

Appendix B

FIGURE 1

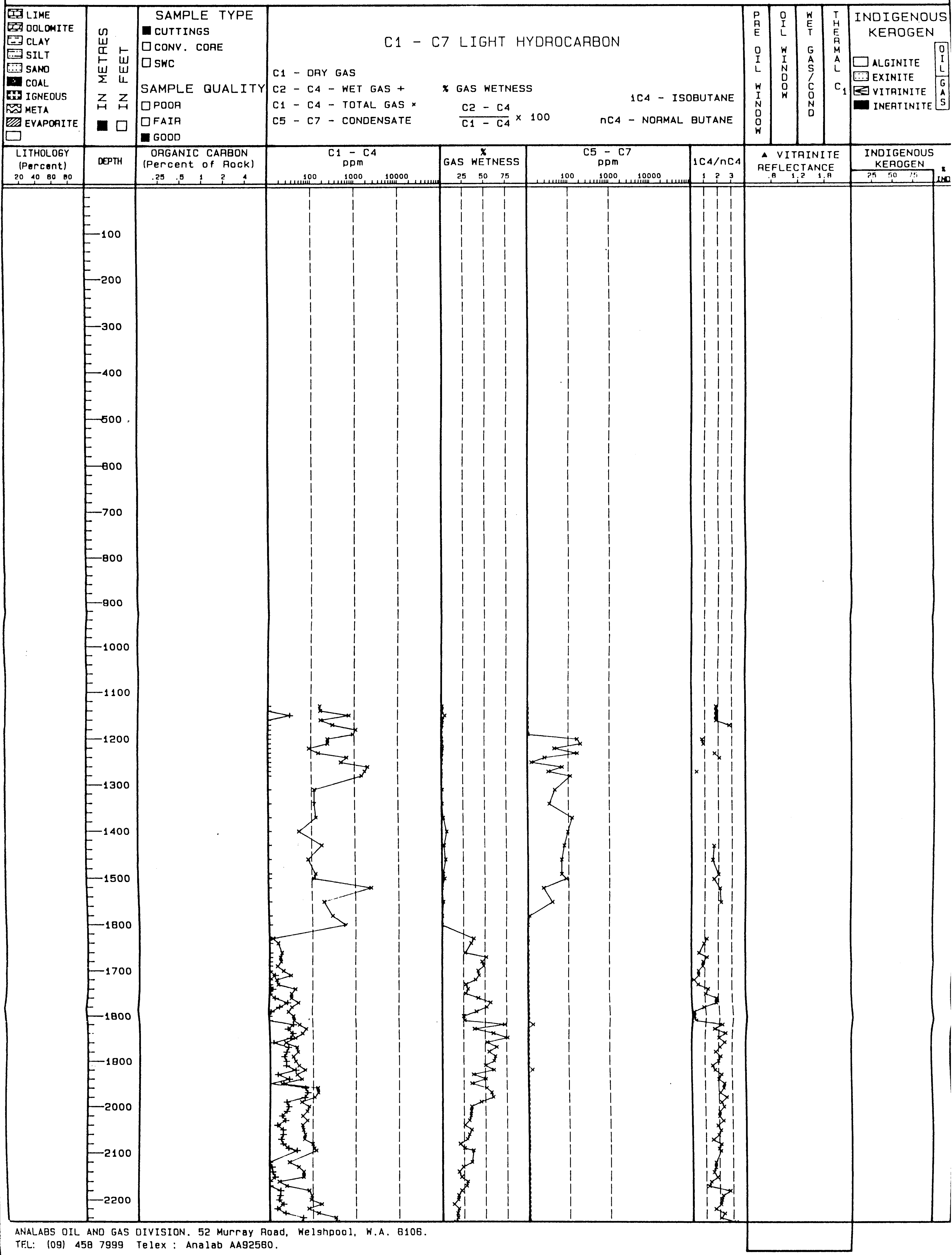
FEBRUARY 1984

ANA-LOG

HYDROCARBON SOURCE ROCK EVALUATION

PHILLIPS AUSTRALIAN OIL COMPANY

BRIDGEWATER BAY #1



ANALABS OIL AND GAS DIVISION. 52 Murray Road, Welshpool, W.A. 6106.
TEL: (09) 458 7999 Telex : Analab AA92580.

FIGURE 1

FEBRUARY 1984

ANA-LOG

HYDROCARBON SOURCE ROCK EVALUATION

PHILLIPS AUSTRALIAN OIL COMPANY

BRIDGEWATER BAY #1

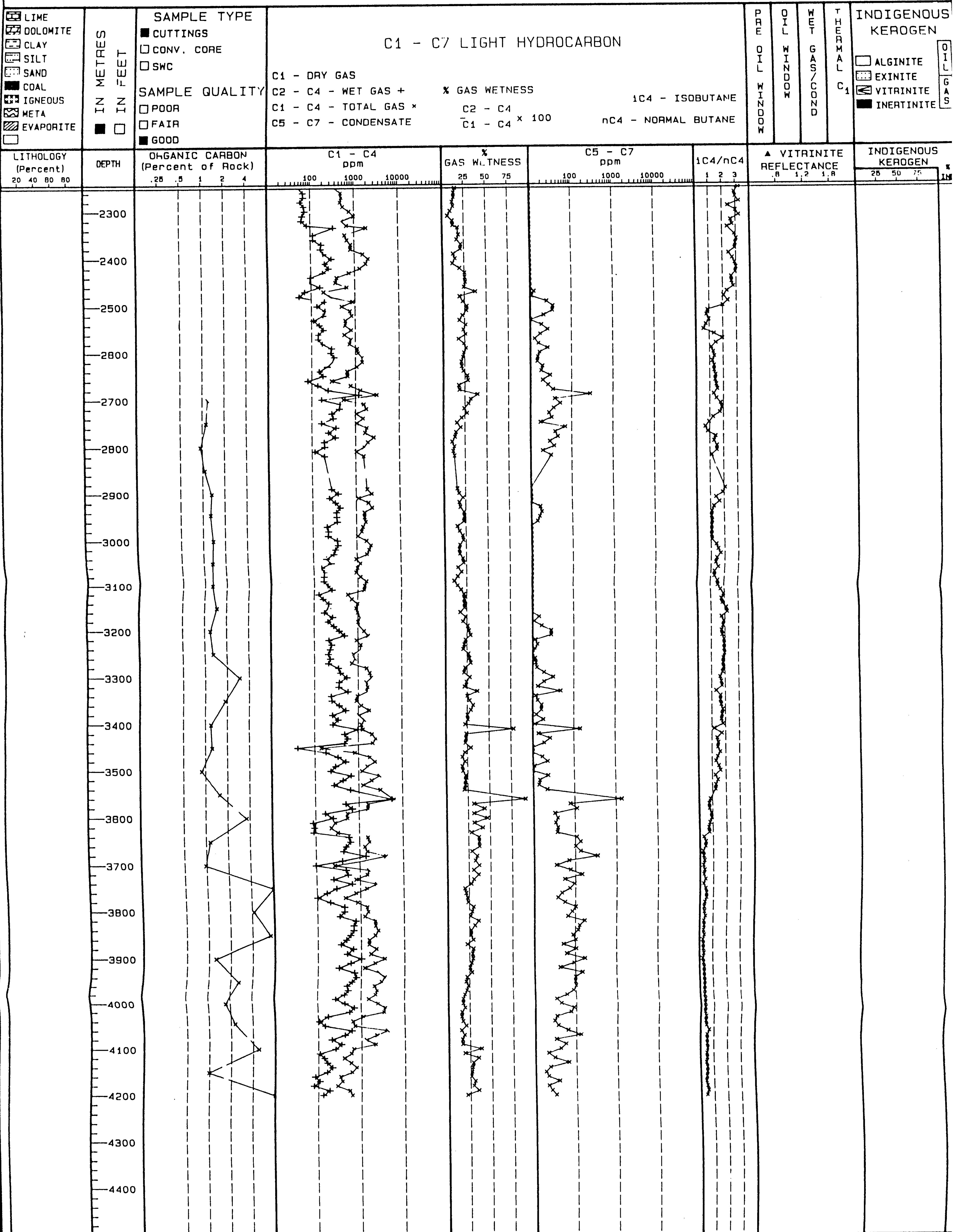


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FIGURE 2

FEBRUARY 1984

ANA-LOG

HYDROCARBON SOURCE ROCK EVALUATION

PHILLIPS AUSTRALIAN OIL COMPANY

BRIDGEWATER BAY #1

LIME
DOLOMITE
CLAY
SILT
SAND
COAL
IGNEOUS
META
EVAPORITE

IN METRES ■ IN FEET □

SAMPLE TYPE
■ CUTTINGS
□ CONV. CORE
□ SWC

SAMPLE QUALITY
□ POOR
□ FAIR
■ GOOD

S_1 - VOLATILE HYDROCARBONS (HC) ×

S_2 - HC GENERATION POTENTIAL

$S_1 + S_2$ - TOTAL HYDROCARBON +

S_3 - ORGANIC CO_2

PI - PRODUCTION INDEX

$PI = \frac{S_1}{S_1 + S_2}$

HI - HYDROGEN INDEX

$HI = \frac{S_2}{TOC} \times 100$

OI - OXYGEN INDEX

$OI = \frac{S_3}{TOC} \times 100$

T_{max} [Max. Temp. S_2]

PRE OIL WINDOW | OIL WINDOW | WET GAS/COND | THERMAL C_1

INDIGENOUS KEROGEN
□ ALGINITE
□ EXINITE
◁ VITRINITE
■ INERTINITE

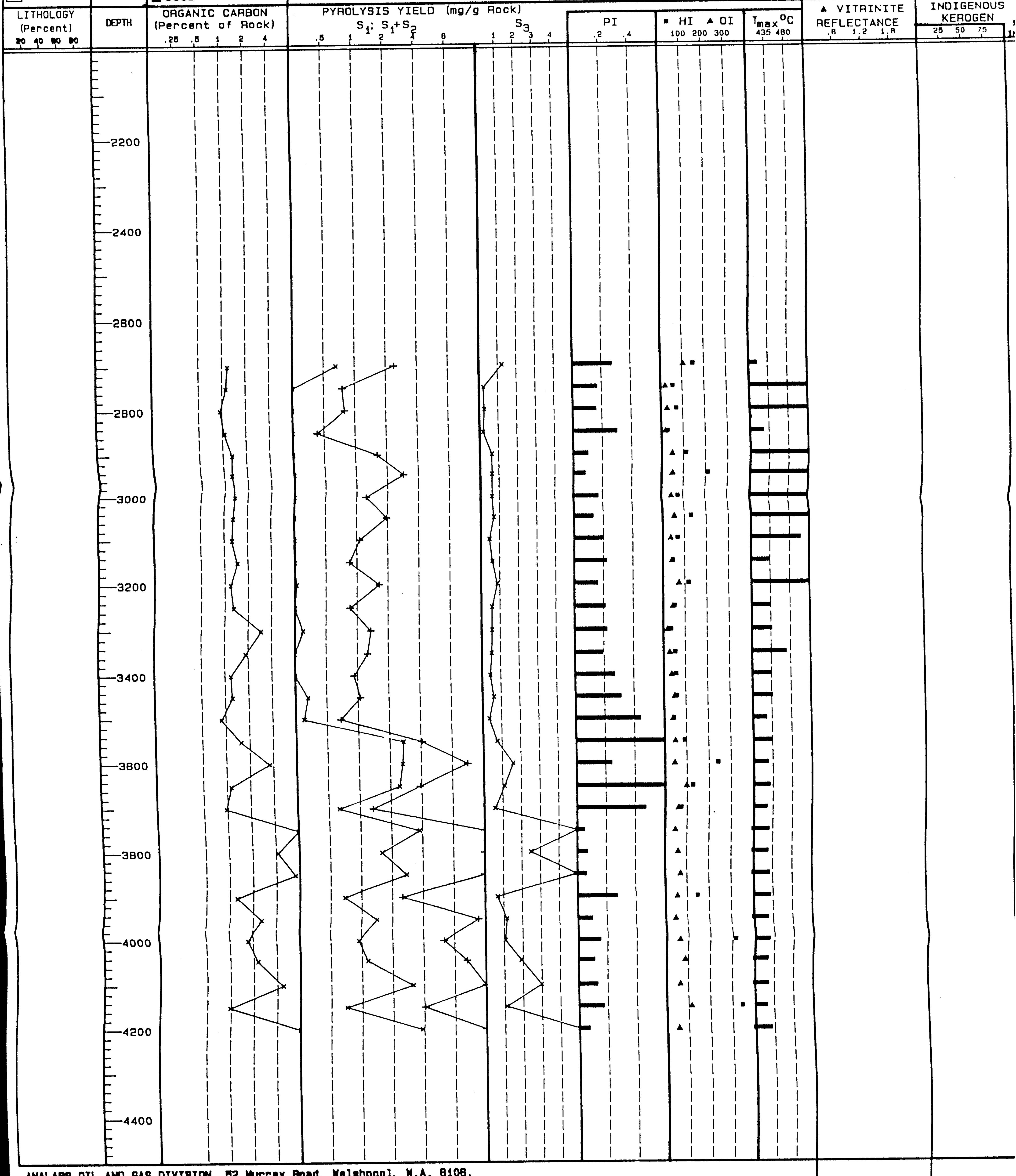

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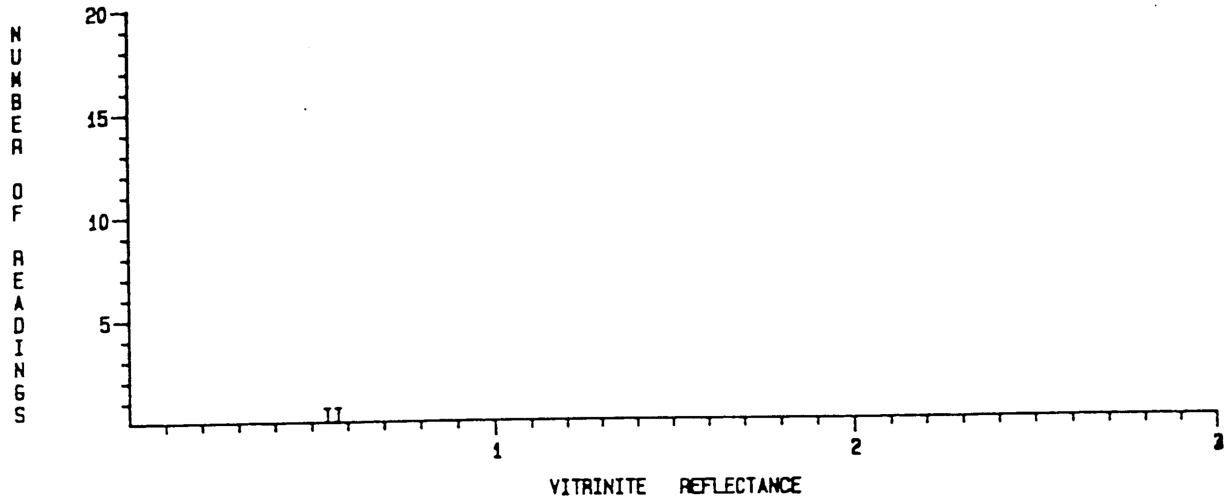
FIGURE : 3

VITRINITE REFLECTANCE AND COAL MACERAL IDENTIFICATION

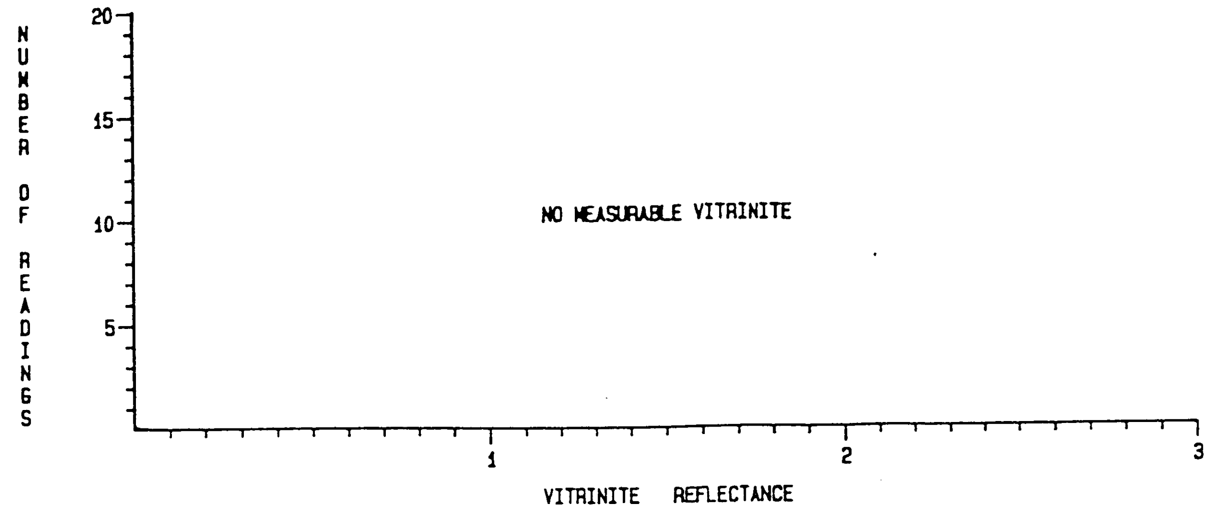
CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984 WELL NAME : BRIDGEWATER BAY #1
DEPTH OR SAMPLE No : 2800 Meters SAMPLE TYPE : CUTTINGS
(Total No. of Readings - 2) 0.54 0.57

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	POPULATION %	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	2	0.56	0.54	0.57	0.02	INDIGENOUS (I)	0.00	60.00	25.00	15.00



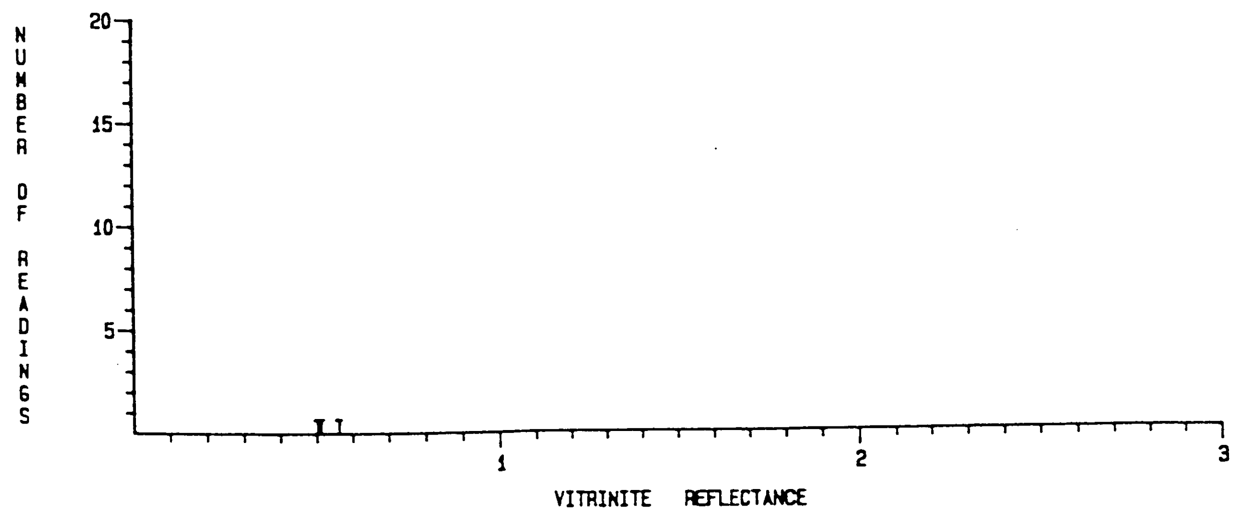
CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984 WELL NAME : BRIDGEWATER BAY #1
DEPTH OR SAMPLE No : 3600 Meters SAMPLE TYPE : CUTTINGS
(Total No. of Readings - 0)

