

**A GEOCHEMICAL
ANALYSIS OF 2 NORTH
SEA OILS FROM WELLS
N7/11-5 AND N7/11-7**

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A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7

Summary

This data report contains the results of geochemical and physical properties analyses carried out on two North Sea oil samples for Phillips Petroleum Company UK.

*A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7***Introduction**

This is the second report (previous report no. 7376/lc) produced as part of a project for the Phillips Petroleum Company UK Ltd which involves geochemical and physical properties analyses of North Sea oils. This report presents results of oils from the following two Norwegian wells:

Well	DST	Interval	Formation
N7/11-5	1	4185m-4197m	Ula
N7/11-7	3	4549m 14925'-14980' and 15007'-15015' 4576m	Smith Bank and Ula

The oil samples arrived at SPT's offices in North Wales on 3 January 1994. Our main contacts at Phillips throughout this project have been Mr Ian Knight and Mr Mike Lines. A preliminary data package was sent by fax on 21 January 1994 with all the results generated by that date. The analytical program has followed that outlined in SPT proposal no. 93/lc/049 and Phillips Service Order No. 8095. The numbers of analyses carried out are as follows:

Analysis	No. of samples
API gravity	2
Sulphur, nitrogen, nickel, vanadium and wax contents	2
Asphaltene content	2
Chromatographic fractionation of the de-asphalted oil	2
Whole oil gas chromatography	2
Gasoline range gas chromatography	2
Saturate fraction gas chromatography	2
Aromatic fraction gas chromatography	2
Saturate fraction gas chromatography-mass spectrometry	2
Aromatic fraction gas chromatography-mass spectrometry	2
Carbon isotope analysis of whole oil, topped oil, saturate fraction, aromatic fraction and polar fraction	2
Carbon isotope analysis of asphaltene fraction	1

The analytical procedures are detailed in the appendices at the back of this report.

A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7

WELL: N7/11-5
DST: 1
INTERVAL: 4185m-4197m
FORMATION: Ula

COMPANY: PHILLIPS

WELL: 7/11-5

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Mtrs)	4185.0-197.0					
SAMPLE FORMATION	ULA					

COMPONENTS	GASOLINE RANGE COMPONENT ABUNDANCE (%)				
i-C4	.569				
n-C4	4.027				
i-C5	3.750				
n-C5	6.590				
2,2,dmb	.192				
cp	1.286				
2,3,dmb	.691				
2,mp	4.254				
3,mp	2.657				
n-C6	8.186				
mcp+2,2,dmp	5.287				
2,4,dmp	.673				
benz	3.556				
3,3,dmp	.233				
ch	5.783				
,mh	5.071				
,1,dmcp	.183				
3,mh	3.906				
cis,1,3,dmcp	.834				
trans,1,3,dmcp	.681				
trans,1,2,dmcp+3,ep	2.383				
n-C7	11.032				
mch+cis,1,2,dmcp	15.701				
ecp	1.365				
tol	11.111				

GENERAL DATA						
Total Abundance(ppb)	17640000					
TOC (% of Rock)						
Abundance at 1% TOC	*					
Alkane Composition	35 26 39					
C7 Alkane Composition	21 19 61					
Aromatic Composition	14.67					

RATIOS						
i/n-C4	.14					
i/n-C5	.57					
cp / 2,3,dmb	1.86					
n-C7 / mch	.70					
2,mp / 3,mp	1.60					
n-C6 / mcp +2,2,dmp	1.55					
mch / tol	1.41					
Late Mature Index	.23					
Aromaticity Index	1.01					
Heptane Index	26.23					
Isoheptane Index	2.20					
Kerogen Type Index	10.10					

LEGEND					
i - iso	c - cyclo	m - methyl	b - butane	h - hexane	tol - toluene
n - normal	d - di	e - ethyl	p - pentane	benz - benzene	
Alkane Composition - % composition of normal, iso and cyclo alkanes					
C7 Alkane Composition - % composition of C7 normal, iso and cyclo alkanes					
Aromatic Composition - % composition of Benzene + Toluene					
For definition of indices - Late Mature, Aromaticity, Heptane, Isoheptane & Kerogen Type - See Appendix 2					

