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HYDROCARBON SOURCE POTENTIAL OF THE OBSERVATORY HILL BEDS, BYILKAOORA No.2, OFFICER BASIN

Comalco Aluminium Limited

F3/1/4/0-5727/84 November, 1983

service report

THE AUSTRALIAN MINERAL DEVELOPMENT LABORATORIES, FLEMINGTON STREET, FREWVILLE, SOUTH AUSTRALIA 5063

HYDROCARBON SOURCE POTENTIAL OF THE OBSERVATORY HILL BEDS, BYILKAOORA No.2, OFFICER BASIN

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amdel

23 November, 1983

F3/1/4/0
5727/84 - Part 2 (Final)

Comalco Aluminium Ltd.,
PO Box 246,
GLENSIDE SA 5065

Attention: Mr G. Weste

REPORT F5727/84 - Part 2 (Final)

CLIENT REFERENCE:	Requisition No.010
TITLE:	Hydrocarbon source potential of the Observatory Hill Beds, Byilkaoora No.2, Officer Basin.
MATERIAL:	Core
LOCALITY:	BYILKAOORA No.2
SAMPLE IDENTIFICATION:	Interval 614-745 metres.
DATE RECEIVED:	9 August, 1983
WORK REQUIRED:	TOC, Rock-Eval pyrolysis (11 samples). Description of dispersed organic matter (5 samples). Solvent extraction, liquid chromatography of extract, gas chromatography of saturates (5 samples). Interpretation.

Investigation and Report by: Dr David M. McKirdy

Chief - Fuel Section: Dr Brian G. Steveson
Manager, Mineral and Materials Sciences Division: Dr William G. Spencer

WG Spencer

for Brian S. Hickman
Managing Director

cah

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1. INTRODUCTION

Total organic carbon and Rock-Eval pyrolysis data on eleven core samples from 688-761 metres depth in Byilkaoora-2 were forwarded to the client as an interim report on 29 August, 1983. This final report formally presents the aforementioned data, and incorporates the results of additional analytical work, as follows:

1. $C_{12}+$ extract analysis (5 samples); and

2. Description of dispersed organic matter (7 samples).

Also included are Rock-Eval data on nine other core samples from the same well analysed previously by WAIT.

The above information is used to assess the hydrocarbon source potential (maturity, organic richness, kerogen type) of the lacustrine sediments of the Early Cambrian Observatory Hill Beds at the Byilkaoora-2 well locality.

The saturated hydrocarbon, aromatic hydrocarbon, resin and asphaltene fractions of the five core extracts have been forwarded to R. Summons (Baas Becking Geobiological Laboratory, Canberra).

2. ANALYTICAL PROCEDURE

2.1 Sample Preparation

Core samples (as received) were ground in a Siebtechnik mill for 20-30 secs.

2.2 Total Organic Carbon (TOC)

Total organic carbon was determined by digestion of a known weight (2-10 g) of powdered rock in 50% HCl to remove carbonates, followed by combustion in oxygen in the induction furnace of a Leco IR-12 Carbon Determinator and measurement of the resultant CO_2 by infra-red detection.

2.3 Rock-Eval Analysis

A 100 mg portion of powdered rock was analysed by the Rock-Eval pyrolysis technique (Girdel IFP-Fina Mark 2 instrument; operating mode, Cycle 1).

2.4 $C_{12}+$ Extractable Organic Matter (EOM)

Powdered rock (30-80 g) was extracted with azeotropic chloroform/methanol (87:13) in a Soxhlet apparatus for 24 hours. Removal of solvent by careful rotary evaporation gave the $C_{12}+$ EOM.

Asphaltenes were precipitated from the EOM with petroleum ether (IP method 143/57), and the asphaltene-free fraction separated into saturated hydrocarbons, aromatic hydrocarbons and polar compounds (resins) by liquid chromatography on 20 parts activated alumina under 80 parts activated silica gel. The saturates were eluted with petroleum ether, the aromatics with petroleum ether/methylene chloride (91:9), and the resins with methanol/methylene chloride (65:35) followed by methanol.

The saturated hydrocarbons were examined by gas chromatography using the following instrumental parameters:

Gas chromatograph:	Perkin Elmer Sigma 2 fitted with Grob injector.
Column:	25 m x 0.33 mm fused silica, SGE QC3/BP1
Detector:	FID
Injector and detector temperature:	280°C
Carrier gas:	H_2 at 9 psi
Column temperature:	60°C for 4 mins, then 5° per minute to 280°C and held at 280° until all peaks eluted.
Quantitation:	Relative concentrations of individual normal and isoprenoid alkanes obtained by measurement of peak areas above naphthene hump.

2.5 Organic Petrology

Representative portions of each rock (crushed to -14+35 BSS mesh) were obtained with a sample splitter and then mounted in cold setting Glasscraft resin using a 2.5 cm diameter mould. Each block was ground flat using diamond impregnated laps and carborundum paper. The surface was then polished with aluminium oxide and finally magnesium oxide.

Reflectance measurements were made with a Leitz MPV1.1 microphotometer fitted to a Leitz Ortholux microscope and calibrated against synthetic standards. All measurements were taken using oil immersion (n = 1.518) and incident monochromatic light (wavelength 546 nm) at a temperature of 24±1°C. Fluorescence observations were made on the same microscope utilizing a 3 mm BG3 excitation filter, a TK400 dichroic mirror and a K510 suppression filter.

3. RESULTS

All available TOC and Rock-Eval data for the Observatory Hill Beds in Byilkaoora-2 are listed in Table 1. The variation of Tmax, production index ($S_1/S_1 + S_2$), TOC, potential yield ($S_1 + S_2$) and hydrogen index with depth is illustrated in Figures 1A and 1B. Figure 2 is a cross plot of hydrogen index versus Tmax which demonstrates kerogen type and maturity.

Dispersed organic matter (DOM) descriptions are summarised in Table 2. Extended descriptions of the DOM for each sample may be found in Appendix 1. The types of DOM present in selected samples are illustrated in Plates 1 to 10.

C_{12}+ extract data on five samples high-graded by TOC and Rock-Eval analyses are presented in Tables 3-7, Figures 3-7 (saturates chromatograms), and Figures 8-12 (*n*-alkane profiles). Figure 13 demonstrates the maturation state and hydrocarbon source potential of the rocks based on their C_{12}+ hydrocarbon yield. Figure 14 shows the genetic affinity and maturity of the extract hydrocarbons as indicated by their pristane/*n*-heptadecane and phytane/*n*-octadecane ratios.

4. DISCUSSION

4.1 Maturity

Tmax values in the range 410-434°C suggest that the Observatory Hill Beds between 614 and 738 metres depth in Byilkaoora-2 are immature to marginally mature (equivalent VR ≤0.6%) (Fig.2). However, the fluorescence characteristics of the lamalginite component of the DOM indicate a somewhat higher rank (equivalent VR = 0.75-0.85%) (Appendix 1). This discrepancy is perhaps attributable to the moderate to high proportion (15-40%) of exsudatinite, bitumen and free oil in the DOM (Table 2). The depression of Tmax values in oil and/or bitumen-saturated source rocks has been described by Clementz (1979). The fact that production indices ($S_1/S_1 + S_2$) are not also markedly anomalous is probably due to the asphaltic nature of the bitumen (cf. Tarafa *et al.*, 1983).

C_{12}+ hydrocarbon yield (Fig. 13) and composition (Fig. 14) are consistent with these carbonate rocks being marginally mature to mature. A similar assessment was made of the thermal maturity of the Observatory Hill Beds at Byilkaoora-1 (McKirdy *et al.*, 1983b).

4.2 Source Richness

Total organic carbon contents are indicative of poor to fair organic richness. Sixty percent of the samples listed in Table 1 have TOC values which exceed the minimum value (TOC = 0.3%) considered necessary for carbonates to generate producible hydrocarbons (Tissot and Welte, 1978; Hunt, 1979). However, only the four richest samples (TOC = 0.53-0.77%) have potential hydrocarbon yields characteristic of oil-prone source rocks ($S_1 + S_2 \geqq 2$ kg/tonne).

Five core samples were nominated for EOM analysis (TOC = 0.31-0.43%: Tables 3-7). Their C_1+ hydrocarbon contents (148-440 ppm) are indicative of fair to good source richness.

4.3 Source Quality and Kerogen Type

Hydrogen indices in the range HI = 134-412 (Fig. 1B) suggest that these carbonates contain organic matter of Type III, tending to Type II, composition (Fig. 2). Optical examination of selected samples revealed the presence of DOM comprising mostly lamalginite (60-90%) (Table 2; Appendix 1, Plates 3-6).

The algal/bacterial affinity of the kerogen is consistent with the composition of its associated C_{12}+ alkanes (Figs. 3-12, 14). The same high abundance of C_{13}-C_{25} regular isoprenoid alkanes and squalane (C_{30} irregular isoprenoid) noted in oils and rock extracts from Byilkaoora-1 (McKirdy and Kantsler, 1980; McKirdy *et al.*, 1983a, b) is also a feature of the Byilkaoora-2 extracts. These isoprenoids (asterisked peaks in Figure 3) are considered to be biological markers of halophilic and/or methanogenic archaebacteria which inhabited the Early Cambrian alkaline, playa-lacustrine environment at Byilkaoora.

On the basis of their C_{12}+ extract data, these carbonate rocks are fair to excellent potential sources of heavy oil (Fig. 13).

Further work is required to resolve the apparent conflict between kerogen type as determined by elemental analysis (Type I-II : McKirdy *et al.*, 1983b) and that indicated by Rock-Eval pyrolysis (Type II-III : Fig. 2).

5. CONCLUSIONS

Evaporitic argillaceous carbonates of the Observatory Hill Beds from 660-738 metres depth in Byilkaoora-2 are marginally mature to mature, fair to good potential source rocks for heavy asphaltic oil.

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TABLE 1

AMDEL

ROCK-EVAL PYROLYSIS

21/10/83

Client COMALCO

Well BYILKAOORA #2

DEPTH	T MAX	S1	S2	S3	S1+S2	PI	S2/S3	PC	TOC	HI	OI
614.10	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0	0
634.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0	0
660.90	434	0.06	0.59	0.34	0.65	0.09	1.74	0.05	0.44	134	77
670.00	417	0.21	1.20	0.50	1.41	0.15	2.40	0.12	0.50	240	100
677.40	416	0.24	1.92	0.50	2.16	0.11	3.84	0.18	0.53	362	94
680.53	422	0.25	3.18	0.33	3.43	0.07	9.64	0.28	0.77	412	42
688.47	415	0.23	0.99	0.25	1.22	0.19	3.96	0.10	0.39	254	64
689.22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0	0
703.30	420	0.05	0.32	0.24	0.37	0.14	1.33	0.03	0.20	160	120
705.75	404	0.00	0.02	0.19	0.02	0.00	0.10	0.00	0.13	15	146
711.91	416	0.23	1.76	0.29	1.99	0.12	6.07	0.17	0.62	283	46
720.10	418	0.06	0.56	0.24	0.62	0.10	2.33	0.05	0.28	200	86
720.35	423	0.12	1.18	0.57	1.30	0.09	2.07	0.10	0.39	303	146
727.40	410	0.17	0.88	0.43	1.05	0.16	2.04	0.08	0.31	284	139
728.05	415	0.26	1.54	0.43	1.80	0.14	3.58	0.15	0.39	395	110
728.50	414	0.11	0.89	0.31	1.00	0.11	2.87	0.08	0.34	262	91
729.15	412	0.26	2.38	0.39	2.64	0.10	6.10	0.22	0.68	350	57
729.70	415	0.14	0.65	0.42	0.79	0.18	1.54	0.06	0.27	241	156
738.00	431	0.28	1.13	0.45	1.41	0.20	2.51	0.11	0.43	263	105
744.30	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0	0

o = not determined

KEY TO ROCK-EVAL PYROLYSIS DATA SHEET

	PARAMETER	SPECIFICITY
T max	position of S_2 peak in temperature program (^{o}C)	Maturity/Kerogen type
S_1	kg hydrocarbons (extractable)/tonne rock	Kerogen type/Maturity/Migrated oil
S_2	kg hydrocarbons (kerogen pyrolysate)/tonne rock	Kerogen type/Maturity
S_3	kg CO_2 (organic)/tonne rock	Kerogen type/Maturity *
$S_1 + S_2$	Potential Yield	Organic richness/Kerogen type
PI	Production Index ($S_1/S_1 + S_2$)	Maturity/Migrated Oil
PC	Pyrolysable Carbon (wt. percent)	Organic richness/Kerogen type/Maturity
TOC	Total Organic Carbon (wt. percent)	Organic richness
HI	Hydrogen Index (mg h'c (S_2)/g TOC)	Kerogen type/Maturity
OI	Oxygen Index (mg CO_2(S_3)/g TOC)	Kerogen type/Maturity *

*Also subject to interference by CO_2 from decomposition of carbonate minerals.

TABLE 2: DISPERSED ORGANIC MATTER TYPE AND ABUNDANCE, BYILKAOORA-2

Depth	Estimated Volume of D.O.M. (Exinite) %	Proportion of		Exinite Macerals
		Primary Exinite	Secondary Exinite	
688.47	<0.5	60	40	lama, bmen, lipto, ?oil, phyto
703.3	∿ 1	90	10	lama, exsu, lipto, ?oil
720.1	< 1	80	20	lama, exsu, bmen, ?oil, lipto
720.35	∿ 1	75	25	lama, exsu, ?oil, bmen, lipto
727.4	∿ 1	70	30	lama, exsu, ?oil, bmen
728.05	∿ 1	85	15	lama, exsu, ?oil
738.0	< 1	70	30	lama, bmen, exsu, ?oil

KEY

lama	lamalginite	Primary Exinite
lipto	liptodetrinite	Primary Exinite
bmen	bitumen	Secondary Exinite
exsu	exsudatinite like material	Secondary Exinite
oil	free oil	Secondary Exinite

TABLE 3

SOURCE ROCK ANALYSIS

WELL: BYILKAOORA NO 2

SAMPLE: 688.47 M
TYPE OF SAMPLE: CORE

B-C Traces.

total organic carbon	.39 %
weight of sample extracted	75.05 g
weight of eom	90.7 mg
extracted organic matter	1209 ppm
eom as fraction of toc	310 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	28.1
AROMATICS	8.3
RESINS	39.6
ASPHALTENES	24.0

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	2.4	17	11.6	22	2.4	27	.8	32	.0
13	8.9	18	8.0	23	1.7	28	.5	33	.0
14	14.0	19	6.0	24	1.3	29	.3	34	.0
15	17.3	20	4.7	25	1.4	30	.0	35	.0
16	14.7	21	2.9	26	1.0	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

pristane/phytane ratio	1.28
pristane/C-17 ratio	1.27
phytane/C-18 ratio	1.44

TABLE 4

SOURCE ROCK ANALYSIS

WELL: BYILKAOORA NO 2

SAMPLE: 720.35 M
TYPE OF SAMPLE: CORE

total organic carbon	.39 %
weight of sample extracted	29.04 g
weight of eom	18.2 mg
extracted organic matter	627 ppm
eom as fraction of toc	160.8 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	18.7
AROMATICS	4.9
RESINS	41.8
ASPHALTENES	34.6

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	.2	17	16.2	22	4.3	27	1.6	32	.0
13	1.5	18	9.4	23	4.1	28	1.2	33	.0
14	6.4	19	7.8	24	2.6	29	1.0	34	.0
15	13.9	20	6.4	25	2.8	30	.4	35	.0
16	12.8	21	5.8	26	1.6	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

pristane/phytane ratio	1.15
pristane/C-17 ratio	.61
phytane/C-18 ratio	.92

CARBON PREFERENCE INDEX (C-23 TO C-33):

C.P.I. = 1.35

TABLE 5

SOURCE ROCK ANALYSIS

WELL: BYILKAOORA NO 2

Unit D

SAMPLE: 727.4 M
TYPE OF SAMPLE: CORE

total organic carbon	.31 %
weight of sample extracted	56.96 g
weight of eom	36.8 mg
extracted organic matter	646 ppm
eom as fraction of toc	208.4 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	29.9
AROMATICS	9.0
RESINS	37.5
ASPHALTENES	23.6

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	1.8	17	12.8	22	2.5	27	1.1	32	.0
13	7.1	18	8.5	23	1.9	28	.9	33	.0
14	12.2	19	6.1	24	1.4	29	.7	34	.0
15	16.5	20	4.5	25	1.8	30	.5	35	.0
16	15.4	21	3.1	26	1.3	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

pristane/phytane ratio	1.14
pristane/C-17 ratio	.89
phytane/C-18 ratio	1.18

CARBON PREFERENCE INDEX (C-23 TO C-33):

C.P.I. = 1.09

TABLE 6

SOURCE ROCK ANALYSIS

WELL: BYILKAOORA NO 2

SAMPLE: 728.05 M
TYPE OF SAMPLE: CORE

total organic carbon	.39 %
weight of sample extracted	80.78 g
weight of eom	115.8 mg
extracted organic matter	1434 ppm
eom as fraction of toc	367.7 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	22.0
AROMATICS	8.2
RESINS	42.7
ASPHALTENES	27.1

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	3.3	17	11.7	22	3.0	27	1.0	32	.0
13	8.4	18	7.8	23	3.0	28	.6	33	.0
14	13.3	19	5.2	24	2.0	29	.3	34	.0
15	16.5	20	4.5	25	1.8	30	.0	35	.0
16	13.3	21	3.3	26	1.2	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

pristane/phytane ratio	1
pristane/C-17 ratio	.81
phytane/C-18 ratio	1.21

TABLE 7

SOURCE ROCK ANALYSIS

WELL: BYILKAOORA NO 2

B-C'...