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	POPULATION %	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite



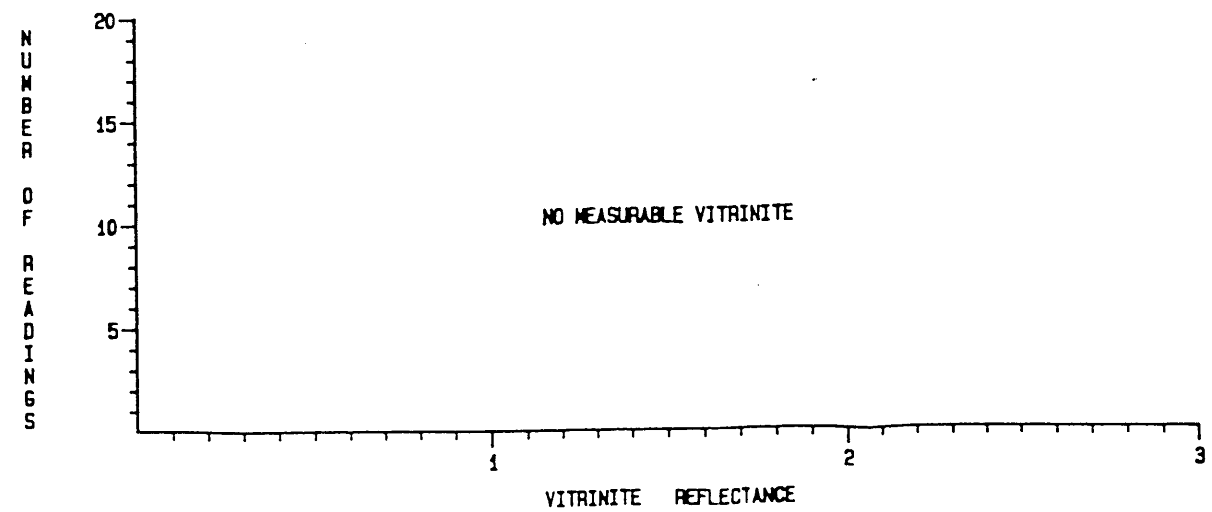
CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984 WELL NAME : BRIDGEWATER BAY #1
DEPTH OR SAMPLE No : 3200 Meters SAMPLE TYPE : CUTTINGS
(Total No. of Readings - 3) 0.50 0.51 0.56

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	POPULATION %	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	3	0.52	0.50	0.56	0.03	INDIGENOUS (I)	0.00	11.00	4.00	85.00



CLIENT NAME : PHILLIPS AUSTRALIA DATE : MARCH 1984 WELL NAME : BRIDGEWATER BAY #1
DEPTH OR SAMPLE No : 4200 Meters SAMPLE TYPE : CUTTINGS
(Total No. of Readings - 0)

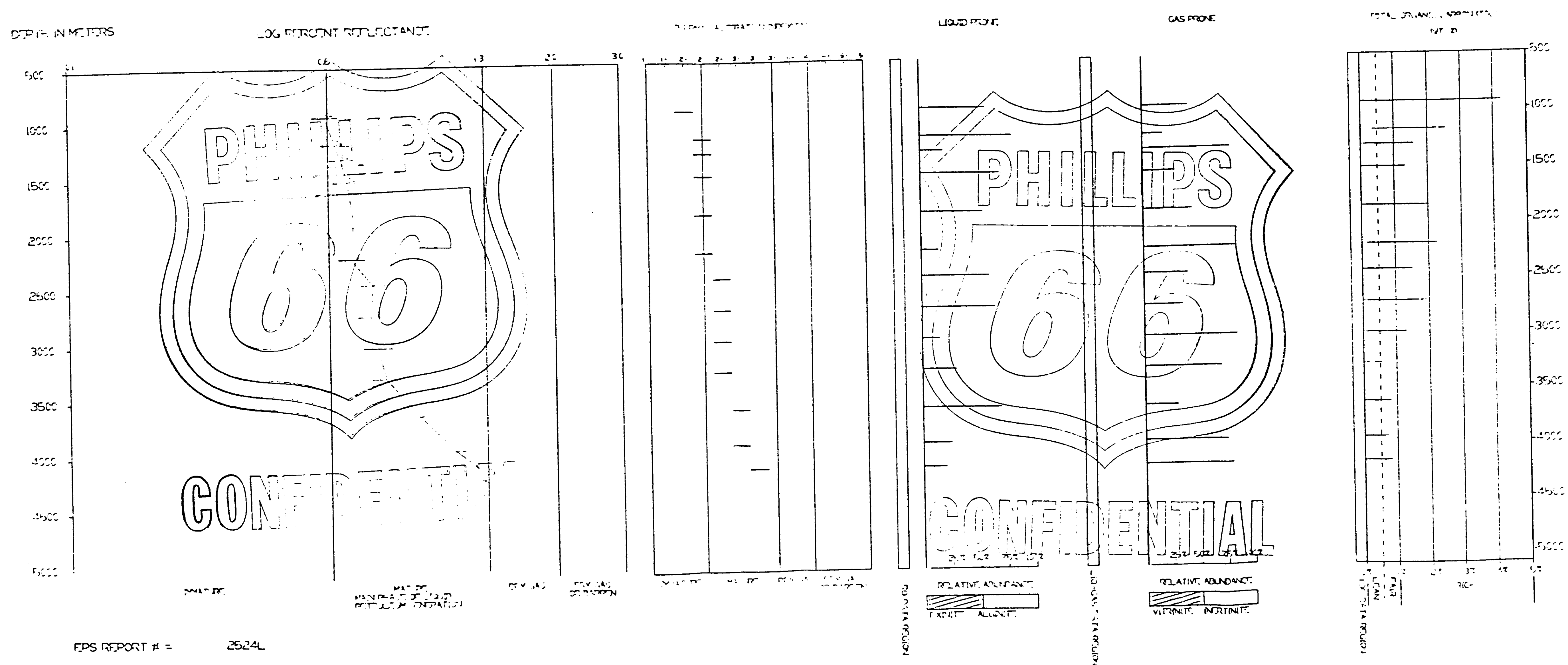
VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	POPULATION %	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite



BRIDGEWATER BAY #1, Otway Basin, Australia

THERMAL ALTERATION AND SOURCE ROCK POTENTIAL OF BRIDGEWATER BAY#1,OTWAY BASIN,AUSTRALIA

FIGURE 1



FPS REPORT # = 2524L

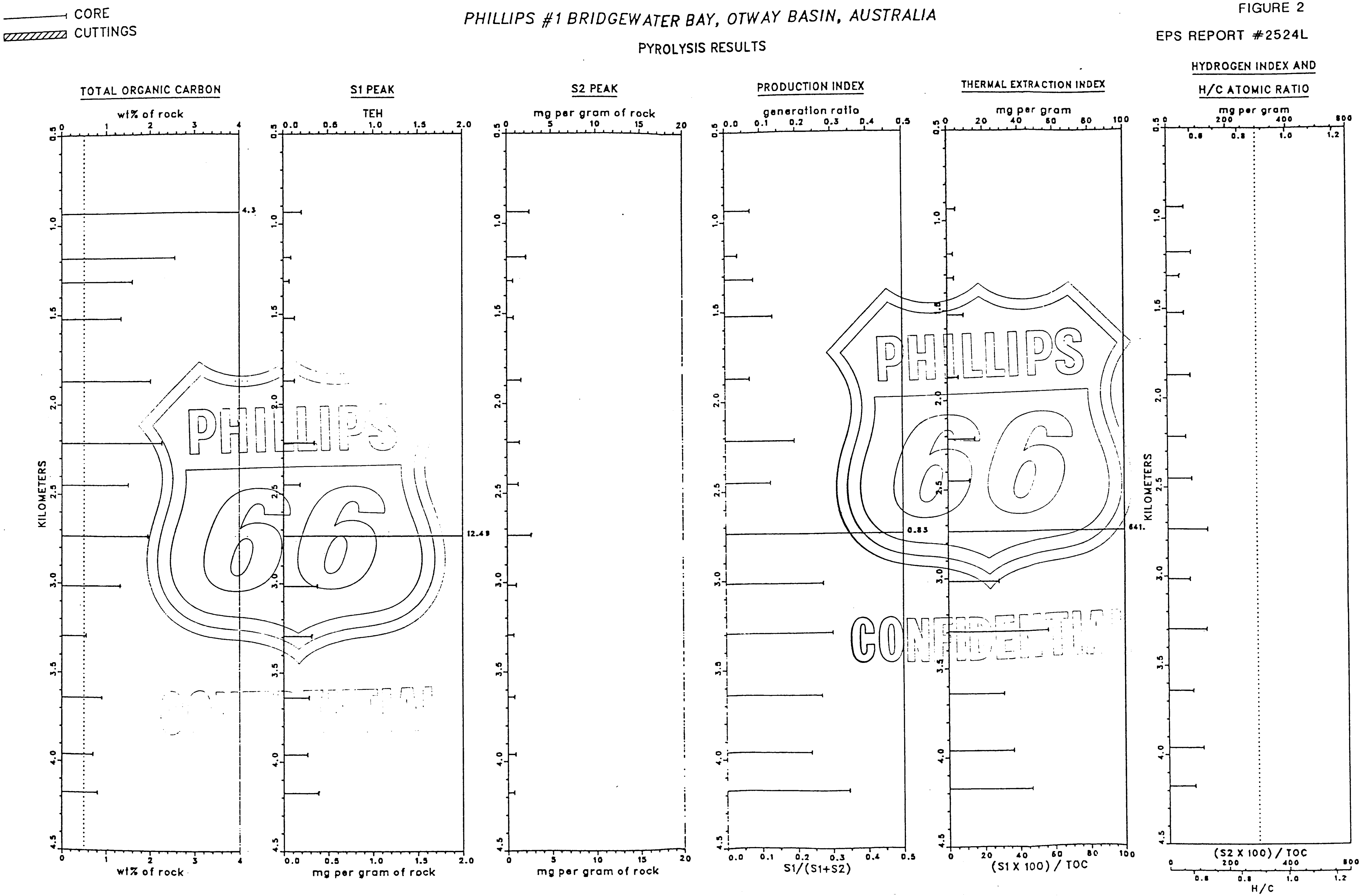
FIGURE 3

FIGURE 2

EPS REPORT #2524L

PHILLIPS #1 BRIDGEWATER BAY, OTWAY BASIN, AUSTRALIA

PYROLYSIS RESULTS



Permission to send this data to Cultus Petroleum NL has been given by Mike Woollands, Minerals & Petroleum, Victoria

23/5/97

D. Edwards

CONFIDENTIAL

HYDROCARBON CHARACTERISATION STUDY

OTWAY BASIN WELLS

Bridgewater Bay-1
Champion-1
Discovery Bay-1
Eric The Red-1
Fahley-1
Furgusons Hill-1
Lindon-1
Mussel-1
Nerita-1
Normanbay-1
North Eumeralla-1
Pecton-1A
Windermere-2

Prepared for:

Energy & Minerals, Victoria

June, 1996

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TABLE 2-1

BRIDGEWATER BAY-1

KK/ref. No.	Depth(m) Type	Rvmax	Range	N	Description Including Liptinite (Exinite) Fluorescence
T2179	1400 Ctgs	0.36	0.26-0.52	25	Sparse sporinite orange to dull orange, sparse cutinite orange rare resinite bright orange. (Siltstone>sandstone>>carbonate> coal>shaly coal. Coal rare, Inertite>Vitrite. Shaly coal rare, clarite. Dom abundant, I>V>L. Inertinite common, vitrinite and liptinite sparse. Mineral fluorescence weak to absent. Iron oxides common. Pyrite abundant.)
T2180	2050 Ctgs	0.43	0.32-0.62	26	Sparse sporinite orange to dull orange, sparse liptodetrinite orange to dull orange, sparse cutinite yellow to bright orange, rare resinite orange. (Siltstone>sandstone>carbonate. Dom abundant, I>L>V. Inertinite abundant, liptinite sparse to common and vitrinite sparse. Mineral fluorescence weak to absent. Iron oxides sparse. Pyrite abundant.)
T2181	2800 Ctgs $\bar{R}_I$max	0.62 1.39	0.46-0.77 0.96-2.44	11 9	Rare sporinite dull orange, rare ?phytoplankton dull orange. (Claystone>>siltstone>carbonate>coal. Coal rare, vitrite. Dom sparse I>L>V. Inertinite sparse, liptinite and vitrinite rare. Dom mainly occur as inertodetrinite in claystone. Mineral fluorescence absent. Pyrite common. Iron oxides abundant.)
T2182	3500 Ctgs	0.80	0.60-1.08	28	Rare lamalginite(?), and liptodetrinite, dull orange. (Siltstone> probable turbodrill debris. Dom common, I>V>L. Inertinite common, liptinite and vitrinite rare. Mineral fluorescence patchy, weak to absent. Iron oxides rare. Pyrite common.)
T2183	4120 Ctgs	?1.10	0.79-1.22	?8	Fluorescing liptinite absent. (Siltstone>carbonate. Many of grains probably artificial composites and cemented in part by bitumen. Dom rare, I>?V. Inertinite and ?vitrinite rare. Liptinite absent. The most unequivocal occurrence of vitrinite has a reflectance of 1.15, similar to that of the mean of all fields of probable vitrinite. Bitumen major, weak brown fluorescence, weak green oil cut. The bitumen may be an additive but the form is consistent with an origin from a high pour point oil. Fluorescence from the mounting polyester resin is intense as a result of hydrocarbons that have been extracted from the bitumen component. Mineral fluorescence pervasive, bright greenish yellow, possibly in part snow through from intensely fluorescing plastic mounting medium. Iron oxides rare. Pyrite common.)

The section is immature to a depth between 2050 and 2800 m, probably closer to the shallower interval than the deeper interval. From 2800 to TD, vitrinite reflectance rises sharply, and the maturation level is near the oil deadline in the deepest sample. Source potential is highest in the shallower samples but humic macerals are much more abundant than liptinite.

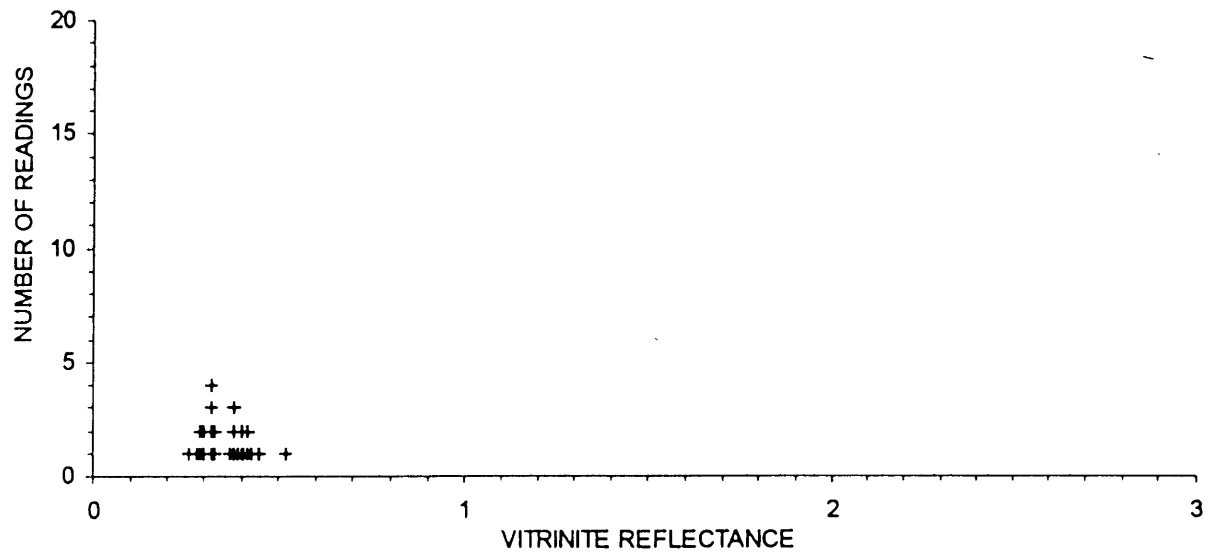
The deepest sample contains a high proportion of bitumen. This may be a mud additive but the form of some occurrences is consistent with an origin as a high pour point oil, or a mobile bitumen. The bitumen contains desiccation cracks that relate to loss of light ends after completion of grinding and polishing. Some Indonesian reservoirs give rise to cuttings with similar characteristics, but these are generally biodegraded oils.