GASOLINE RANGE HYDROCARBON DATA

TABLE : 2

COMPANY: PHILLIPS

WELL: 7/11-5

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Mtrs)	4185.0-197.0					
SAMPLE FORMATION	ULA					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13	4.72					
n-C14	6.27					
n-C15	7.01					
n-C16	6.94					
n-C17	6.68					
n-C18	6.00					
n-C19	6.60					
n-C20	5.83					
n-C21	5.16					
n-C22	5.06					
n-C23	4.06					
n-C24	4.51					
n-C25	4.31					
n-C26	3.12					
n-C27	2.43					
n-C28	2.09					
n-C29	1.86					
n-C30	1.40					
n-C31	1.07					
n-C32	.71					
n-C33	.96					
n-C34	.96					
n-C35	.63					
n-C36	.31					
i-C15 (Farnesane)	1.01					
i-C16	2.28					
i-C18 (Norpristane)	1.91					
i-C19 (Pristane)	3.92					
i-C20 (Phytane)	2.18					

GENERAL DATA						
Total Abundance(%)	100					
TOC (% of Rock)						
Extract (ppm)						
Hydrocarbons (ppm)						
Hydrocarbon(mg/gTOC)						
Alks(% Hydrocarbons)						
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	1.09					
CPI-2	1.10					
CPI-3	.93					
Bias	1.59					
i-C19 / n-C17	.59					
i-C20 / n-C18	.36					
i-C19 / i-C20	1.80					

LEGEND						
i - isoprenoid	n - normal	For definition of Ratios CPI-1,-2,-3 and Bias - see Appendix 2				

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 3

Company: PHILLIPS

Well: NORTH SEA OIL STUDY

Location: NORTH SEA

Well	DST	Interval	Formation	Peak Area %				Ratios	
				DBT	4MDBT	3+2MDBT	1MDBT	TH-1	TH-2
N7/11-5	1	4185m-4197m	U1a	17	67	16	0	3.9	-

TH-1 = 4MDBT/DBT

TH-2 = 4MDBT/1MDBT



TABLE 4 Aromatic GC (FPD) data

Compound	Well: N7/11-5 Depth: 4185m-4197m Formation: Ula		Terpane Ratios	
	Peak height	Peak area		
m/z 191 t21	-	-	h27s/h27m	-
m/z 191 t22	-	-	m30/h30	-
m/z 191 t23	2439	258869	h31S/h31R	-
m/z 191 t24	-	-	(t23 + t24 + t25 + t26)/h30	-
m/z 191 t25	-	-	T24/h30%	-
m/z 191 t26	-	-	B/h30%	-
m/z 191 t27	-	-	X/h30%	-
m/z 191 t28	-	-	O/h30%	-
m/z 191 t29	-	-	G/h30%	-
m/z 191 h27s	-	-	Sterane Ratios	
m/z 191 h27m	-	-	s29c/(s29c + s29b)	-
m/z 191 B	-	-	(s29d + s29e)/	-
m/z 191 h29	-	-	(s29c + s29d + s29e + s29b)	-
m/z 191 X	-	-	s27b/(s27b + s28b + s29b)%	-
m/z 191 m29	-	-	s28b/(s27b + s28b + s29b)%	-
m/z 191 O	-	-	s29b/(s27b + s28b + s29b)%	-
m/z 191 h30	-	-	s27b/s29b	-
m/z 191 m30	-	-	h30/(s29c + s29d + s29e + s29b)	-
m/z 191 h31S	-	-		
m/z 191 h31R	-	-		
m/z 191 G	-	-		
m/z 191 h32S	-	-		
m/z 191 h32R	-	-		
m/z 217 r27d	4923	455599		
m/z 217 r27c	2642	270060		
m/z 217 s27b	-	-		
m/z 217 r29c	3155	745895		
m/z 217 s28b	-	-		
m/z 217 s29c	-	-		
m/z 217 s29d	1808	202569		
m/z 217 s29e	-	-		
m/z 217 s29b	-	-		
m/z 259 r27d	1627	152927		
m/z 259 r27c	1195	145156		
m/z 259 r28d	1388	182504		
m/z 259 r28c	+1217	+165980		
m/z 259 r28c	782	57977		
m/z 259 r29d	+1179	+147821		
m/z 259 r29d	1984	268947		
m/z 259 r29c	1263	183053		

