SOURCE ROCK AND OIL ANALYSES OF FIVE CORE SAMPLES FROM THE GEORGINA BASIN, NORTHERN TERRITORY

Northern Territory Department
of Mines & Energy

F4/880/0-6223/85 January 1986

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24 January 1986

F 4/880/0
F 6223/85 - Part 2 (Final)

Northern Territory Department of
Mines and Energy
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Attention: P. Stidolph

REPORT F 6223/85 - Part 2 (Final)

YOUR REFERENCE: Order no. 7713-9

TITLE: Source rock and oil analyses of five core samples from the Georgina Basin, Northern Territory

MATERIAL: Core (4 samples). Oil-stained core (1 sample)

LOCALITIES: ELK-2, 3, 7A

IDENTIFICATION: As in Table 1 of report

DATE RECEIVED: 17 May 1985

WORK REQUIRED: Rock-Eval pyrolysis (R3/2). Solvent extraction (R3/6). Liquid chromatography (R3/7). GC of saturates (R3/8). Gasoline-range hydrocarbons (R3/10). Urea adduction (R3/9). GC-MS of naphthenes (R3/12). Organic petrology (R3/16).

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1. INTRODUCTION

This final report contains the results of analytical work undertaken on a suite of core samples from three stratigraphic drill holes in the western Georgina Basin, N.T. (Table 1).

Rock-Eval pyrolysis data were forwarded to the client in an interim report on 13 June 1985.

2. RESULTS

Analytical data are summarised and presented herein as follows:

	Table	Figure	Appendix
Source Rock Analysis			
TOC, Rock-Eval pyrolysis	2	1	–
Extractable organic matter	3-6	–	–
C_{15+} saturated hydrocarbons	3-6	2-9	–
Organic petrology			
- reflectance data	7	–	1
- dispersed organic matter	8-10	–	2
Comparative maturity data	11	–	–
Oil Analysis			
Gasoline-range (C_5-C_7) hydrocarbons	12	10	–
C_{12+} bulk composition	13	11	–
C_{12+} saturated hydrocarbons	13	12,13	–
GC-MS of naphthenes	14	14-16	3

3. CONCLUSIONS

1. Organic-rich carbonates (0.7-2.9% TOC; S_1+S_2 = 3-12 kg hydrocarbons/tonne) of the Arthur Creek Formation from ELK-2 and ELK-7A contain good quality oil-prone Type II kerogen which is mature for oil generation.

2. Carbonaceous siltstone (14.2% TOC; S_1+S = 13 kg hydrocarbons/tonne) from the same formation in ELK-3 is over-mature and hence gas-prone.

3. The major organic maceral (65-85% of DOM) in these Middle Cambrian sediments is vitrinite-like material of presumed algal/bacterial affinity (cf. McKirdy *et al.*, 1984; Jackson *et al.*, 1984).

4. Oil staining dolomite of the Middle Cambrian Chabalowe Formation at ELK-7A (208.96-209.84 metres) is a mature aromatic crude of marine algal/bacterial origin. Its bulk composition, source affinity and thermal maturity are similar to those of the ELK-6 (Chabalowe) oil analysed previously (McKirdy and O'Leary, 1985). However, the ELK-7A crude has a higher pristane/phytane ratio (pr/ph = 1.8), lower hopane/sterane ratio (C_{30} hop/C_{29} ster = 1.1), and a more marked predominance of odd-carbon-numbered n-alkanes in the C_{12}-C_{20} range.

5. On the basis of the limited available source rock data, both oils can be tentatively correlated with source rocks in the Arthur Creek Formation. Their respective source beds were deposited in environments of slightly different oxicity (ELK-7A more oxic than ELK-6).

4. REFERENCES

JACKSON, K.S. McKIRDY, D.M. and DECKELMAN, J.A., 1984. Hydrocarbon generation in the Amadeus Basin, central Australia. *APEA J.* 24(1), 42-65.

McKIRDY, D.M. and O'LEARY, T., 1984. Analysis of a Cambrian oil show from ELK-6, Georgina Basin, Northern Territory. *AMDEL Report F6168/85 for Northern Territory Dept. of Mines and Energy* (unpubl.).

McKIRDY, D.M., WATSON, B.L. and MOONEY, B.A., 1984. Optical and pyrolytic characterisation of pre-Devonian oil-prone kerogens. *Geol. Soc. Aust. Abstracts* 12, 375.

TABLE 1: CORE SAMPLES SUBMITTED FOR ORGANIC GEOCHEMICAL ANALYSIS

	Drill Hole	Depth (metres)	Formation
Source rock analysis	ELK-2	487.90-488.50	Arthur Creek
	ELK-3	106.84-107.58	Arthur Creek
	ELK-7A	278.83-279.53	Arthur Creek
		298.50-299.53	Arthur Creek
Residual oil analysis	ELK-7A	208.96-209.94	Chabalowe

TABLE 2

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ROCK-EVAL PYROLYSIS

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DEPTH	T MAX	S1	S2	S3	S1+S2	PI	S2/S3	PC	TOC	HI	OI
ELK-2 487.90	435	0.27	3.25	0.24	3.52	0.08	13.54	0.29	0.68	477	35
ELK-3 106.84	463	1.52	11.33	1.77	12.85	0.12	6.40	1.07	14.20	79	12
ELK-7A 278.83	443	2.77	8.84	0.28	11.61	0.24	31.57	0.96	2.93	301	9
ELK-7A 298.50	445	1.25	5.75	0.57	7.00	0.18	10.08	0.58	1.59	361	35

KEY TO ROCK-EVAL PYROLYSIS DATA SHEET

	PARAMETER	SPECIFICITY
T max	position of S_2 peak in temperature program (^oC)	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 3

AMDEL

SOURCE ROCK ANALYSIS

WELL: ELK-2

SAMPLE: 487.90-488.50 M
TYPE OF SAMPLE: CORE

total organic carbon	.68 %
weight of sample extracted	52 g
weight of eom	40.6 mg
extracted organic matter	781 ppm
eom as fraction of toc	114.9 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	25.1
AROMATICS	15.8
RESINS	36.1
ASPHALTENES	23.0

N-ALKANE DISTRIBUTION IN SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	.0	17	6.8	22	5.3	27	3.9	32	3.5
13	.8	18	6.0	23	5.4	28	3.7	33	2.3
14	2.3	19	8.0	24	4.7	29	5.4	34	1.8
15	4.4	20	6.1	25	4.8	30	5.3	35	.8
16	4.3	21	5.8	26	4.0	31	4.6	36	.0

ISOPRENOID RATIOS

TMTD/pristane ratio	.31
norpristane/pristane ratio	.66
pristane/phytane ratio	1.40
pristane/C-17 ratio	.39
phytane/C-18 ratio	.32

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

C.P.I. = 1.07

TABLE 4

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SOURCE ROCK ANALYSIS

WELL: ELK-3

SAMPLE: 106.84-107.58 M
TYPE OF SAMPLE: CORE

total organic carbon	14.2 %
weight of sample extracted	60.22 g
weight of eom	134.9 mg
extracted organic matter	2240 ppm
eom as fraction of toc	15.8 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	11.9
AROMATICS	12.0
RESINS	61.4
ASPHALTENES	14.7

N-ALKANE DISTRIBUTION IN SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	3.0	17	10.4	22	1.7	27	.4	32	.0
13	11.6	18	6.8	23	1.3	28	.3	33	.0
14	18.5	19	4.6	24	1.0	29	.0	34	.0
15	19.5	20	3.2	25	.7	30	.0	35	.0
16	14.4	21	2.1	26	.5	31	.0	36	.0

ISOPRENOID RATIOS

TMTD/pristane ratio	2.57
norpristane/pristane ratio	2.35
pristane/phytane ratio	3.20
pristane/C-17 ratio	.14
phytane/C-18 ratio	.07

TABLE 5

AMDEL

SOURCE ROCK ANALYSIS

WELL: ELK-7A

SAMPLE: 278.83-279.53 M
TYPE OF SAMPLE: CORE

total organic carbon	2.93 %
weight of sample extracted	43.12 g
weight of eom	448.6 mg
extracted organic matter	10404 ppm
eom as fraction of toc	355.1 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	16.7
AROMATICS	26.9
RESINS	33.7
ASPHALTENES	22.6

N-ALKANE DISTRIBUTION IN SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	.6	17	13.7	22	2.1	27	1.1	32	.8
13	6.6	18	6.4	23	1.8	28	1.1	33	.8
14	13.3	19	6.1	24	1.4	29	1.2	34	.4
15	20.6	20	3.8	25	1.3	30	.9	35	.4
16	10.9	21	2.8	26	1.1	31	1.0	36	.0

ISOPRENOID RATIOS

TMTD/pristane ratio	1.30
norpristane/pristane ratio	1.77
pristane/phytane ratio	2.38
pristane/C-17 ratio	.15
phytane/C-18 ratio	.14

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

C.P.I. = 1.14

AMDEL

SOURCE ROCK ANALYSIS

WELL: ELK-7A

SAMPLE: 298.50-299.53 M
TYPE OF SAMPLE: CORE

total organic carbon	1.59 %
weight of sample extracted	57.32 g
weight of eom	467.5 mg
extracted organic matter	8156 ppm
eom as fraction of toc	513 mg/g

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

SATURATES	17.7
AROMATICS	36.4
RESINS	31.7
ASPHALTENES	14.2

N-ALKANE DISTRIBUTION IN SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	2.2	17	13.4	22	3.6	27	1.8	32	.0
13	8.3	18	8.2	23	2.2	28	1.7	33	.0
14	11.3	19	9.2	24	2.1	29	3.7	34	.0
15	4.6	20	5.7	25	2.2	30	2.0	35	.0
16	11.1	21	4.2	26	1.2	31	1.5	36	.0

ISOPRENOID RATIOS

TMTD/pristane ratio	1.08
norpristane/pristane ratio	.87
pristane/phytane ratio	2.04
pristane/C-17 ratio	.45
phytane/C-18 ratio	.36

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

C.P.I. = 1.58

TABLE 7: SUMMARY OF REFLECTANCE MEASUREMENTS ON VITRINITE-LIKE ORGANIC MATTER

Drillhole/ Depth (m)	Mean Maximum Reflectance (%)	Standard Deviation	Range (%)	Number of Determinations
ELK-2				
487.90	0.49	0.04	0.40-0.57	31
ELK-3				
106.84	1.44	0.17	1.01-1.72	32
ELK-7A				
278.83	0.82	0.07	0.67-1.00	29
298.50	0.76	0.08	0.57-0.91	34

TABLE 8: RELATIVE PROPORTIONS OF MACERALS IN DISPERSED ORGANIC MATTER

Drillhole/ Depth (m)		Percentage of		
		Vitrinite*	Inertinite	Exinite
ELK-2	487.90	65	20	15
ELK-3	106.84	85	10	5
ELK-7A	278.83	80	10	10
	298.50	80	10	5

*Vitrinite-like organic matter.

TABLE 9: ORGANIC MATTER TYPE AND ABUNDANCE

Drillhole/ Depth (m)	Relative Maceral Group Abundance	Estimated Volume of		Exinite Macerals
		DOM (%)	Exinites	
ELK-2				
487.90	V>I>E	1-2	Ra	bmite,lama,?thuc,?oil
ELK-3				
106.84	V>I>E	5-10	Ra-Vr	lipto,?phyto,oil
ELK-7A				
278.83	V>I>E	~1	Ra-Vr	oil
298.50	V>I>E	~1	Vr	oil,bmen

TABLE 10: EXINITE MACERAL ABUNDANCE AND FLUORESCENCE CHARACTERISTICS

Drillhole/Depth (m)		Exinite Macerals	Lithology/Comments
ELK-2	487.90	bmite(Ra;mO-dO),lama(Vr;mO),?thuc(Vr;mO-dO),?oil(Tr;iG)	carbonate; ?oil is generally associated with mineral grains rather than DOM and therefore may be migrated; ?thuc is associated with lamalginite.
ELK-3	106.84	lipto(Ra-Vr;mO),?phyto(Vr;mO),oil(Tr;iG)	siltstone; phytoplankton appears to be biodegraded; ?calcareous algae are closely associated with vitrinite-like material.
ELK-7A	278.83	oil(Ra-Vr;iG-iY)	carbonate; oil is generally associated with mineral grains.
ELK-7A	298.50	oil(Vr;iG-iY),bmen(Vr;mO-dO)	carbonate; oil and bmen as above.

KEY TO DISPERSED ORGANIC MATTER DESCRIPTIONS

MACERAL GROUPS

V	Vitrinite
I	Inertinite
E	Exinite

EXINITE MACERALS

spo	Sporinite
cut	Cutinite
res	Resinite
sub	Suberinite
lipto	Liptodetrinite
fluor	Fluorinite
exs	Exsudatinite
phyto	Phytoplankton
tela	Telalginite
lama	Lamalginite
bmite	Bituminite
bmen	Bitumen
thuc	Thucholite

ABUNDANCE (by vol.)

Ma	Major	>15%
Ab	Abundant	2-15%
Co	Common	1-2%
Sp	Sparse	0.5-1%
Ra	Rare	0.1-0.5%
Vr	Very Rare	∿0.1%
Tr	Trace	<0.1%

FLUORESCENCE COLOUR AND INTENSITY

G	Green	i	Intense
Y	Yellow	m	Moderate
O	Orange	d	Dull
B	Brown		

TABLE 11: COMPARATIVE MATURITY OF ELK-2, 3, 7A SOURCE ROCKS*

Drillhole/Depth (m)		VR %	Tmax °C	PI	H'c Yield		$Pr/n-C_{17}$	$Ph/n-C_{18}$
					mg/g TOC	% EOM		
ELK-2	487.90	0.49	435	0.08	47	40.9	0.39	0.32
ELK-7A	278.83**	0.82	443	0.24	155	43.6	0.15	0.14
	298.50**	0.76	445	0.18	278	54.1	0.45	0.36
ELK-3	106.84	1.44	463	0.12	4	23.9	0.14	0.07

*Samples listed in order of increasing maturity; VR refers to mean maximum reflectance of vitrinite-like organic matter.

**Stained with free oil (visible in DOM as major liptinite).

TABLE 12: COMPARATIVE GASOLINE-RANGE DATA ON OIL SHOWS FROM ELK-6 AND ELK-7A

Drillhole	Depth (m)	Formation	i-C_5/n-C_5	2MP/3MP
*ELK-6	736.48-736.82	Chabalowe	0.79	0.76
**ELK-7A	208.96-209.94	Chabalowe	0.16	4.2

*Data from McKirdy and O'Leary (1975).