FIGURE 1-1

WELL: BRIDGEWATER BAY 1 CLIENT: ENERGY & MINERALS, VICTORIA SAMPLE TYPE: CTGS
SAMPLE ID: 1400 METRES DATE: MAY 1996

(Total No. of Readings=25) 0.26 0.28 0.29 0.29 0.30 0.30 0.32 0.32 0.32 0.32 0.33 0.33 0.37 0.38 0.38 0.38 0.39 0.40 0.40 0.41 0.42 0.42 0.43 0.45 0.52

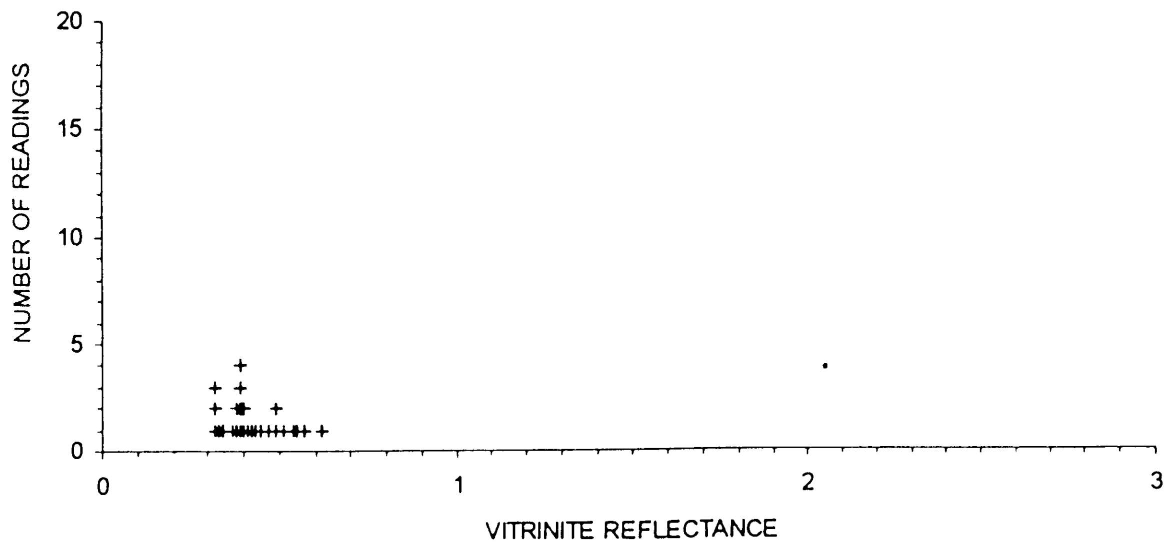
VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min Ro (%)	Max Ro (%)	STD Dev (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100.0	25	0.36	0.26	0.52	0.06	INDIGENOUS (+)	0.00	4.35	17.39	78.26



SAMPLE ID: 2050 METRES SAMPLE TYPE: CTGS

(Total No. of Readings=26) 0.32 0.32 0.32 0.33 0.34 0.37 0.38 0.38 0.39 0.39 0.39 0.39 0.40 0.40 0.41 0.42 0.43 0.45 0.47 0.49 0.49 0.51 0.54 0.55 0.57 0.62

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min Ro (%)	Max Ro (%)	STD Dev (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100.0	26	0.43	0.32	0.62	0.08	INDIGENOUS (+)	0.00	17.24	13.79	68.97



WELL: BRIDGEWATER BAY 1 CLIENT: ENERGY & MINERALS, VICTORIA SAMPLE TYPE: CTGS
SAMPLE ID: 2800 METRES DATE: MAY 1996

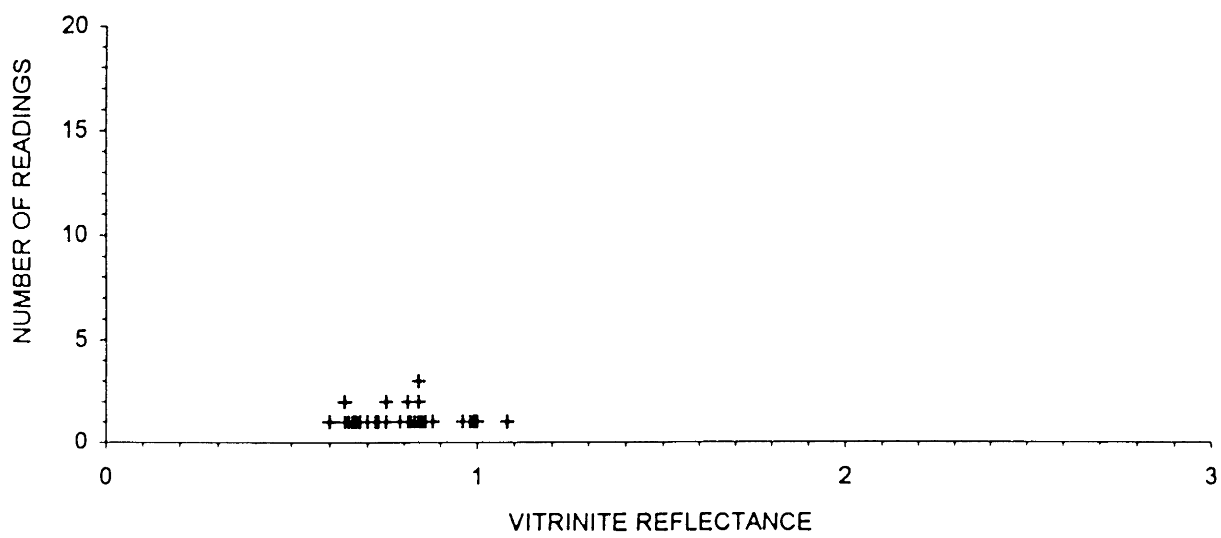
(Total No. of Readings=20) 0.46 0.54 0.56 0.59 0.60 0.62 0.62 0.63 0.67 0.74 0.77 0.96 1.00 1.08 1.14 1.16 1.40 1.56 1.88 2.44

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min Ro (%)	Max Ro (%)	STD Dev (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	55.0	11	0.62	0.46	0.77	0.09	INDIGENOUS (+)	0.00	0.00	0.00	100.00
2	45.0	9	1.40	0.96	2.44	0.49	INERTINITE (x)				

SAMPLE ID: 3500 METRES SAMPLE TYPE:CTGS

(Total No. of Readings=28) 0.60 0.64 0.64 0.65 0.66 0.67 0.68 0.70 0.72 0.73 0.75 0.75 0.79 0.81 0.81 0.82 0.83 0.84 0.84 0.84 0.85 0.86 0.88 0.96 0.98 0.99 1.00 1.08

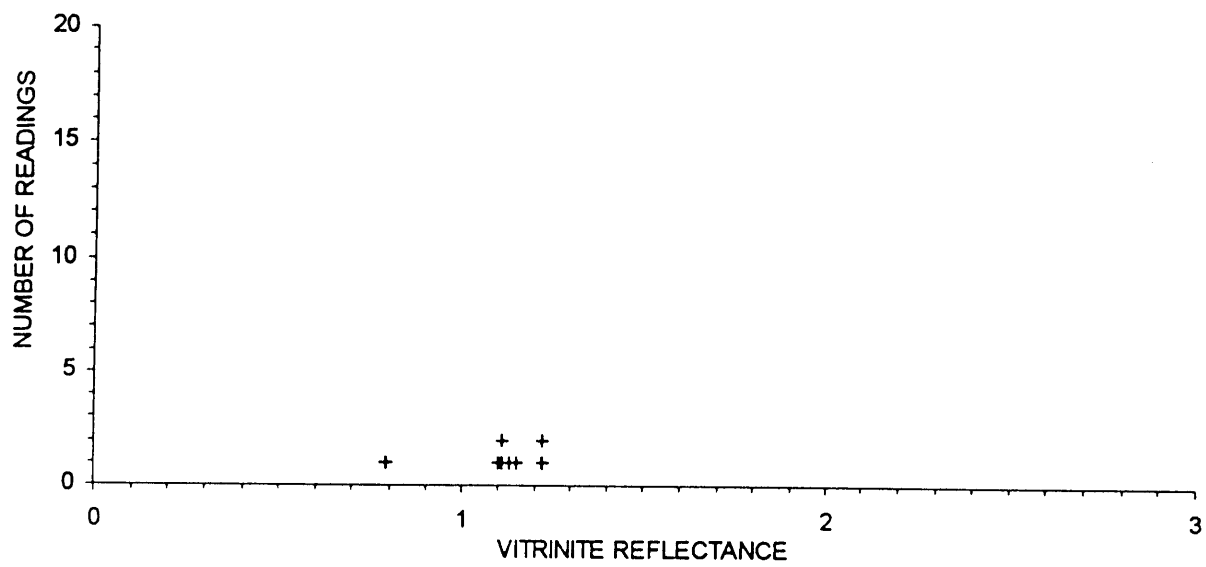
VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min Ro (%)	Max Ro (%)	STD Dev (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100.0	28	0.80	0.60	1.08	0.13	INDIGENOUS (+)	0.00	0.00	0.00	100.00



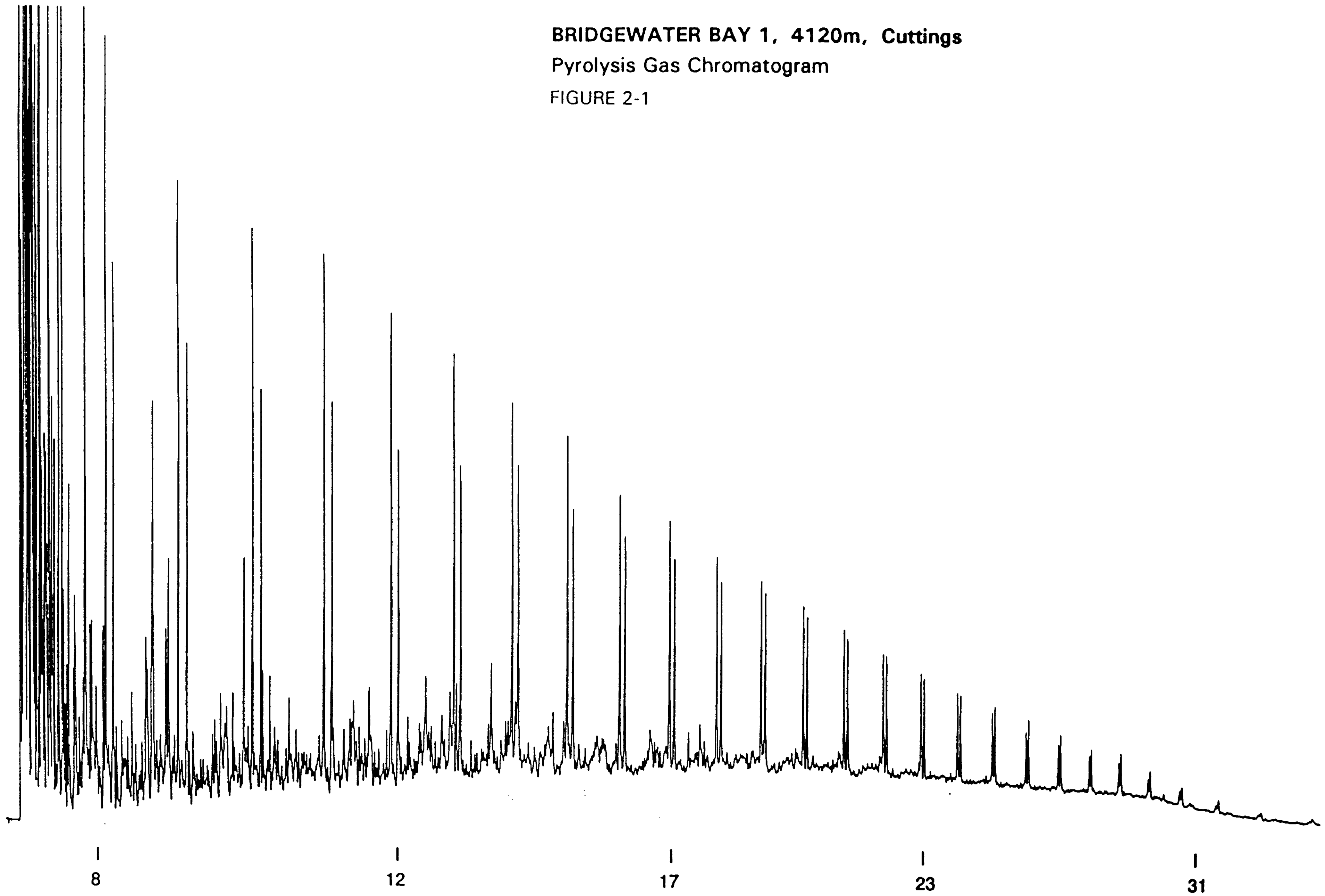
WELL: BRIDGEWATER BAY 1 CLIENT: ENERGY & MINERALS, VICTORIA SAMPLE TYPE: CTGS
SAMPLE ID: 4120 METRES DATE: MAY 1996

(Total No. of Readings=8) 0.79 1.10 1.11 1.11 1.13 1.15 1.22 1.22

VITRINITE REFLECTANCE								MACERAL IDENTIFICATION			
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min Ro (%)	Max Ro (%)	STD Dev (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100.0	8	1.10	0.79	1.22	0.14	INDIGENOUS (+)	0.00	0.00	0.00	0.00



BRIDGEWATER BAY 1, 4120m, Cuttings
Pyrolysis Gas Chromatogram
FIGURE 2-1



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ALKENE AND ALKANE COMPONENT ANALYSIS FROM PYROLYSIS-GC

BRIDGEWATER BAY 1, 4120m, Cuttings Apr-96

Carbon No.	----Alkane + Alkene----			-------Alkane-------			-------Alkene-------			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	5.099	2.534	0.246	2.716	1.350	0.131	2.383	1.184	0.115	1.14
6	3.350	1.665	0.162	1.200	0.596	0.058	2.150	1.069	0.104	0.56
7	3.247	1.614	0.157	1.345	0.668	0.065	1.902	0.945	0.092	0.71
8	2.463	1.224	0.119	1.050	0.522	0.051	1.413	0.702	0.068	0.74
9	2.170	1.078	0.105	0.914	0.454	0.044	1.256	0.624	0.061	0.73
10	1.905	0.947	0.092	0.764	0.380	0.037	1.141	0.567	0.055	0.67
11	1.931	0.960	0.093	0.770	0.383	0.037	1.161	0.577	0.056	0.66
12	1.711	0.850	0.083	0.687	0.341	0.033	1.024	0.509	0.049	0.67
13	1.596	0.793	0.077	0.688	0.342	0.033	0.908	0.451	0.044	0.76
14	1.287	0.640	0.062	0.589	0.293	0.028	0.698	0.347	0.034	0.84
15	1.204	0.598	0.058	0.575	0.286	0.028	0.629	0.313	0.030	0.91
16	1.055	0.524	0.051	0.506	0.251	0.024	0.549	0.273	0.026	0.92
17	1.021	0.507	0.049	0.469	0.233	0.023	0.552	0.274	0.027	0.85
18	0.820	0.408	0.040	0.370	0.184	0.018	0.450	0.224	0.022	0.82
19	0.717	0.356	0.035	0.343	0.170	0.017	0.374	0.186	0.018	0.92
20	0.681	0.338	0.033	0.326	0.162	0.016	0.355	0.176	0.017	0.92
21	0.587	0.292	0.028	0.293	0.146	0.014	0.294	0.146	0.014	1.00
22	0.491	0.244	0.024	0.256	0.127	0.012	0.235	0.117	0.011	1.09
23	0.413	0.205	0.020	0.207	0.103	0.010	0.206	0.102	0.010	1.00
24	0.362	0.180	0.017	0.173	0.086	0.008	0.189	0.094	0.009	0.92
25	0.295	0.147	0.014	0.154	0.077	0.007	0.141	0.070	0.007	1.09
26	0.252	0.125	0.012	0.143	0.071	0.007	0.109	0.054	0.005	1.31
27	0.205	0.102	0.010	0.113	0.056	0.005	0.092	0.046	0.004	1.23
28	0.144	0.072	0.007	0.076	0.038	0.004	0.068	0.034	0.003	1.12
29	0.129	0.064	0.006	0.077	0.038	0.004	0.052	0.026	0.003	1.48
30	0.073	0.036	0.004	0.048	0.024	0.002	0.025	0.012	0.001	1.92
31	0.057	0.028	0.003	0.035	0.017	0.002	0.022	0.011	0.001	1.59

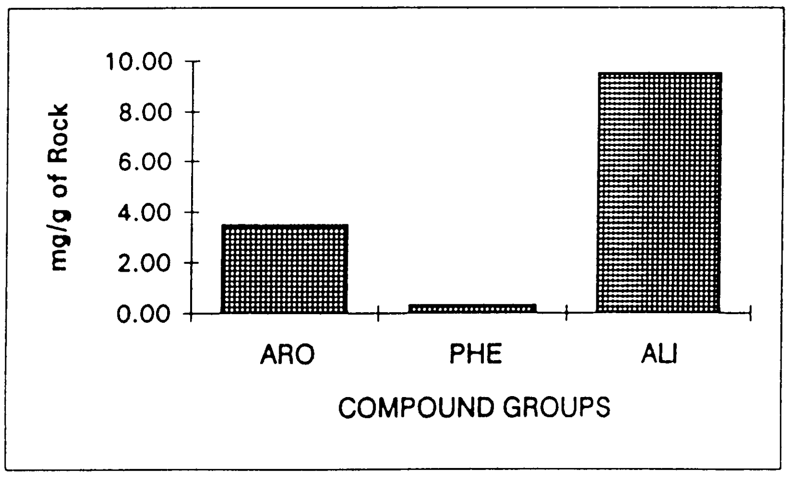
nd = no data
A = % of resolved compounds in S2
B = mg/g Rock (Rock-Eval)
C = (mg/g Rock)/TOC

TABLE 4-1

AROMATIC AND PHENOLIC COMPONENT ANALYSIS FROM PYROLYSIS-GC

BRIDGEWATER BAY 1, 4120m, Cuttings Apr-96

Key	Compound Name	Value A	Value B	Value C
A.	Benzene	2.049	1.018	0.099
B.	Toluene	1.936	0.962	0.093
C.	Ethylbenzene	0.501	0.249	0.024
D.	m- + p-xylene	1.343	0.667	0.065
E.	Styrene	0.471	0.234	0.023
F.	o-xylene	0.644	0.320	0.031
G.	Phenol	0.587	0.292	0.028
H.	o-cresol	0.000	0.000	0.000
I.	m- + p-cresol	0.000	0.000	0.000
J.	C2 phenol	0.000	0.000	0.000
K.	C2 phenol	0.000	0.000	0.000



nd = no data
A = % of resolved compounds in S2
B = mg/g Rock (Rock-Eval)
C = (mg/g Rock)/TOC
ARO = aromatic compounds (A to F)
PHE = phenolic compounds (G to K)
ALI = aliphatic compounds (C9 to C31 alkenes + alkanes)

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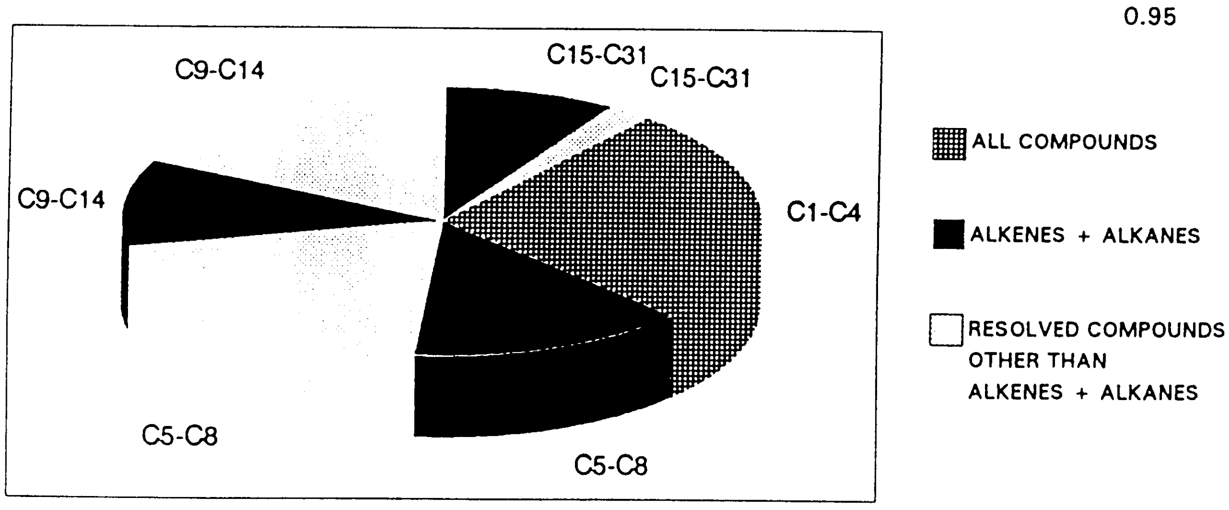
PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