TABLE 5 Alkane GC-MS data and ratios

Compound	Well: N7/11-5 Depth: 4185m-4197m	
	Peak height	Peak area
m/z 154 BiP	7416	370798
m/z 168 1MBiP		
m/z 168 2MBiP		
m/z 168 3MBiP		
m/z 178 P	31310	1663624
m/z 184 DBT	4023	197113
m/z 192 3MP	16840	797750
m/z 192 2MP	18145	1046084
m/z 192 9MP	12507	594825
m/z 192 1MP	10760	578792
m/z 198 4MDBT	10132	502377
m/z 198 2+3MDBT	3398	259811
m/z 198 1MDBT	1101	52051
m/z 231 TAS20	-	-
m/z 231 TAS21	-	-
m/z 231 TAS26S	-	-
m/z 231 TAS26R+27S	-	-
m/z 231 TAS28S	-	-
m/z 231 TAS27R	-	-
m/z 231 TAS28R	-	-
m/z 253 MAS21	-	-
m/z 253 MAS22	-	-
m/z 253 MAS29 β 28 α	-	-
m/z 253 MAS29 α	-	-

MPI-1	F1	F2	TAS-1	TAS-2	DBT/P	TH-1	TH-2
0.98	0.61	0.35	-	-	0.12	2.55	9.65

Key:

MPI-1	=	$([3MP+2MP]/[P+9MP+1MP])*1.5$
F1	=	$([3MP+2MP]/[3MP+2MP+9MP+1MP])$
F2	=	$(2MP/[3MP+2MP+9MP+1MP])$
TAS-1	=	$(TAS20+TAS21)/(TAS26+TAS27+TAS28)$
TAS-2	=	$TAS20/TAS28(S+R)$
TH-1	=	$4MDBT/DBT$
TH-2	=	$4MDBT/1MDBT$

NB: Calculations based on peak areas.