**Chips of oil-stained core yielded insufficient light hydrocarbons for a complete C_5-C_7 analysis (see Fig. 10). Nonetheless, the low i-C_5/n-C_5 ratio of this oil precludes alteration by biodegradation.

i-C_5	=	isopentane
n-C_5	=	normal pentane
2MP	=	2-methylpentane
3MP	=	3-methylpentane

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RESIDUAL OIL ANALYSIS

WELL: ELK-7A

SAMPLE: 208.96-209.84 M

weight of sample extracted	500 g
weight of eom	13730.4 mg
extracted organic matter	27461 ppm

ANALYSIS OF EXTRACTED ORGANIC MATTER, (%)

N+ISO PARAFFINS	17.1
NAPHTHENES	25.0
AROMATICS	20.4
RESINS	37.2
ASPHALTENES	.3

N-ALKANE DISTRIBUTION OF SATURATES

C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%	C-NO.	%
12	6.0	17	12.1	22	2.4	27	1.0	32	.0
13	13.7	18	5.5	23	1.8	28	.9	33	.0
14	13.3	19	5.8	24	1.7	29	.0	34	.0
15	17.3	20	3.6	25	1.5	30	.0	35	.0
16	9.3	21	2.8	26	1.2	31	.0	36	.0

ISOPRENOID DISTRIBUTION IN SATURATES

TMTD/pristane ratio	1.67
norpristane/pristane ratio	1.89
pristane/phytane ratio	1.82
pristane/c-17 ratio	.14
phytane/c-18 ratio	.17

ODD EVEN PREDOMINANCE

O.E.P. C-17 = 1.61
O.E.P. C-19 = 1.37
O.E.P. C-25 = 1.03
O.E.P. C-27 = .91

TABLE 14: BIOMARKER PARAMETERS OF SOURCE, MATURITY, MIGRATION AND BIODEGRADATION IN OIL FROM THE CHABALOWE FORMATION, DDH ELK-7A, GEORGINA BASIN

ll	AMDEL Sample No.	Formation	Depth m	Steranes							Terpanes						Acyclic Alkanes			
Parameter*				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
-7A	MS-206	Chabalowe	208.96-209.84	38:21:41	0.91	0.95	1.1	0.94	1.7	0.31	0.13	0.67	0.51	[1.0]	0.17	-	1.8	1.7	0.14	0.17

e key (next page) for derivation and specificity

Measured from C_{33} homohopane

plementary source parameter : C_{30} hopane/C_{29} steranes = 1.1 (m/z 191, 217)

KEY TO BIOMARKER PARAMETERS OF SOURCE, MATURITY, MIGRATION AND BIODEGRADATION

Parameter	* Derivation	Specificity
1	C_{27} : C_{28} : C_{29} 5α(H)14α(H)17α(H) 20R steranes	Source
2	C_{29} 5α(H)14α(H)17α(H) 20R sterane / C_{27} 5α(H)14α(H)17α(H) 20R sterane	Source
3	C_{29} 13β(H)17α(H) 20R diasterane / C_{27} 13β(H)17α(H) 20R diasterane	Source
4	C_{29} 5α(H)14α(H)17α(H) 20S sterane / C_{29} 5α(H)14α(H)17α(H) 20R sterane	Maturity, Biodegradation
5	C_{27} 13β(H)17α(H) 20S diasterane / C_{27} 13β(H)17α(H) 20R diasterane	Maturity
6	C_{29} 5α(H)14β(H)17β(H) 20R sterane / C_{29} 5α(H)14α(H)17α(H) 20R sterane	Maturity, Migration
7	C_{29} 13β(H)17α(H) 20R+20S diasteranes / C_{29} 5α(H) steranes	Migration, Source
8	C_{31} tricyclic terpane / C_{30} 17α(H)21β(H) hopane	Source
9	C_{27} 17α(H)-22,29,30-trisnorhopane / C_{27} 18α(H)-22,29,30-trisnorhopane (T_m/T_s)	Maturity, Source
10	T_s / C_{30} 17α(H)21β(H) hopane	Maturity
11	C_{32} 17α(H)21β(H) 22S homohopane / C_{32} 17α(H)21β(H) 22R homohopane	Maturity
12	C_{30} 17β(H)21α(H) moretane / C_{30} 17α(H)21β(H) hopane	Maturity
13	C_{29} 17α(H)-25-norhopane / C_{29} 17α(H)-30-norhopane	Biodegradation
14	pristane / phytane	Source
15	2,6,10-trimethyltridecane / pristane	Maturity
16	pristane / _n_-heptadecane	Source, Biodegradation, Maturity
17	phytane / _n_-octadecane	Source, Biodegradation, Maturity

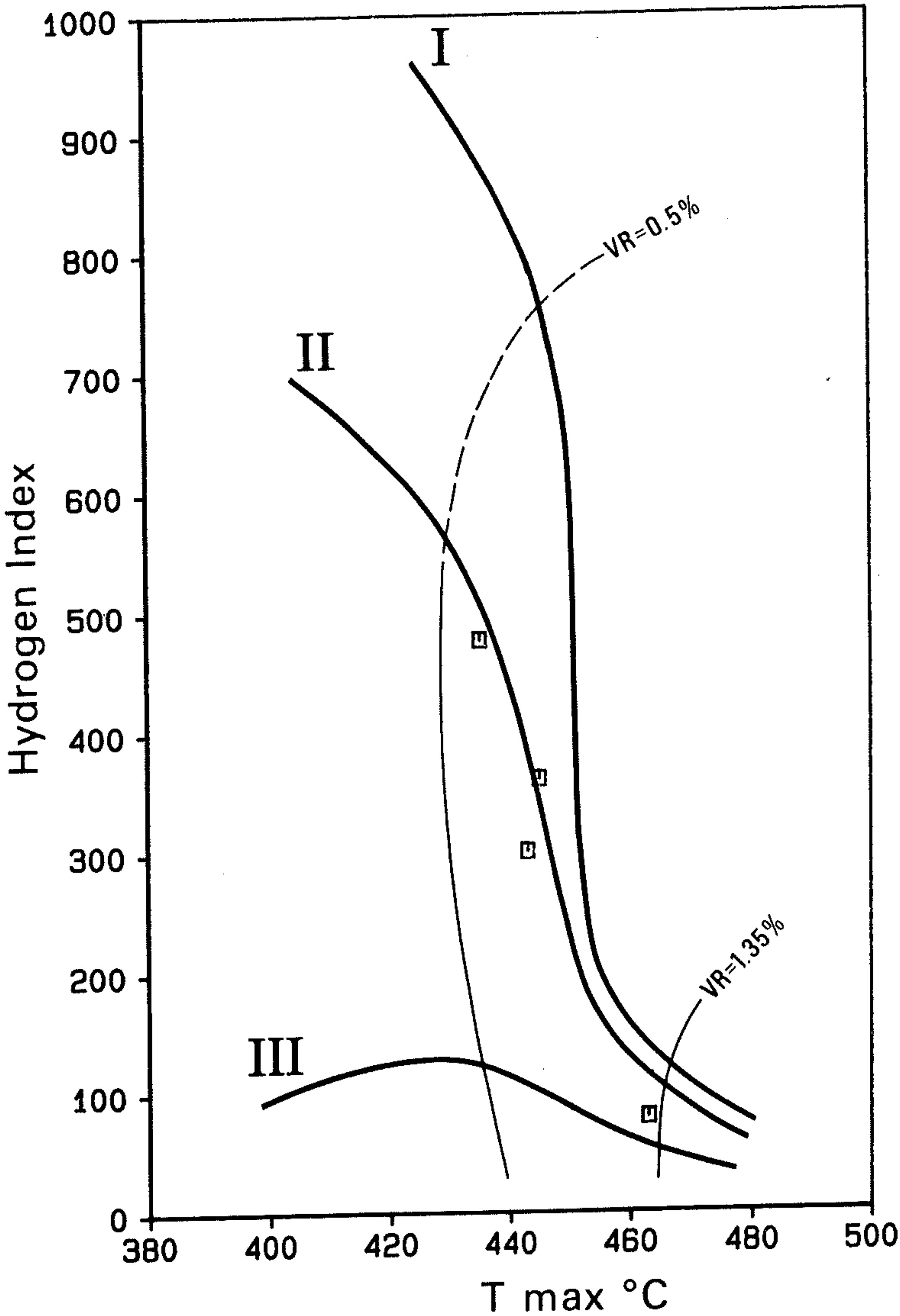
* Ratios calculated from peak areas as follows:

Parameters 1-6 m/z = 217 mass fragmentogram
Parameter 7 m/z = 217, 259 mass fragmentograms
Parameters 8-13 m/z = 191 mass fragmentogram
Parameters 14-17 capillary gas chromatogram of alkanes or whole oil/extract