BRIDGEWATER BAY 1, 4120m, Cuttings Apr-96

Parameter	A	B	C	D
	-------------------Value-------------------			
C1-C4 abundance (all compounds)	26.18	13.01	1.26	
C5-C8 abundance (all resolved compounds)	34.49	17.14	1.66	
C5-C8 abundance (alkanes + alkenes)	14.16	7.04	0.68	
C9-C14 abundance (all resolved compounds)	28.41	14.12	1.37	
C9-C14 abundance (alkanes + alkenes)	10.60	5.27	0.51	
C15-C31 abundance (all resolved compounds)	10.92	5.43	0.53	
C15-C31 abundance (alkanes + alkenes)	8.51	4.23	0.41	
C9-C31 abundance (all resolved compounds)	39.33	19.55	1.90	
C9-C31 abundance (alkanes + alkenes)	19.11	9.50	0.92	
C5-C31 abundance (all resolved compounds)	73.82	36.69	3.56	
C5-C31 abundance (alkanes + alkenes)	33.27	16.53	1.61	
C5-C31 alkane abundance	14.89	7.40	0.72	
C5-C31 alkene abundance	18.38	9.13	0.89	
C5-C8 alkane/alkene				0.80
C9-C14 alkane/alkene				0.71
C15-C31 alkane/alkene				0.96
C5-C31 alkane/alkene				0.81
(C1-C5)/C6+				0.52
R				0.95



nd = no data
A = % of resolved compounds in S2
B = mg/g Rock (Rock-Eval)
C = (mg/g Rock)/TOC
D = no units
R = m + p-xylene/n-octene

TABLE 6-1

Summary of Extraction and Liquid Chromatography

BRIDGEWATER BAY 1 May-96

A. Concentrations of Extracted Material

	Weight of Rock Extd	Total Extract	Loss on Column	-------Hydrocarbons-------			----Nonhydrocarbons----		
DEPTH(m)	(grams)	(ppm)	(ppm)	Saturates (ppm)	Aromatics (ppm)	HC Total (ppm)	NSO's (ppm)	Asphalt. (ppm)	NonHC Total (ppm)
4120.0	2.8	16113.1	5123.7	2791.5	812.7	3604.2	7385.2	nd	7385.2

TABLE 6-1

Summary of Extraction and Liquid Chromatography

BRIDGEWATER BAY 1 May-96

B. Compositional Data

	---Hydrocarbons----			---Nonhydrocarbons-----			EOM(mg	SAT(mg)	SAT	ASPH	HC
DEPTH(m)	%SAT	%AROM	%HC's	%NSO's	%ASPH	%Non HC's	TOC(g)	TOC(g)	AROM	NSO	Non HC
4120.0	25.4	7.4	32.8	67.2	nd	67.2	156.4	27.1	3.4	nd	0.5

nd = no data

TABLE 7-1

BRIDGEWATER BAY 1 Summary of Gas Chromatography Data

A. Alkane Compositional Data SATURATE FRACTION

DEPTH(m)	Prist./Phyt.	Prist./n-C17	Phyt./n-C18	CPI(1)	CPI(2)	(C21+C22)/(C28+C29)
4120.0	3.55	1.13	0.20	1.29	1.25	42.5

TABLE 7-1

BRIDGEWATER BAY 1 Summary of Gas Chromatography Data

B. n-Alkane Distributions SATURATE FRACTION

DEPTH(m)	nC12	nC13	nC14	nC15	nC16	nC17	iC19	nC18	iC20	nC19	nC20	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29	nC30	nC31
4120.0	0.1	0.3	0.4	1.1	3.3	7.2	8.1	11.4	2.3	14.7	14.8	11.7	9.2	6.5	3.3	2.1	0.9	0.5	0.1	0.4	0.3	0.8

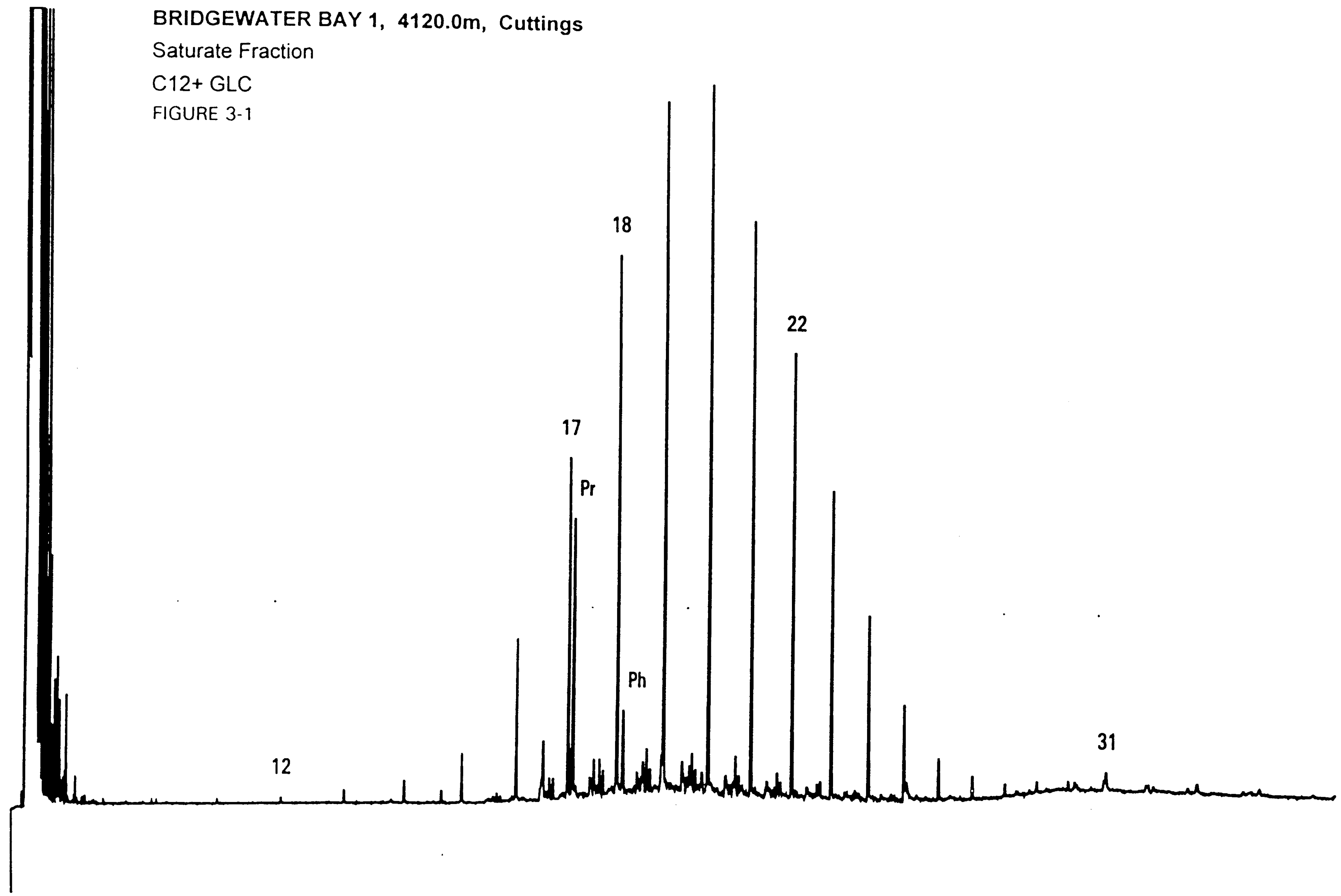
nd = no data

BRIDGEWATER BAY 1, 4120.0m, Cuttings

Saturate Fraction

C12+ GLC

FIGURE 3-1



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SELECTED PARAMETERS FROM GC/MS ANALYSIS

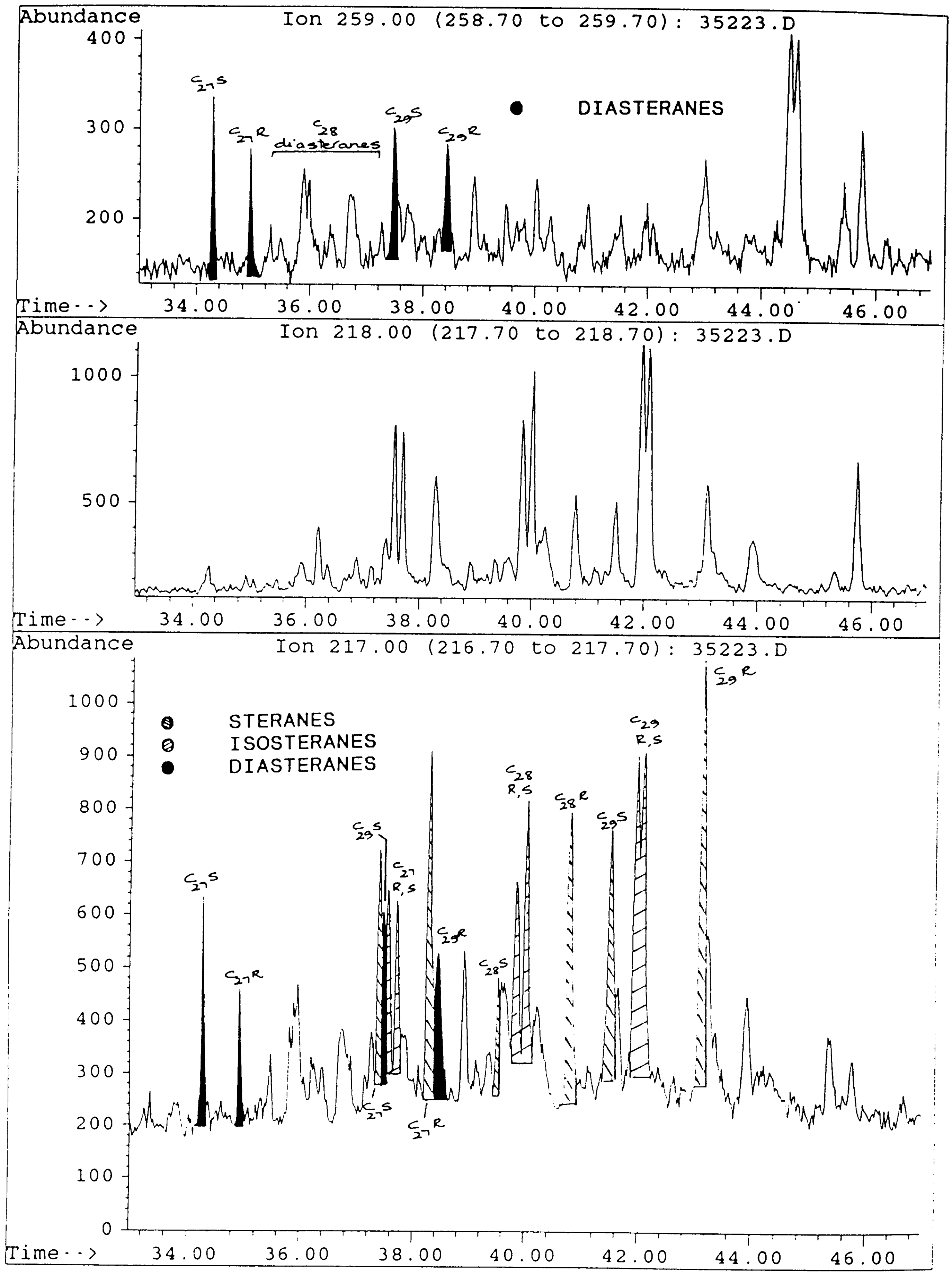
BRIDGEWATER BAY 1, 4120m, Cuttings

	Parameter	Ion(s)	Value
1.	18 α (H)- hopane/17 α (H)-hopane (Ts/Tm)	191	1.00
2.	C30 hopane/C30 moretane	191	6.22
3.	C31 22S hopane/C31 22R hopane	191	1.35
4.	C32 22S hopane/C32 22R hopane	191	1.28
5.	C29 20S ααα sterane/C29 20R ααα sterane	217	0.59
6.	C29 ααα steranes (20S / 20S+20R)	217	0.37
7.	C29 αββ steranes / (C29 ααα steranes + C29 αββ steranes)	217	0.50
8.	C27/C29 diasteranes	259	1.17
9.	C27/C29 steranes	217	0.81
10.	18 α (H)-oleanane/C30 hopane	191	nd
11.	C29 diasteranes / (C29 ααα steranes + C29 αββ steranes)	217	0.23
12.	C30 (hopane + moretane) / C29 (steranes + diasteranes)	191/217	4.94
13.	C15 drimane/C16 homodrimane	123	0.19
14.	Rearranged drimanes/normal drimanes	123	0.23

nd = not detectable

File : 35223.D
Sample : BRIDGEWATER BAY-1 4120m B/C
Misc. Info : COL#164.DJ. 28-5-96

FIGURE 4-1



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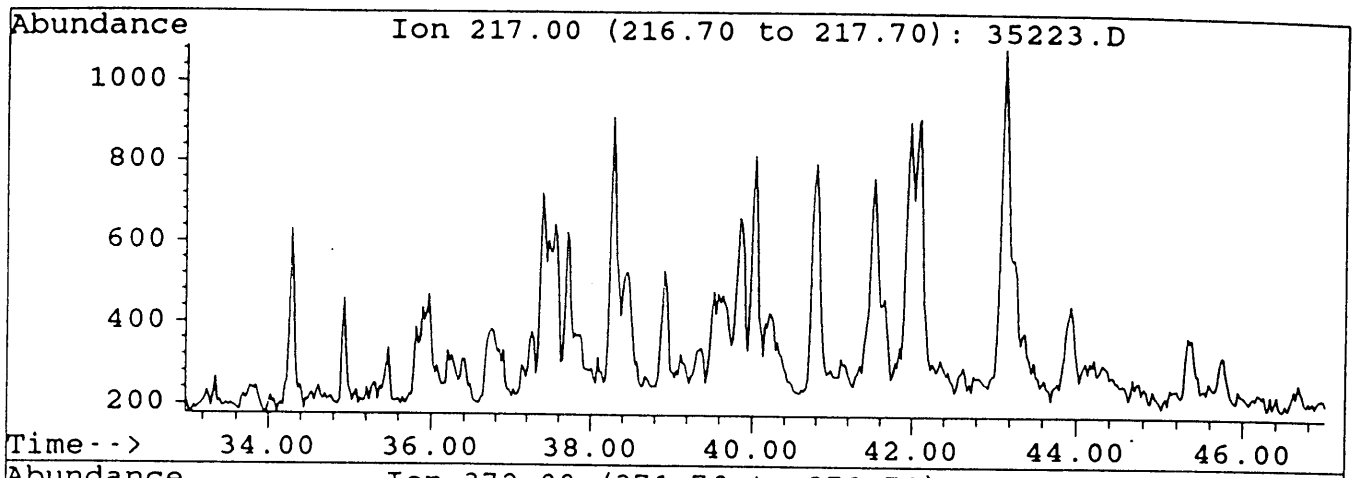