TABLE 6 Aromatic GC-MS data and ratios

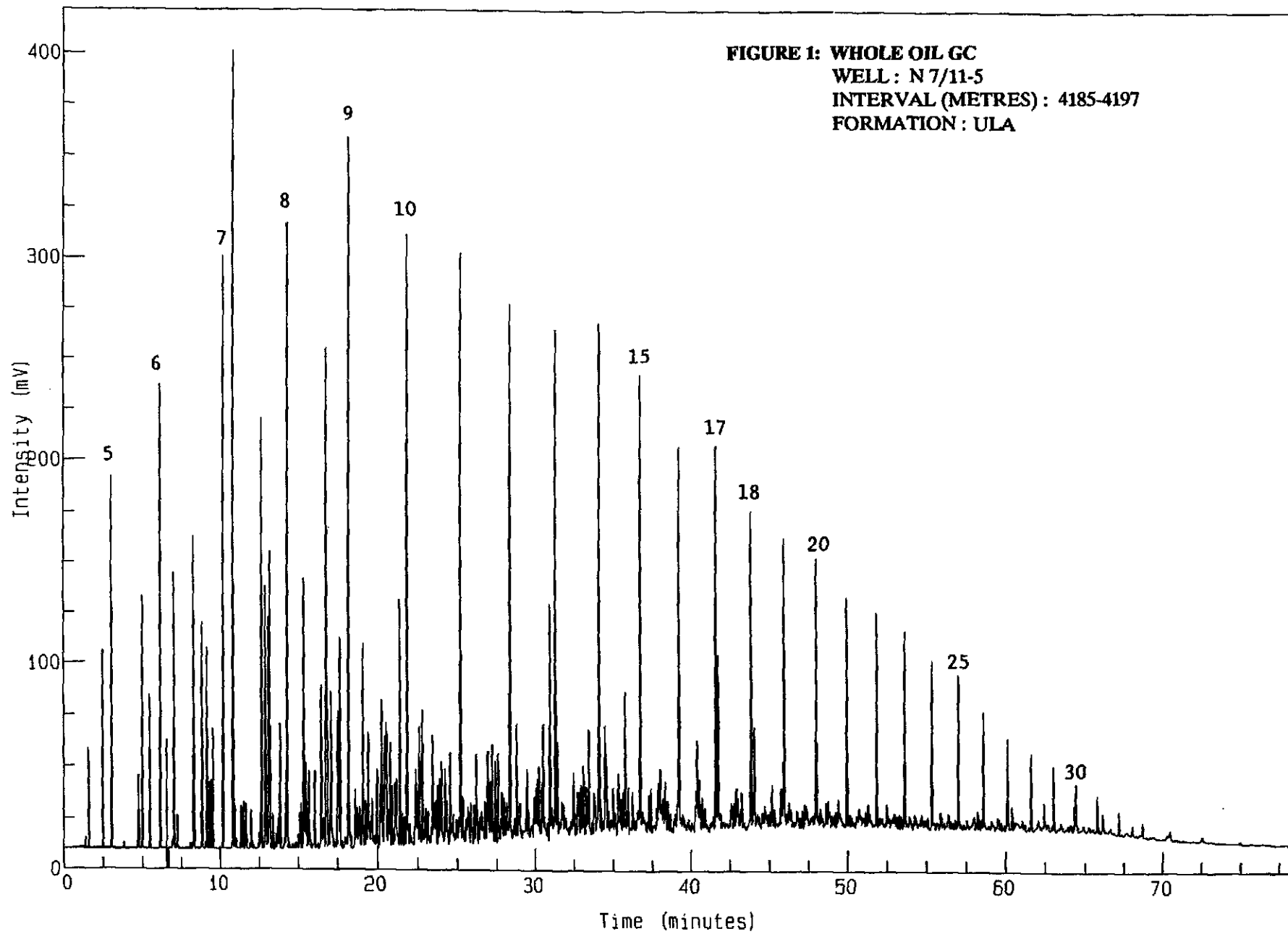


SIMON LABORATORIES

Analysis Name : 7 W94A0002R0, 1, 1.