SAMPLE: 738.00 M
TYPE OF SAMPLE: CORE

total organic carbon	.43 %
weight of sample extracted	63 g
weight of eom	75.7 mg
extracted organic matter	1202 ppm
eom as fraction of toc	279.5 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	27.2
AROMATICS	8.9
RESINS	36.1
ASPHALTENES	27.9

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	1.5	17	17.4	22	1.8	27	.9	32	.0
13	5.1	18	9.2	23	2.2	28	.7	33	.0
14	10.6	19	6.8	24	1.5	29	.6	34	.0
15	17.2	20	5.2	25	1.5	30	.0	35	.0
16	13.2	21	3.6	26	1.2	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

pristane/phytane ratio	1.18
pristane/C-17 ratio	.51
phytane/C-18 ratio	.82

CARBON PREFERENCE INDEX (C-23 TO C-33):

C.P.I. = 1.25

Client : COMALCO Well name : BYILKAOORA-2

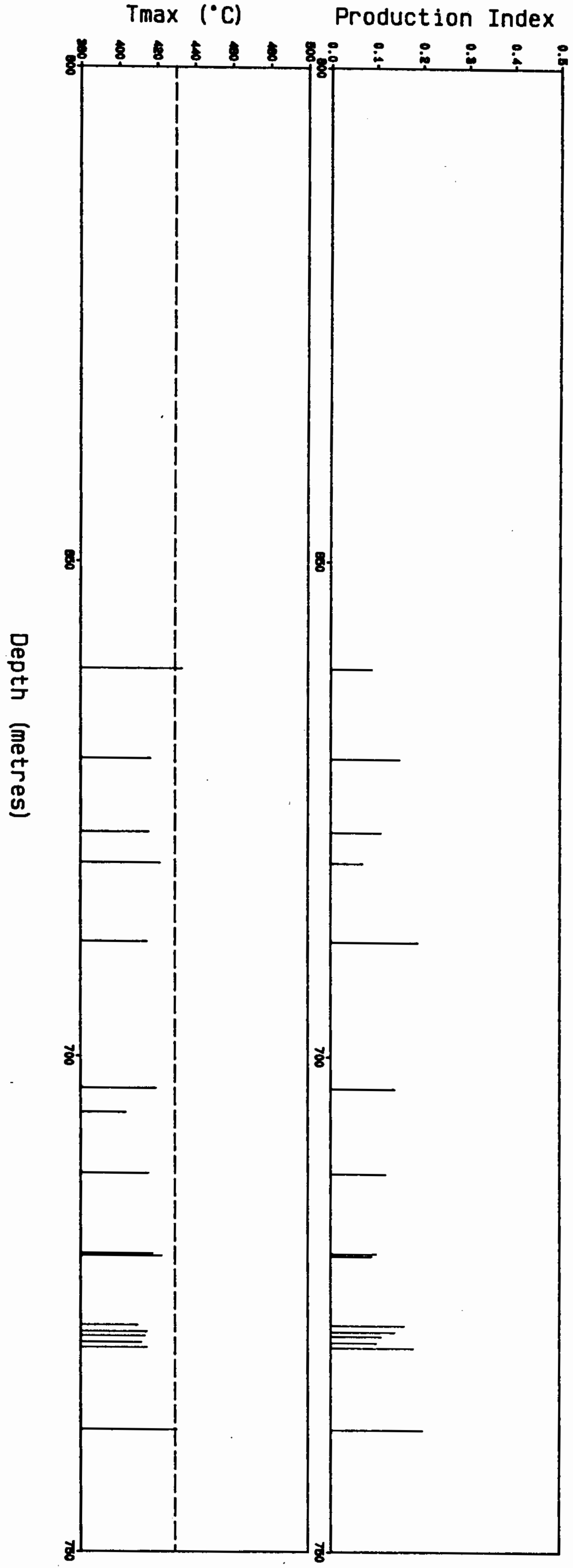


FIGURE 1A

Client : COMALCO Well name : BYILKAOORA-2

% TOC Potential Yield Hydrogen Index

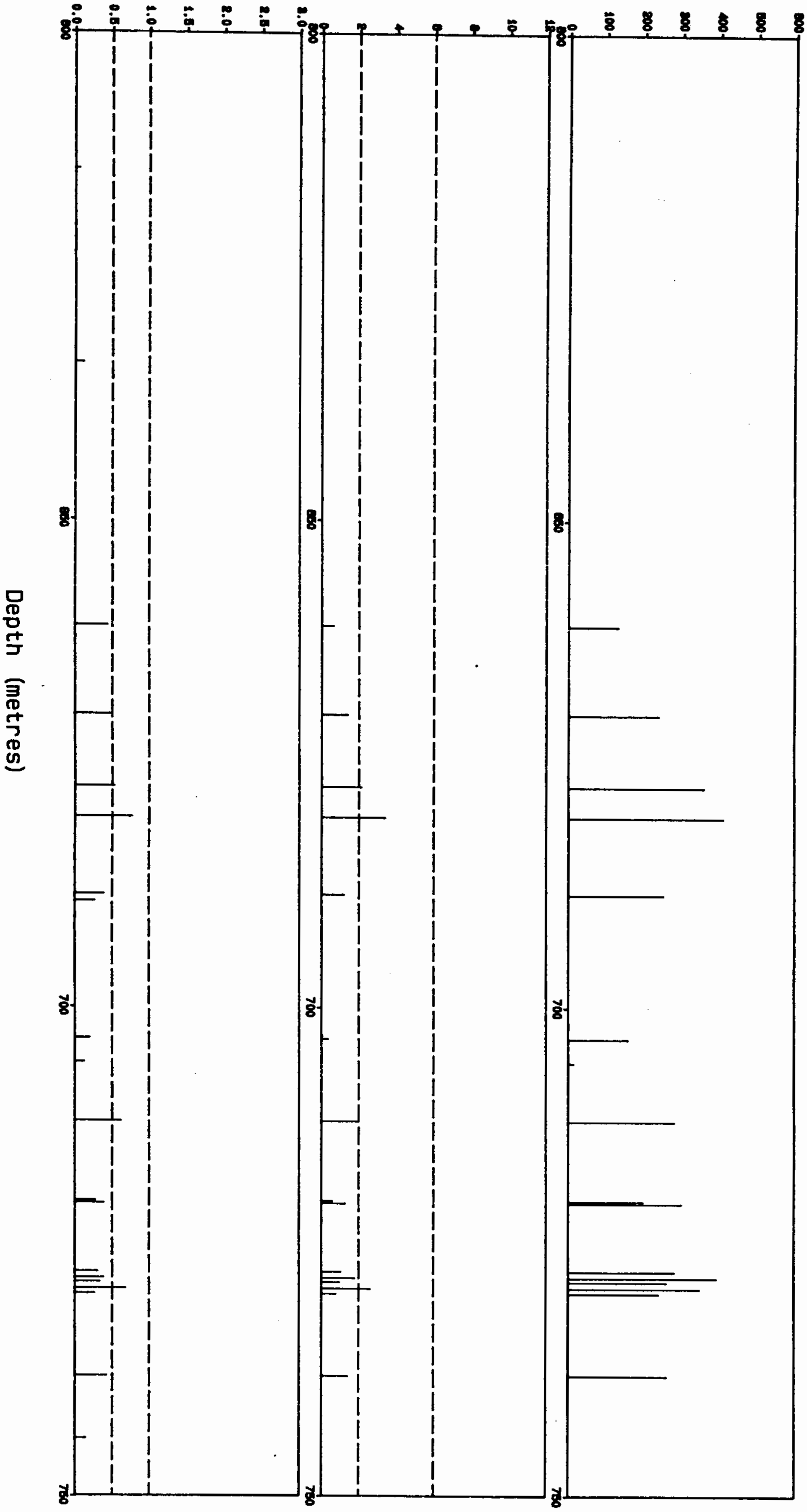


FIGURE 1B

Client : COMALCO
Well name : BYILKAOORA-2
Interval : OBSERVATORY HILL BEDS

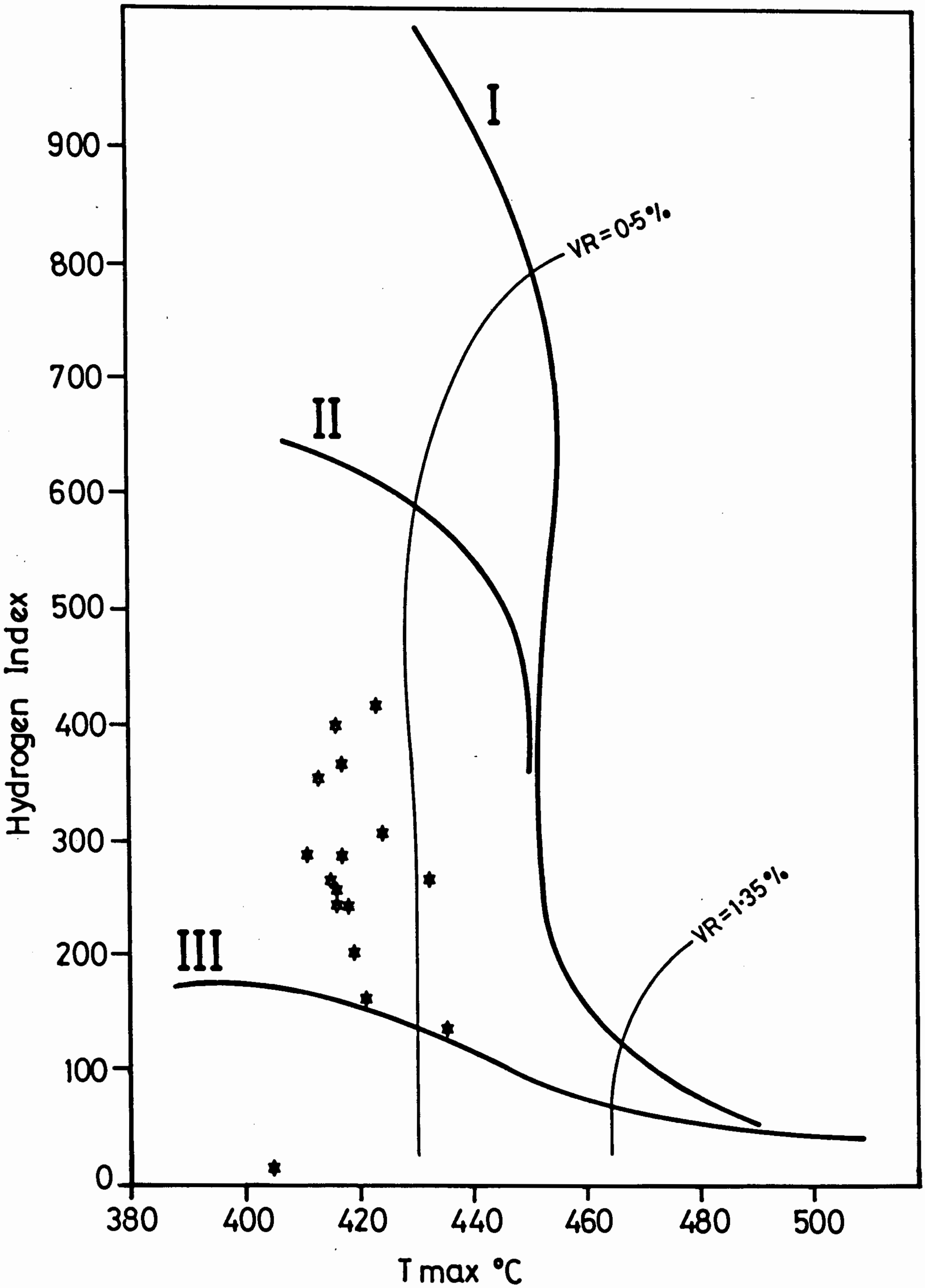
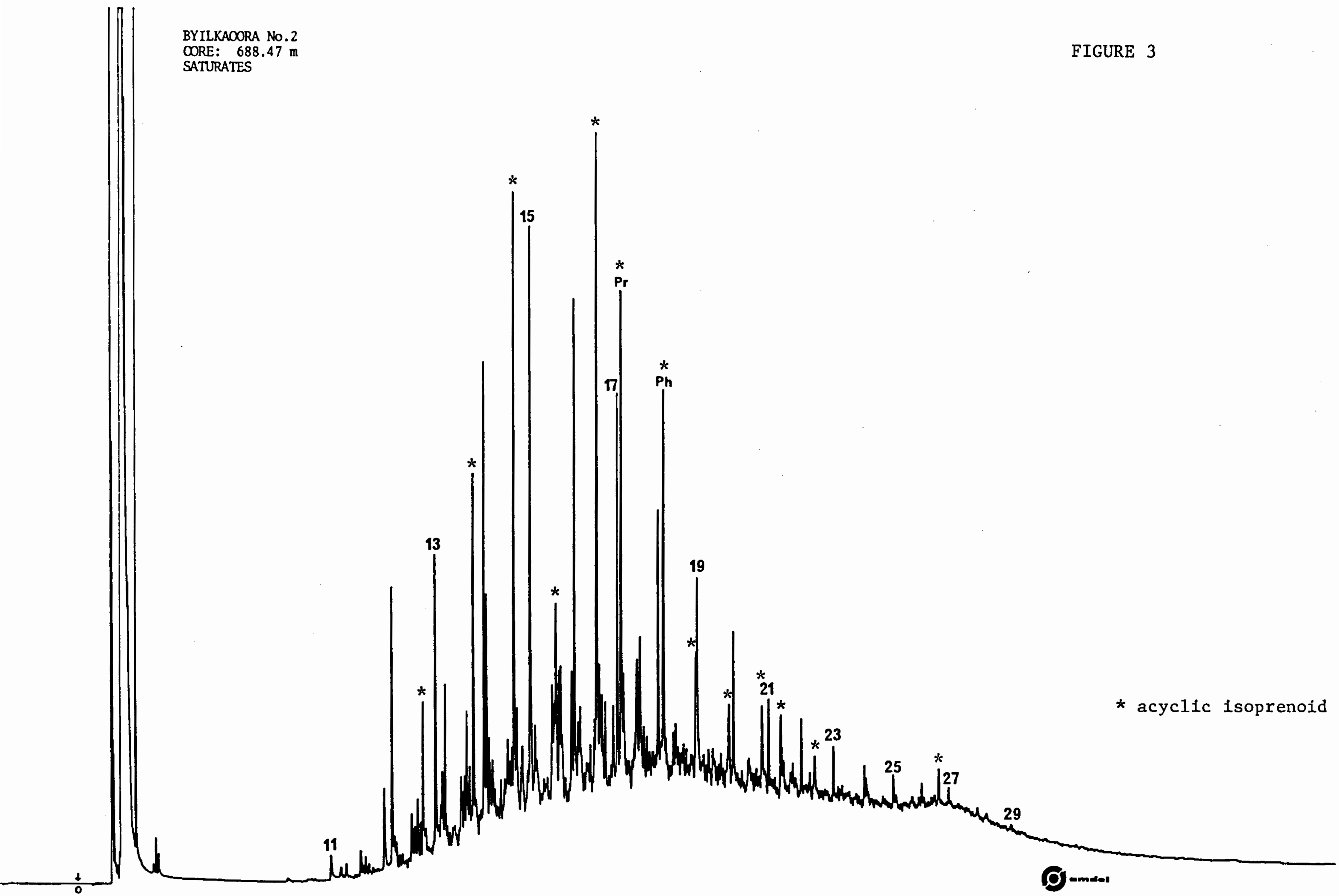