FIGURE 1

Client : Northern Territory Department of Mines & Energy

Well name : ELK-2, 3, 7A



amdel

FIGURE 2

ELK-2, 487.90-488.50 m
SATURATES

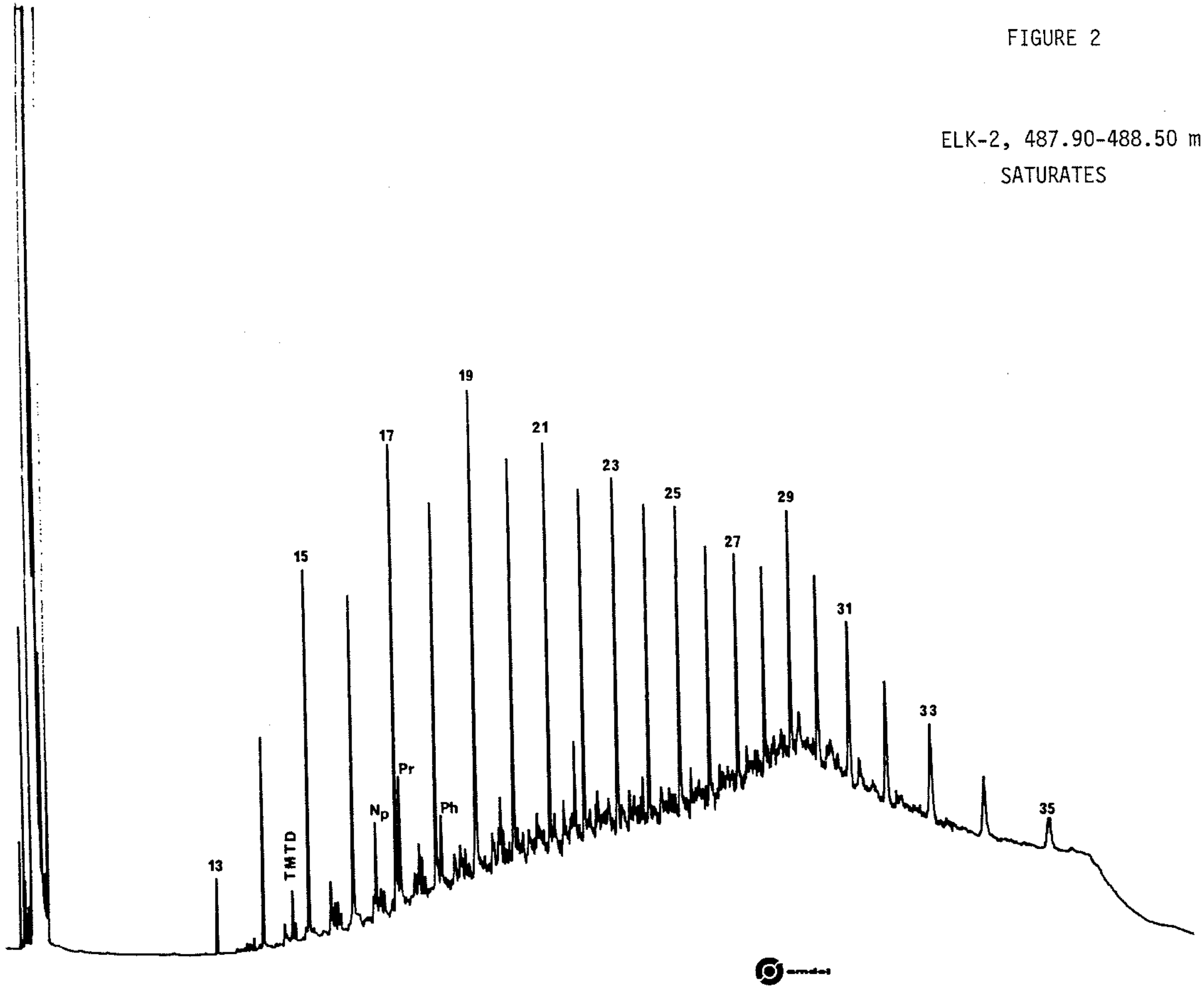


FIGURE 3

ELK-3, 106.84-107.58 m
SATURATES

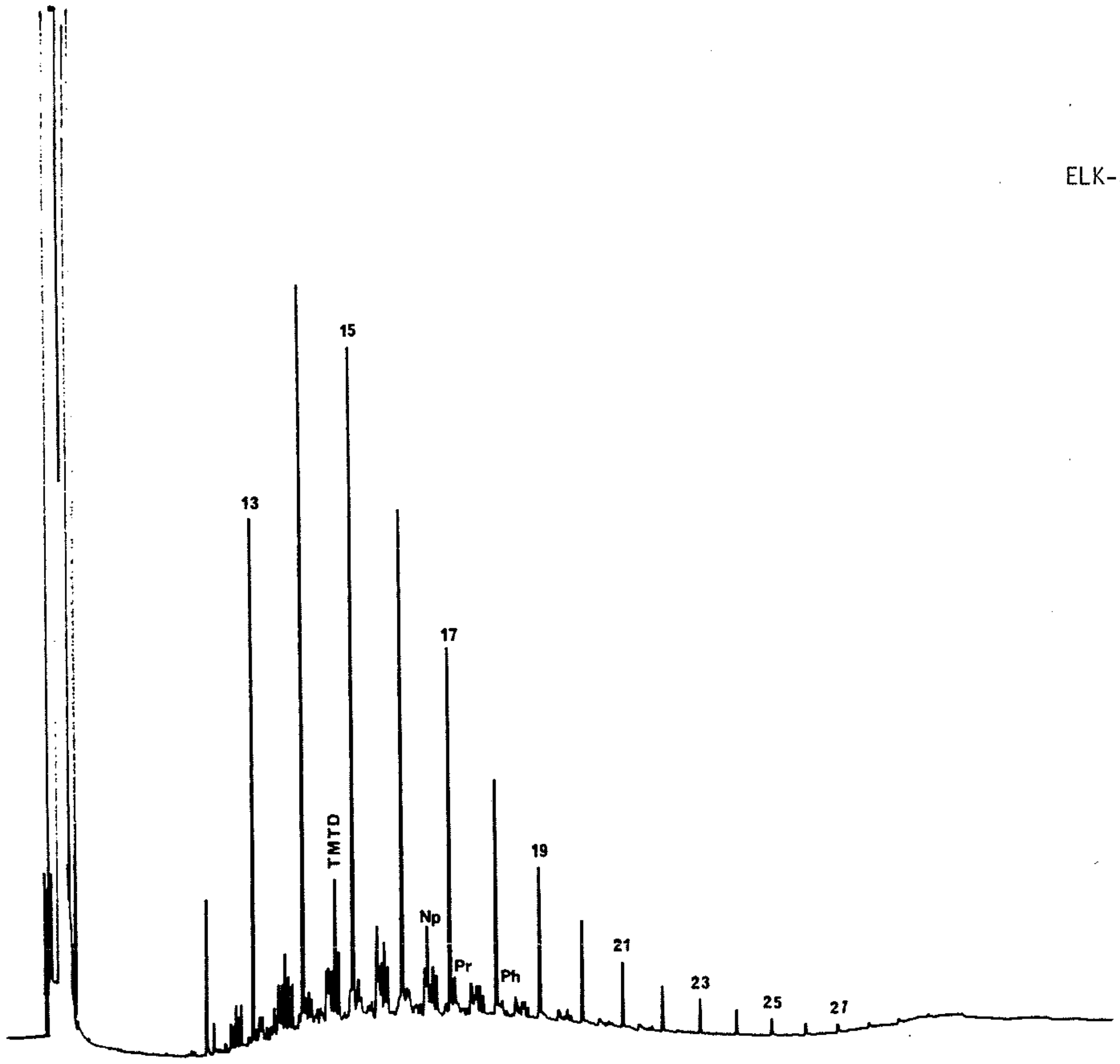


FIGURE 4

ELK-7A, 278.83-279.53 m
SATURATES

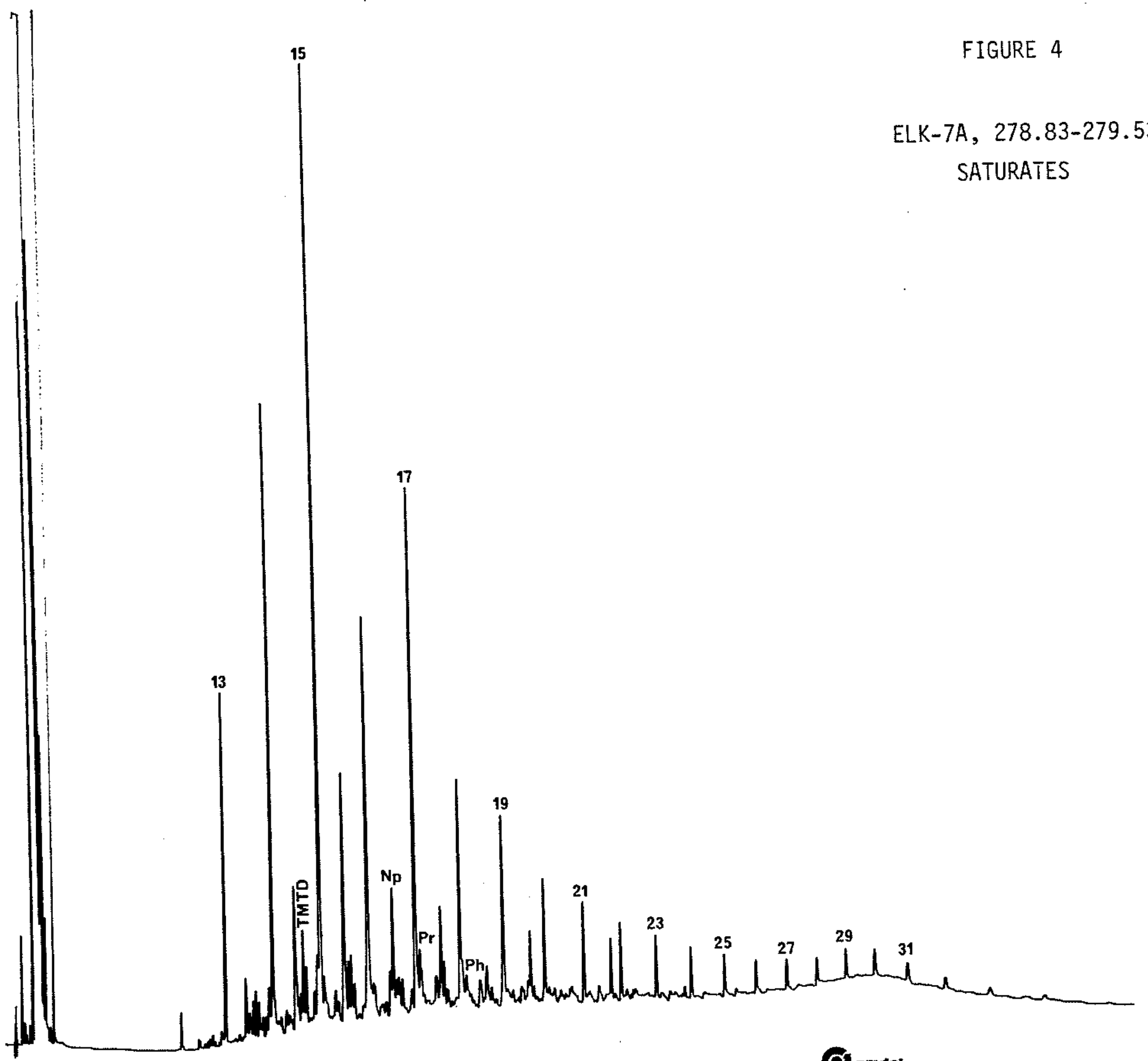


FIGURE 5

ELK-7A, 298.50-299.53 m
SATURATES

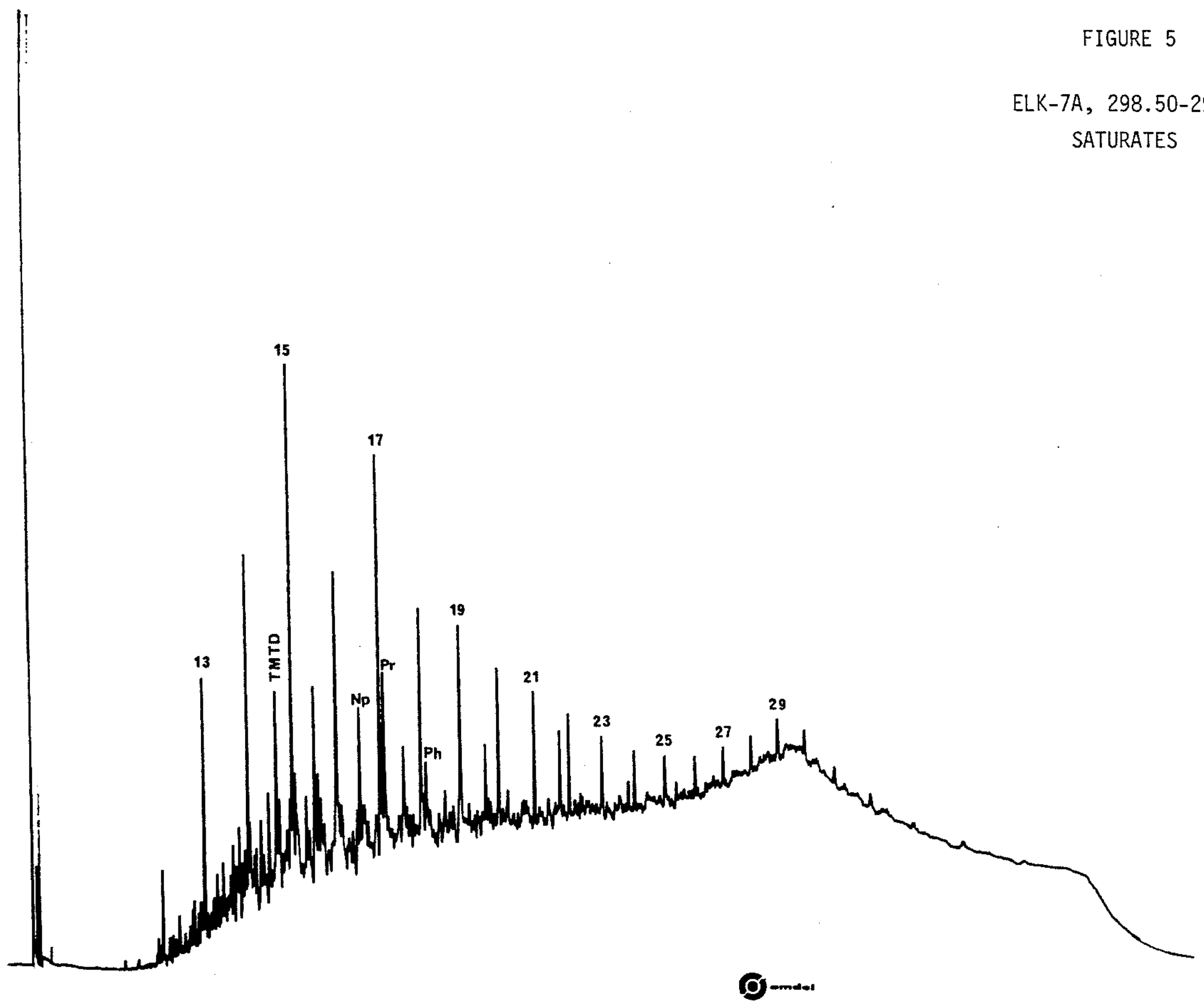


FIGURE 6

ELK-2
487.90-488.50 M

N-ALKANE AND ISOPRENOID DISTRIBUTION IN SATURATES

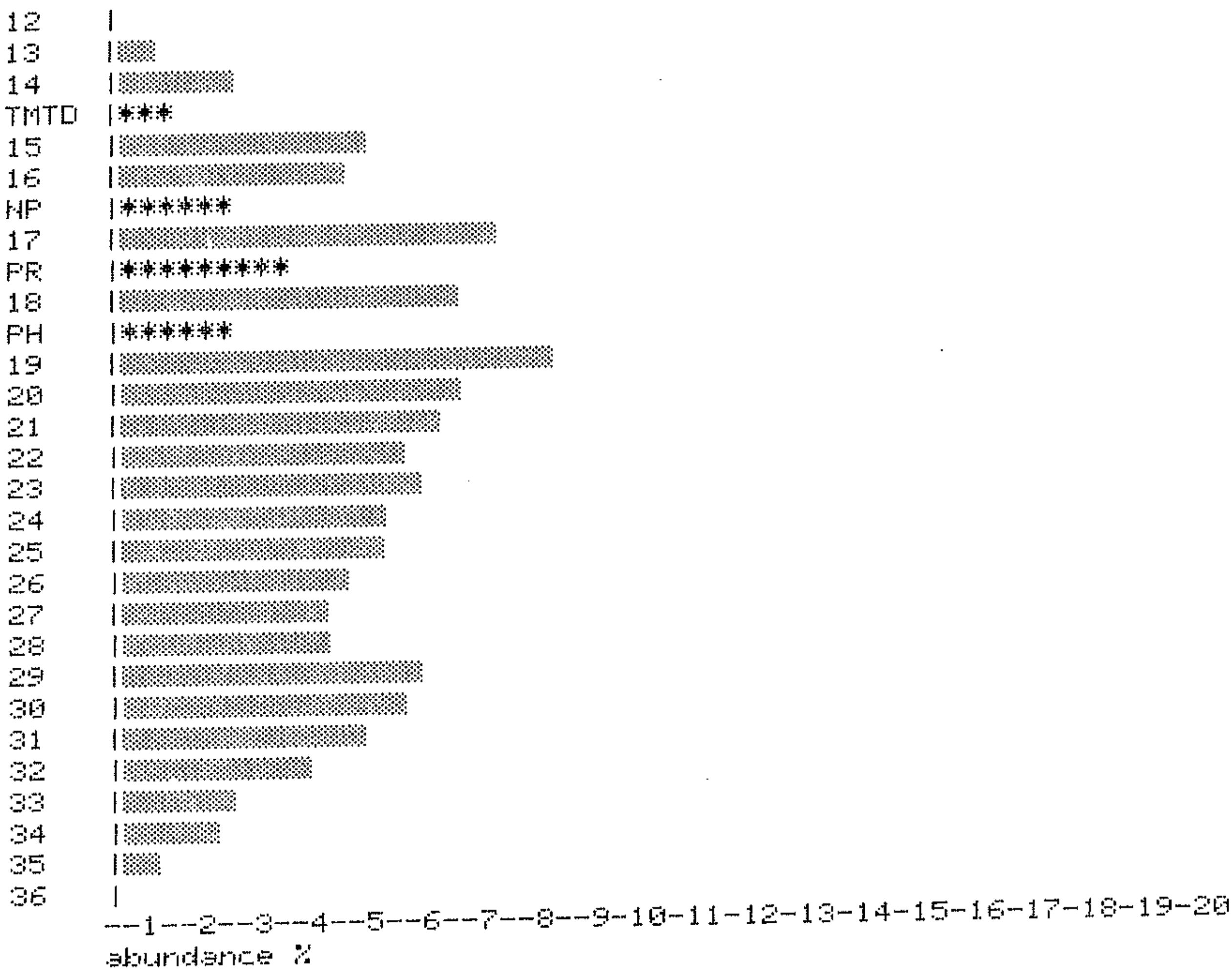
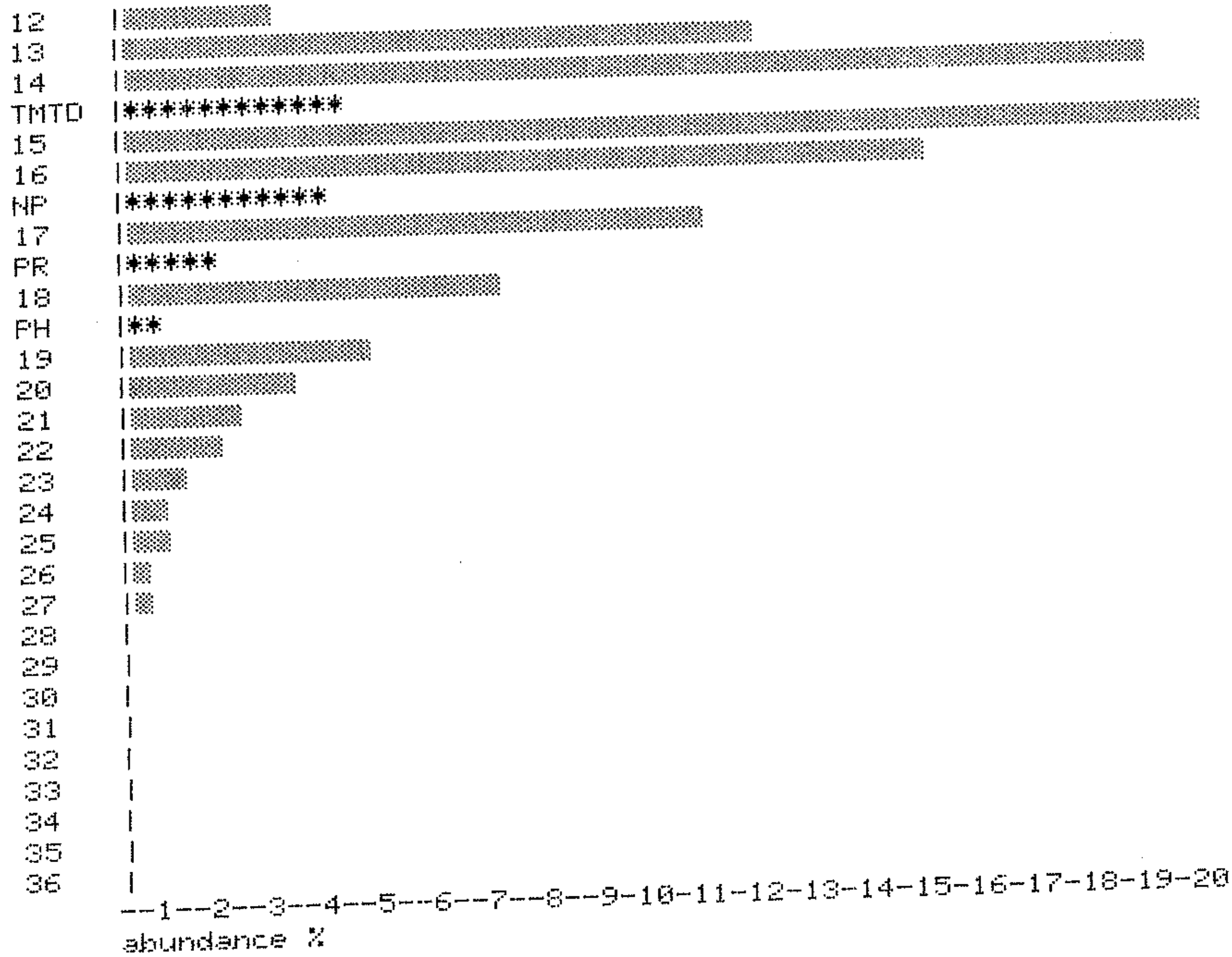