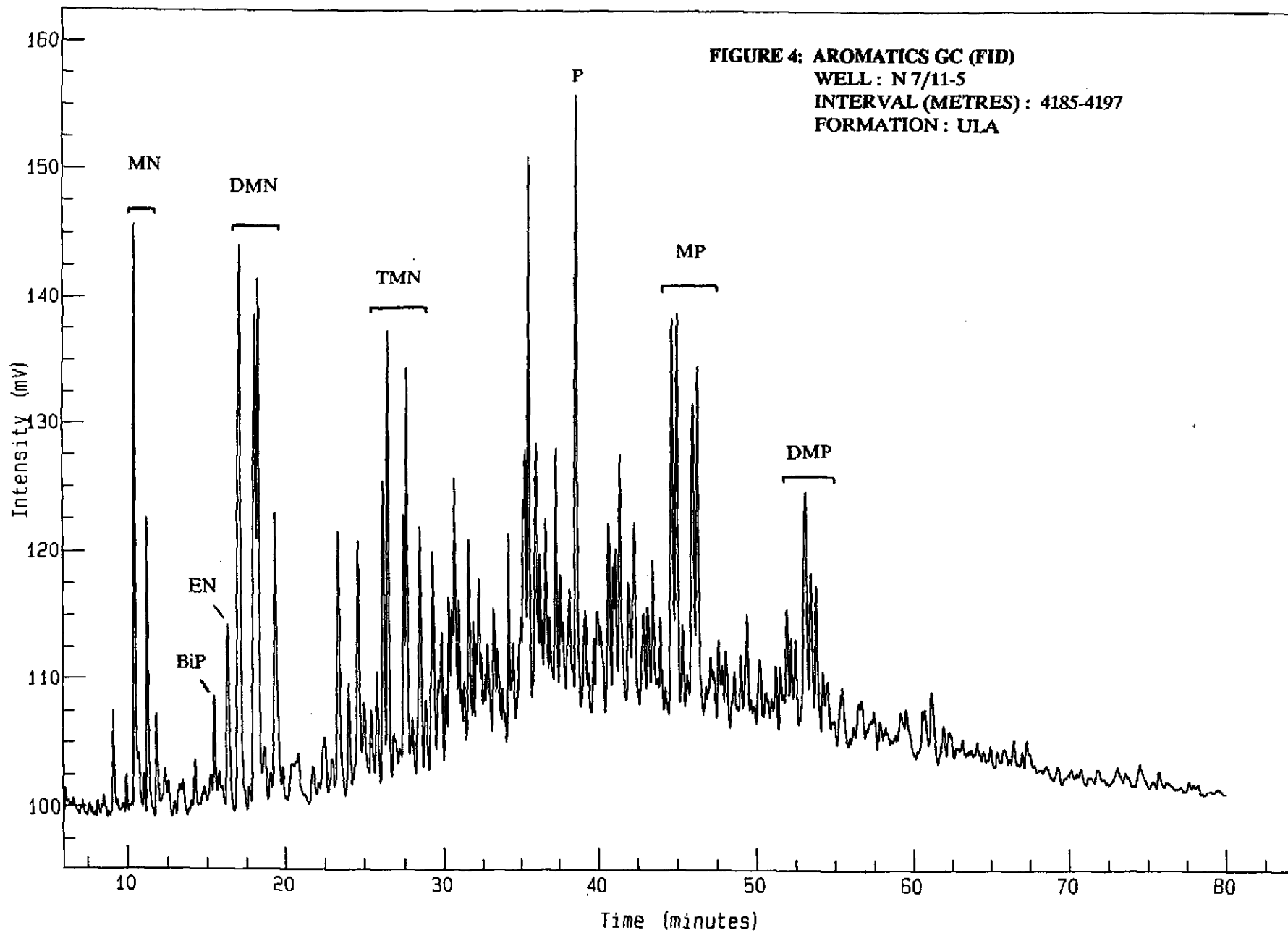
94A 2 PHILLIPS 7/11-5 Amount : 1.000

Whole Oil Gas Chromatography



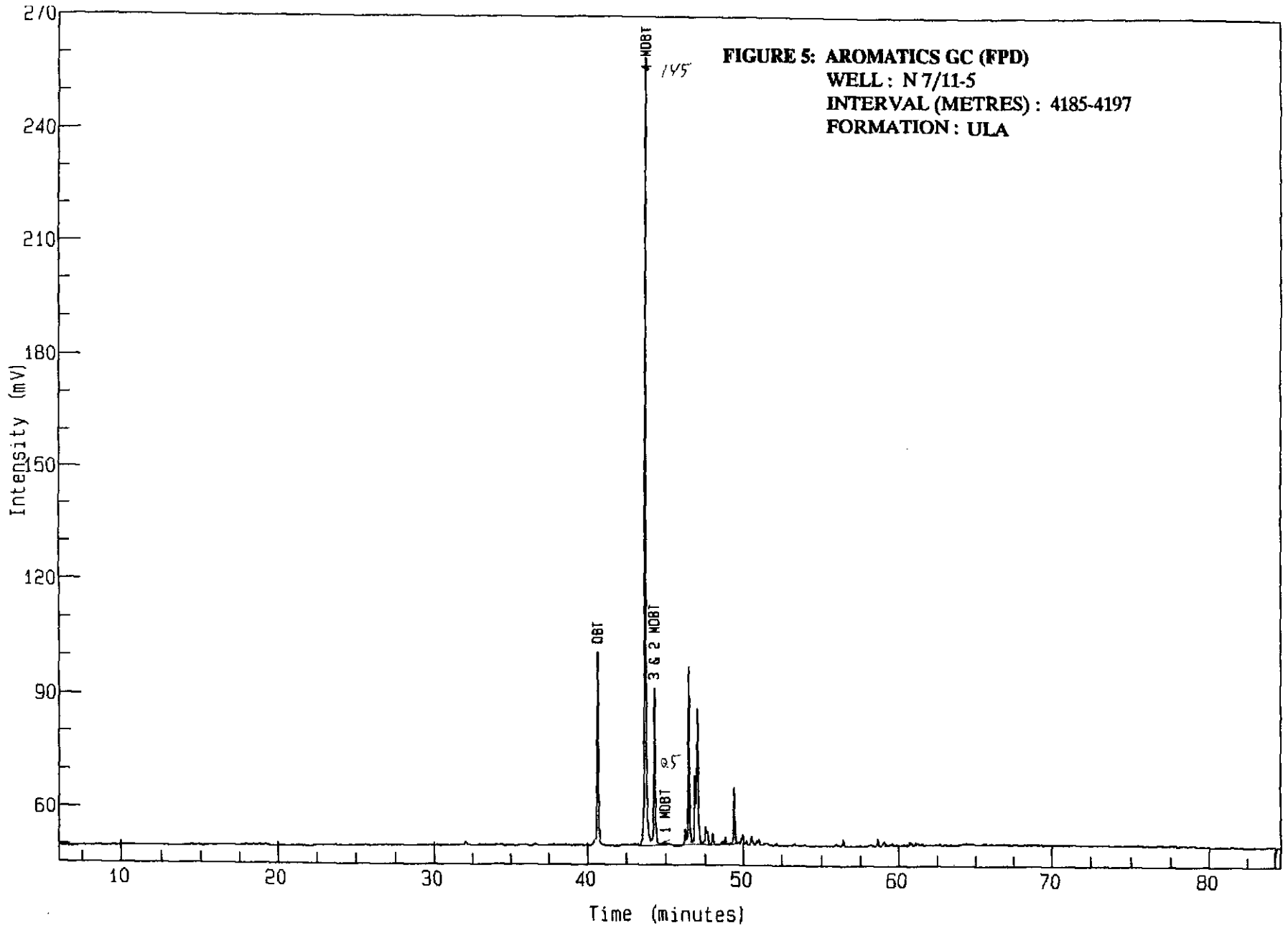