FIGURE 3


BYILKAOORA No.2
CORE: 688.47 m
SATURATES
11
13
15
17
19
21
23
25
27
29
Pr
Ph
* acyclic isoprenoid
amdel

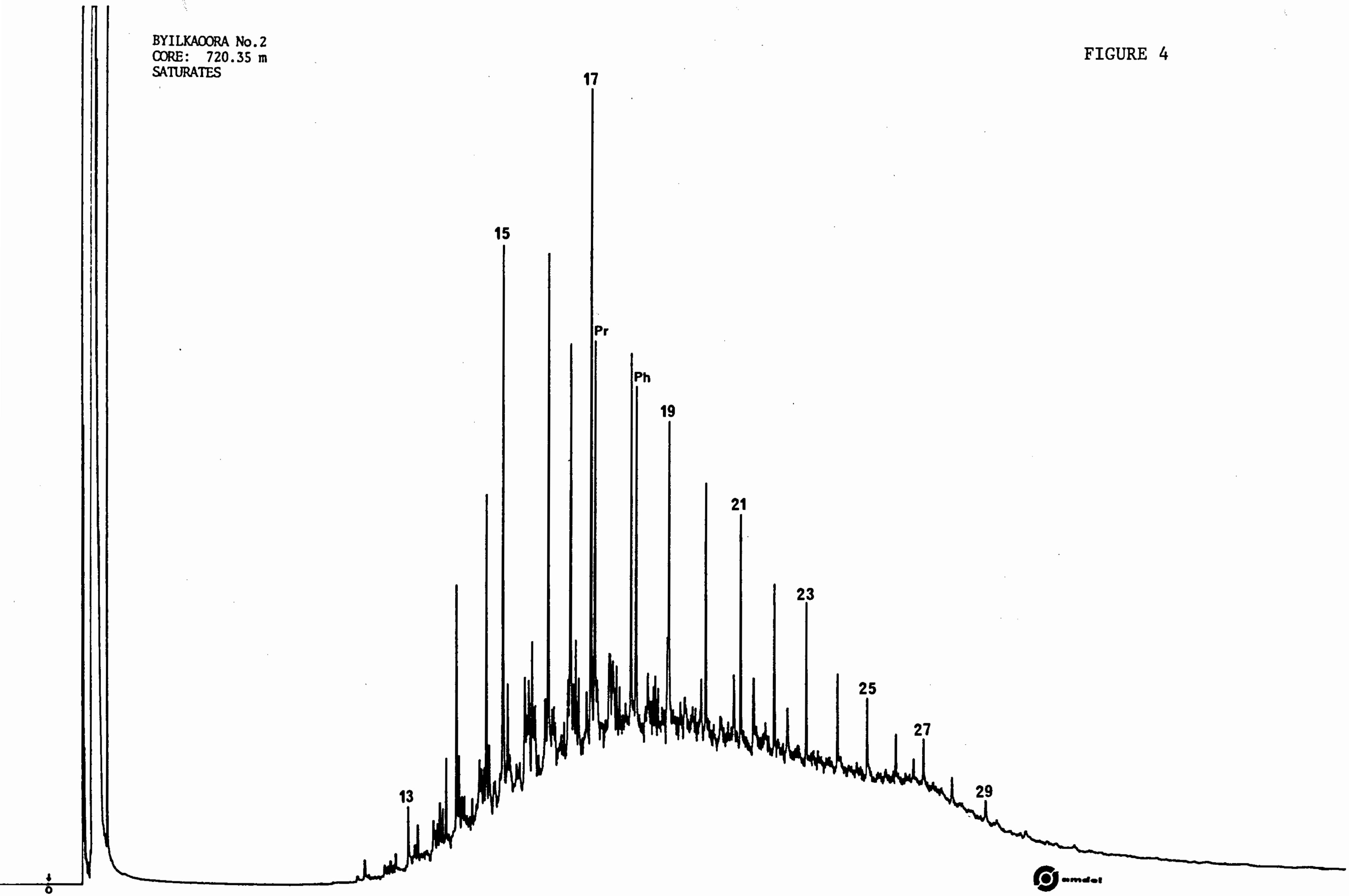

BYILKAOORA No.2
CORE: 720.35 m
SATURATES
13
15
17
Pr
Ph
19
21
23
25
27
29
0
amdel

FIGURE 4

FIGURE 5

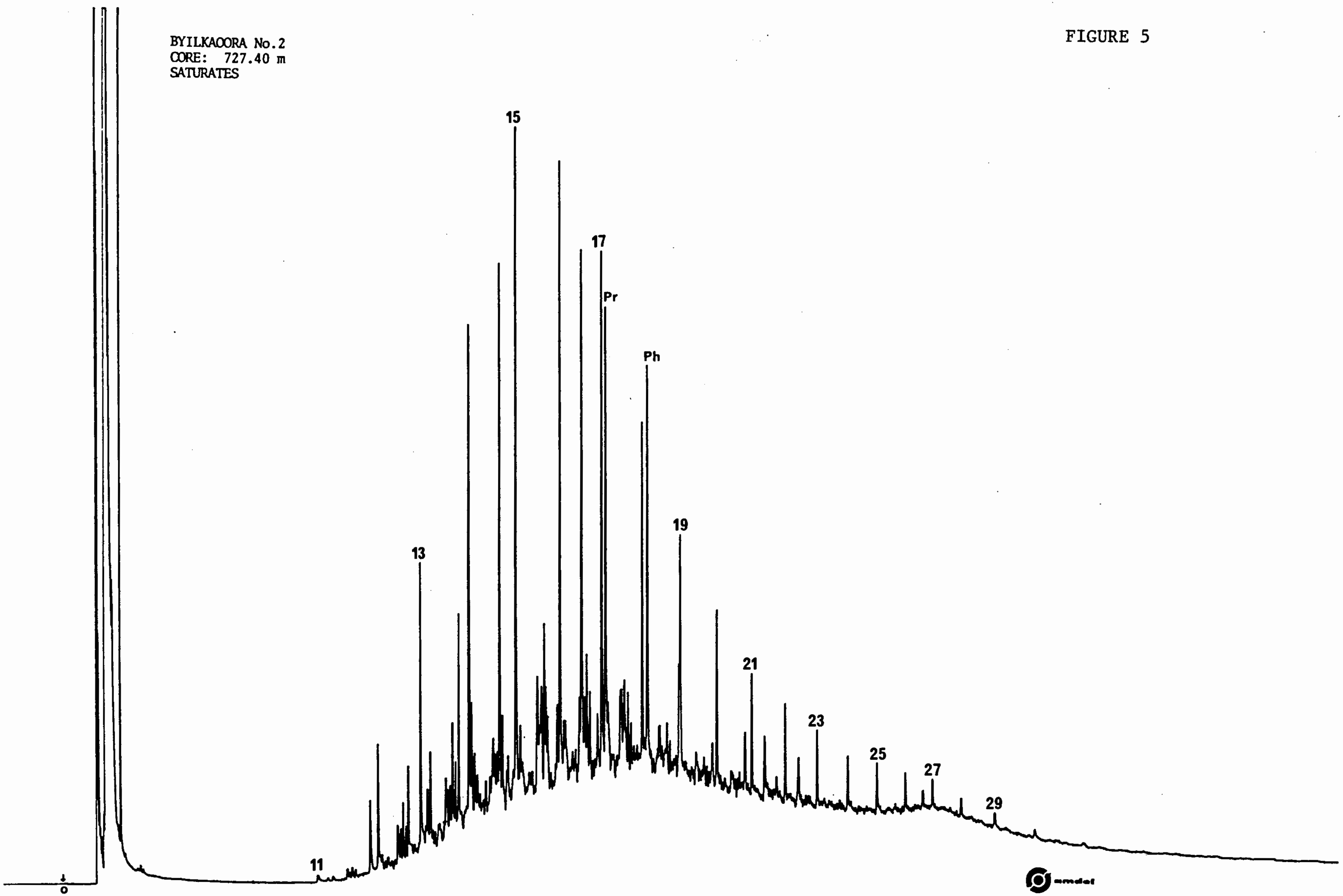
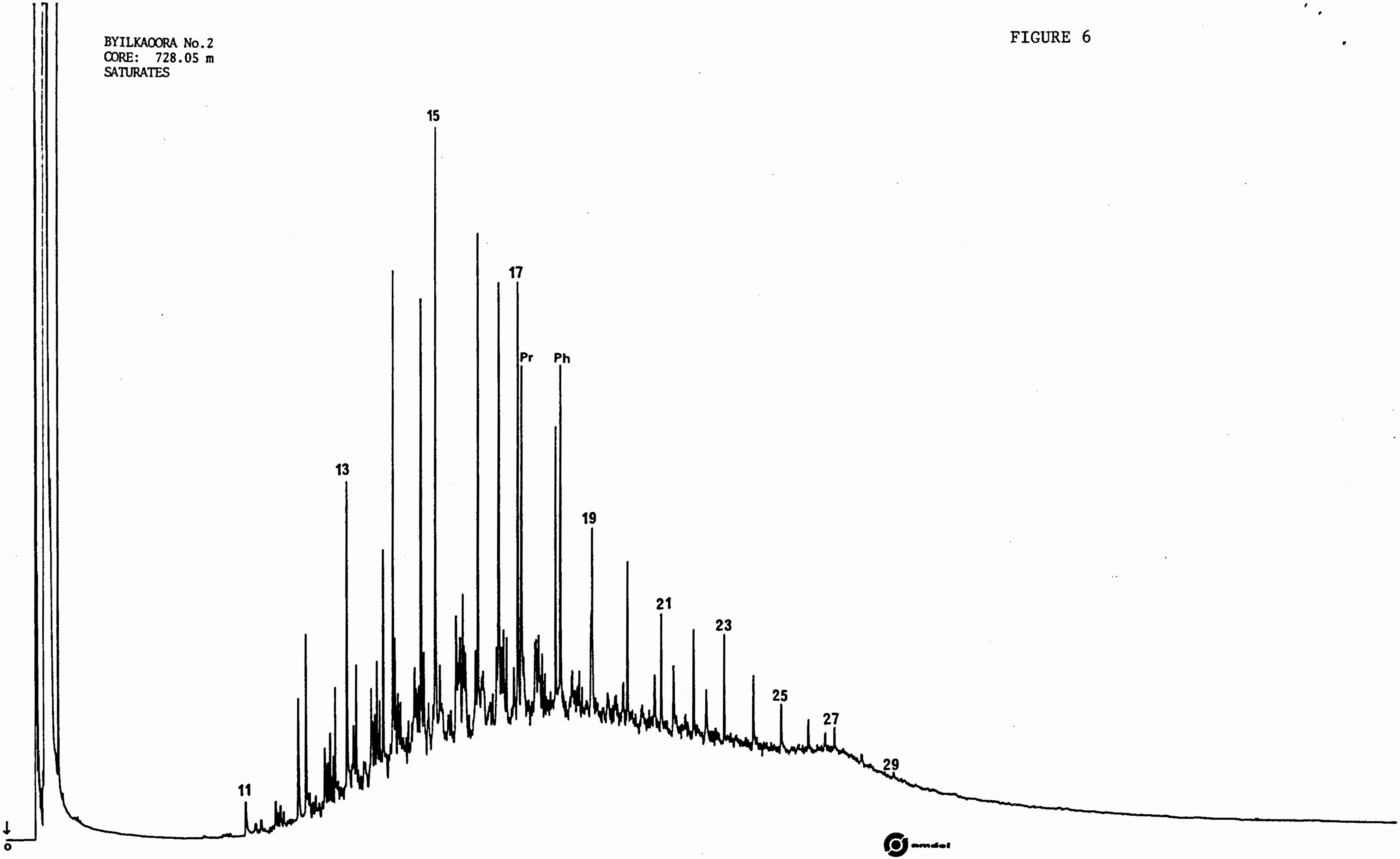

BYILKAOORA No.2
CORE: 727.40 m
SATURATES
15
17
Pr
Ph
13
19
21
23
25
27
29
11
0
amdel