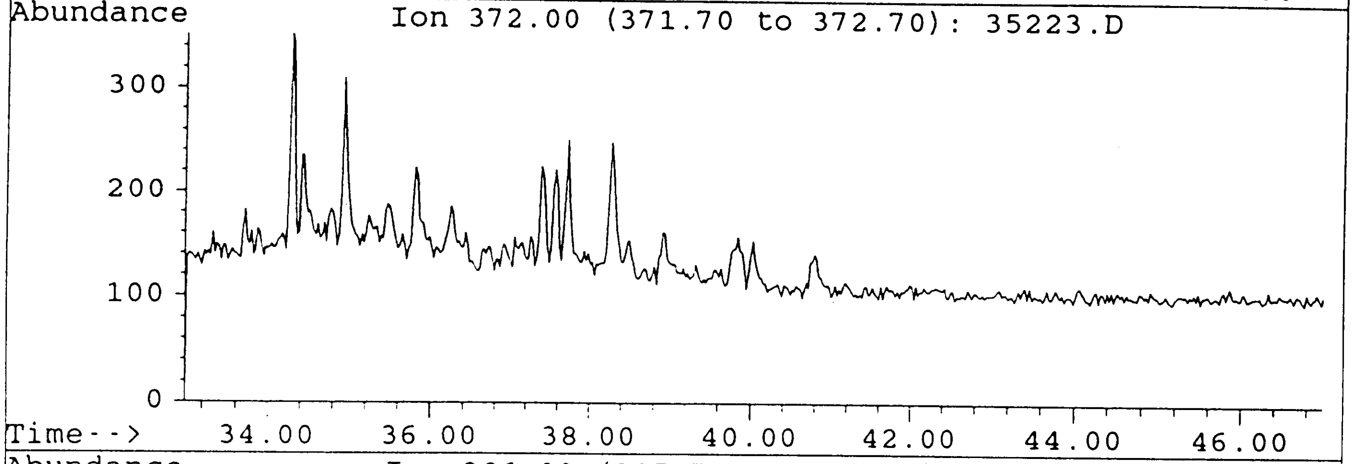

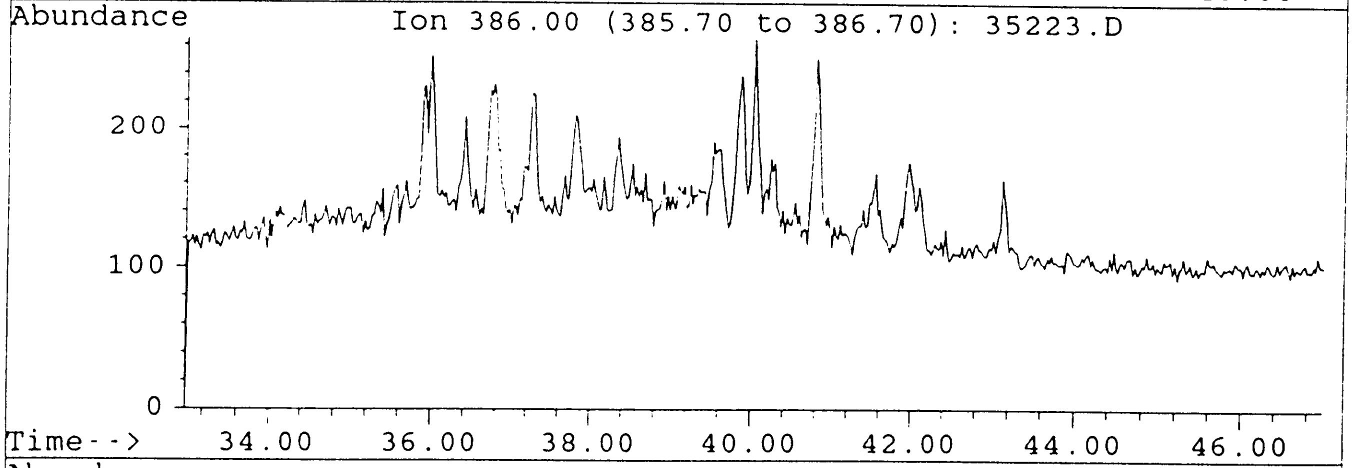

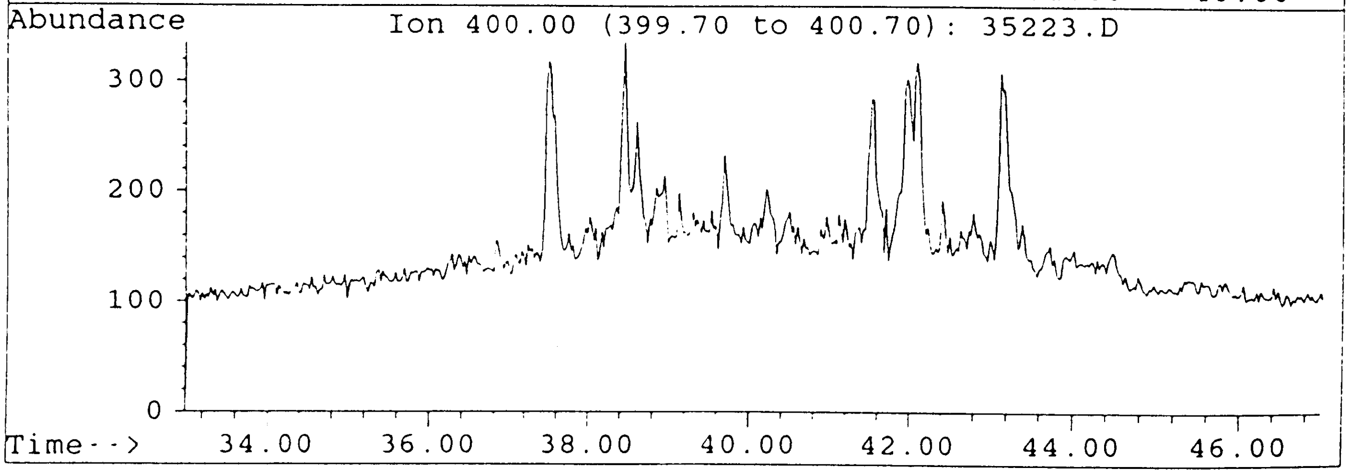

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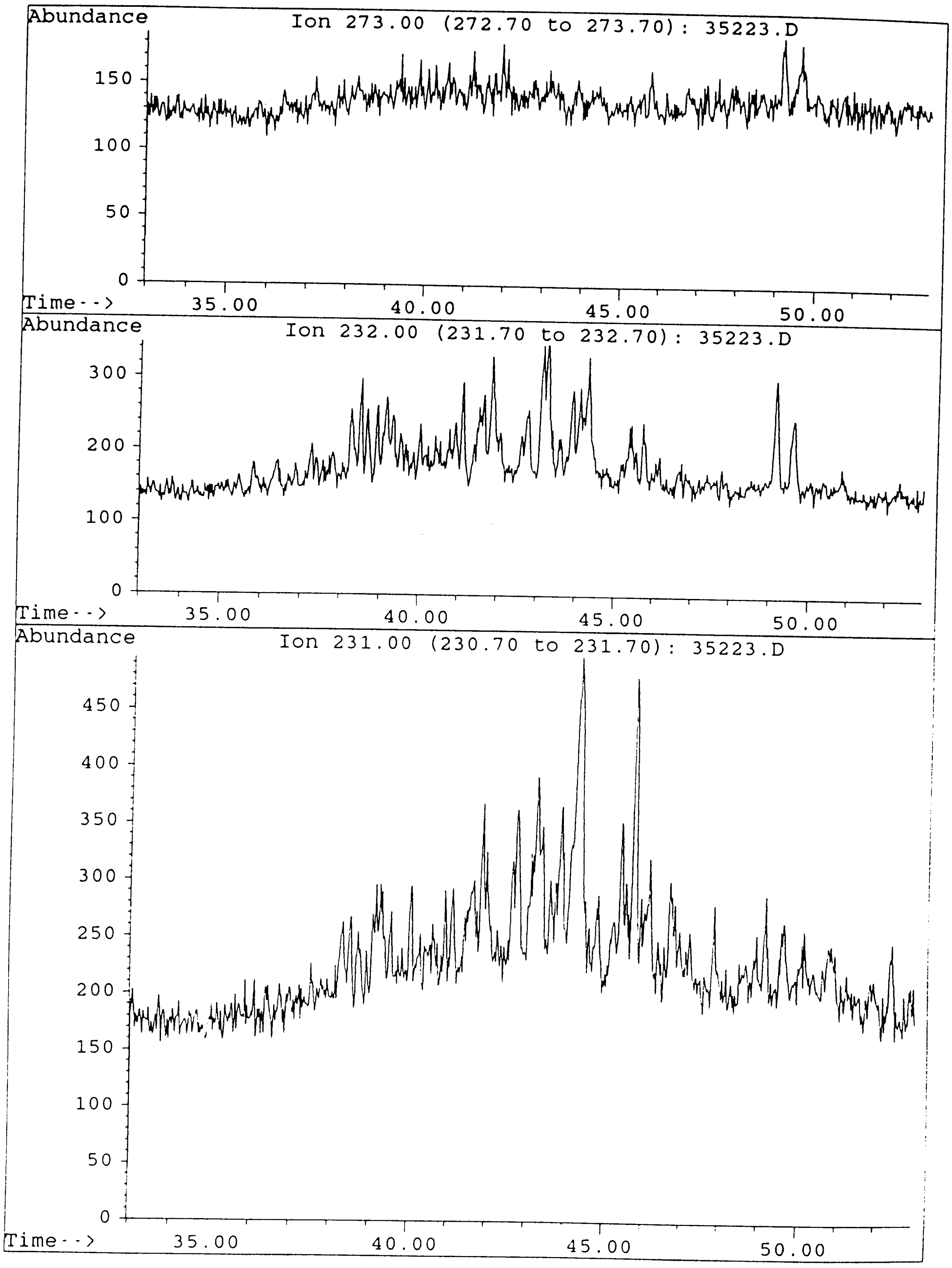

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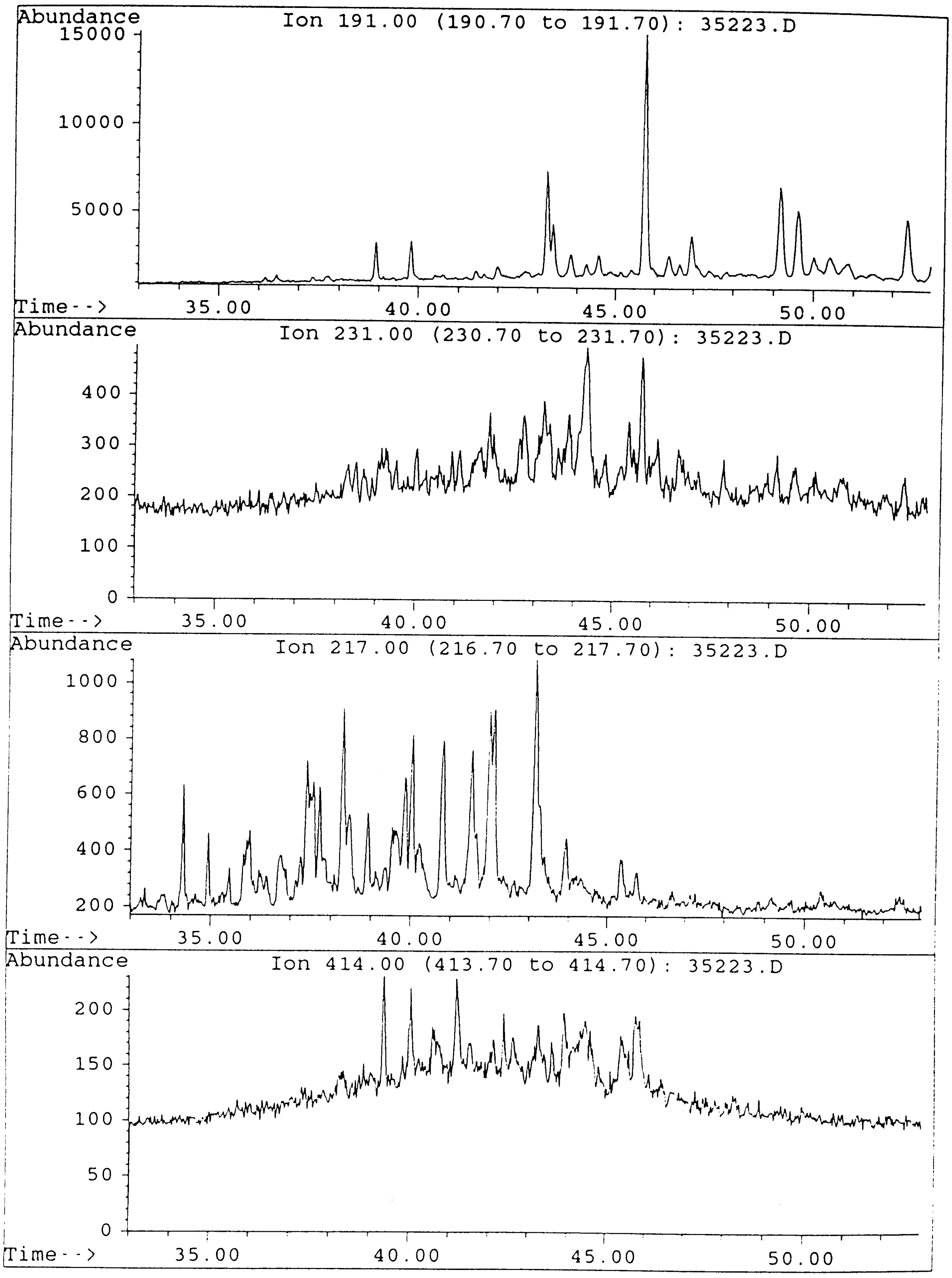

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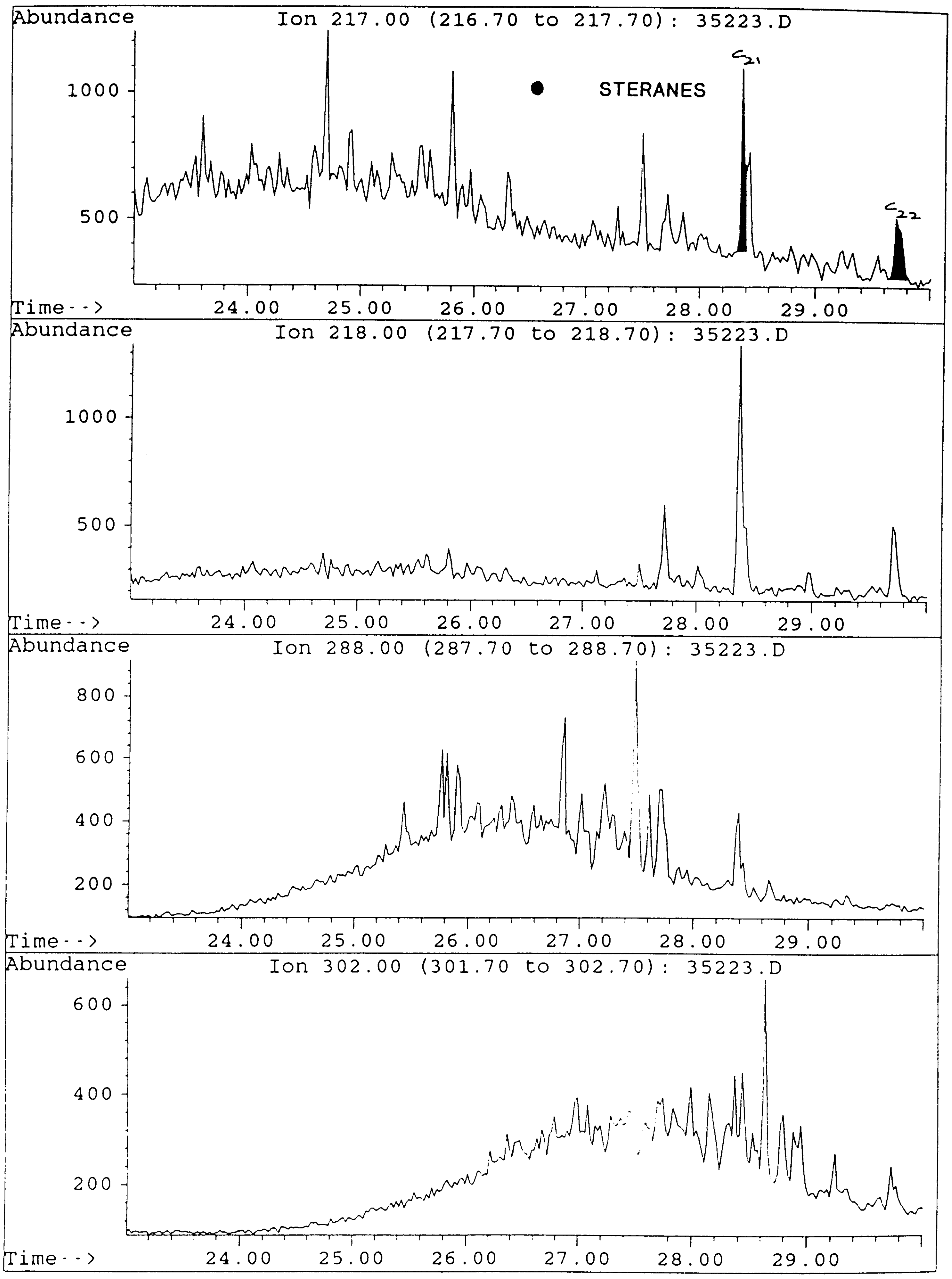

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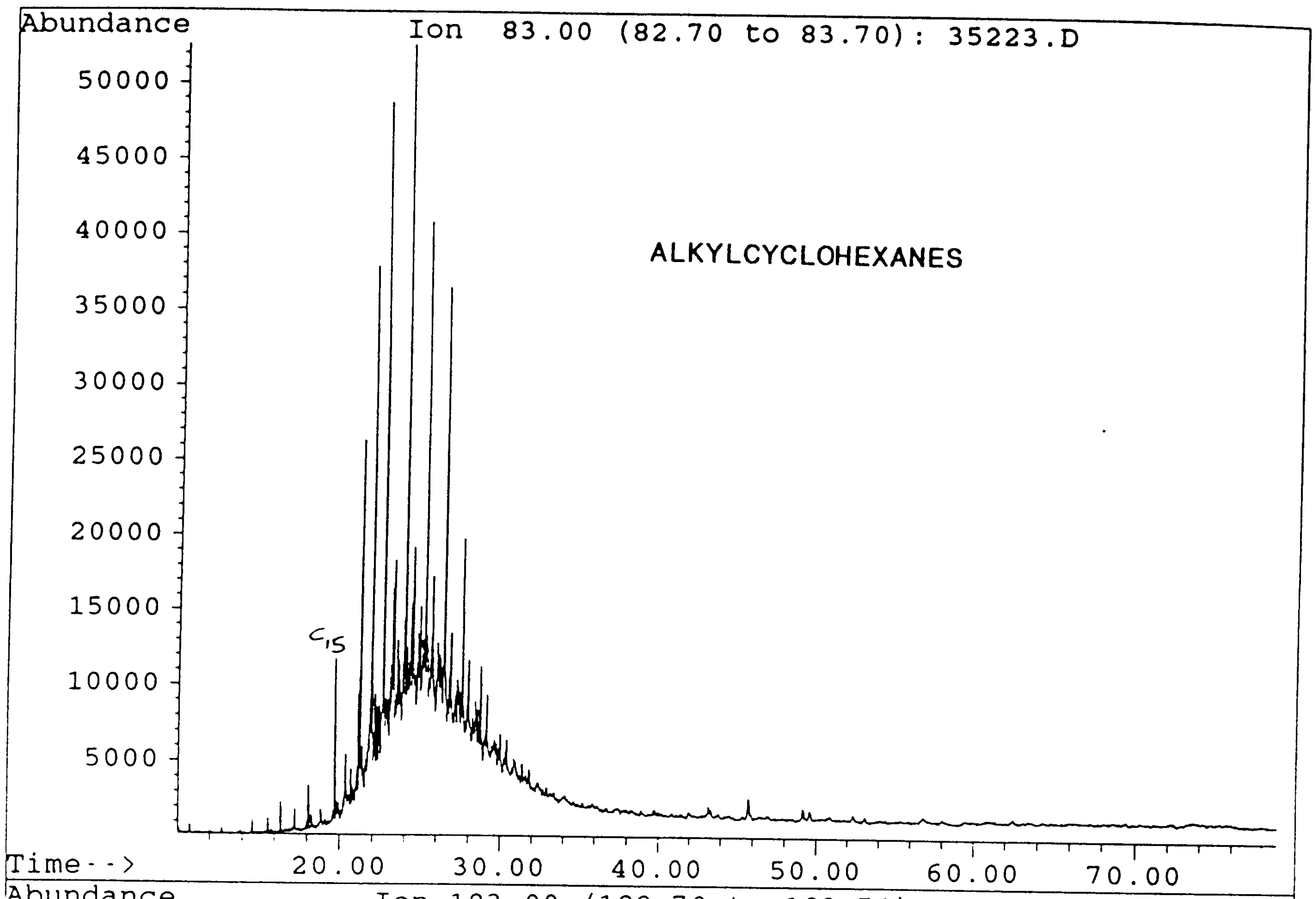