SIMON LABORATORIES

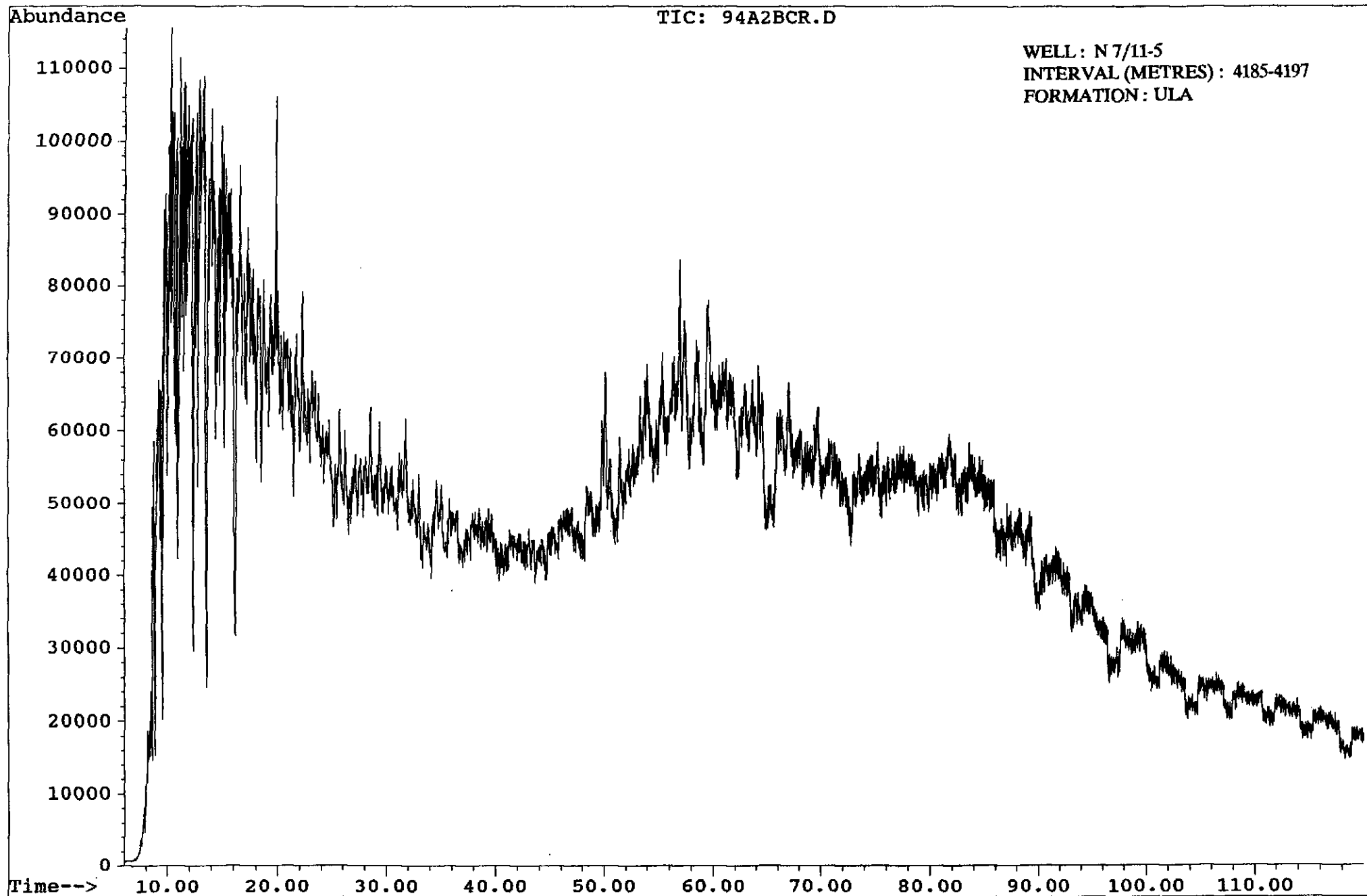
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S4A 2 PHILLIPS 7/11-5 Amount : 1.000
AROMATIC GC