FIGURE 6



BYILKAOORA No.2
CORE: 728.05 m
SATURATES
15
17
Pr
Ph
13
19
21
23
25
27
29
11
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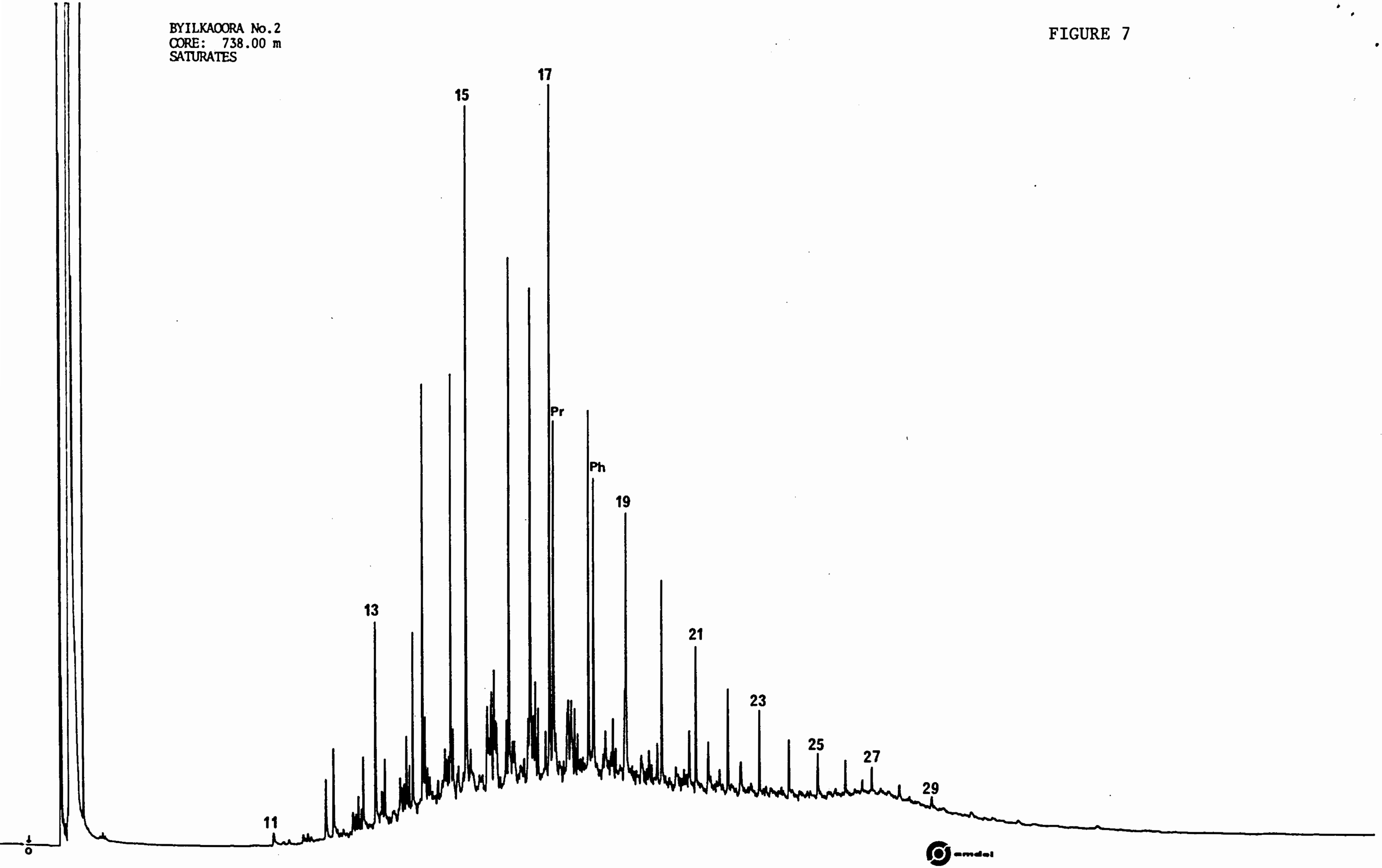
BYILKAOORA No.2
CORE: 738.00 m
SATURATES
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FIGURE 7