FIGURE 7

ELK-3
106.84-107.58 M

N-ALKANE AND ISOPRENOID DISTRIBUTION IN SATURATES



ELK-7A
278.83-279.53 M

N-ALKANE AND ISOPRENOID DISTRIBUTION IN SATURATES

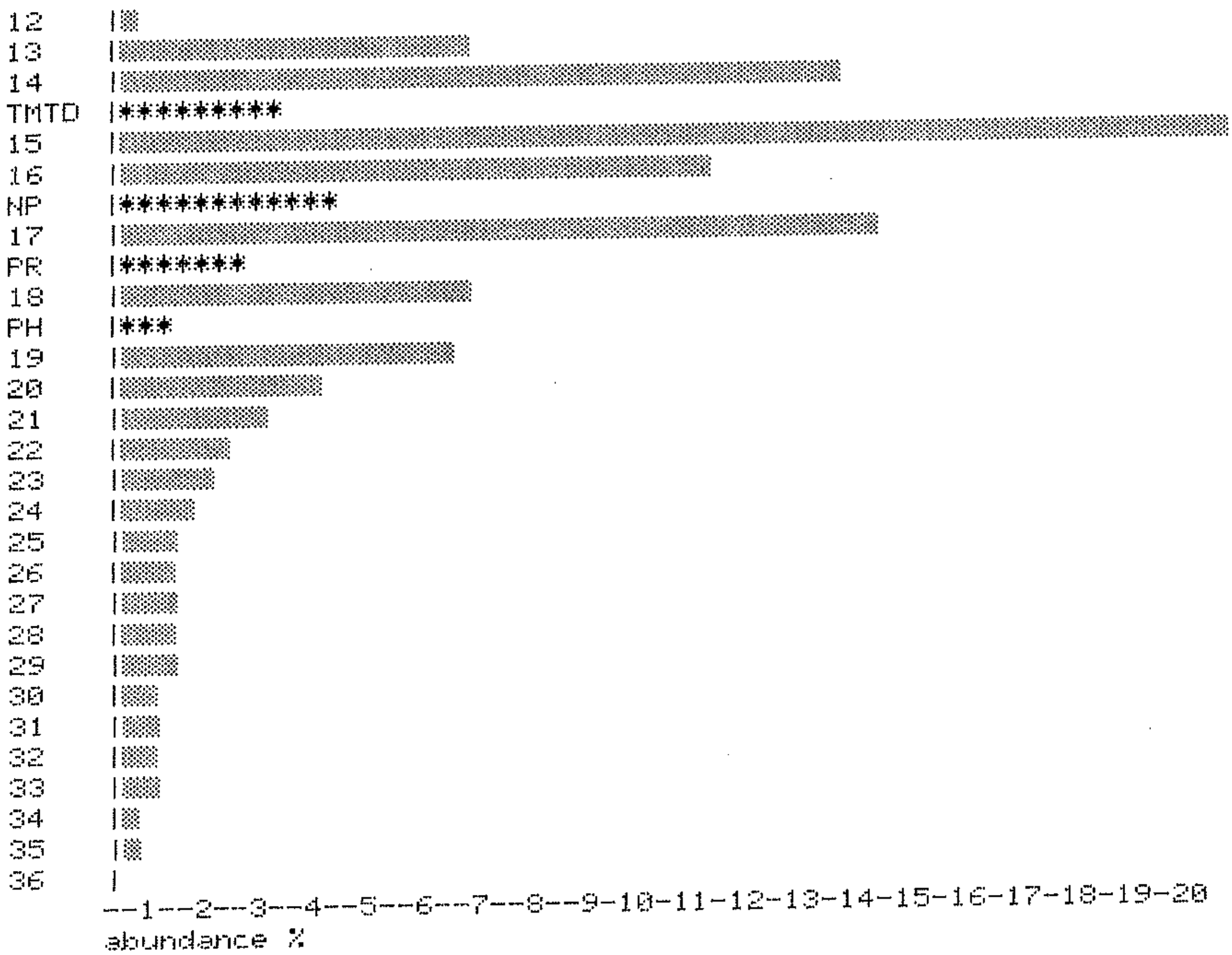


FIGURE 9

ELK-7A
298.50-299.53 M

N-ALKANE AND ISOPRENOID DISTRIBUTION IN SATURATES

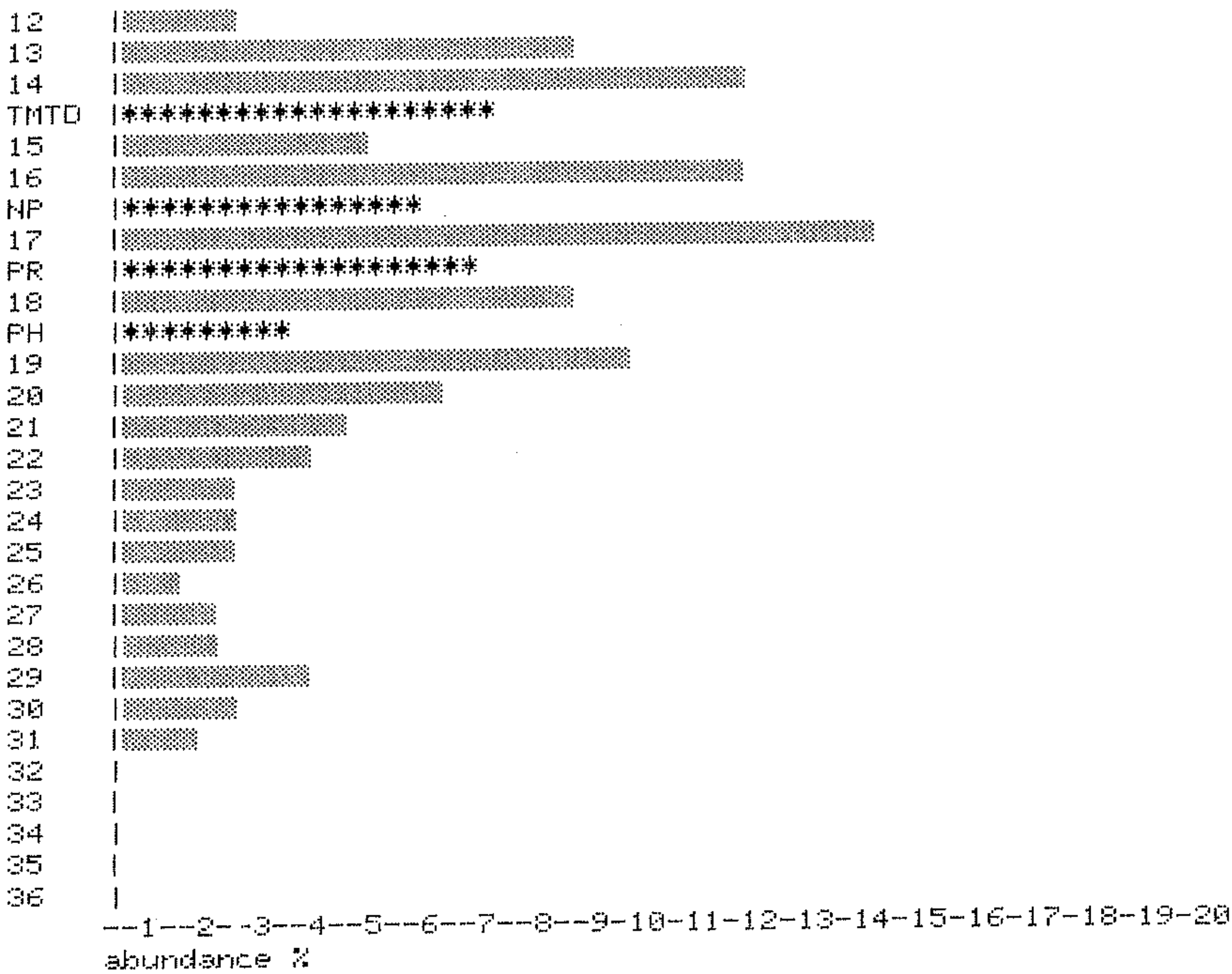
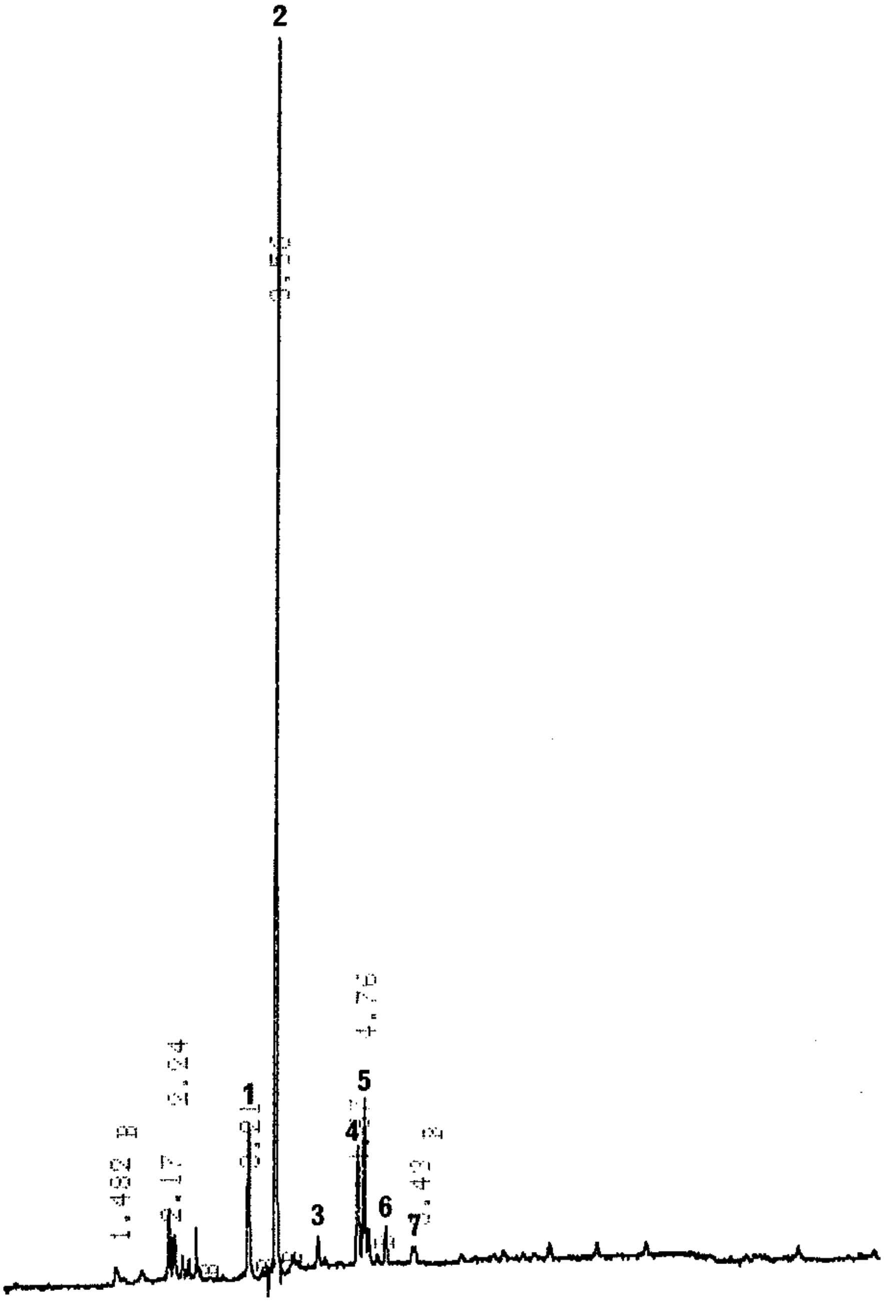