SIMON LABORATORIES

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94A2 PHILLIPS OILS Amount : 1.000
AROMATIC GC

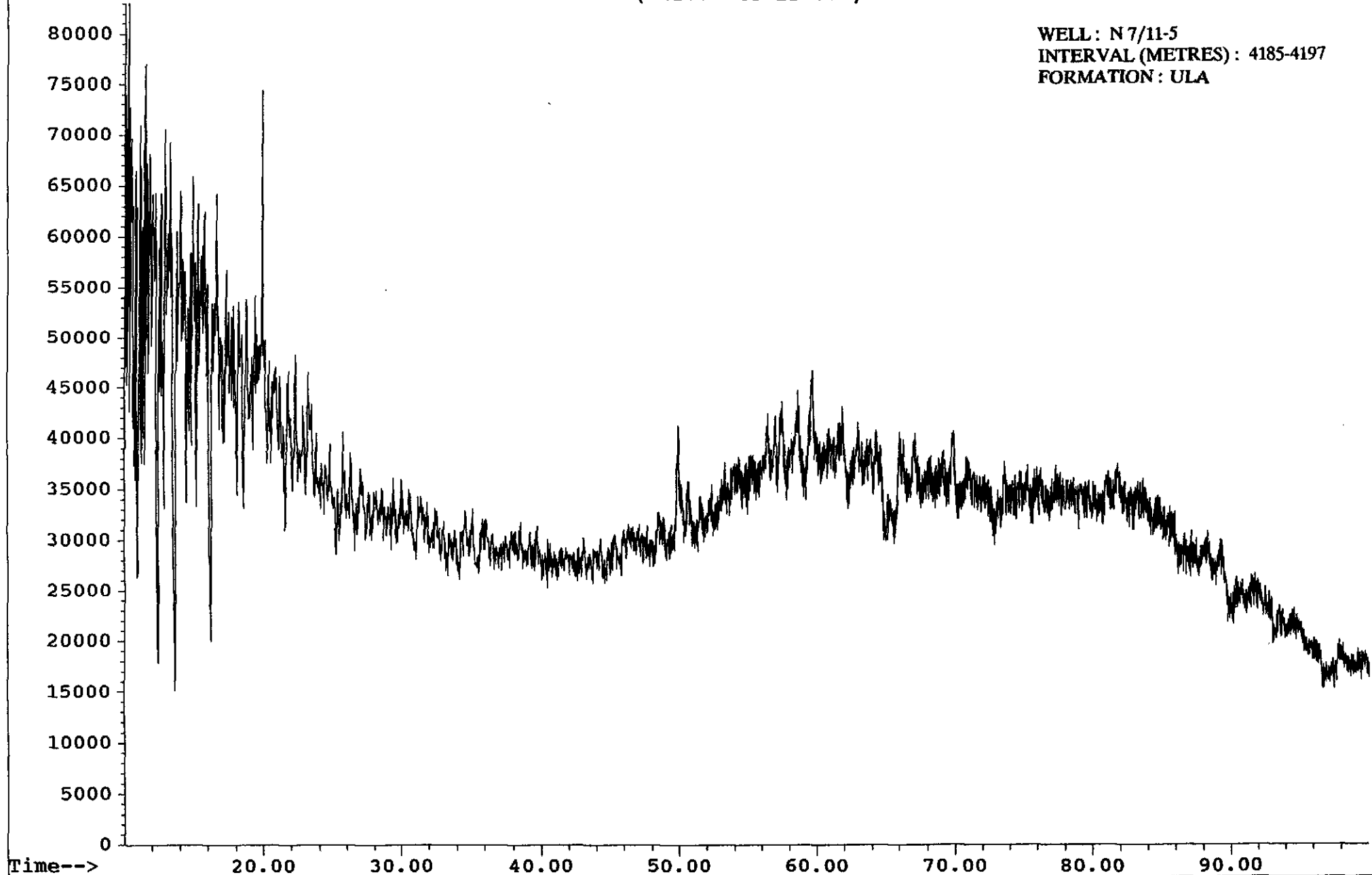