FIGURE 8

BYILKAOORA NO 2
688.47 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES

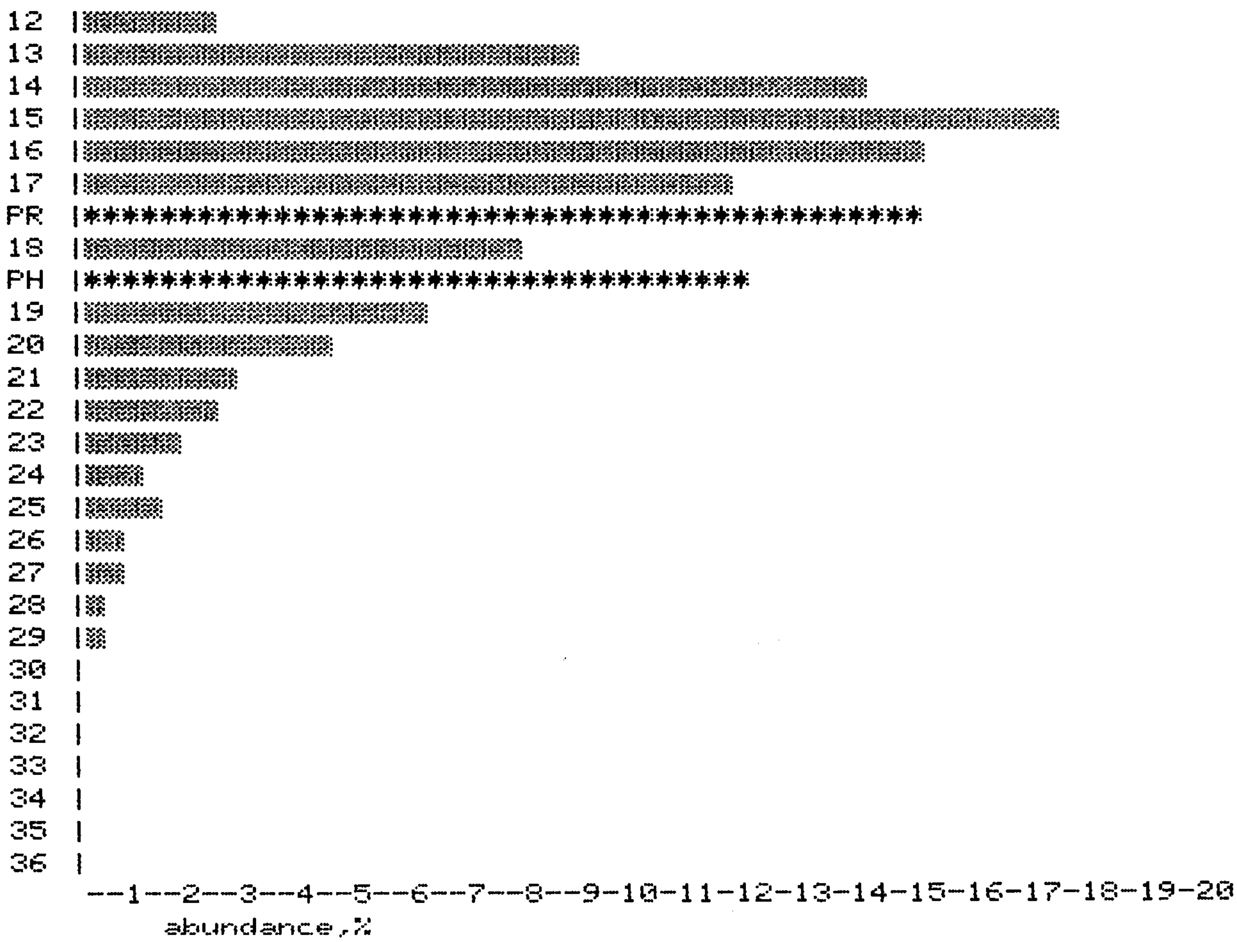


FIGURE 9

BYILKAOORA NO 2
720.35 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES

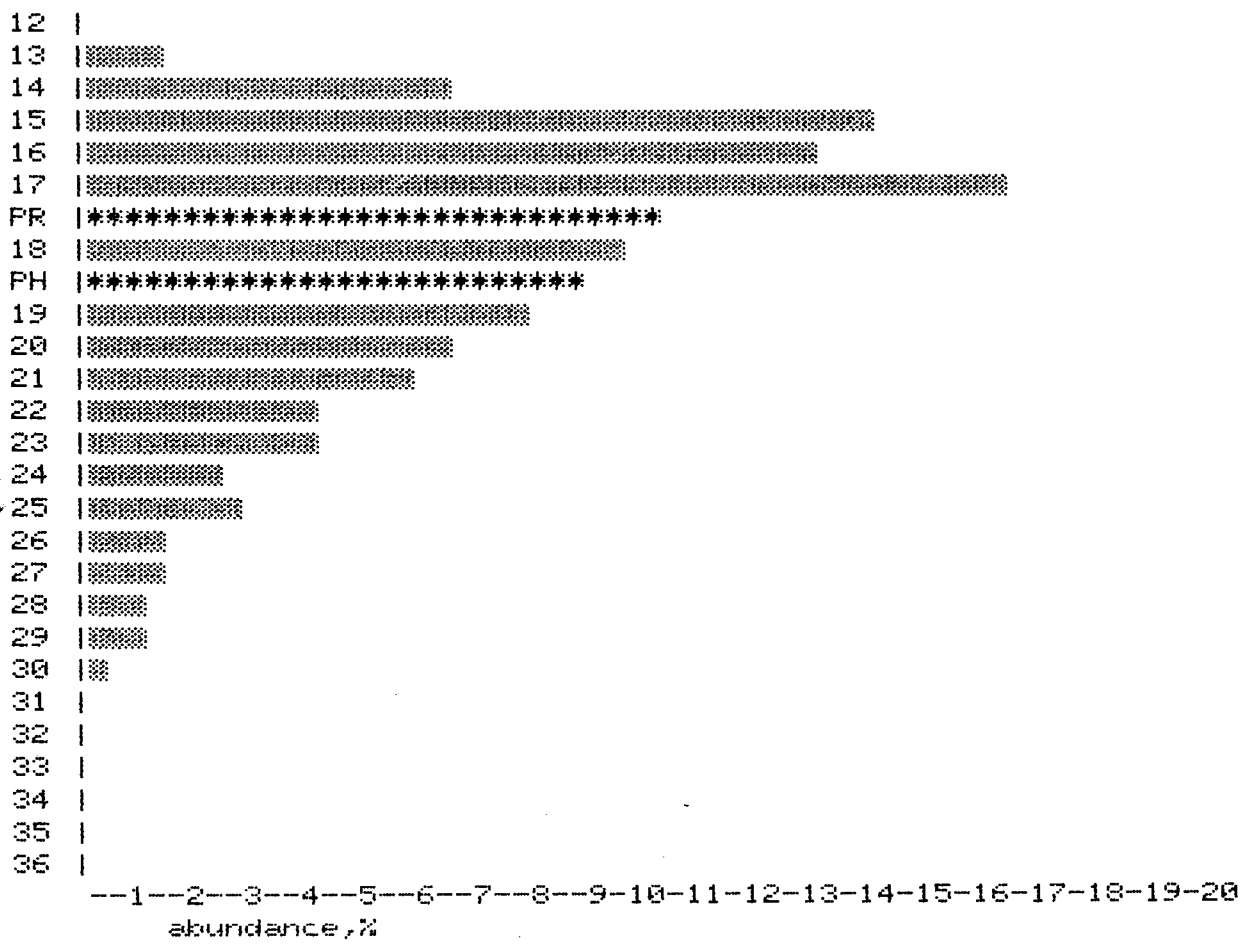


FIGURE 10

BYILKAOORA NO 2
727.4 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES

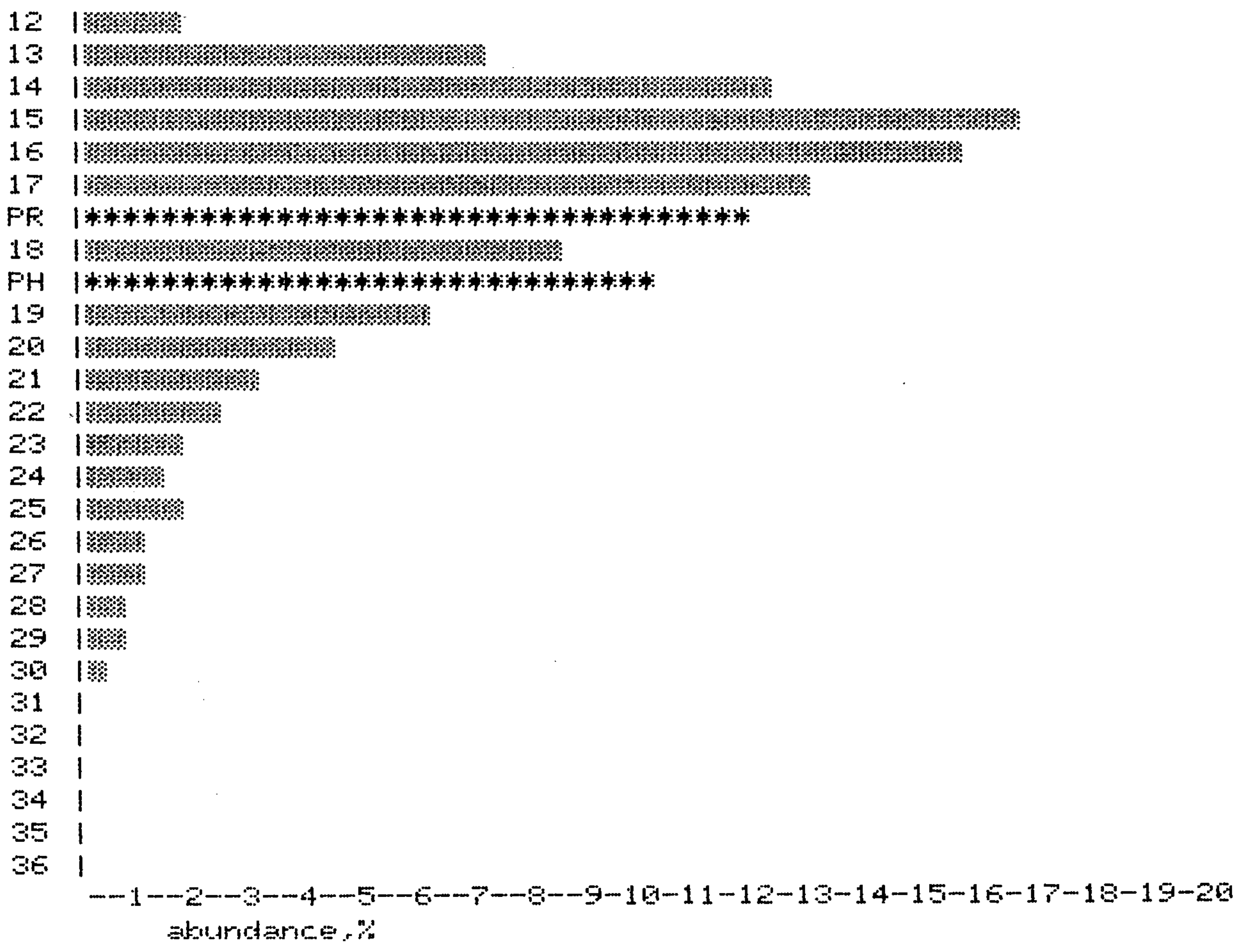


FIGURE 11

BYILKAOORA NO 2
728.05 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES

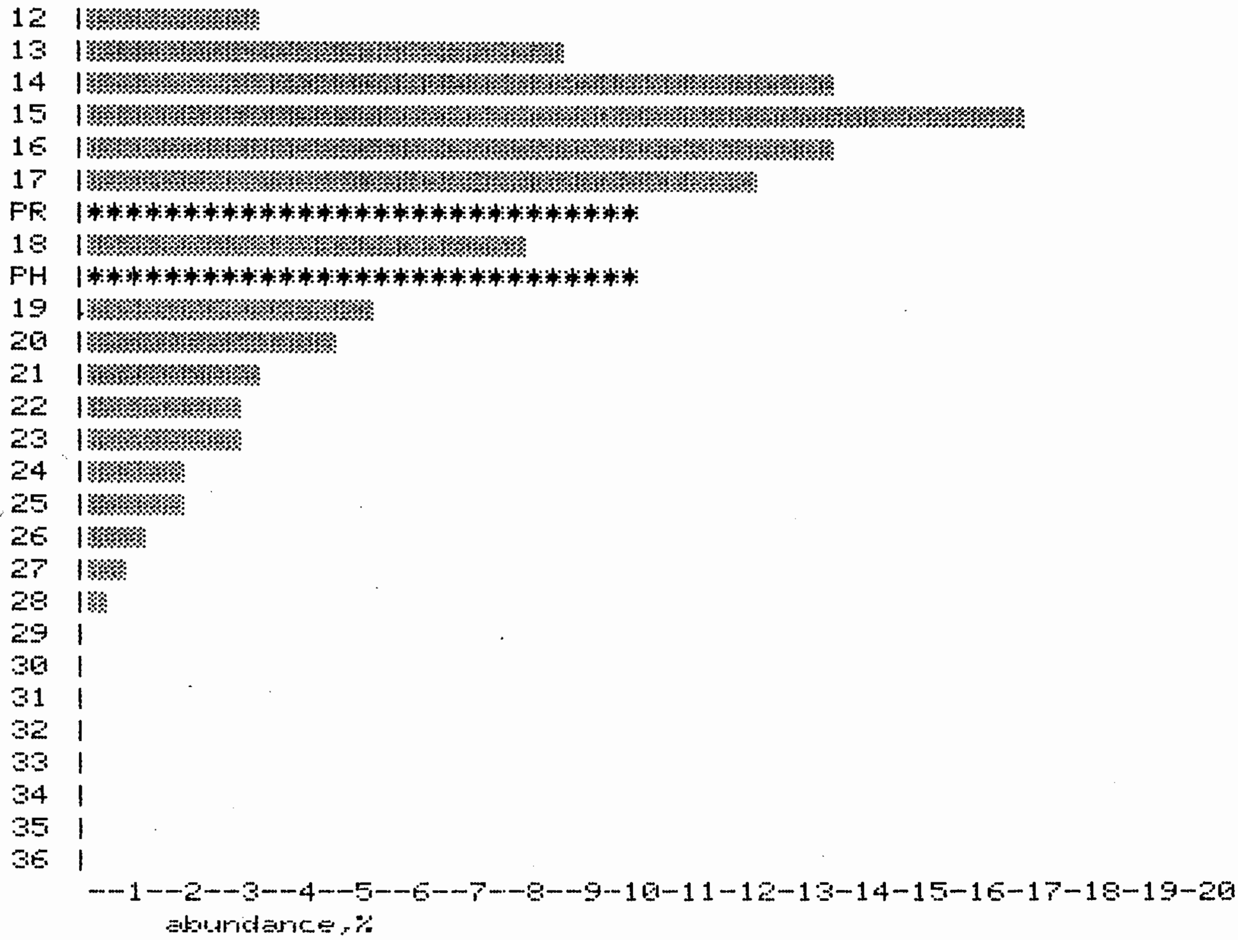


FIGURE 12

BYILKAOORA NO 2
738.00 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES

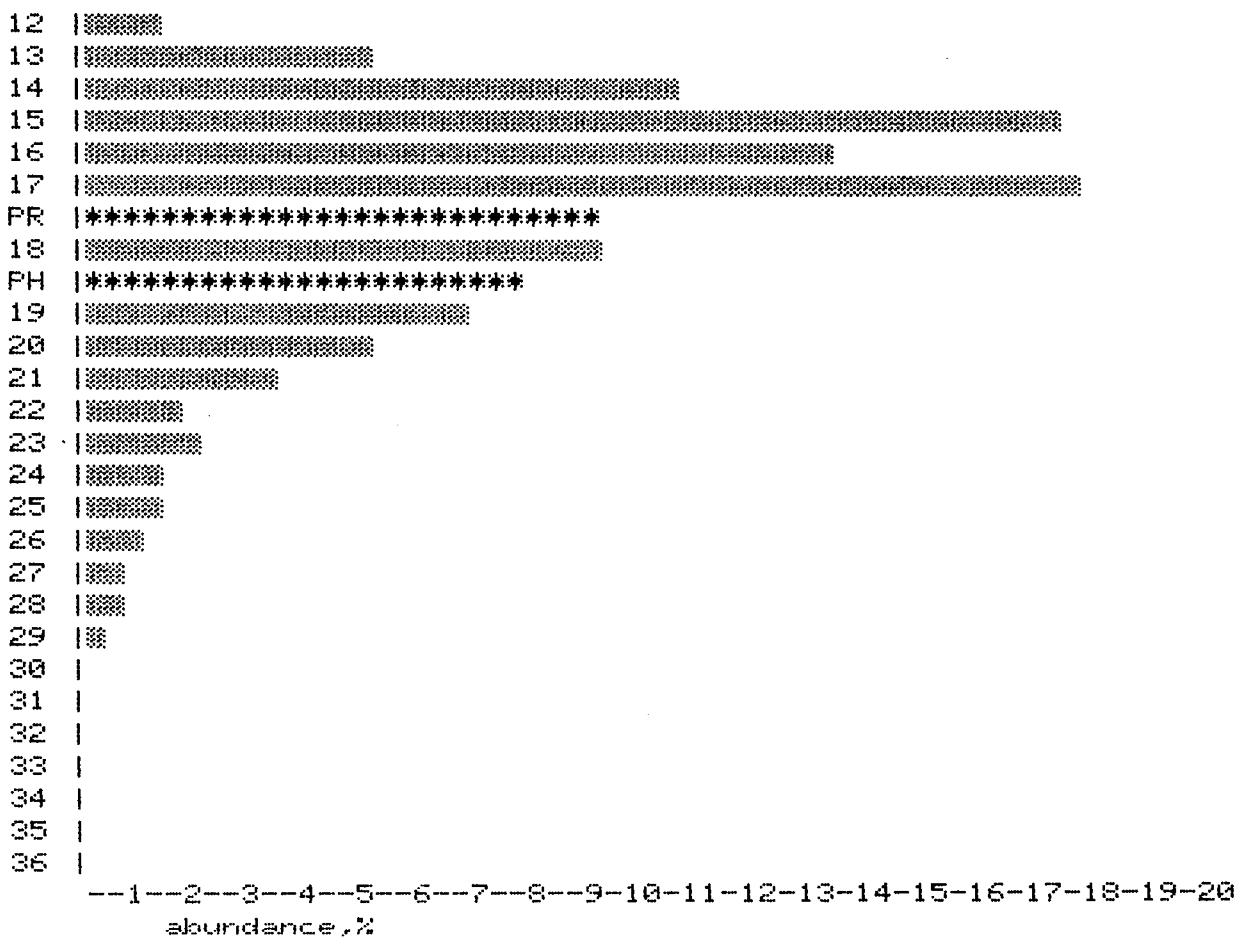
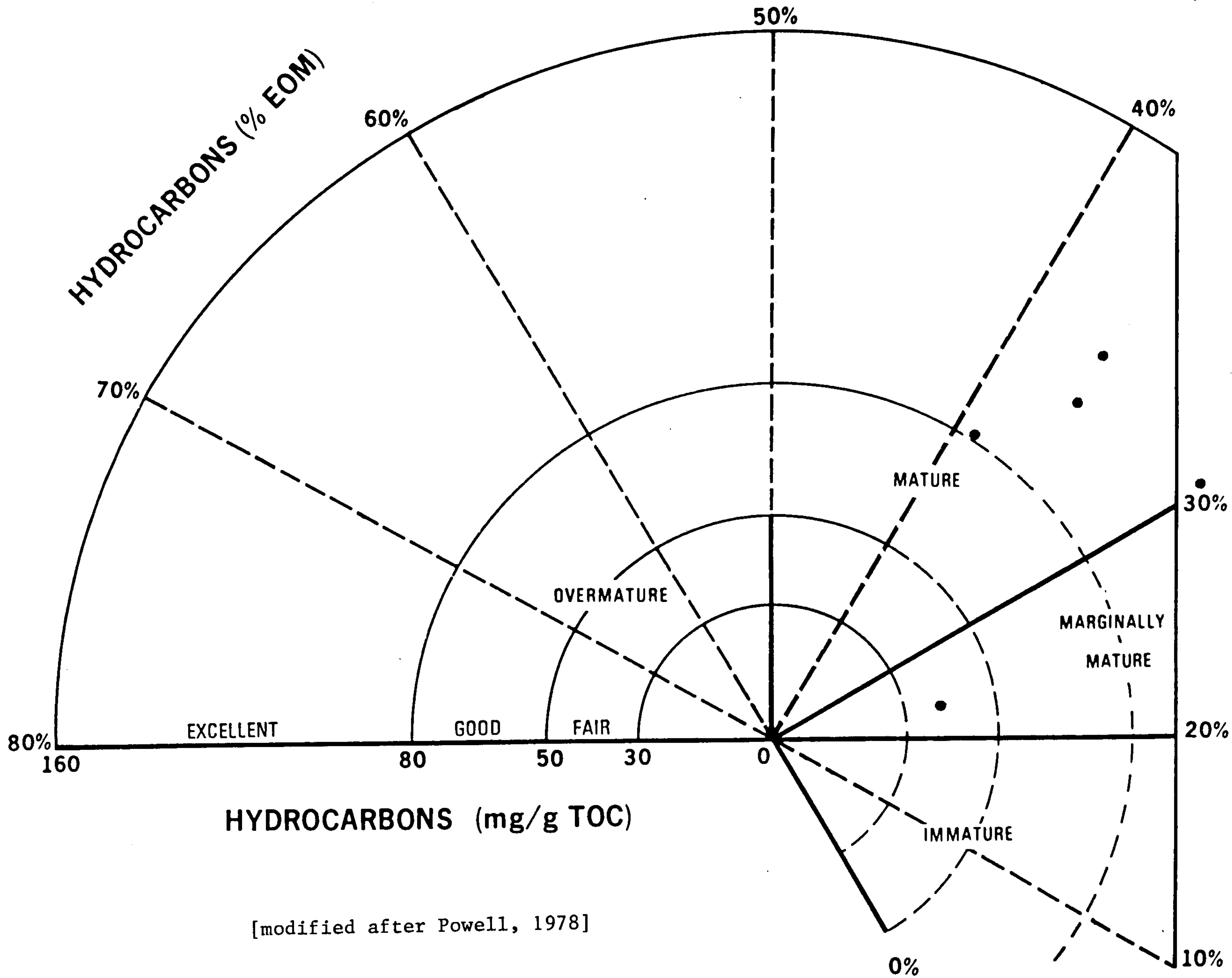


FIGURE 13

MATURATION STATE
AND HYDROCARBON POTENTIAL

BYILKAOORA - 2

• Observatory Hill Beds

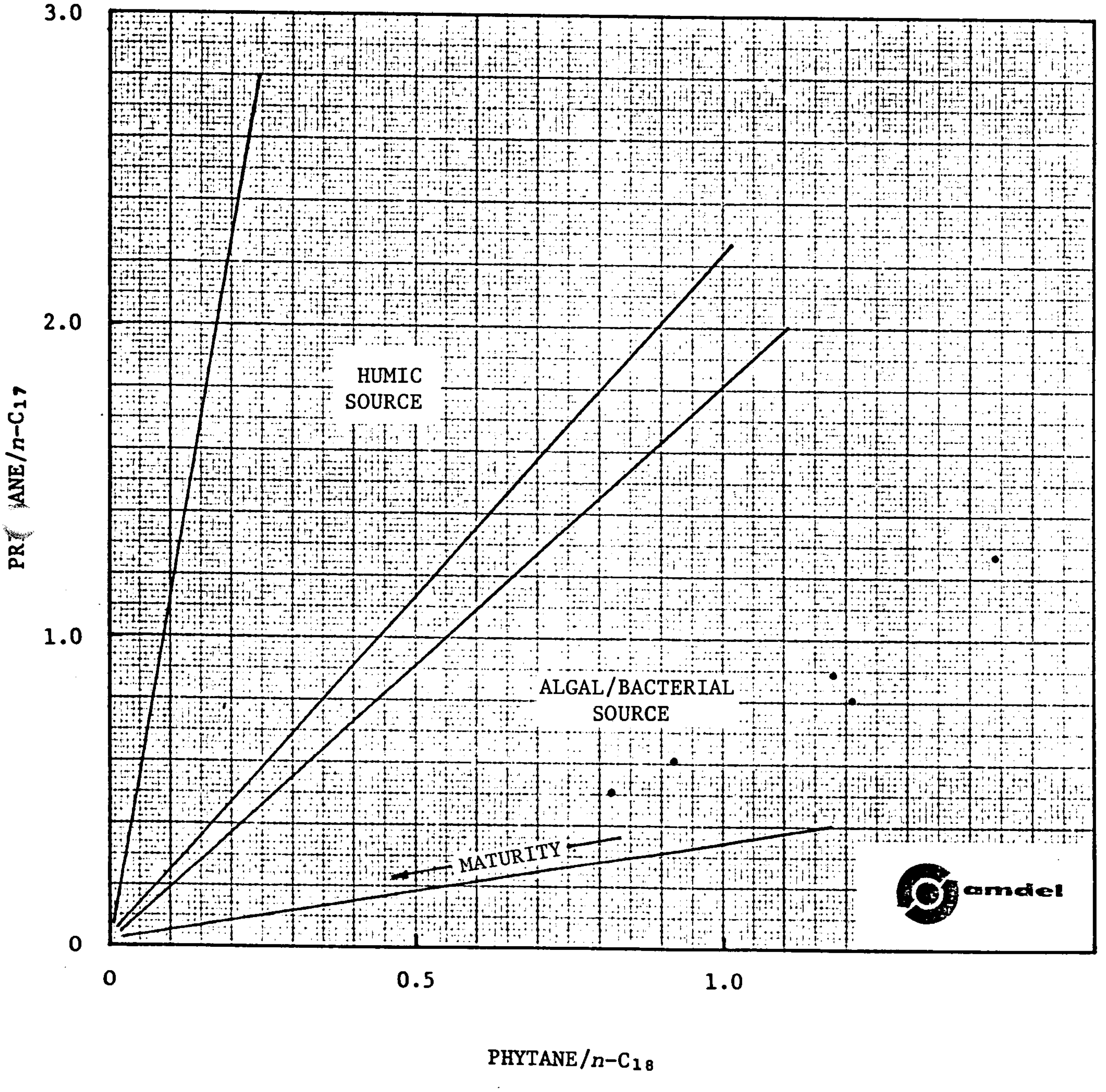


[modified after Powell, 1978]

amdel

FIGURE 14

SOURCE AND MATURITY OF ROCK
EXTRACTS, OBSERVATORY HILL BEDS
BYILKAOORA - 2



[based on Connan and Cassou, 1980, fig.12]

APPENDIX 1

DESCRIPTION OF DISPERSED ORGANIC MATTER
OBSERVATORY HILL BEDS, BYILKAOORA-2

Sample No.1: 688.47 metres

This core comprises argillaceous carbonate containing rare dispersed organic matter. The types of dispersed organic matter present are lamalginite (moderate yellow to moderate orange and dull orange fluorescence), bitumen (moderate to dull orange fluorescence), liptodetrinite (moderate to dull orange fluorescence), ?oil (bright yellow-green to bright yellow fluorescence) and ?phytoplankton (bright yellow fluorescence). Lamalginite is rare and slightly more abundant than bitumen. Liptodetrinite, ?oil and ?phytoplankton occur in trace amounts. The ?oil is generally closely associated with the bitumen in this sample.

The overall volume of organic matter in this core is estimated to be less than 0.5%.

Sample No.2: 703.30 metres

This core consists chiefly of carbonate (calcite pseudomorphs of trona). Argillaceous silty carbonate occupies approximately 20-30% of the total sample. Organic matter is generally absent from the calcite but abundant in the argillaceous part of the core where it is intimately associated with fine-grained pyrite.