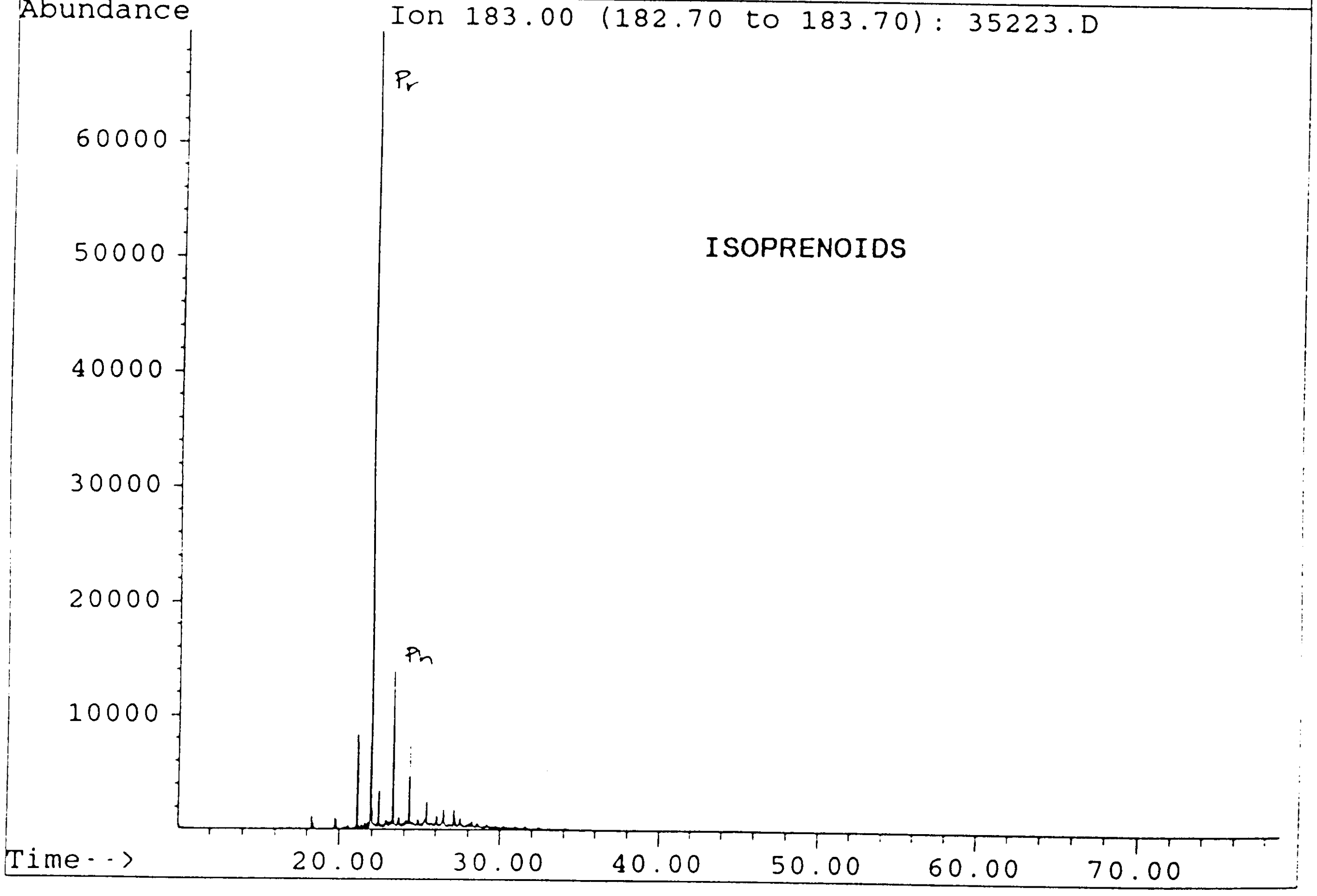

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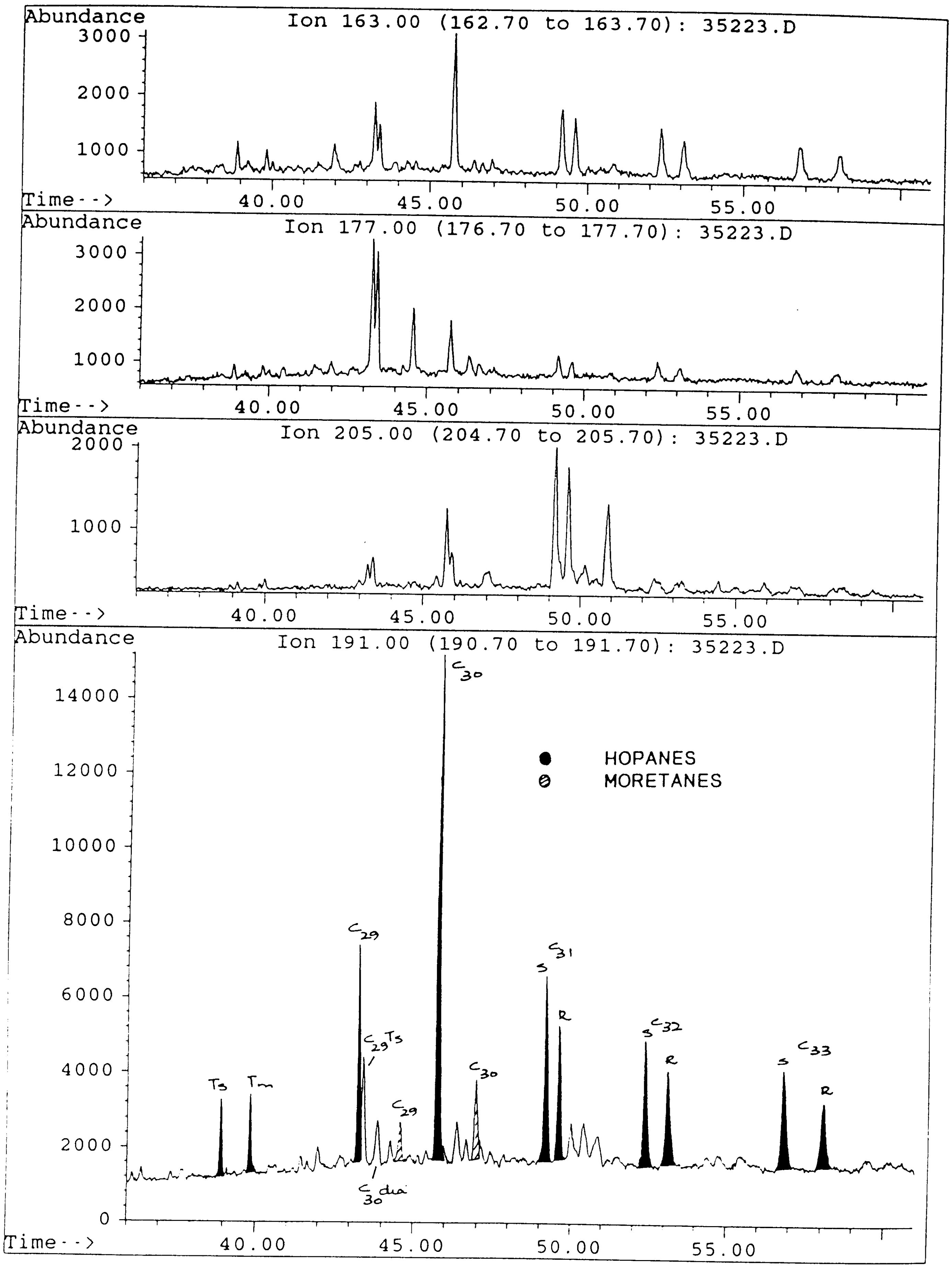

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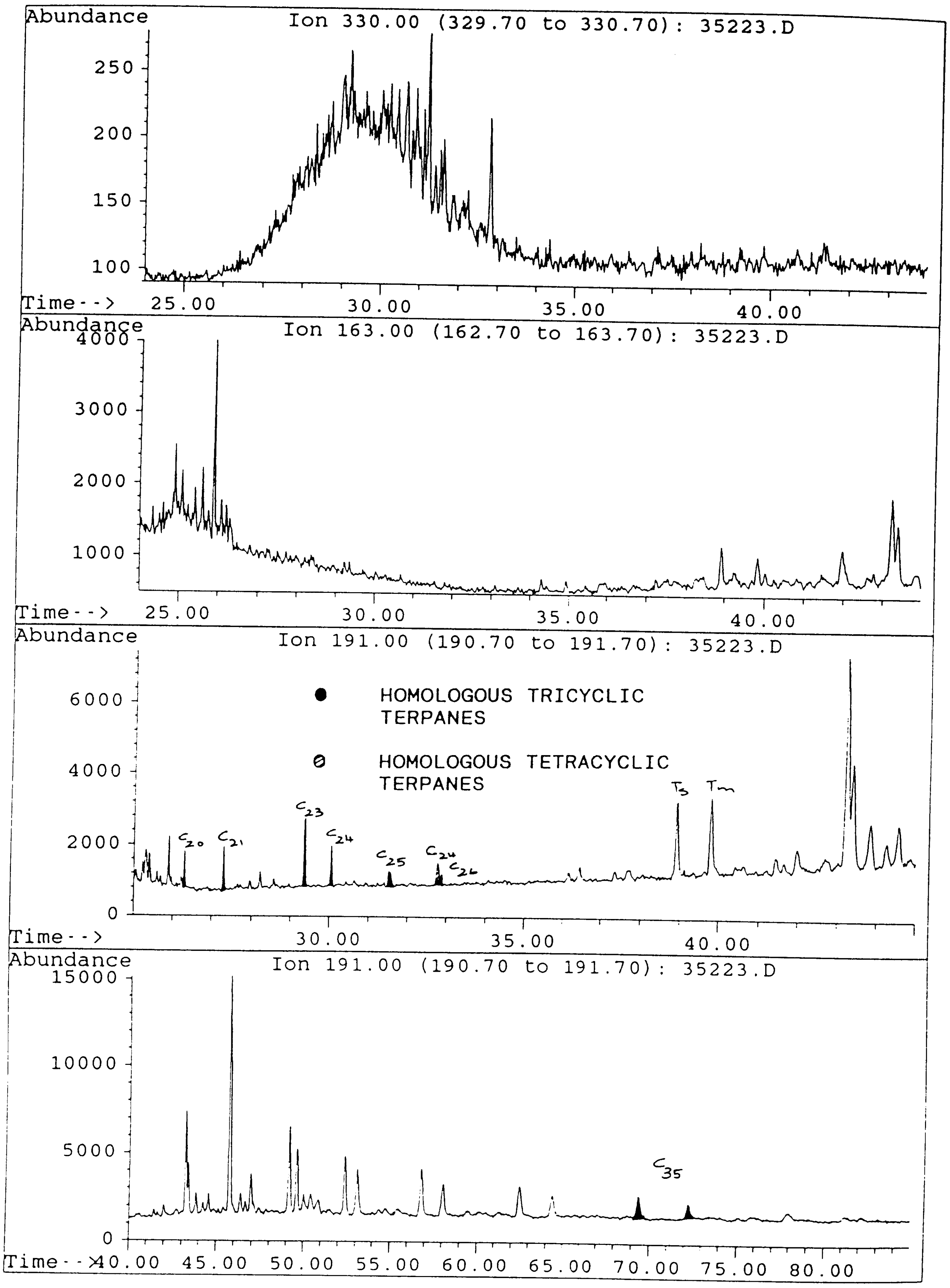

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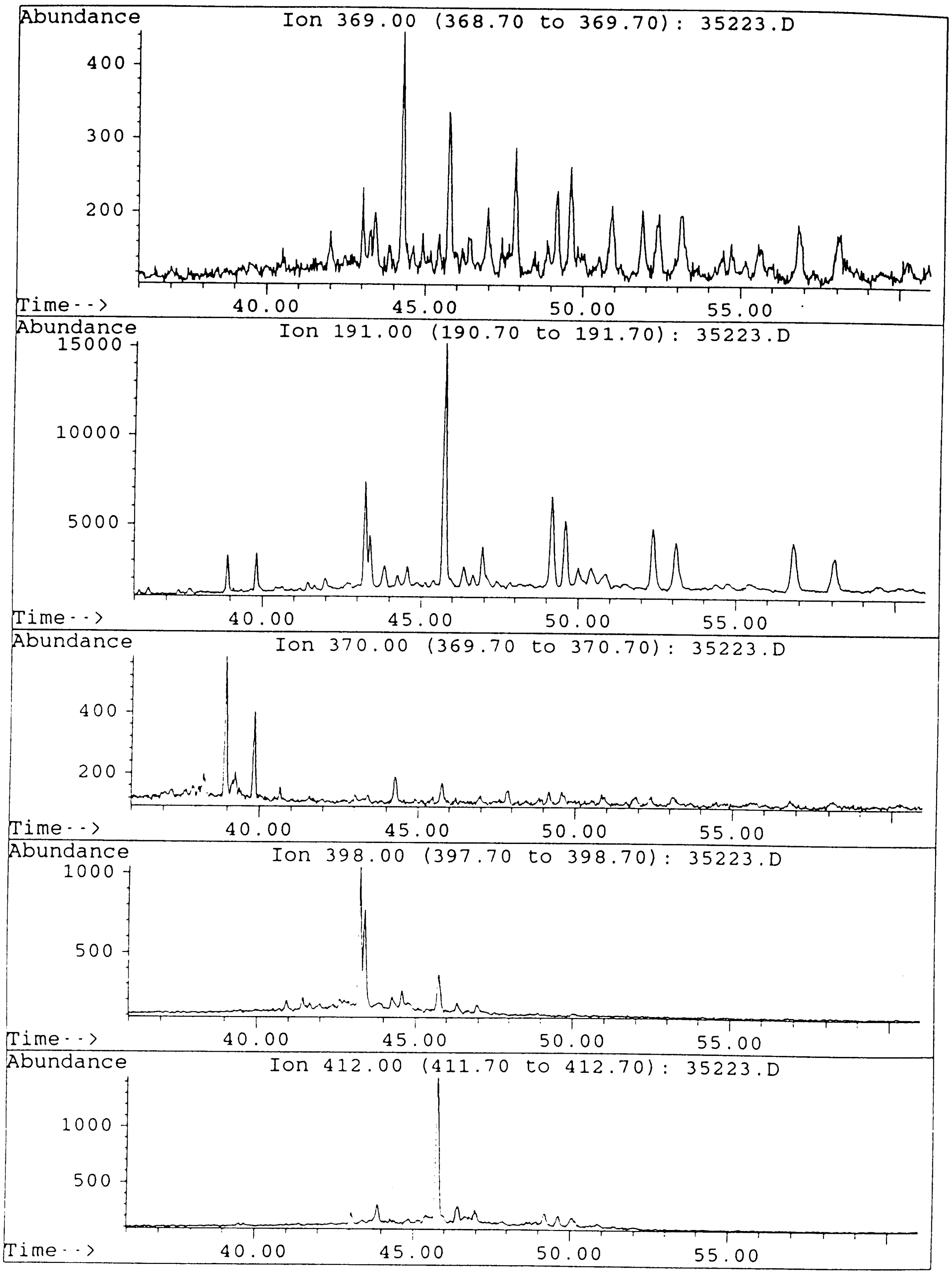

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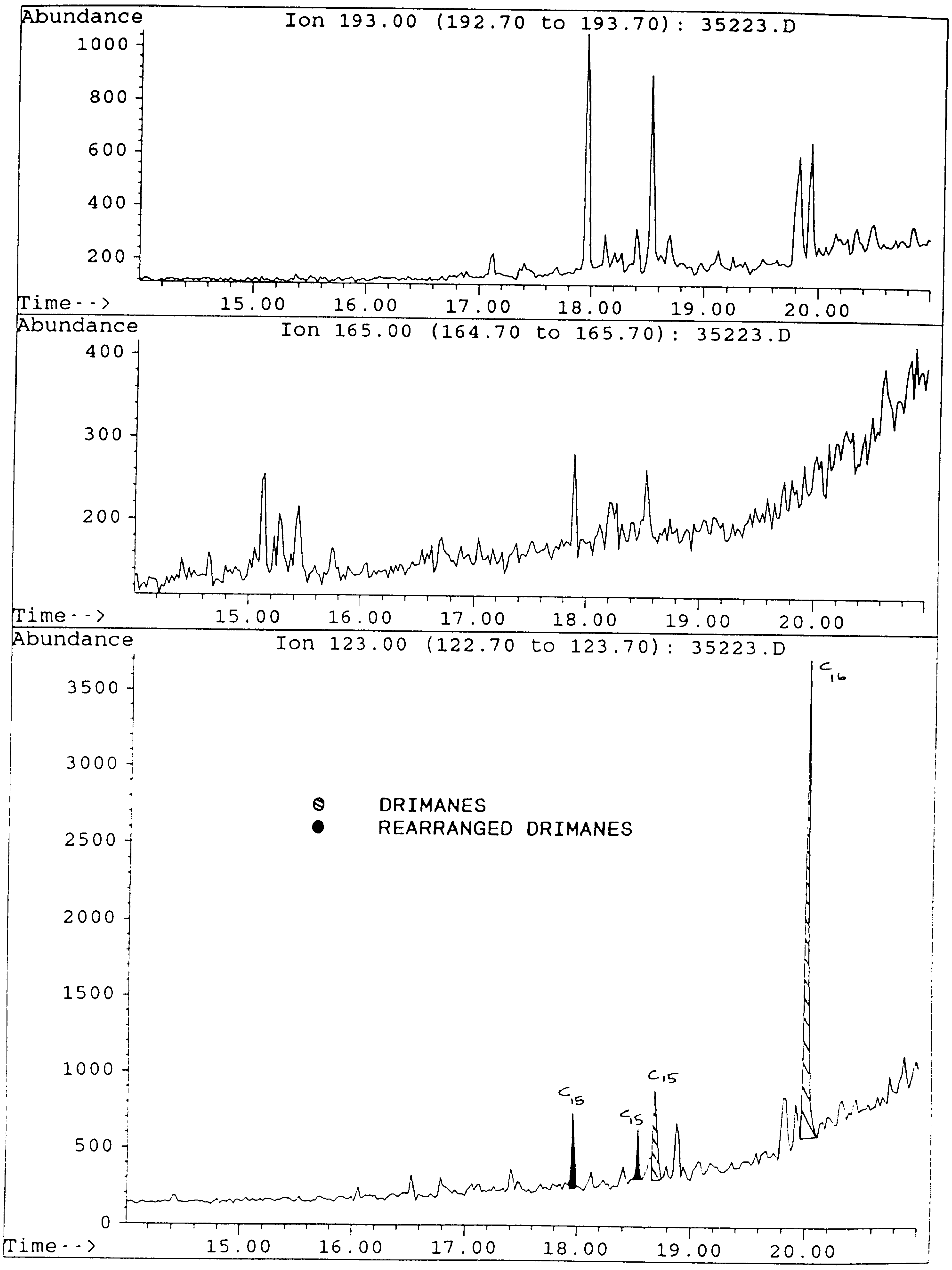

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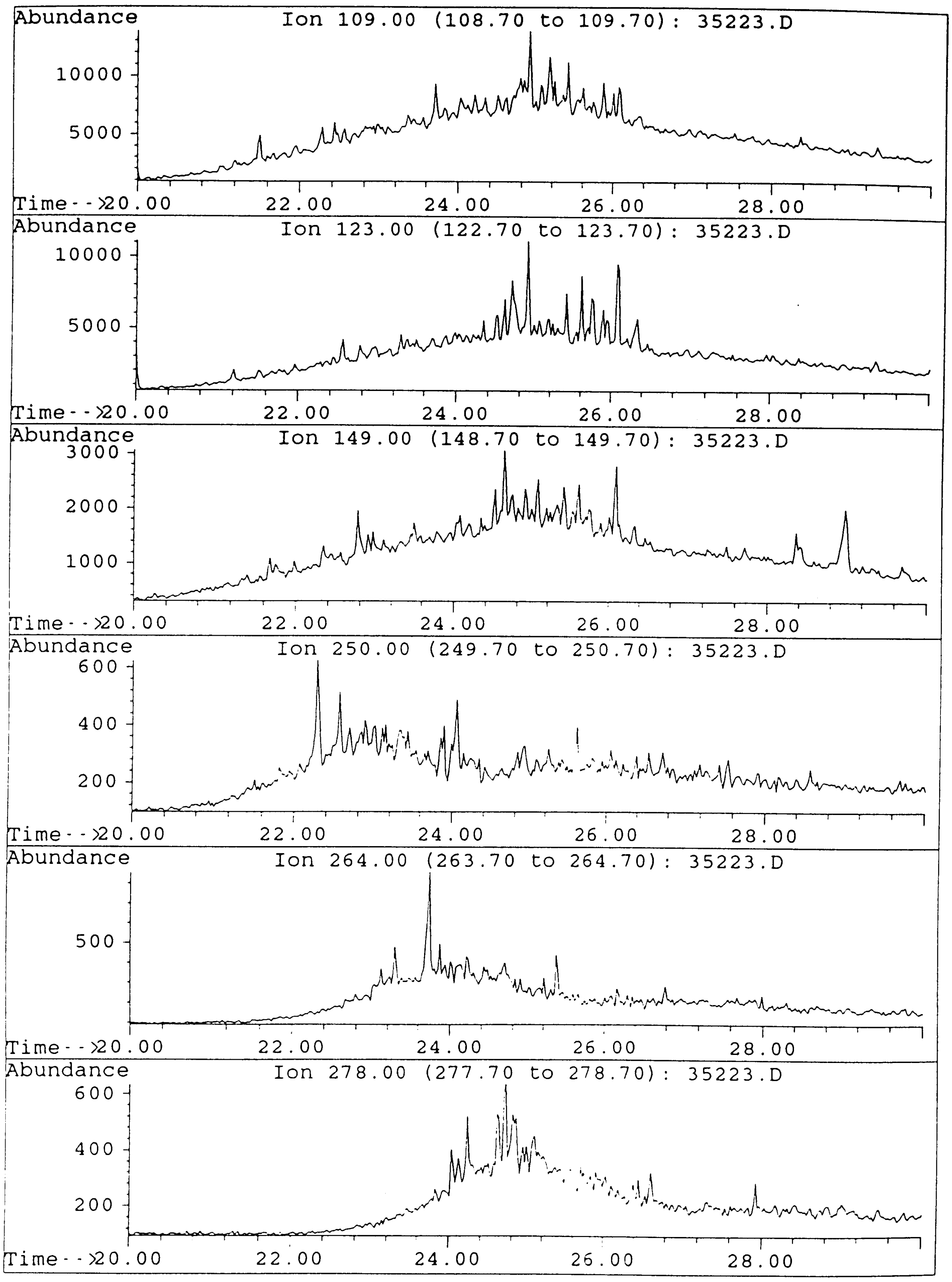