FIGURE 10

CHROMATOGRAM OF GASOLINE-RANGE HYDROCARBONS IN RESIDUAL OIL, ELK-7A, 208.96-209.94 m



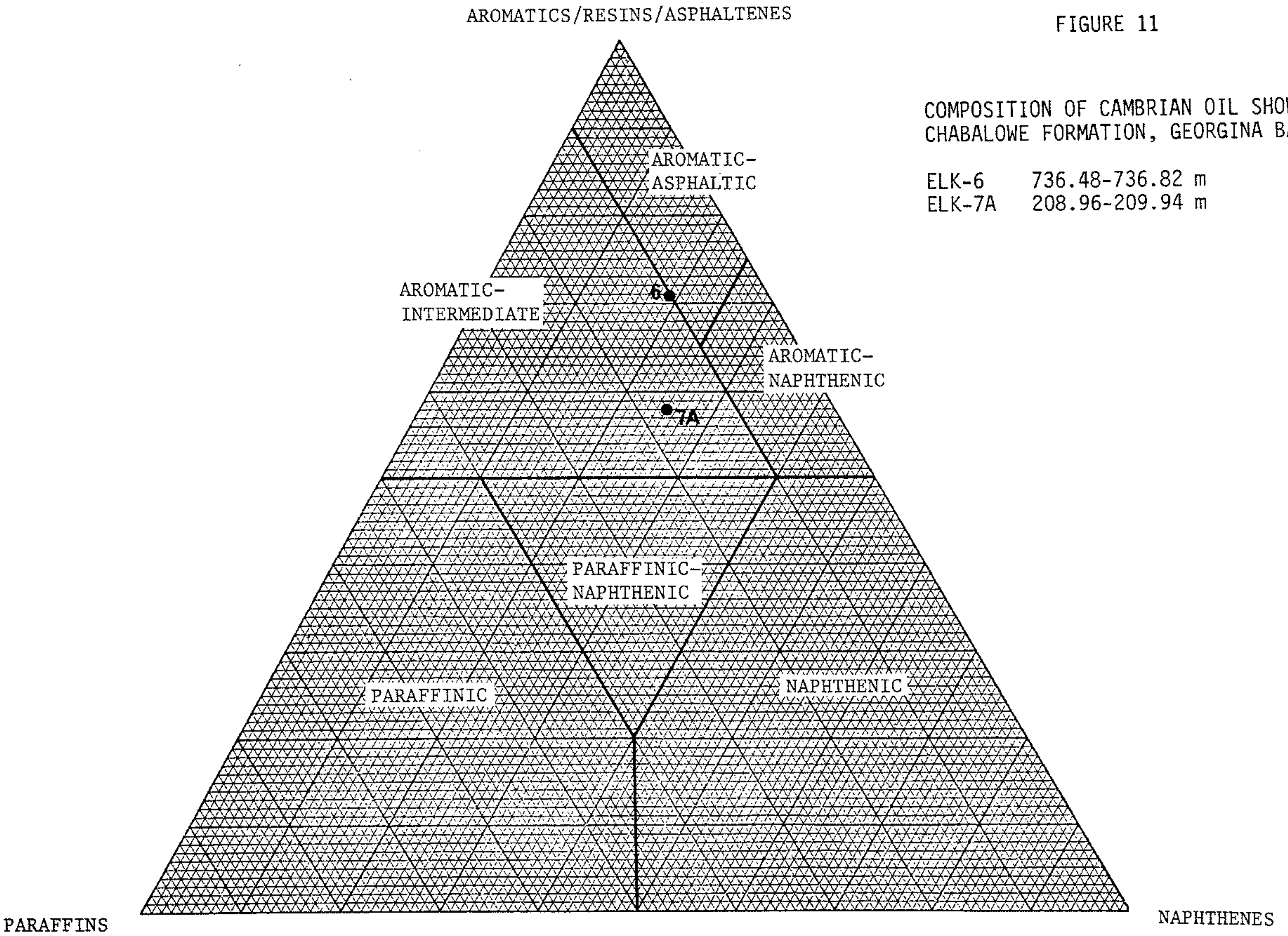
KEY TO GASOLINE-RANGE CHROMATOGRAM

1. 2-Methylbutane
2. *n*-Pentane
3. 2,2-Dimethylbutane
4. Cyclopentane and 2,3-Dimethylbutane
5. 2-Methylpentane
6. 3-Methylpentane
7. *n*-Hexane
8. Methylcyclopentane
9. 2,4-Dimethylpentane
10. Cyclohexane
11. 2-Methylhexane
12. 2,3-Dimethylpentane
13. 1,1-Dimethylcyclopentane
14. 3-Methylhexane
15. *cis*-1,3-Dimethylcyclopentane
16. *trans*-1,3-Dimethylcyclopentane
17. 3-Ethylpentane and *trans*-1,2-Dimethylcyclopentane
18. *n*-Heptane
19. Methylcyclohexane
20. Benzene
21. Toluene
22. *n*-Octane
23. Ethylbenzene
24. *p*-Xylene and *m*-Xylene
25. *o*-Xylene
26. *n*-Nonane

FIGURE 11

COMPOSITION OF CAMBRIAN OIL SHOWS
CHABALOWE FORMATION, GEORGINA BASIN

ELK-6 736.48-736.82 m
ELK-7A 208.96-209.94 m



amdel

FIGURE 12

OIL SHOW
ELK-7A, 208.96-209.94 m
SATURATES

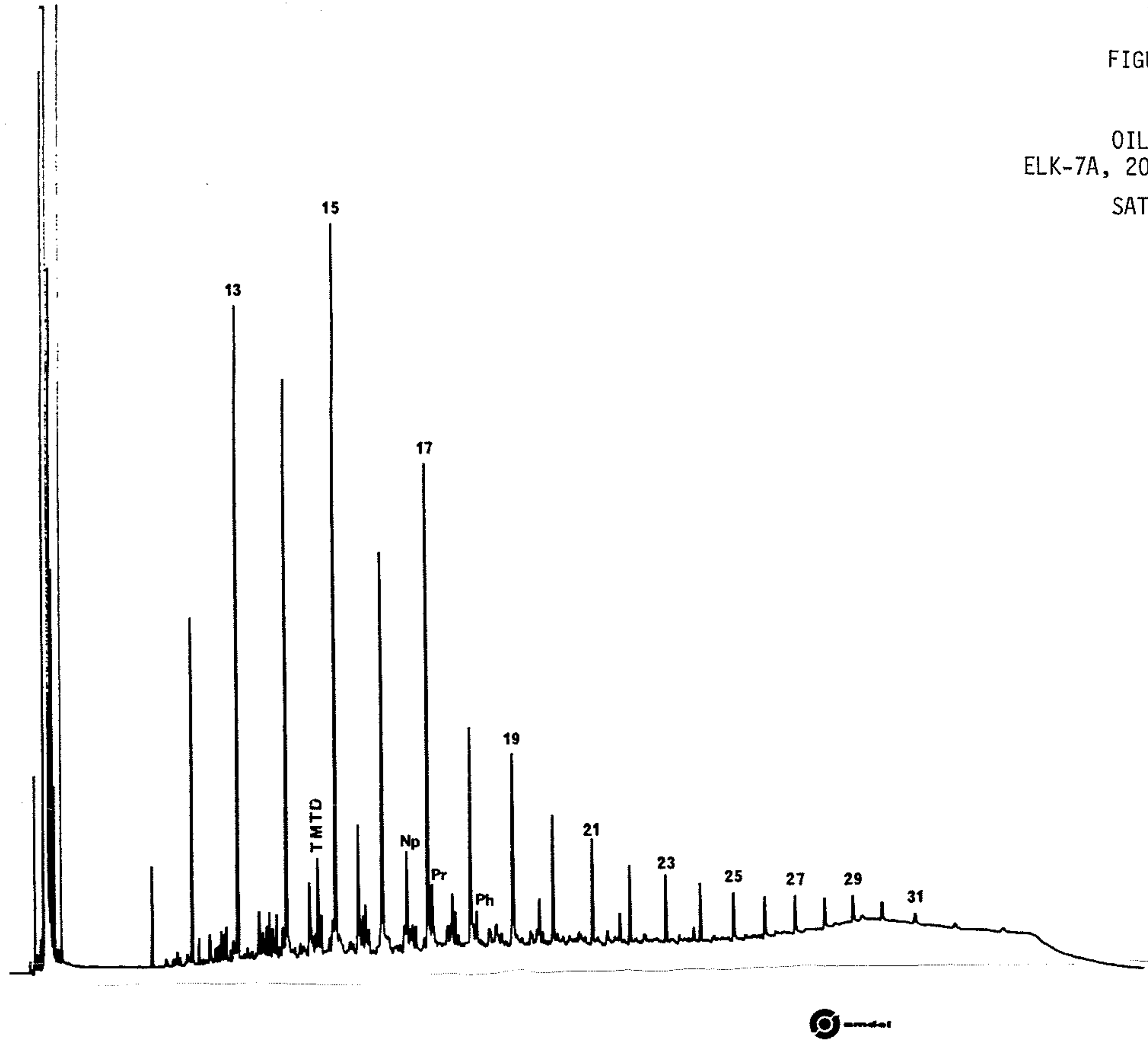
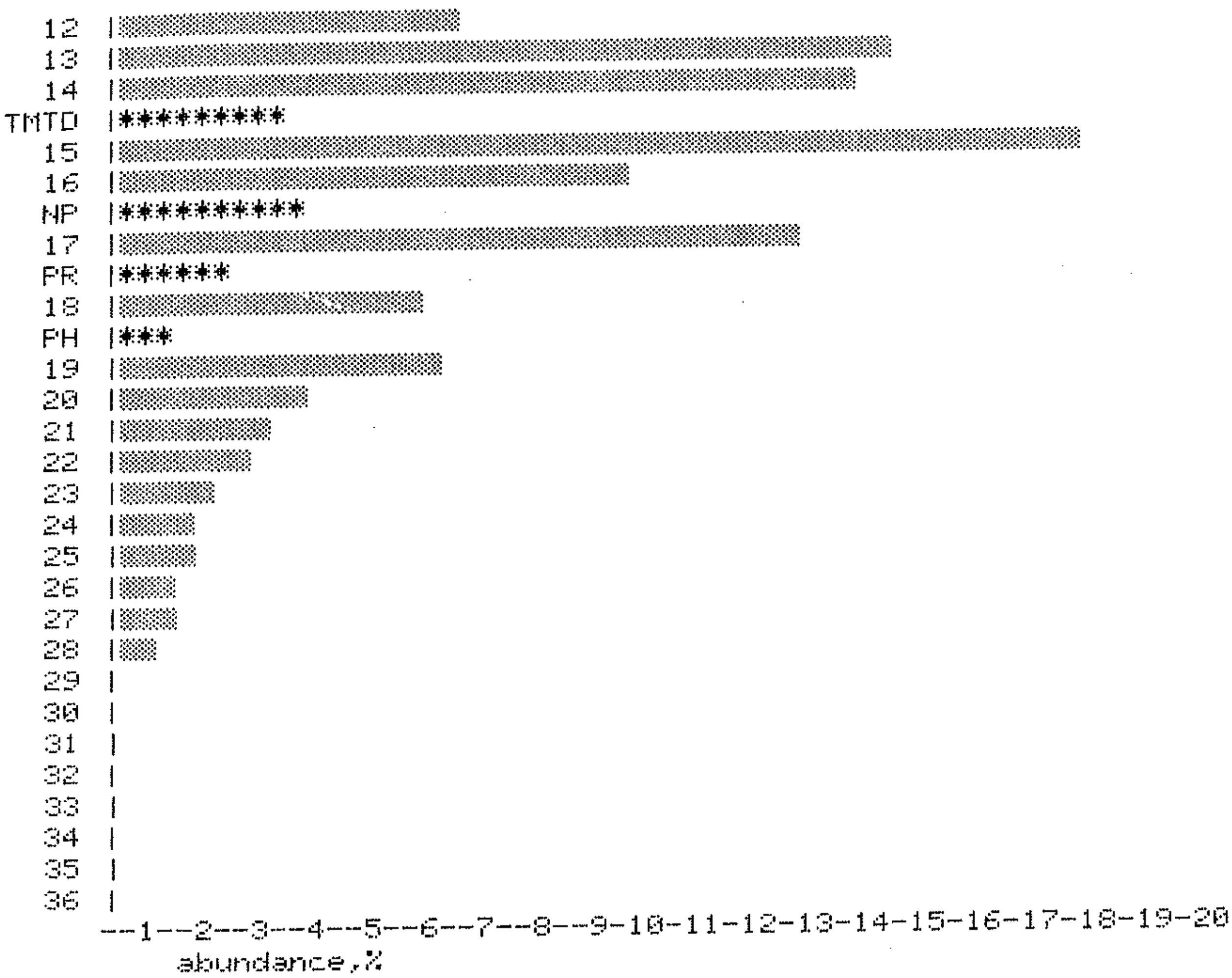


FIGURE 13

ELK-7A
208.96-209.84 M

HISTOGRAM OF N-ALKANE DISTRIBUTION OF SATURATES



KEY TO MASS FRAGMENTOGRAMS

m/z 191

1-6	C_{20}-C_{25}	tricyclic terpanes
7	C_{24}	tetracyclic terpane
8	C_{26}	tricyclic terpane
9	C_{27}	18α(H)-22,29,30-trisnorhopane (Ts)
10	C_{27}	17α(H)-22,29,30-trisnorhopane (Tm)
11	C_{28}	17α(H)-28,30-bisnorhopane
12	C_{29}	17α(H)-25-norhopane
13	C_{29}	17α(H)21β(H) norhopane
14	?C_{31}	tricyclic terpane
15	C_{29}	17β(H)21α(H) moretane
16	C_{30}	17α(H)21β(H) hopane
17	C_{30}	17β(H)21α(H) moretane
18-22	C_{31}-C_{35}	17α(H)21β(H) 22S (left) and 22R (right) homohopanes