The types of organic matter present in the argillaceous carbonate are lamalginite (moderate to dull orange fluorescence), exsudatinite-like material (bright yellow-green to bright yellow fluorescence), liptodetrinite (moderate to dull orange fluorescence) and ?oil (bright yellow-green to bright yellow fluorescence). Lamalginite is common and exsudatinite-like material is very rare. Liptodetrinite and ?oil occur in very rare to trace amounts.

The overall volume of organic matter in this core is estimated to be approximately 1%.

Sample No.3: 720.10 metres

This sample consists chiefly of argillaceous carbonate which contains rare to sparse dispersed organic matter. Calcite pseudomorphs of shortite occupy approximately 30-40% of the core and generally contain no dispersed organic matter.

The types of organic matter present in the argillaceous portion of the core are lamalginite (moderate to dull orange fluorescence), exsudatinite-like material (bright yellow-green fluorescence), bitumen (moderate to dull orange fluorescence), ?oil (bright yellow-green to green fluorescence) and liptodetrinite (moderate to dull orange fluorescence). Lamalginite is sparse in this core and exsudatinite-like material is very rare. Bitumen, ?oil and liptodetrinite occur in trace amounts. Bitumen is generally interstitial to carbonate crystals. ?Oil occurs mostly as coatings on carbonate grains in the argillaceous matrix. Exsudatinite occurs as fillings in microfractures in the argillaceous carbonate.

The overall volume of organic matter in this core is estimated to be less than 1%.

Sample No.4: 720.35 metres

This core is similar to that of Sample 3. It consists chiefly of argillaceous carbonate which contains common to abundant dispersed organic matter. Discrete euhedral carbonate (calcite pseudomorphs of shortite) occupies approximately 20-30% of this core and generally contains no dispersed organic matter. However, some of this calcite is host to rare oil and bitumen.

The types of organic matter present in this core in order of abundance are lamalginite (moderate to dull orange fluorescence), exsudatinite-like material (bright yellow-green to bright yellow fluorescence), ?oil (bright yellow-green to bright green fluorescence), liptodetrinite (moderate yellow to moderate orange and dull orange fluorescence) and bitumen (moderate orange to dull orange and dull brown fluorescence). Lamalginite is common and occurs only in the argillaceous part of the rock. Exsudatinite-like material is rare to sparse and also occurs only in the argillaceous matrix. ?Oil is rare and slightly more abundant than liptodetrinite. Bitumen is present in trace amounts. ?Oil generally occurs as coatings on carbonate crystals.

The overall volume of organic matter in this core is estimated to be approximately 1%.

Sample No.5: 727.40 metres

This core comprises chiefly argillaceous mudstone with common to abundant dispersed organic matter. Carbonate (as calcite pseudomorphs of trona) occupies approximately 30-40% of the core. Organic matter is generally absent from this carbonate although rare oil and bitumen were noted in some core fragments.

The types of organic matter present in this core in order of abundance are lamalginite (moderate to dull orange fluorescence), exsudatinite-like material (bright yellow-green to bright yellow fluorescence), oil (bright yellow-green fluorescence) and bitumen (moderate to dull orange fluorescence). Lamalginite is common in this core and exsudatinite-like material is rare. Bitumen is very rare and slightly less abundant than oil. Bitumen commonly occurs as stringers in this sample, in contrast to the previous samples where it is present as bitumen balls.

The overall volume of organic matter in this sample is estimated to be approximately 1%.

Sample No.6: 728.05 metres

This core consists chiefly of argillaceous carbonate which contains common to abundant dispersed organic matter. Calcite (replacing trona) forms approximately 20-30% of the core. Organic matter is generally absent from this carbonate, although some carbonate core fragments contain rare oil.

The types of organic matter present in this core in order of abundance are lamalginite (moderate orange fluorescence), exsudatinite-like material (bright yellow-green fluorescence) and ?oil (bright yellow-green to bright yellow fluorescence). Lamalginite is common in this core whereas exsudatinite and ?oil occur in very rare to trace amounts.

The overall volume of organic matter in this core is estimated to be approximately 1%.

Sample No.7: 738.00 metres

This core consists chiefly of carbonate (calcite replacements of shortite). This carbonate contains rare bitumen, although some individual carbonate grains are devoid of all organic matter. Argillaceous carbonate occupies approximately 20-30% of the sample and contains sparse to common dispersed organic matter.

The types of organic matter present in this core are lamalginite (moderate to dull orange fluorescence), bitumen (moderate to dull orange fluorescence) exsudatinite-like material (bright yellow-green to bright yellow fluorescence) and oil (bright yellow fluorescence). Lamalginite is sparse to common and bitumen is rare. Exsudatinite-like material is very rare and oil occurs only in trace amounts. The fluorescence emissions of lamalginite in this core are slightly duller than those of the same maceral in the previously described samples. This implies that the present core is slightly more mature. Conversely, the bitumen in this sample has a slightly brighter fluorescence than do the bitumens in the previous samples. A different (? more recent) origin for the bitumen in this sample is implied.

The overall volume of organic matter in this core is estimated to be less than 1%.

<u>KEY</u>

Abundant	>2%
Common	1-2%
Sparse	0.5-1%
Rare	0.1-0.5%

DISCUSSION

Maturity

The lamalginite in these samples generally has a moderate to dull orange fluorescence indicating an equivalent mean maximum vitrinite reflectance in the range of 0.75 to 0.85%. However, in the core sample from 738.0 metres this lamalginite has a slightly duller orange fluorescence suggestive of a somewhat higher rank ($\overline{R}v$ max = 0.8-0.9%). This inferred maturity is within the main generation range for lamalginite (Cook 1982).

Organic Matter

The majority of the dispersed organic matter in these sediments is lamalginite. This lamalginite has a pale brown to brown colour in white light. In UV-blue light, the lamalginite has a moderate to dull orange fluorescence. This fluorescence becomes noticeably duller with increasing depth in the sequence. The lamalginite content of the samples examined ranges from less than 0.5 to approximately 1% by volume. Lamalginite occurs preferentially in argillaceous bands and layers within the core and is very rarely found in the coarser-grained carbonate portion of the rock.

Bitumen is present mostly as 'bitumen balls'. These balls are spherical aggregates of bitumen which are similar to thucholite but show no evidence of a uraniferous core. They have a reflectance ranging from 0.4% (rim) to 0.9% (core). The core of a typical bitumen ball has a dull orange fluorescence in UV-blue light, whereas the rim fluoresces a moderate orange colour. In some cases, lamalginite fluorescence is slightly enhanced immediately adjacent to these balls. 'Free oil' is seen to be associated with some bitumen balls. Bitumens occurring as stringers and vug infillings are much less common. These bitumens have a more uniform fluorescence and reflectance (generally in the range 0.5%-0.7%).

Exsudatinite-like material occurs only in the argillaceous mudstone and generally has a bright yellow-green to bright yellow fluorescence. This material occurs as infillings in microfractures running both perpendicular and parallel to bedding. This exsudatinite-like material is thought to be a primary expulsion product of the oil-prone lamalginite.

Liptodetrinite is found in most samples and generally has a moderate to dull orange fluorescence. The thin-walled nature of this material, and the intensity and colour of its fluorescence in UV light, suggest that this liptodetrinite may in fact be fragmented lamalginite.

PLATES

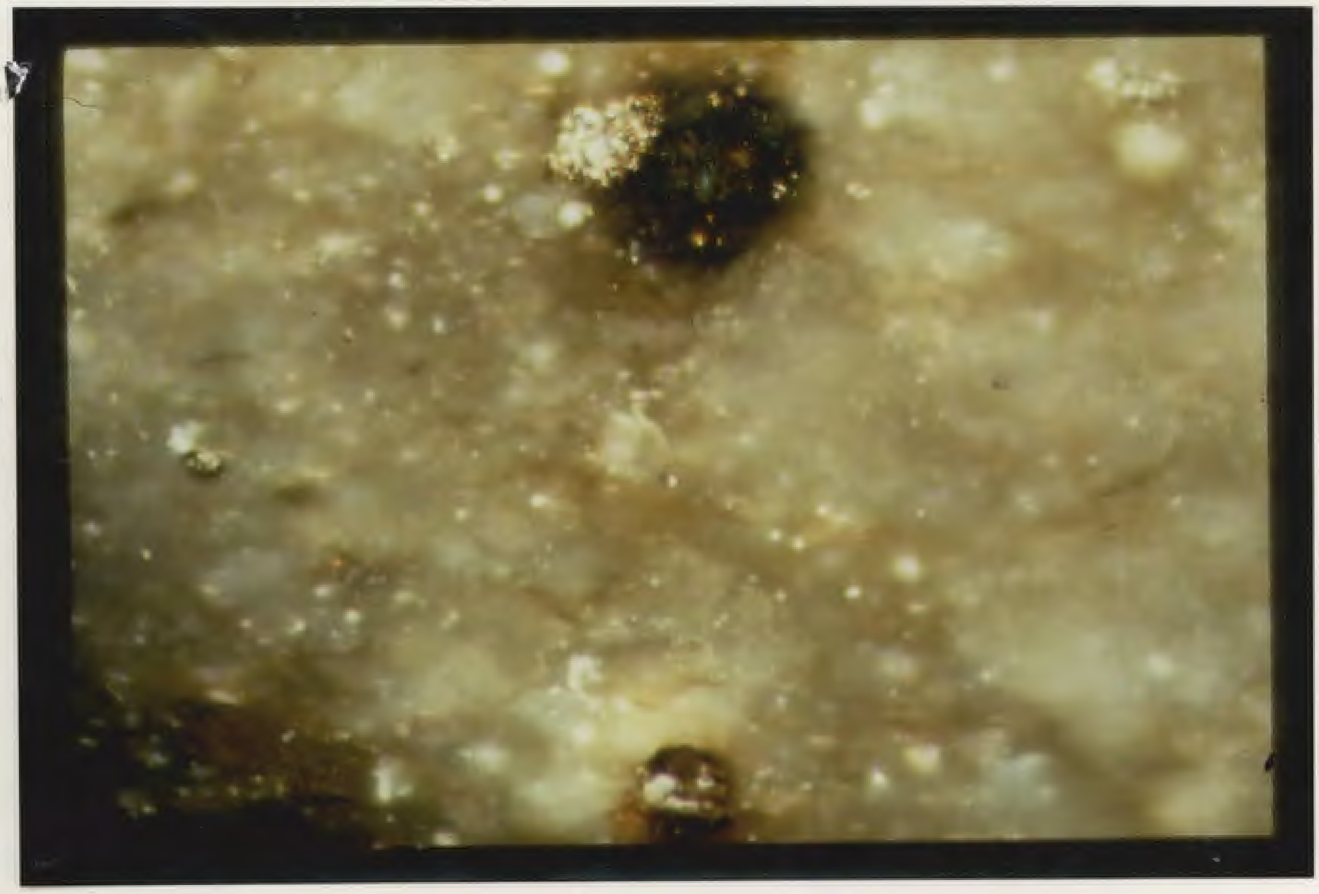


PLATE 1: 688.47 m BYILKAOORA-2 Reflected Light

Bitumen balls (centre top and bottom) associated with pyrite (white) in a silty carbonate.

Field Dimensions 0.26 mm x 0.18 mm

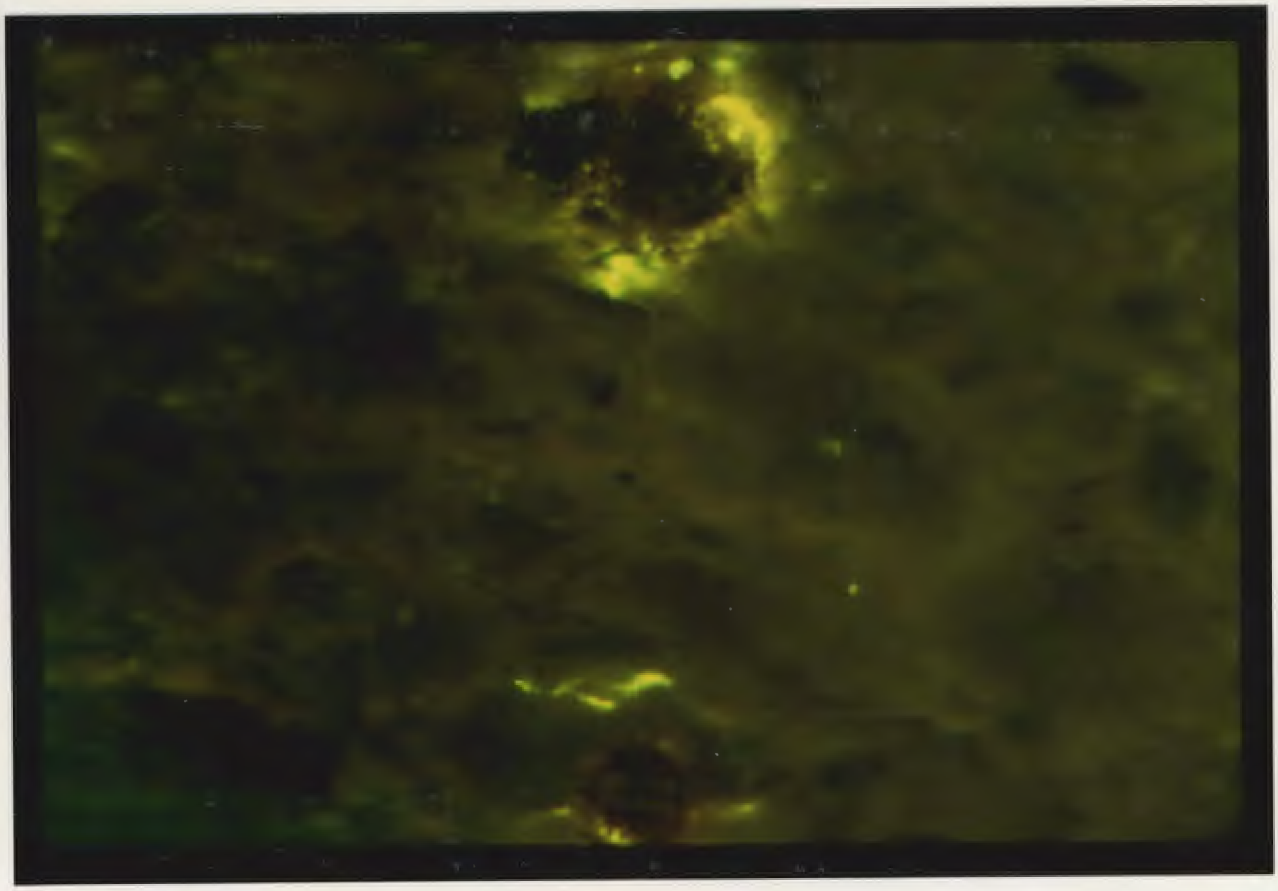


PLATE 2: 688.47 m BYILKAOORA-2 Fluorescence Mode

The same field as Plate 1 illustrating the bright yellow to bright yellow-green fluorescence of ?oil associated with the bitumen balls.