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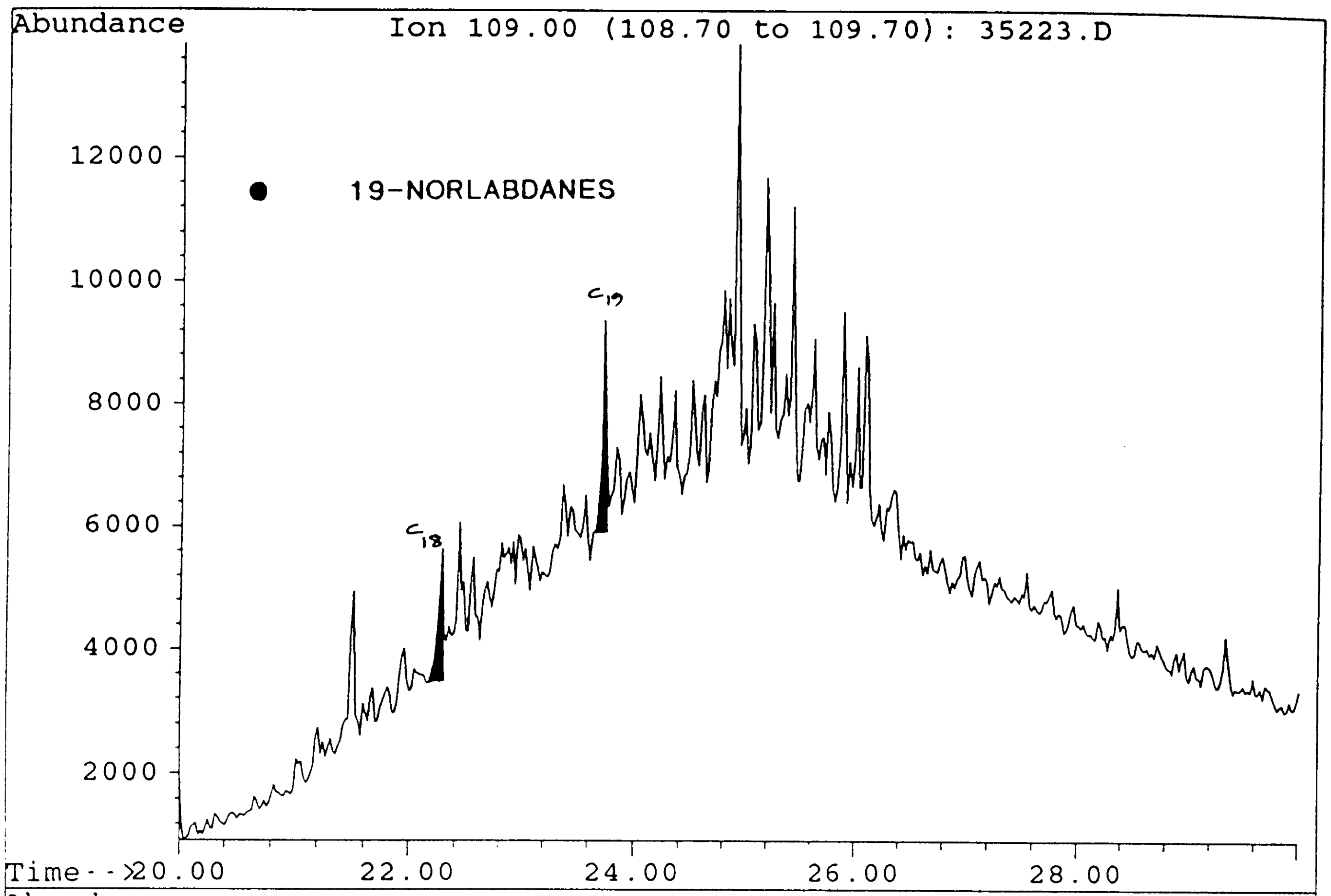

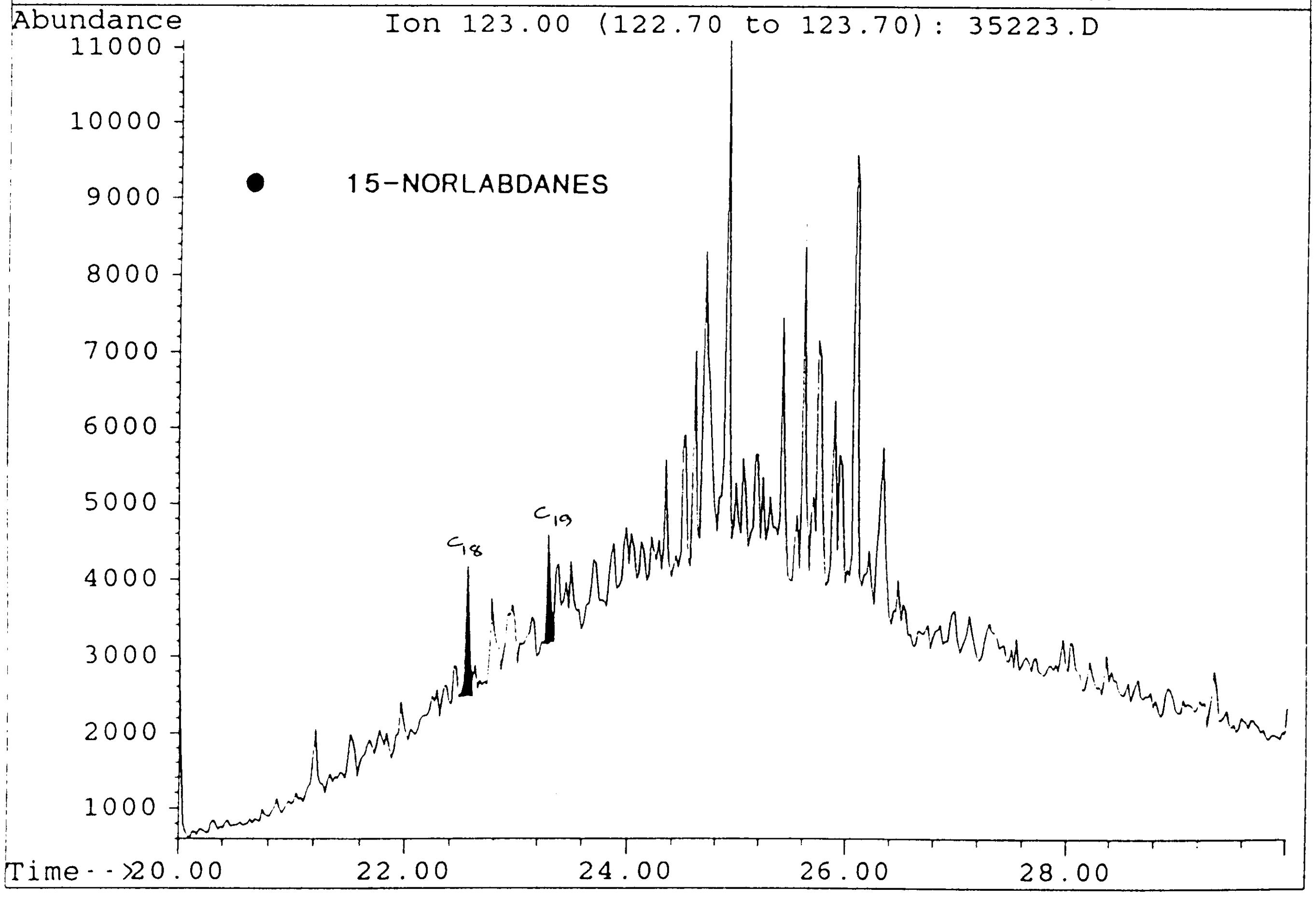

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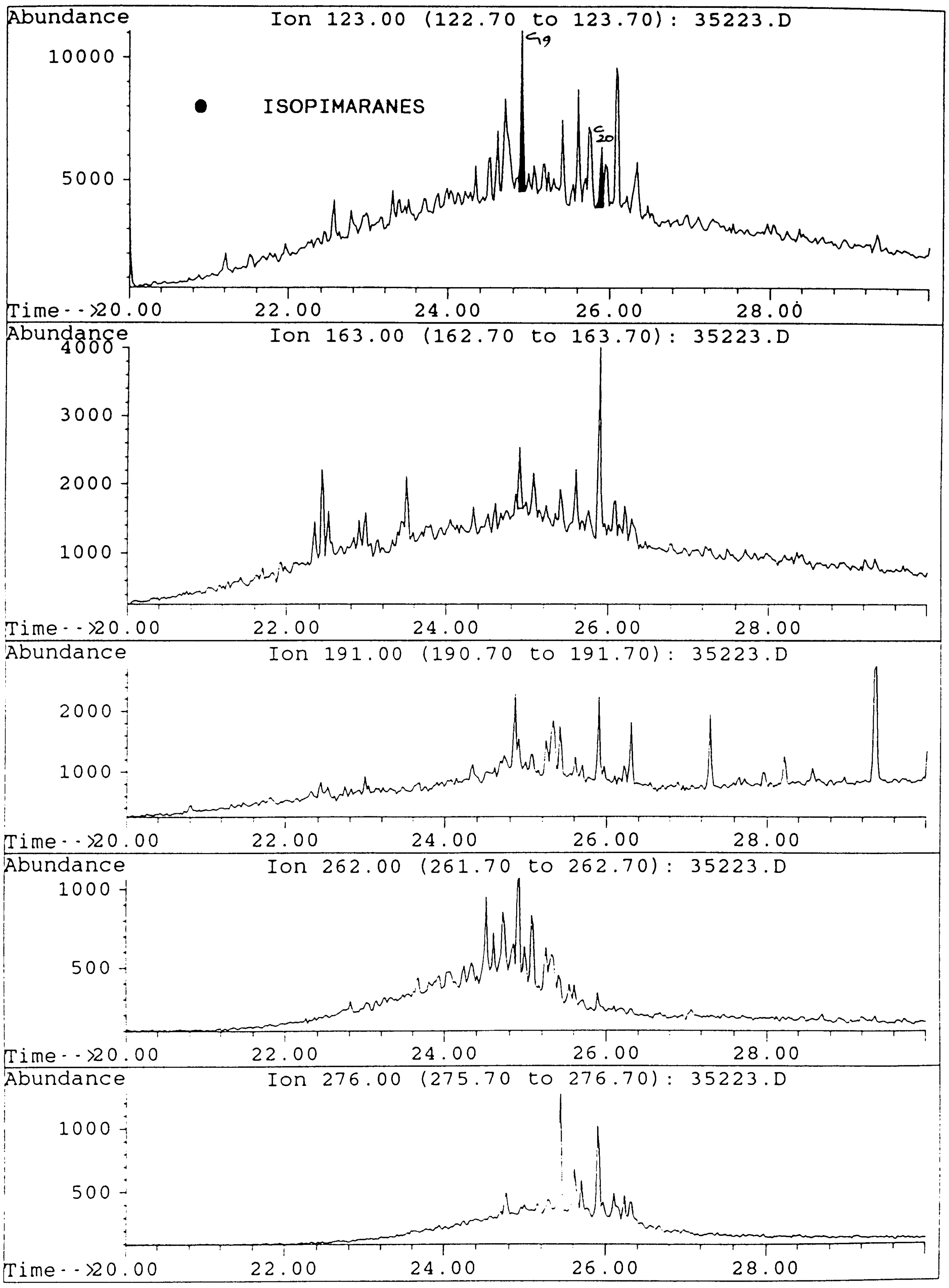

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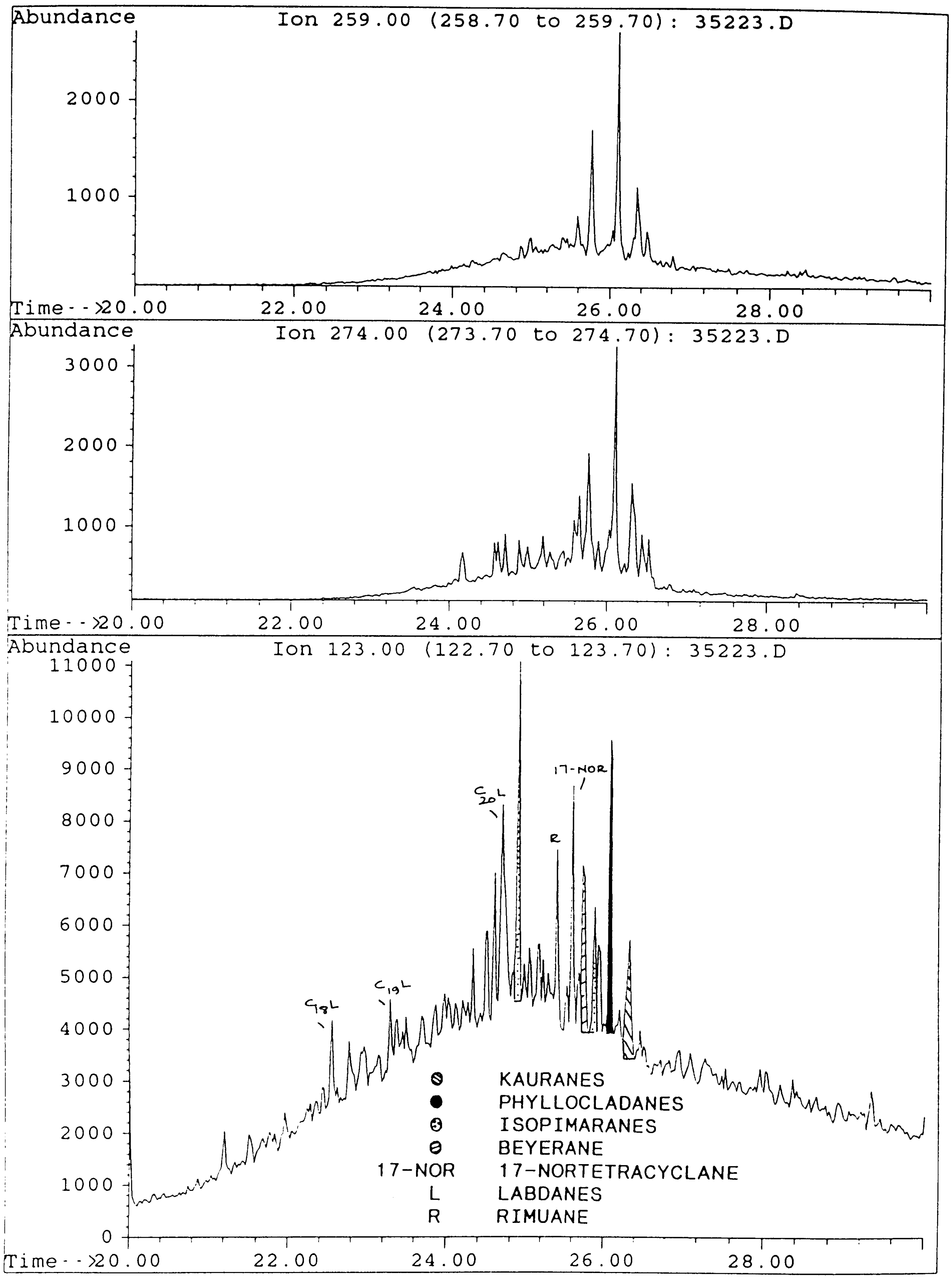

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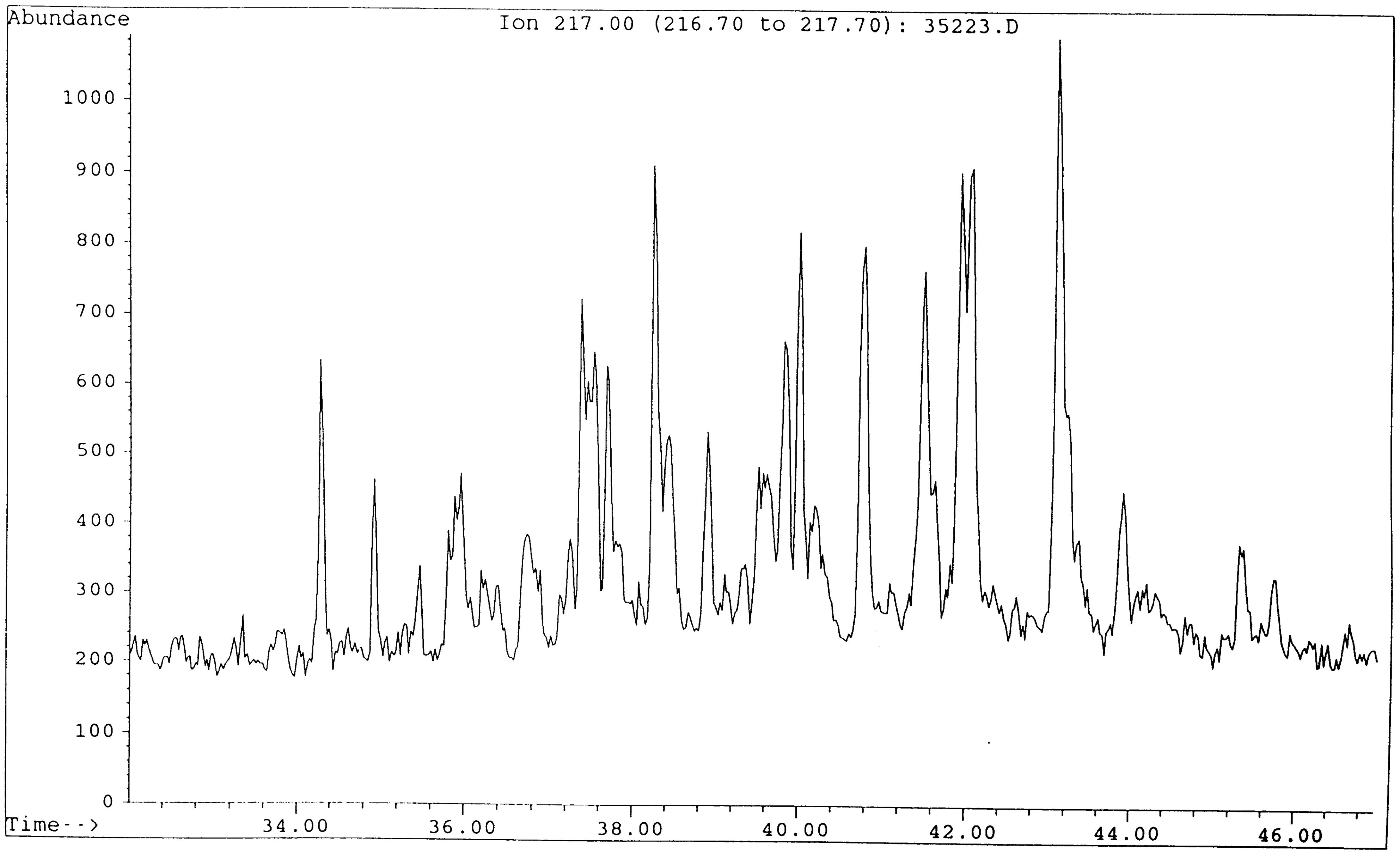