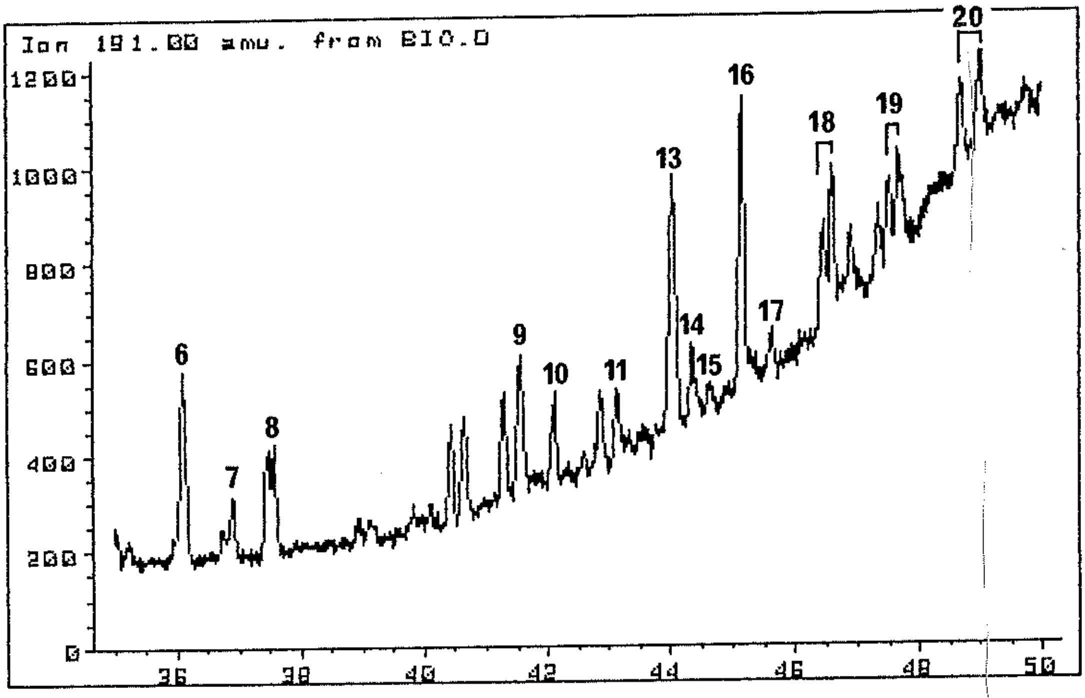
m/z 205

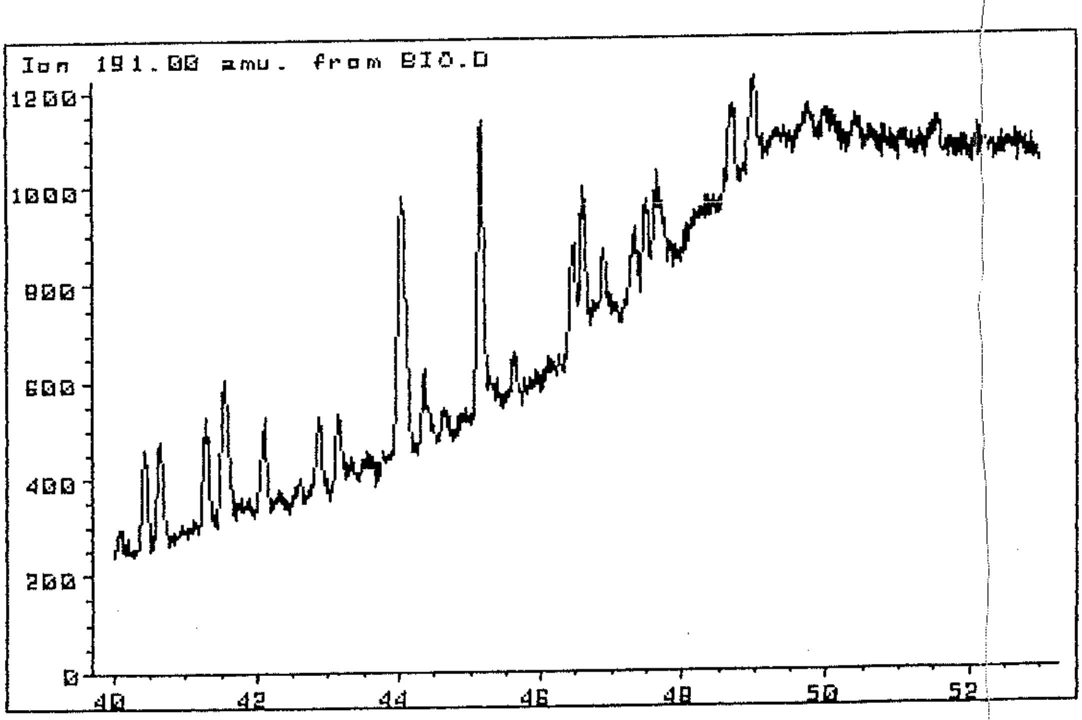
1	C_{28}	3-methyltrisnorhopanes
2	C_{29}	norhopane
3	C_{30}	3-methylnorhopane
4	C_{30}	hopane
5	C_{31}	3-methylhopane
6	C_{31}	22S homohopane
7	C_{32}	22S 3-methylhomohopane + C_{31} 22R homohopane
8	C_{32}	22R 3-methylhomohopane
9-12	C_{33}-C_{36}	3-methylhomohopanes

m/z 217, 259

1	C_{21}	sterane
2	C_{22}	sterane
3 & 4	C_{27}	20S and 20R diasteranes
5 & 8	C_{27}	5α(H)14α(H)17α(H) 20S and 20R steranes
6	C_{27}	5α(H)14β(H)17β(H) 20R sterane
7	C_{27}	5α(H)14β(H)17β(H) 20S sterane + C_{29} 20S diasterane
9	C_{29}	20R diasterane
10 & 13	C_{28}	5α(H)14α(H)17α(H) 20S and 20R steranes
11 & 12	C_{28}	5α(H)14β(H)17β(H) 20R and 20S steranes
14 & 17	C_{29}	5α(H)14α(H)17α(H) 20S and 20R steranes
15 & 16	C_{29}	5α(H)14β(H)17β(H) 20R and 20S steranes

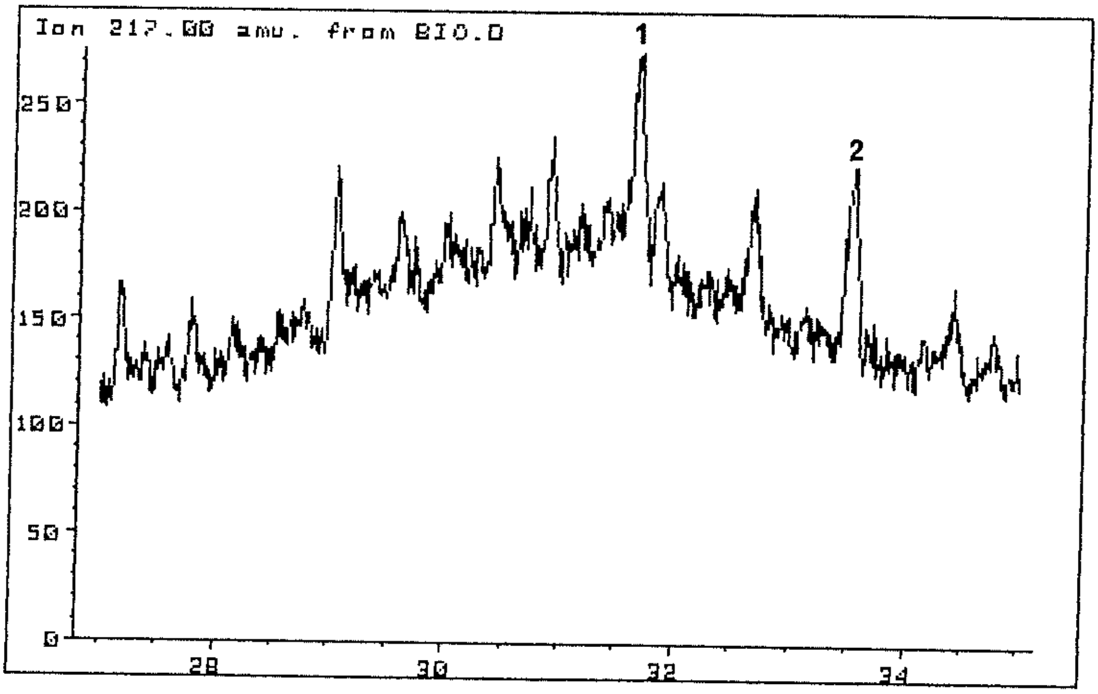
FIGURE 14



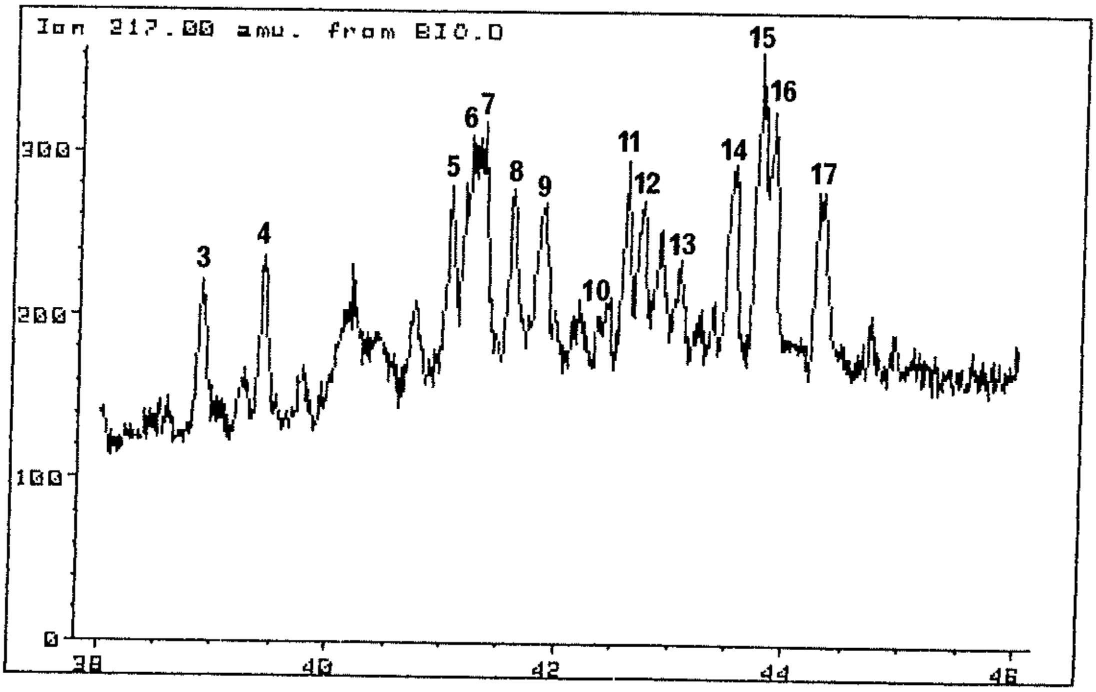


amdel

FIGURE 15



Ion 217.00 amu. from BIO.D
1
2
250
200
150
100
50
0
28
30
32
34

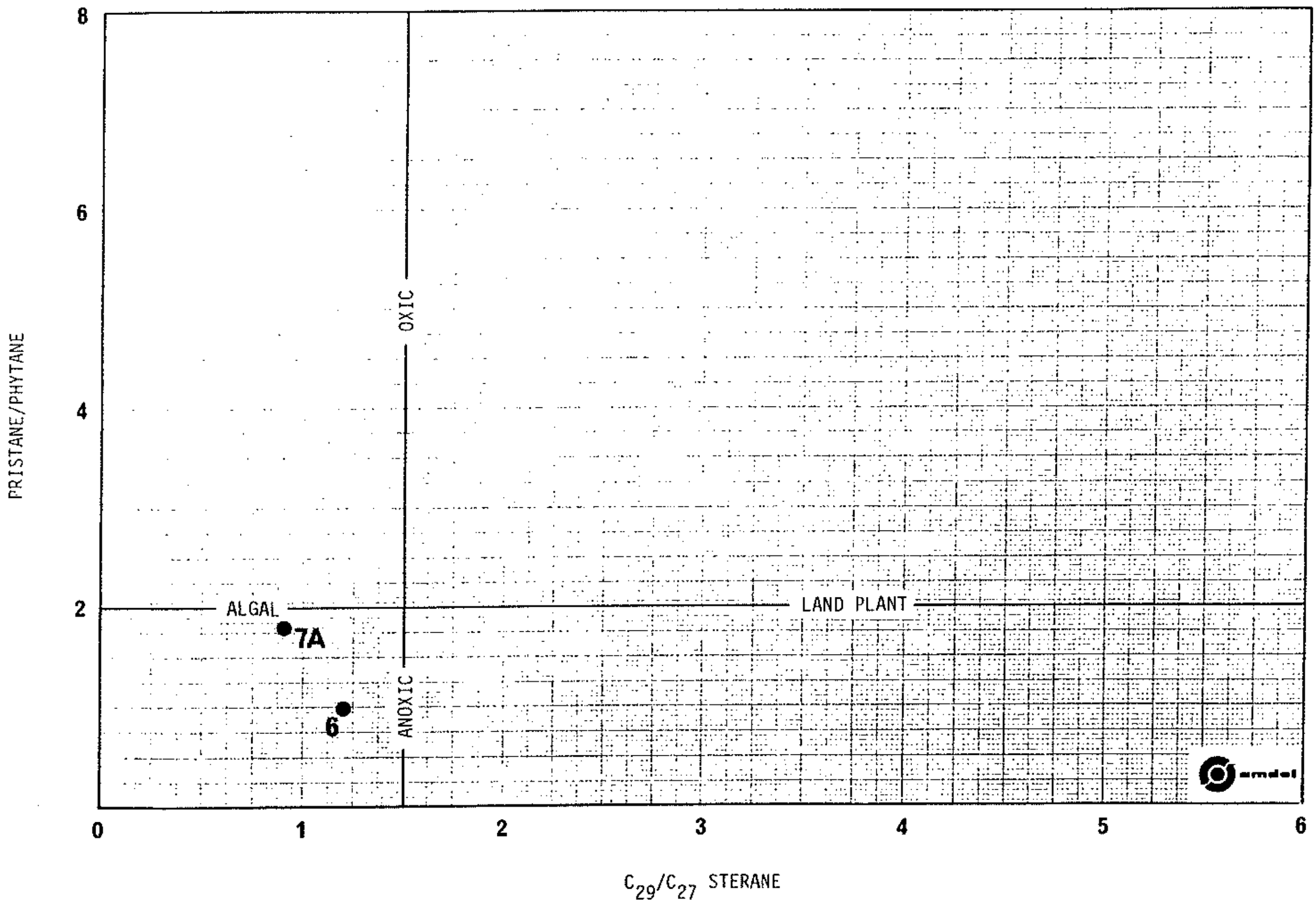


Ion 217.00 amu. from BIO.D
15
16
7
6
5
8
9
11
12
14
17
3
4
13
10
300
200
100
0
38
40
42
44
46