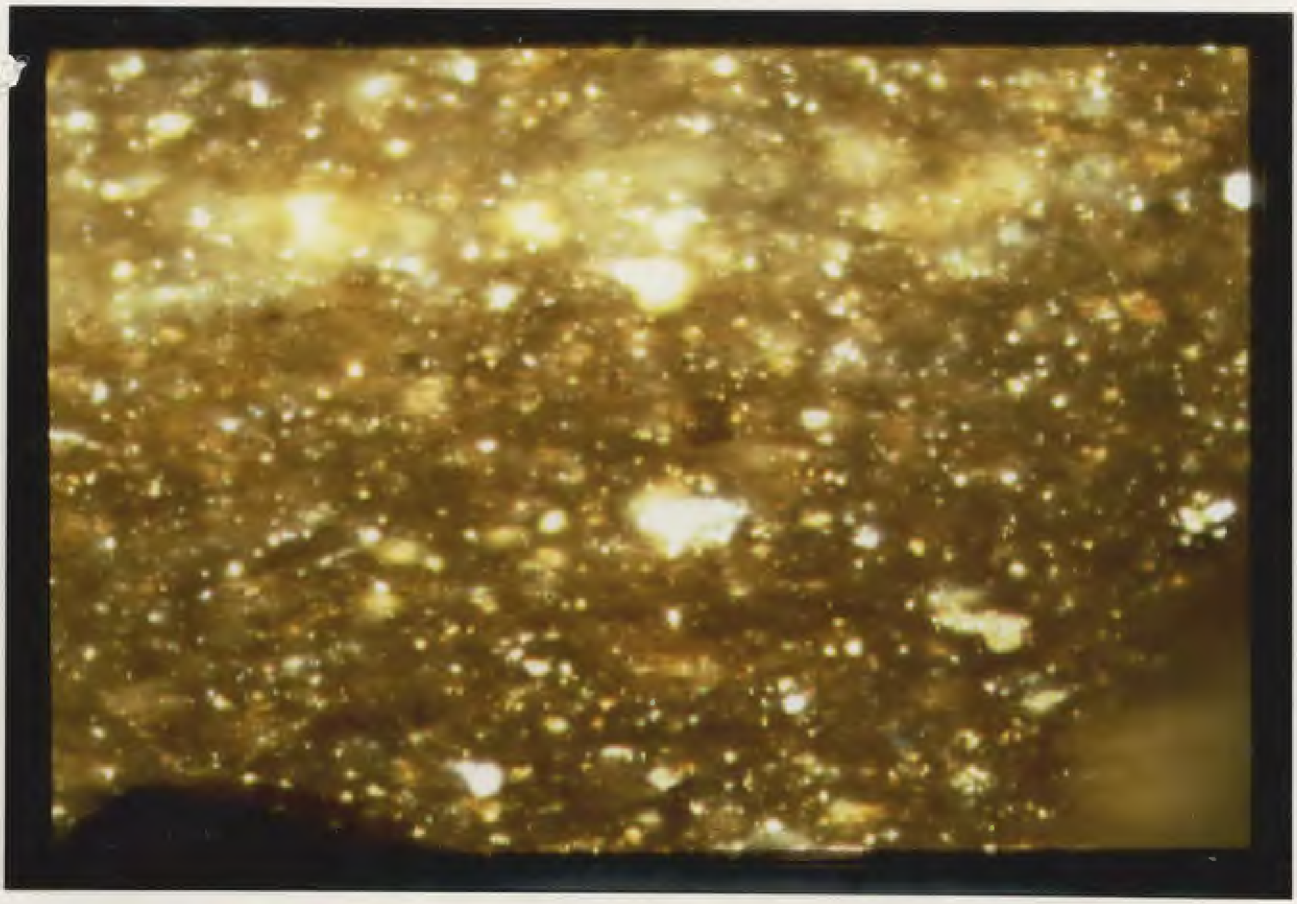


PLATE 3: 703.30 m BYILKAOORA-2 Reflected Light

Argillaceous silty carbonate rich in lamalginite and liptodetrinite (translucent, brown) with associated fine-grained sulphide, probably pyrite (white).

Field Dimensions 0.26 mm x 0.18 mm

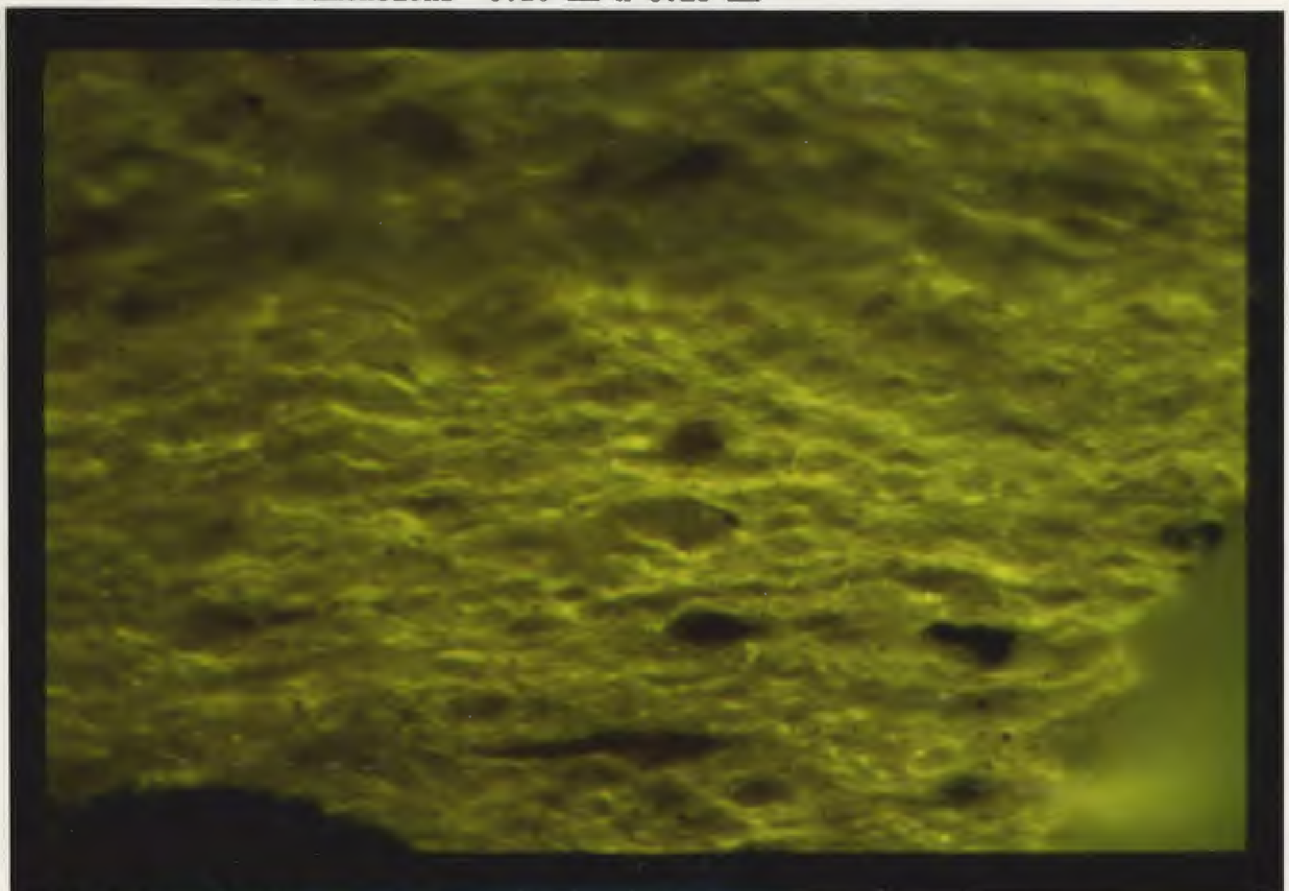


PLATE 4: 703.30 m BYILKAOORA-2 Fluorescence Mode

The same field as Plate 3 showing more clearly the morphology and distribution of the lamalginite and liptodetrinite (moderate to dull yellow-orange).

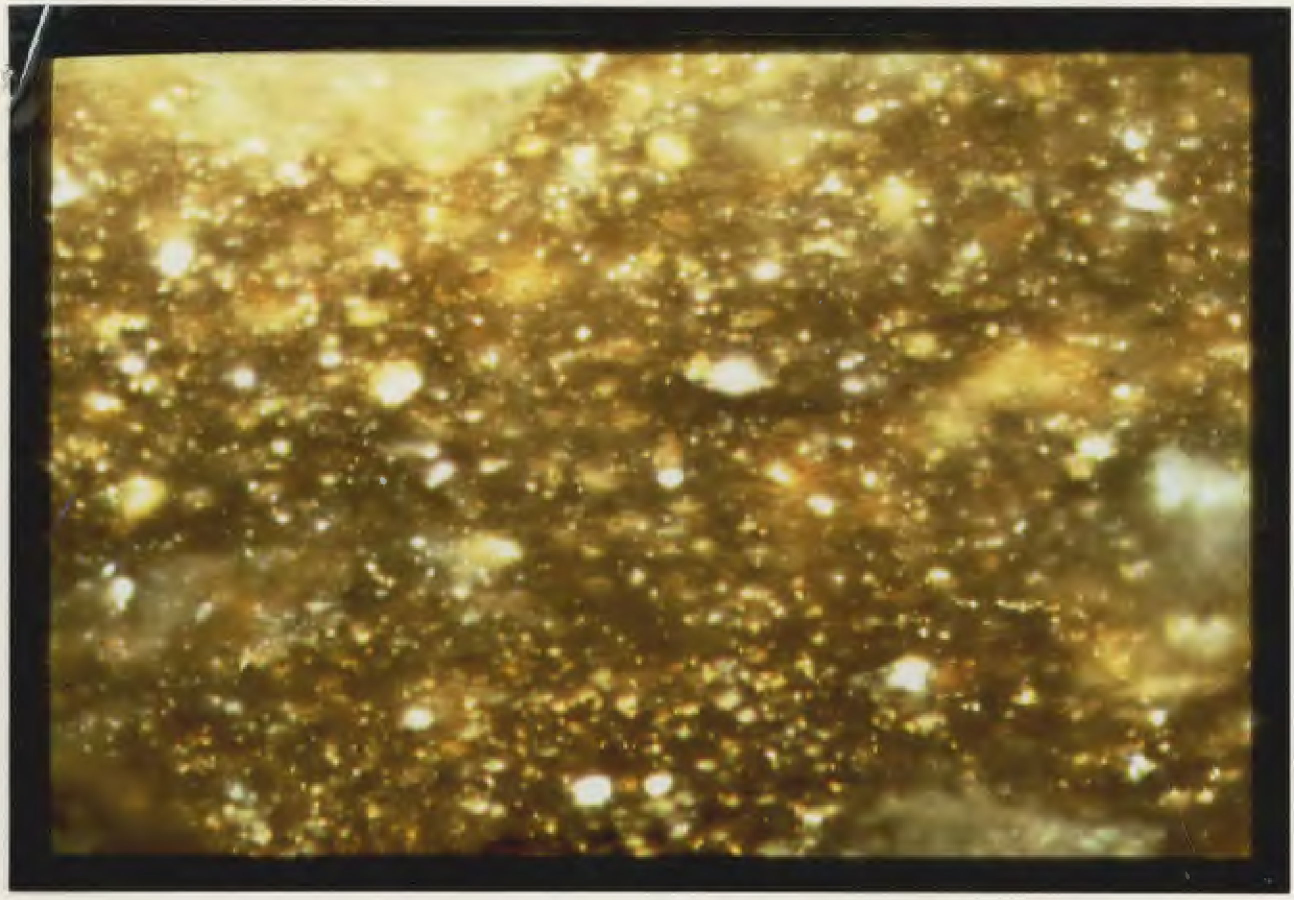


PLATE 5: 703.30 m BYILKAOORA-2 Reflected Light

A similar field of view to that of Plate 3 illustrating pyritic argillaceous sediment containing lamalginite and liptodetrinite (translucent, brown).

Field Dimensions 0.26 mm x 0.18 mm

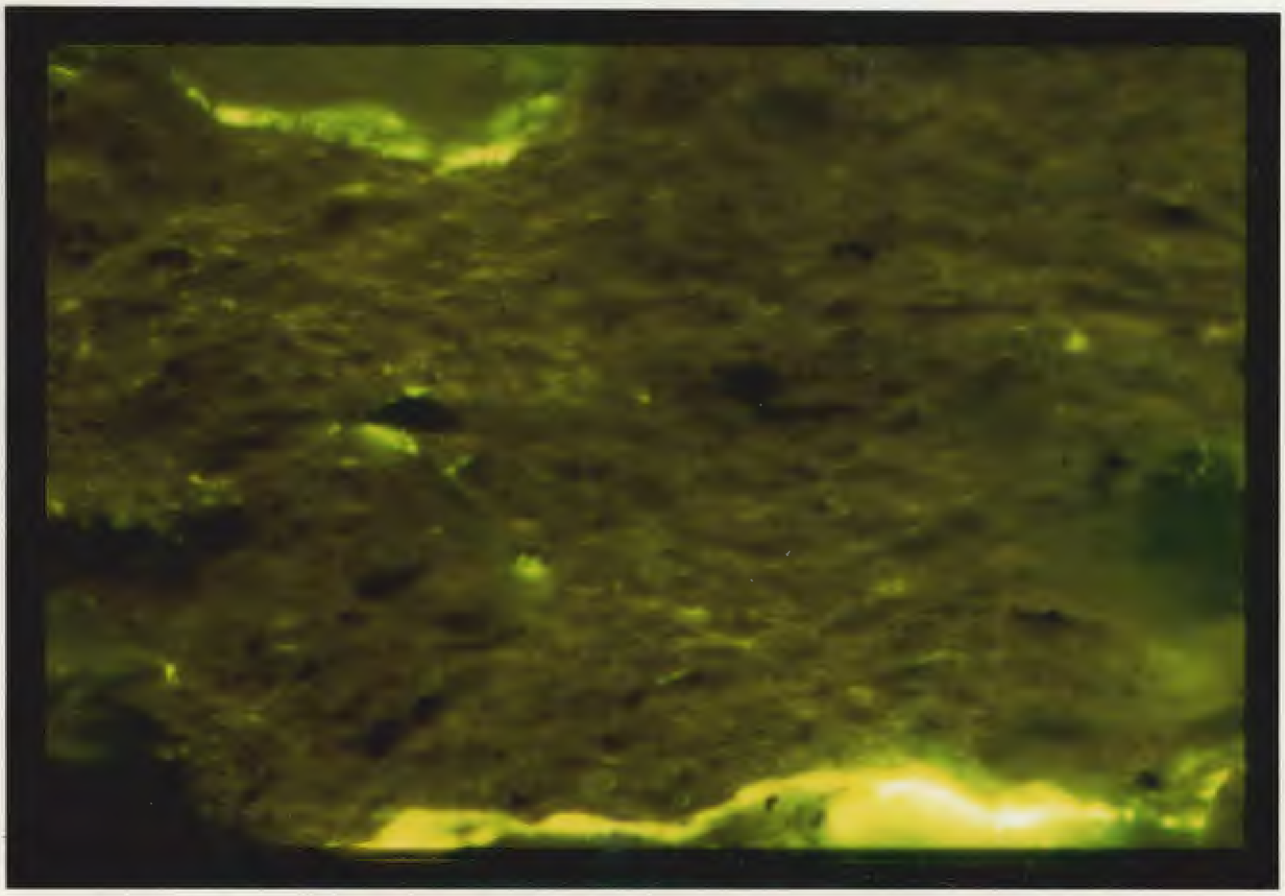


PLATE 6: 703.30 m BYILKAOORA-2 Fluorescence Mode

Same field as Plate 5. The intense yellow and green fluorescing exsudatinite-like material contrasts with the moderate orange fluorescing lamalginite.