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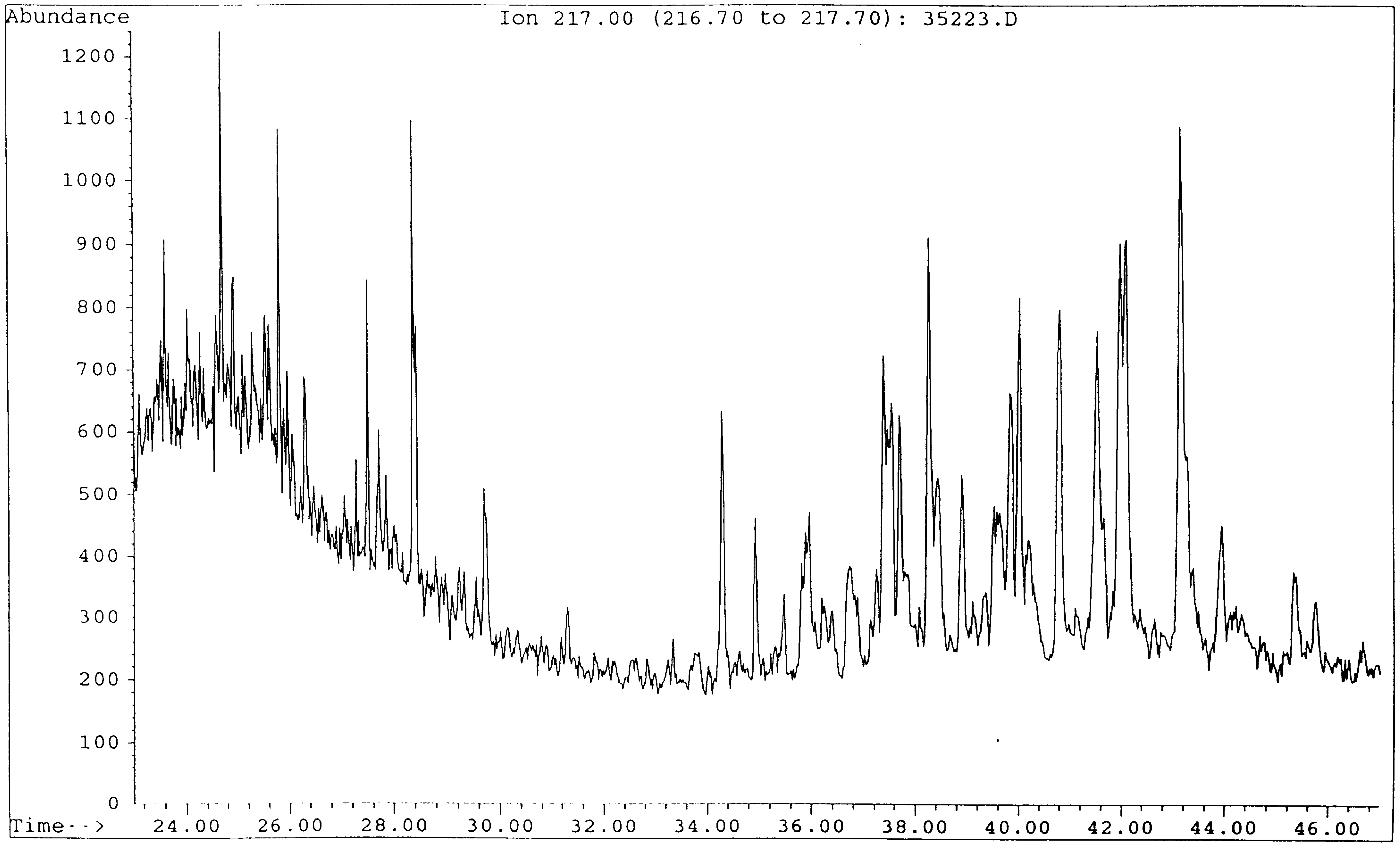

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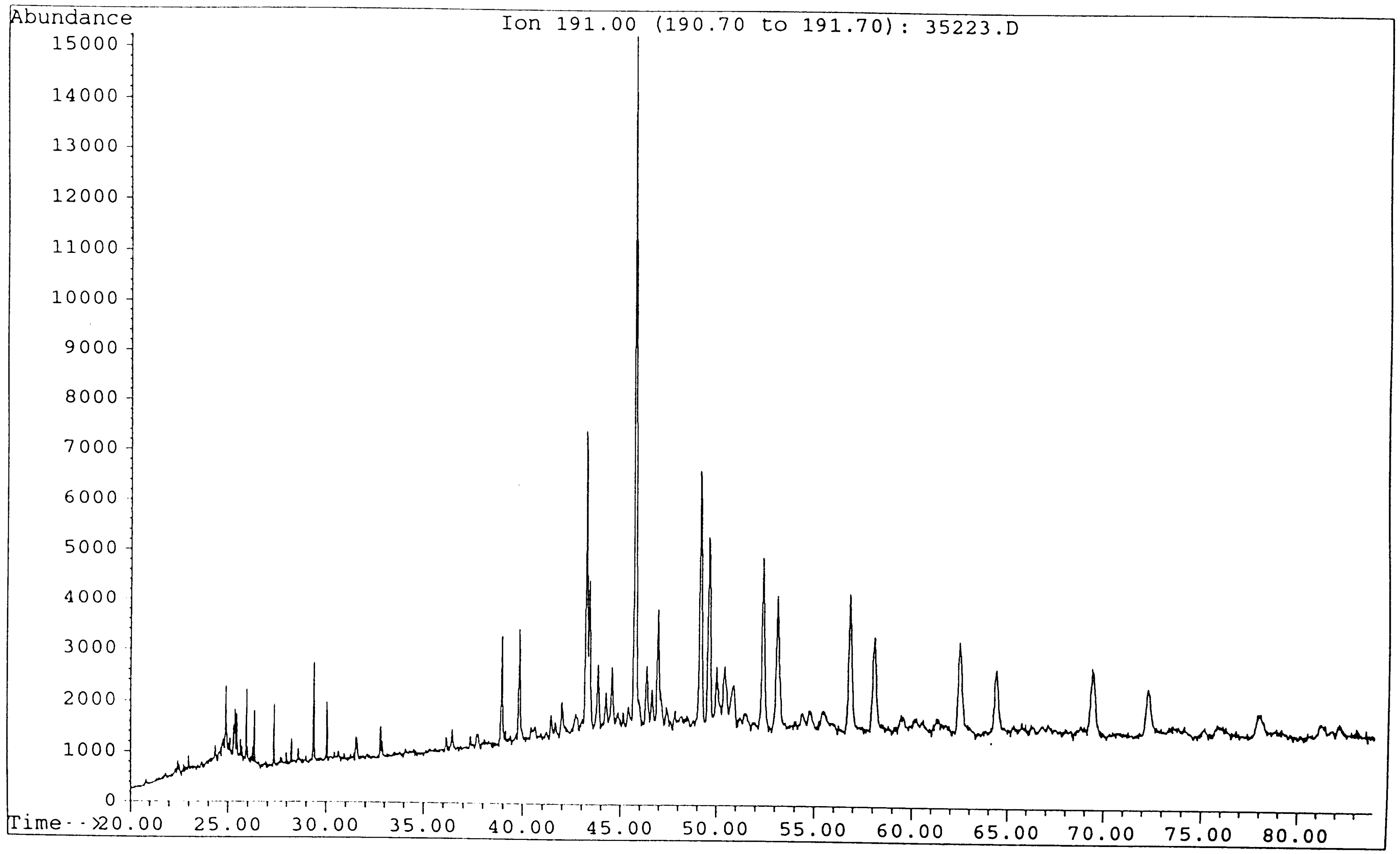

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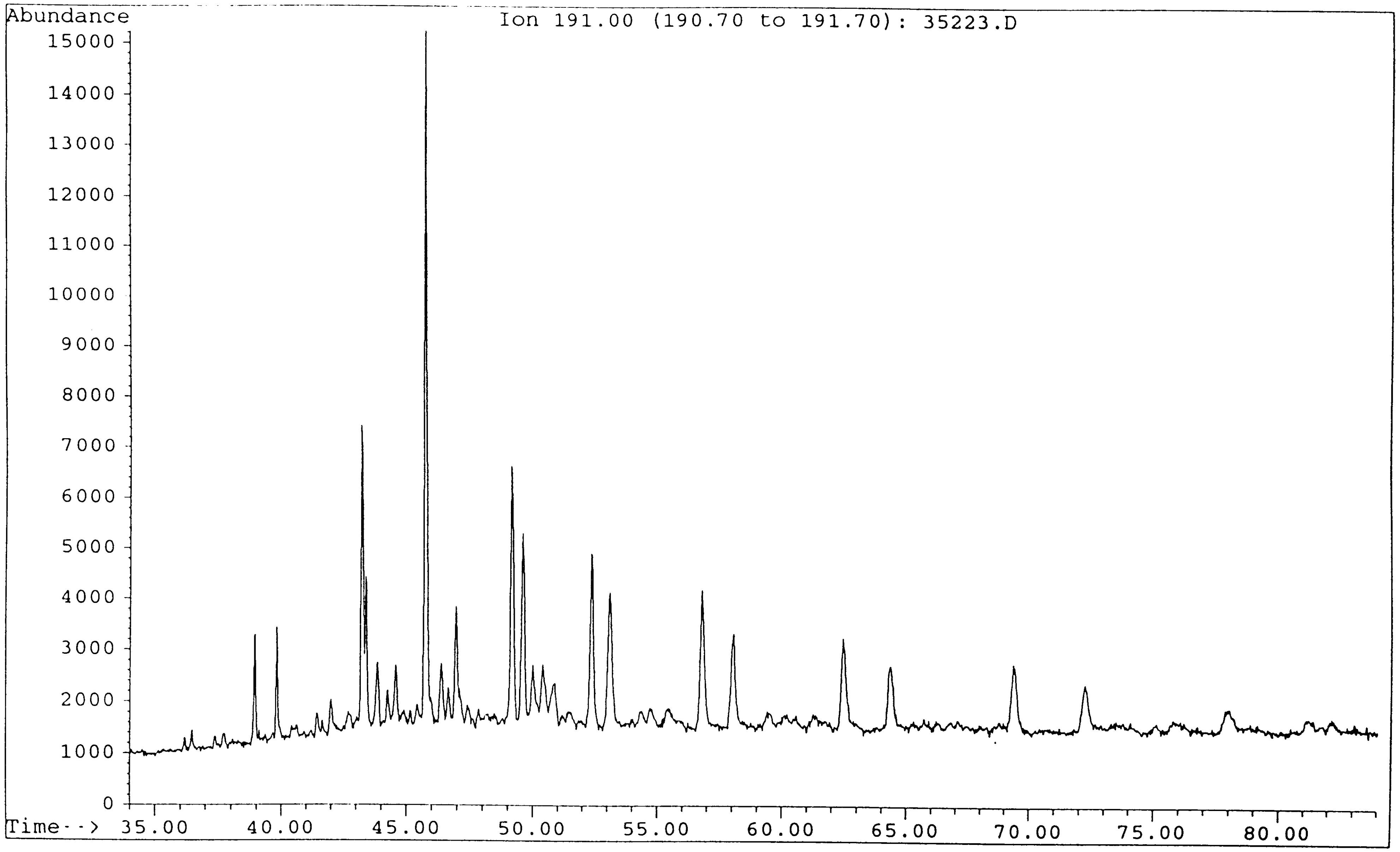

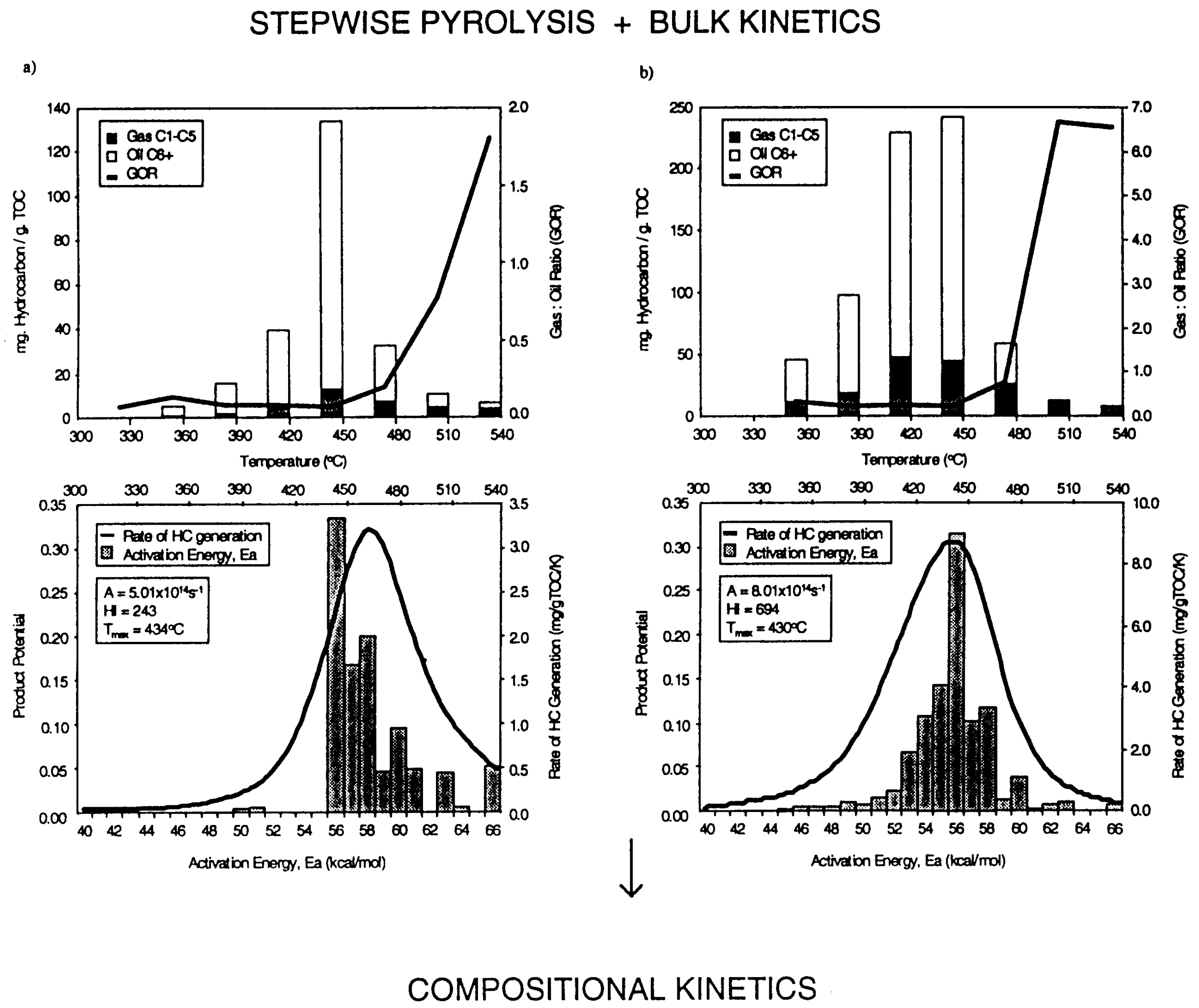

Figure 1. Methodology used to generate 'composite' compositional kinetics with stepwise pyrolysis at 30°C increments (eg. 300-330°C) at 10°C/min (hydrocarbon yields are normalised to HI) and bulk kinetics (modelled rate of hydrocarbon generation at 10°C/min; product potential is the proportion of HI for each activation energy) for a) Type III terrestrial organic matter b) Type II marine organic matter using..

Predicting the quantities of oil and gas generated from source rocks using chemical kinetics derived from pyrolytic methods

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Great care and thought are usually taken to produce a 'realistic' burial and maturation history model for a particular well/basin and the constraints of the model are well recognised. Generally, the same cannot be said for the subsequent handling of source rock catagenesis with chemical kinetic data. The use of default chemical kinetics for different organic matter types or combinations of such can lead to erroneous predictions on the timing of oil and gas generation and an ineffective recognition of petroleum systems (Boreham et al., 1996). Although kinetic models of the types described below only approximate the sum total of the individual chemical reactions, there still appears to be a remarkable ability of the model to quantify geochemical processes based on extrapolation from laboratory timescales of up to weeks to the geological timescales occurring over millions of years (Forbes et al., 1991)

Various reaction models have been invoked over the last three decades to describe the transformation of kerogen to petroleum. The most widely accepted method for the determination of 'bulk' kinetic parameters for primary generation of petroleum is to divide the the total petroleum potential into so-called product potentials (Ungerer, 1990; Schenk and Horsfield, 1993). During pyrolytic and/or natural evolution of organic matter, these potentials are considered to be more or less simultaneously transformed from precursor (kerogen) into the product (oil plus gas) by a discrete number of parallel reactions each of which is kinetically characterised by a reaction order and a rate constant. Bulk kinetic parameters are the crudest, but nevertheless an effective, means of predicting rates of petroleum generation under geological heating rates.

In a 'compositional' kinetic treatment of petroleum generation, the products can be considered in more detail (Ungerer, 1990) ranging from individual components (eg. methane or non-hydrocarbons like CO_2) to groups of genetically related compounds, for example C_1-C_5 (gas), C6-C14 (condensate), and C15+ (oil). Each component is related to a common precursor using the above parallel reaction mechanism and open system pyrolysis methodology. Closed system pyrolysis has also been employed to determine the kinetic parameters for these primary products as well as for secondary oil-to-gas cracking processes (Horsfield et al., 1992; Schenk and Horsfield, 1993). These compositional kinetic approachs are very time consuming.

Described here is a simplified adaptation of the full compositional kinetic approach above which combines open system bulk kinetic parameters with compositional data derived from open system step-wise pyrolysis (Fig. 1). Gas-to-oil ratios determined for each individual pyrolysis step (30°C increments) are assigned over the appropriate activation energy range and the product potential apportioned accordingly to gas and oil. For example, for the terrestrial source rock (Fig. 1a) the activation energy at 56kcal has product potentials of 8 mg HC/g TOC and 73 mg HC/g TOC for gas and oil, respectively. Additional data compiled for a wide variety of source rocks from the NW Shelf and eastern Australian basins highlights the need for sample-specific compositional kinetic analysis in order to gain a realistic understanding of the timing of hydrocarbon generation and the distribution of oil and gas in the basin of interest.

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