FIGURE 16

SOURCE AFFINITY OF CAMBRIAN OIL SHOWS
CHABALOWE FORMATION, GEORGINA BASIN

ELK-6 736.48-736.82 m
ELK-7A 208.96-209.94 m



APPENDIX 1

HISTOGRAM PLOTS OF REFLECTANCE MEASUREMENTS ON VITRINITE-LIKE ORGANIC MATTER, ELK-2, 3 AND 7A

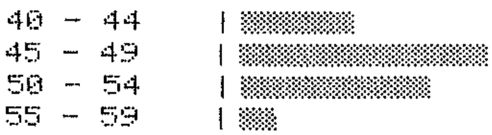
ELK #2

487.90-488.50 metres

SORTED LIST
.4 .41 .42 .43 .44 .44 .45 .45 .46 .47
.47 .47 .48 .48 .48 .49 .49 .49 .49 .5
.5 .5 .51 .52 .52 .54 .54 .54 .54 .55
.57
Number of values= 31

MEAN OF VALUES .485
STD DEVIATION .042

HISTOGRAM OF RESULTS
Values are reflectance multiplied by 100



ELK #3

106.84-107.58 metres

SORTED LIST
1.01 1.17 1.19 1.23 1.25 1.26 1.26 1.28 1.31 1.31
1.34 1.36 1.37 1.43 1.47 1.5 1.51 1.52 1.53 1.53
1.54 1.55 1.55 1.56 1.57 1.57 1.59 1.62 1.63 1.65
1.67 1.72
Number of values= 32

MEAN OF VALUES 1.439
STD DEVIATION .17

HISTOGRAM OF RESULTS
Values are reflectance multiplied by 100

```
101 - 105  | ▒
106 - 110  |
111 - 115  |
116 - 120  | ▒▒
121 - 125  | ▒▒
126 - 130  | ▒▒▒
131 - 135  | ▒▒▒
136 - 140  | ▒▒
141 - 145  | ▒
146 - 150  | ▒▒
151 - 155  | ▒▒▒▒▒▒▒
156 - 160  | ▒▒▒▒
161 - 165  | ▒▒▒
166 - 170  | ▒
171 - 175  | ▒
```

ELK #7A

278.83-279.53 metres

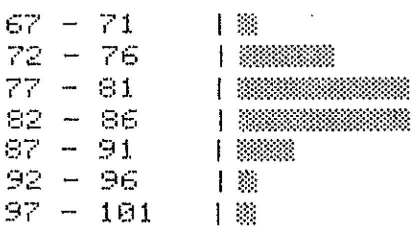
SORTED LIST

.67	.72	.74	.75	.76	.76	.77	.77	.78	.78
.78	.79	.79	.8	.81	.82	.83	.84	.85	.85
.85	.85	.85	.86	.87	.88	.9	.92	1	

Number of values= 29

MEAN OF VALUES .815
STD DEVIATION .065

HISTOGRAM OF RESULTS
Values are reflectance multiplied by 100



ELK #7A

298.50-299.53 metres

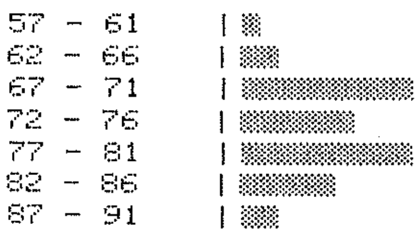
SORTED LIST

.57	.62	.65	.67	.68	.69	.69	.7	.7	.7
.71	.71	.73	.74	.75	.76	.76	.76	.77	.77
.78	.78	.79	.79	.8	.81	.81	.82	.82	.84
.85	.86	.89	.91						

Number of values= 34

MEAN OF VALUES .755
STD DEVIATION .075

HISTOGRAM OF RESULTS
Values are reflectance multiplied by 100

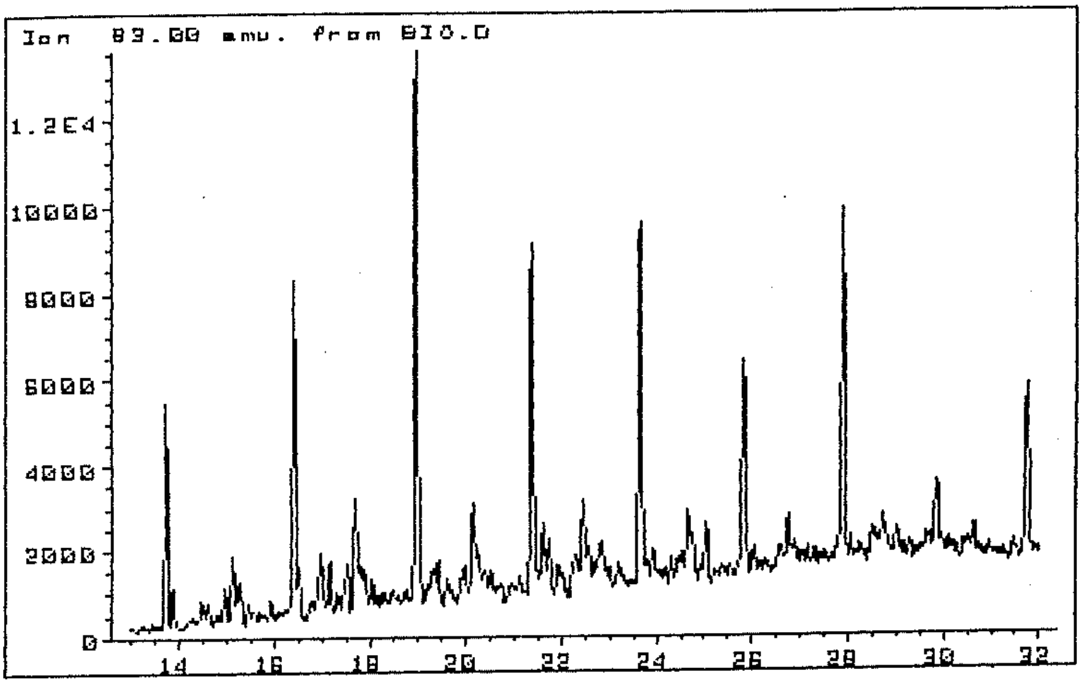


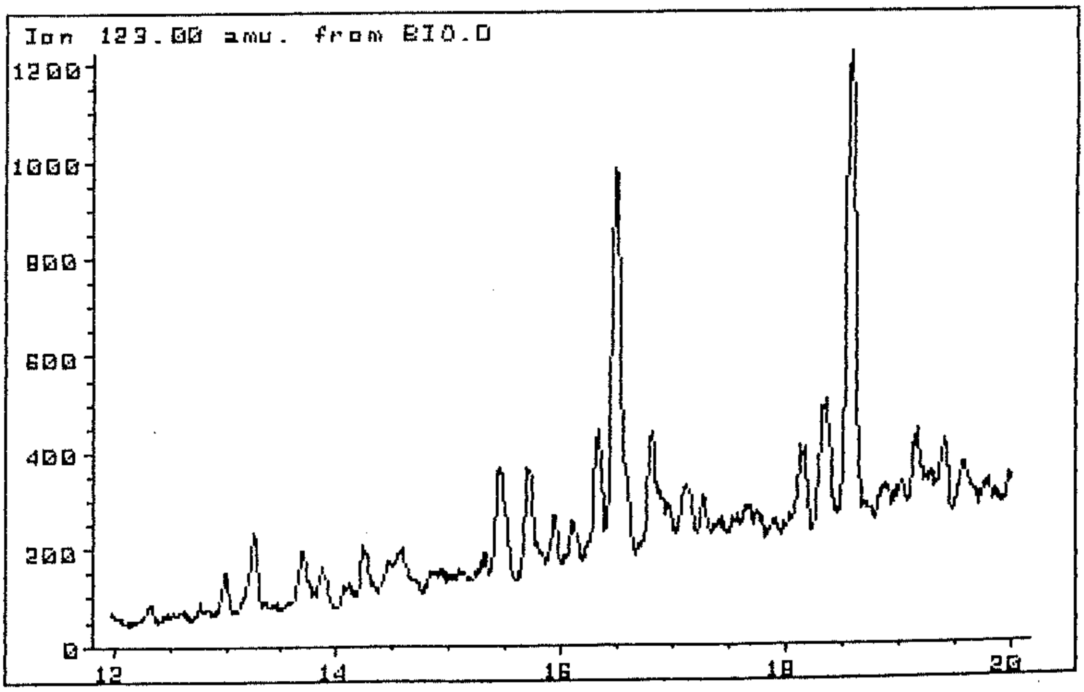
APPENDIX 3

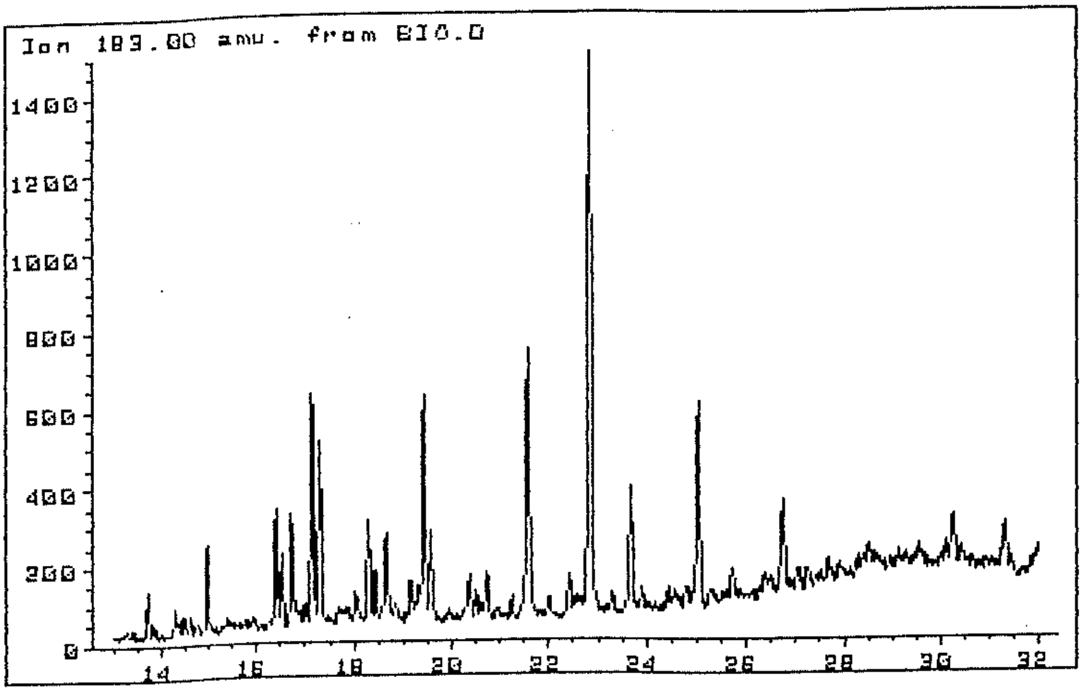
OTHER MASS FRAGMENTOGRAMS OF NAPHTHENES IN RESIDUAL OIL, ELK-7A (208.96-209.94 m)

[AMDEL Sample MS-206]

m/z 83	alkylcyclohexanes
m/z 123	sesquiterpanes (incl. drimanes)
m/z 183	acyclic alkanes (incl. isoprenoids)
m/z 177	demethylated triterpanes
m/z 205	methyl triterpanes
m/z 217	steranes
m/z 218	steranes
m/z 231	4-methyl steranes
m/z 259	diasteranes


Ion 83.00 amu. from BIO.D
1.2E4
10000
8000
6000
4000
2000
0
14
16
18
20
22
24
26
28
30
32


Ion 123.00 amu. from BIO.D
1200
1000
800
600
400
200
0
12
14
16
18
20


Ion 183.00 amu. from BIO.D
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200
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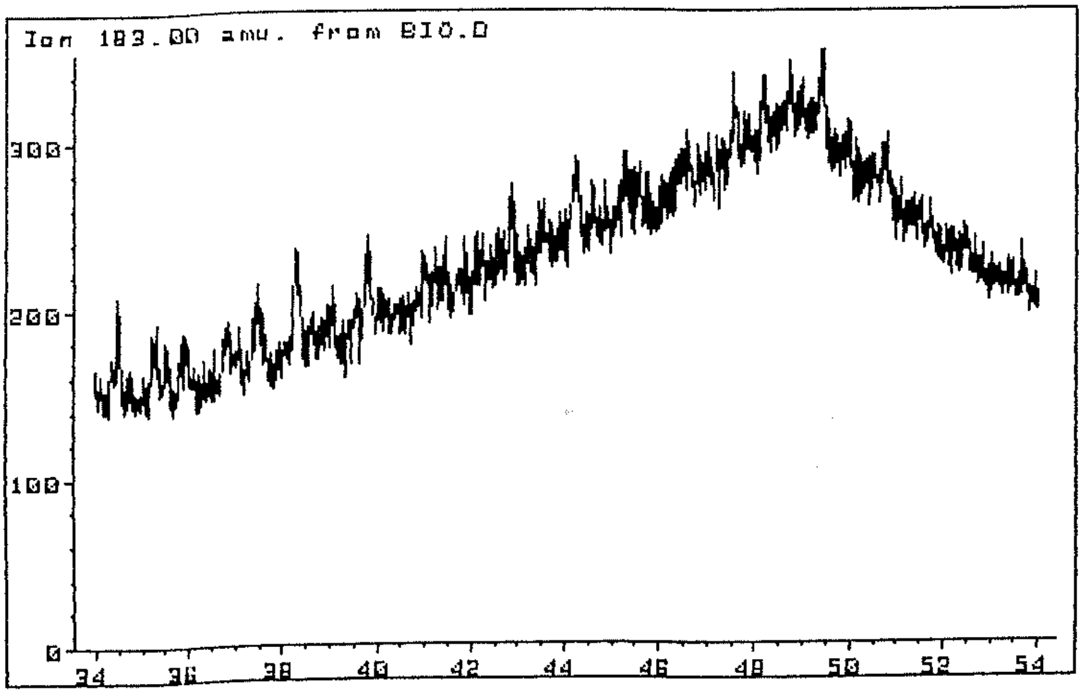
600
800
1000
1200
1400
14
16
18
20
22
24
26
28
30
32