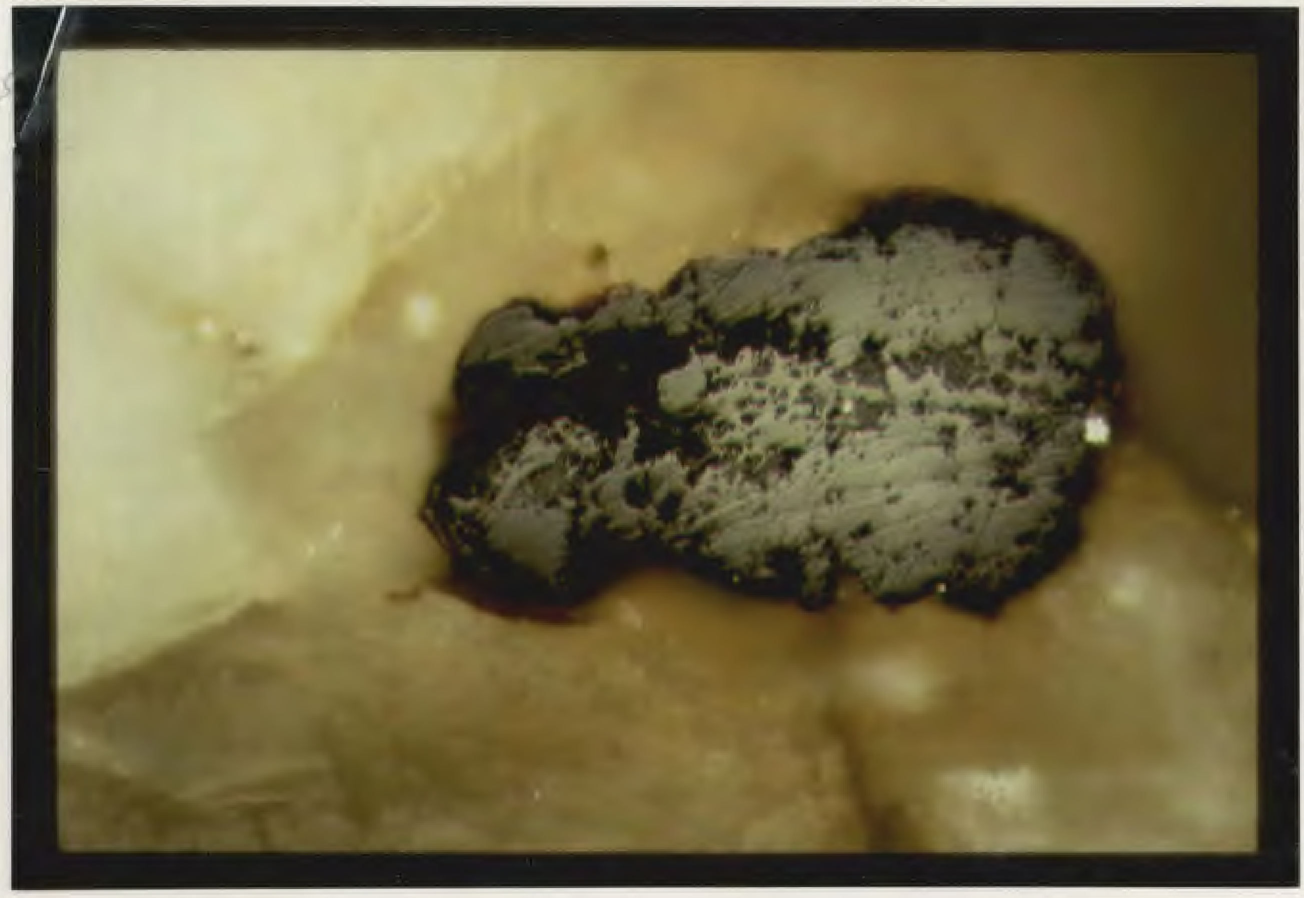


PLATE 7: 720.10 m BYILKAOORA-2 Reflected Light

The bitumen in this carbonate core fragment has a zoned appearance in reflected light suggestive of gradual devolatilisation.

Field Dimensions 0.26 mm x 0.18 mm

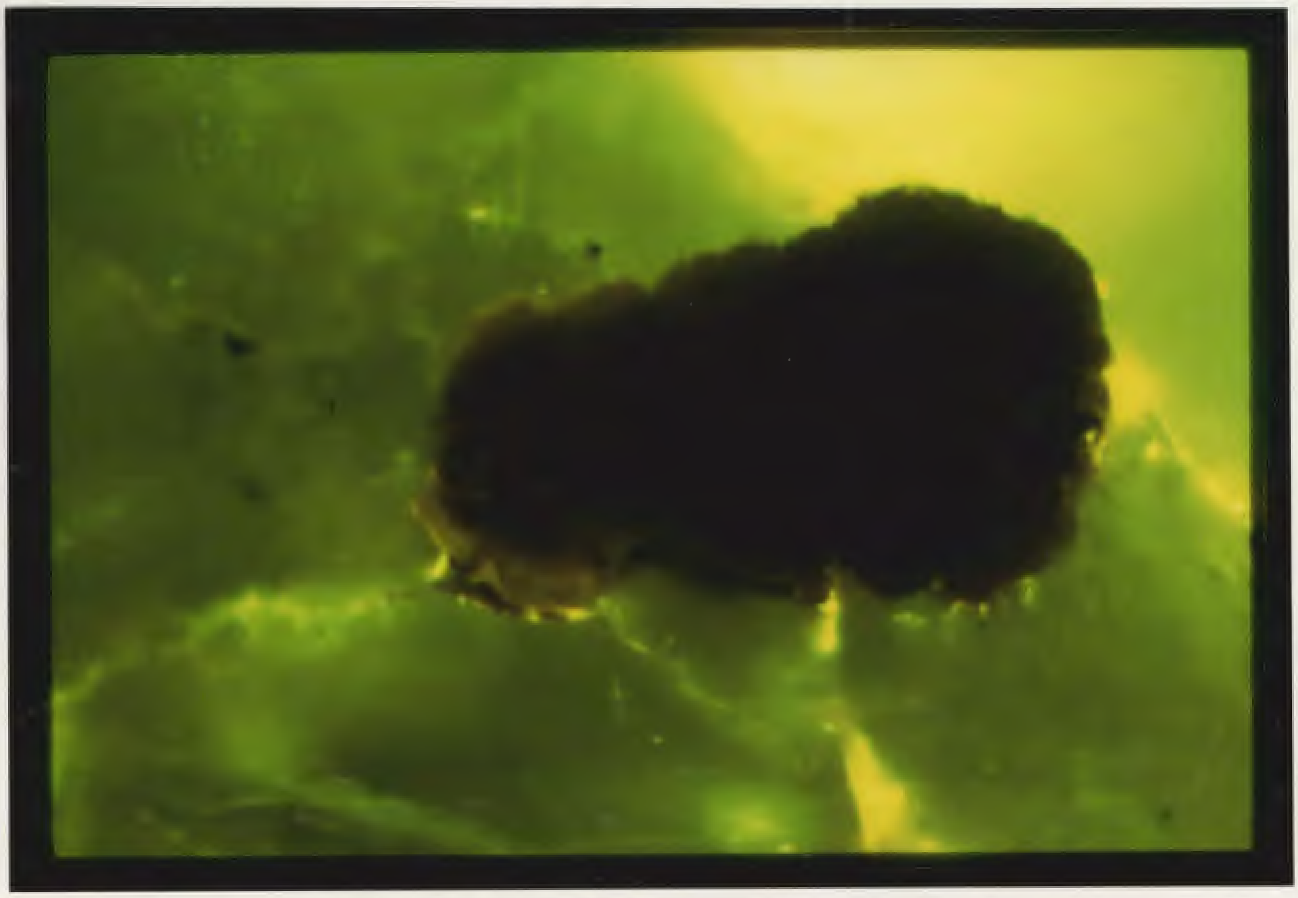


PLATE 8: 720.10 m BYILKAOORA-2 Fluorescence Mode

Same field as Plate 7 showing the moderate orange fluorescence of the outer rim of the bitumen.

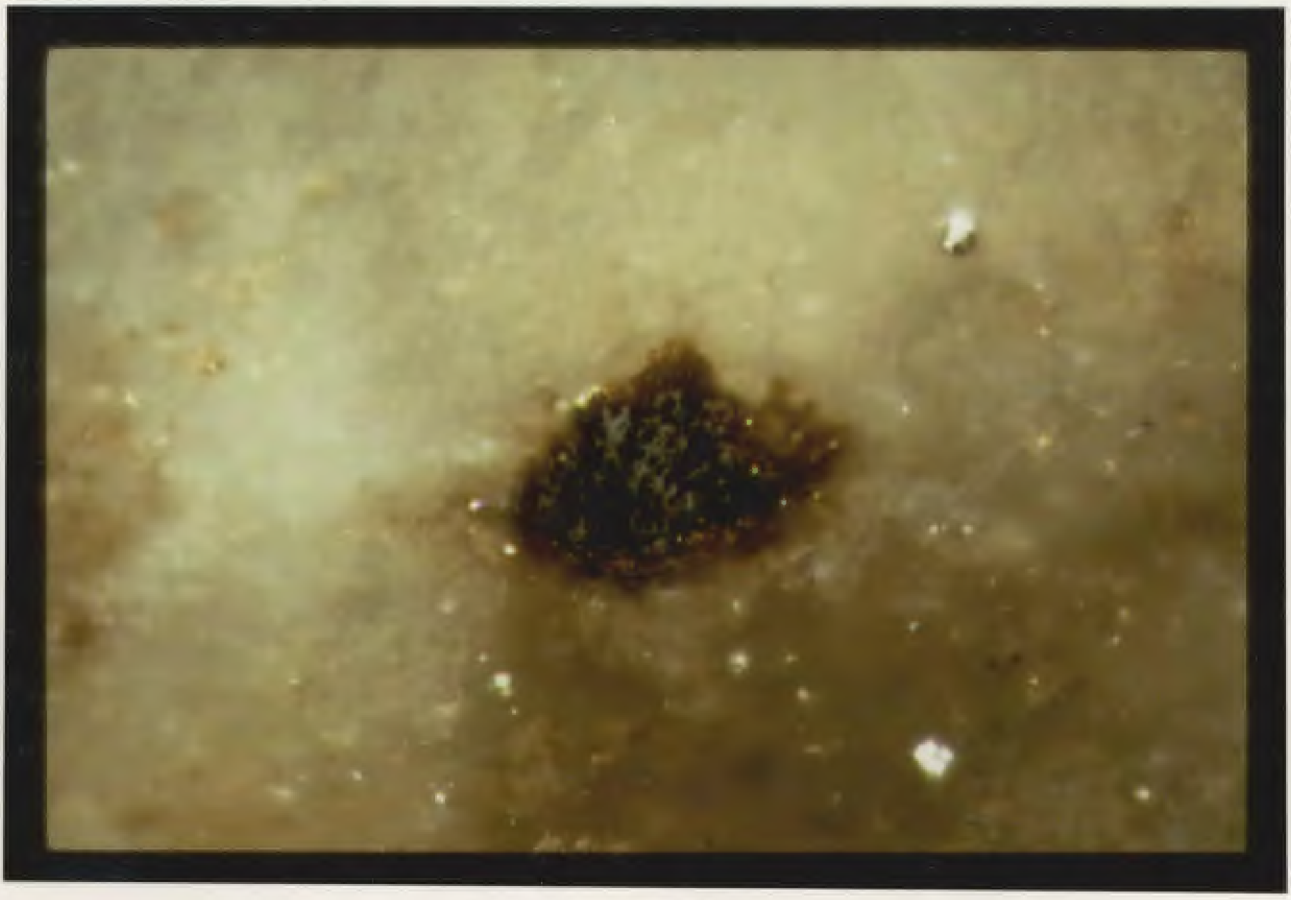


PLATE 9: 738.00 m BYILKAOORA-2 Reflected Light

Bitumen in this carbonate has a markedly lower reflectance than that shown in Plate 7.

Field Dimensions 0.26 mm x 0.18 mm

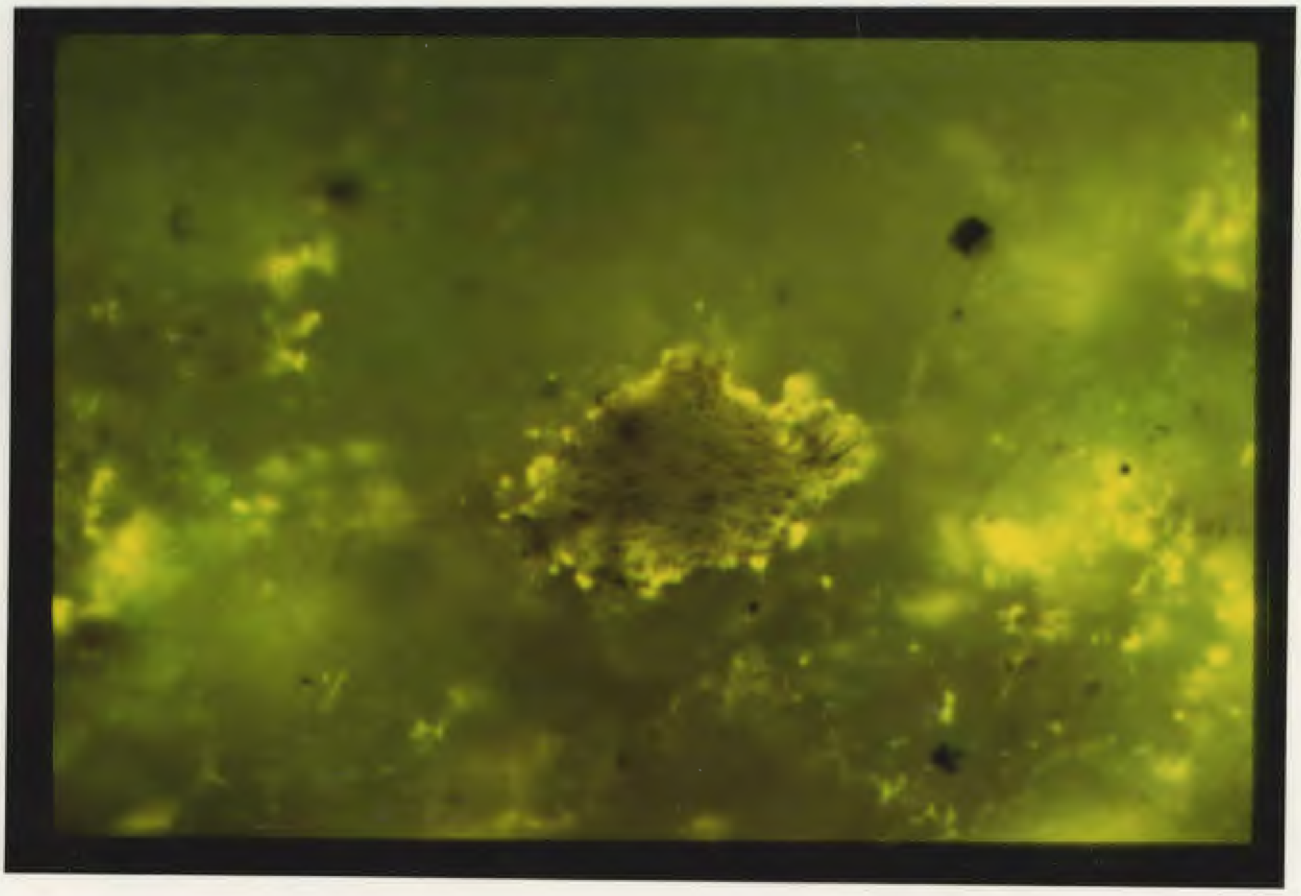


PLATE 10: 738.00 m BYILKAOORA-2 Fluorescence Mode

Same field as Plate 9 illustrating the more intense fluorescence of this bitumen ball (cf. Plate 8).