Ion 183.00 amu. from BIO.D
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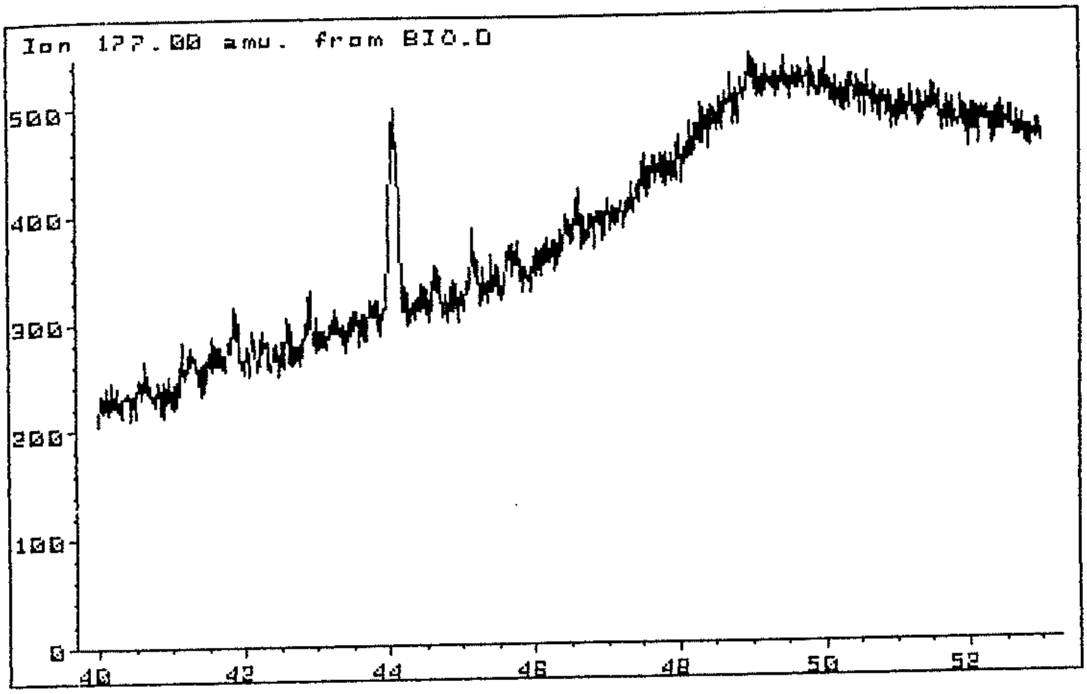
100
200
300
34
36
38
40
42
44
46
48
50
52
54



Ion 177.00 amu. from BIO.D
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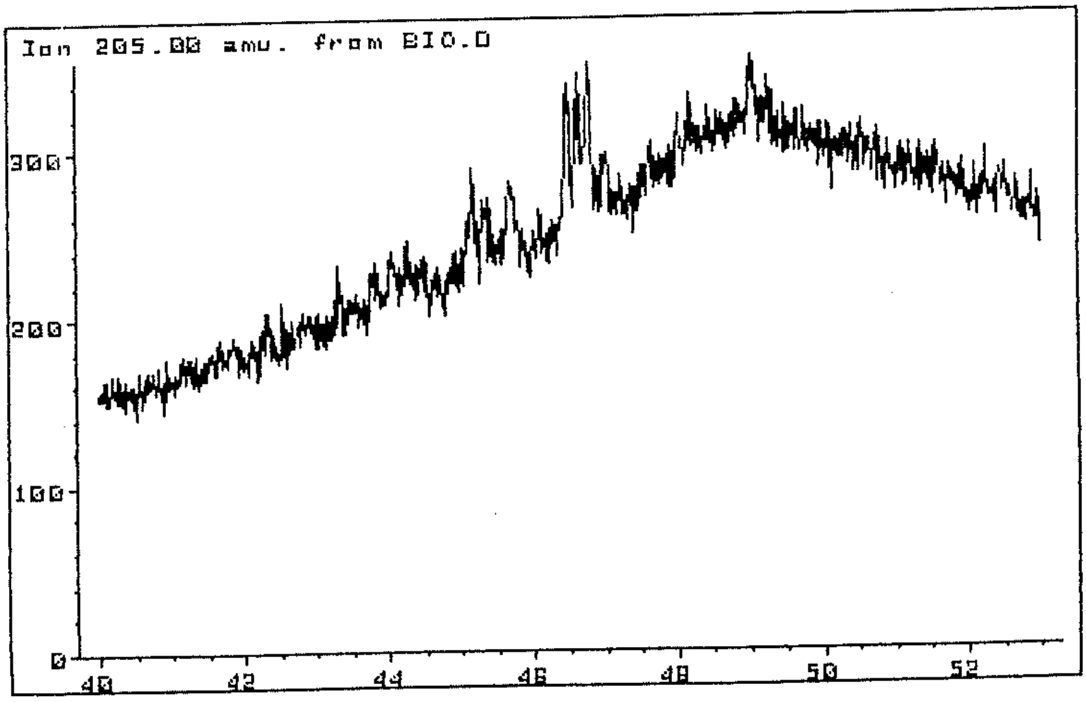
0
40
42
44
46
48
50
52



Ion 205.00 amu. from BIO.D
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42
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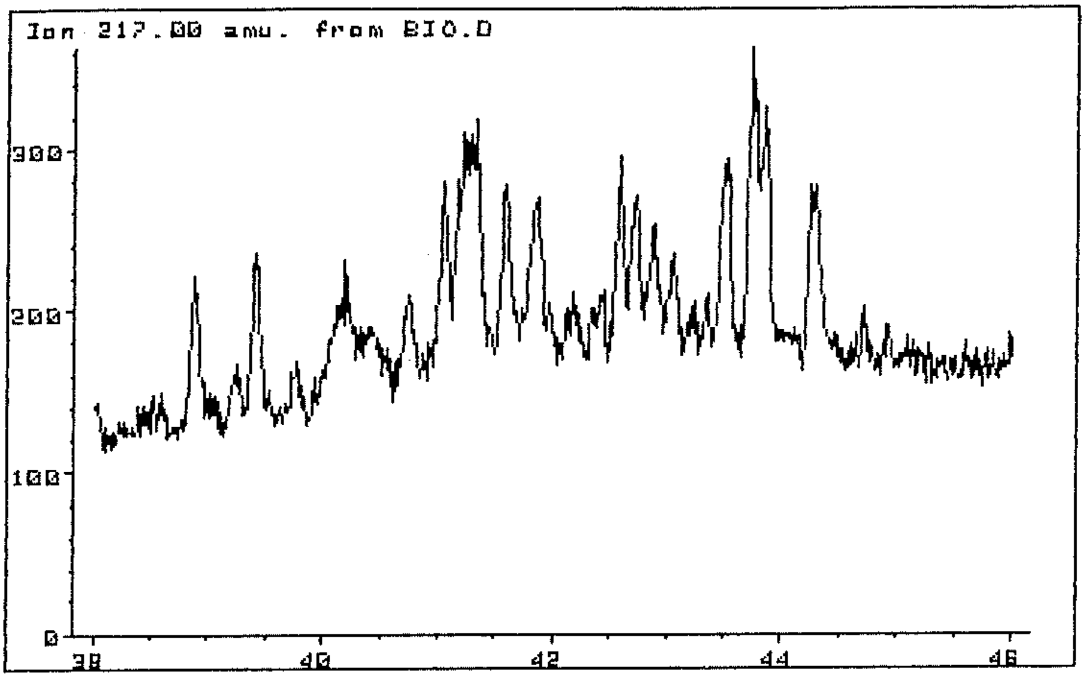
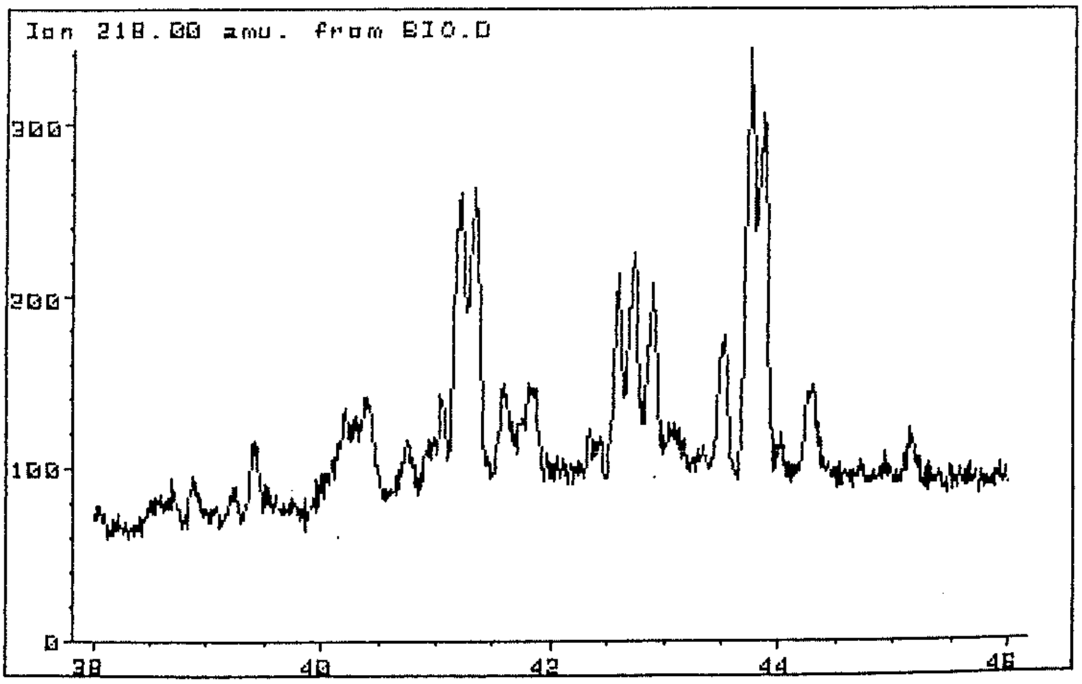
46
48
50
52


Ion 217.00 amu. from BIO.D
300
200
100
0
38
40
42
44
46


Ion 218.00 amu. from BIO.D
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200
100
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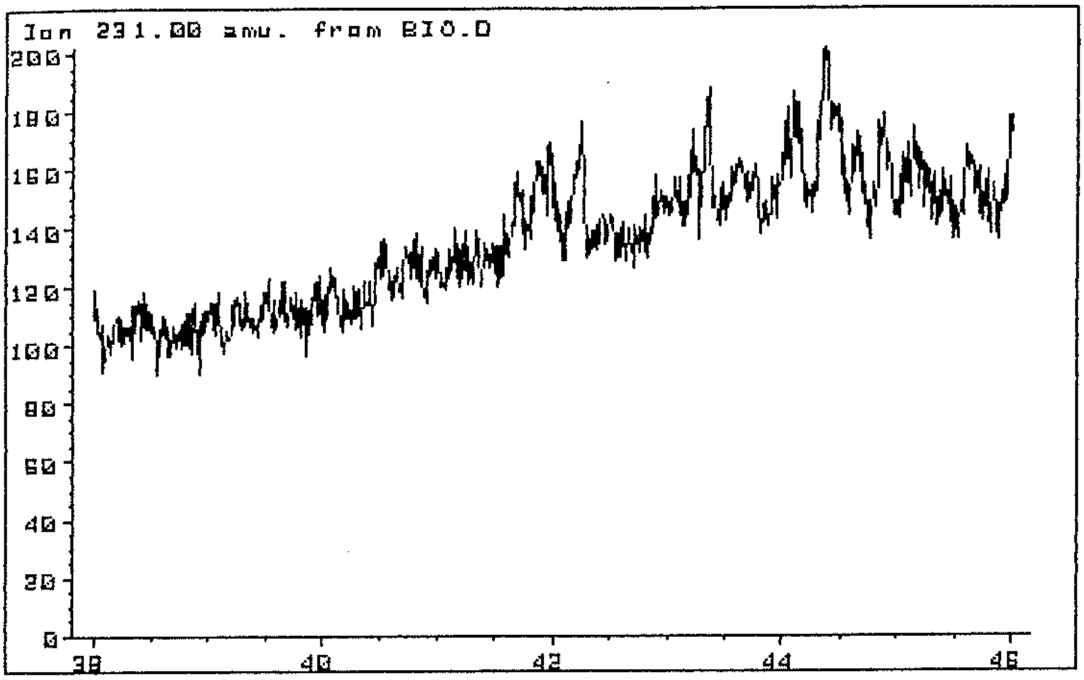
40
42
44
46


Ion 231.00 amu. from BIO.D
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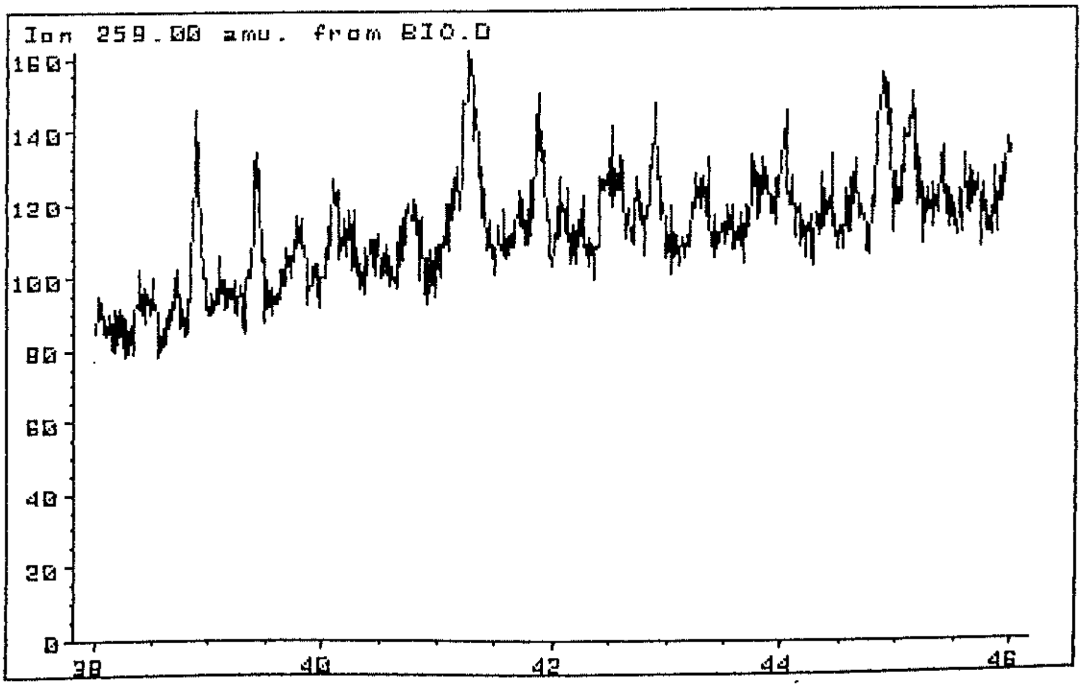
120
100
80
60
40
20
0
38
40
42
44
46


Ion 259.00 amu. from BIO.D
160
140
120
100
80
60
40
20
0
38
40
42
44
46