Abundance

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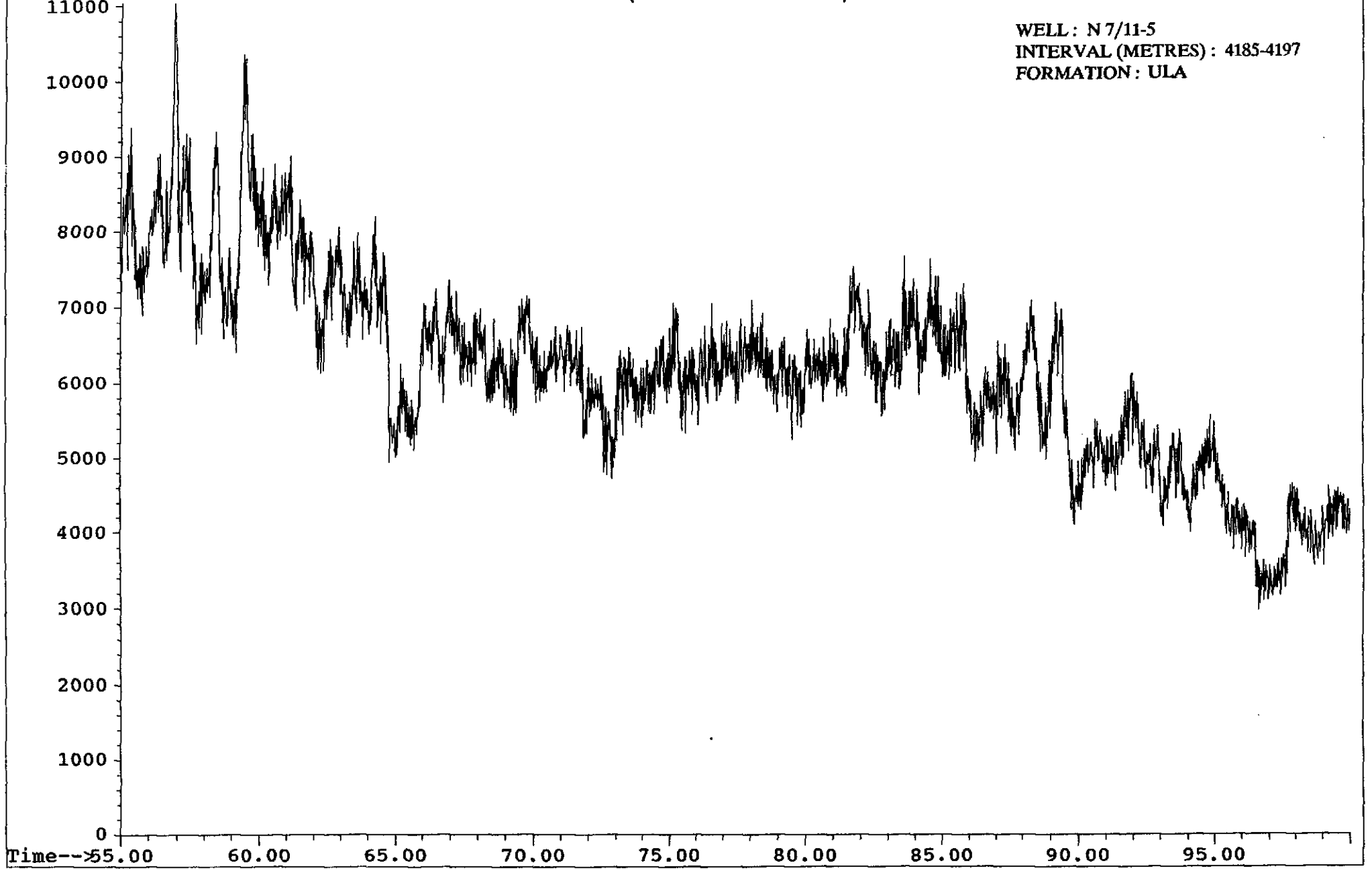
WELL: N7/11-5
INTERVAL (METRES): 4185-4197
FORMATION: ULA

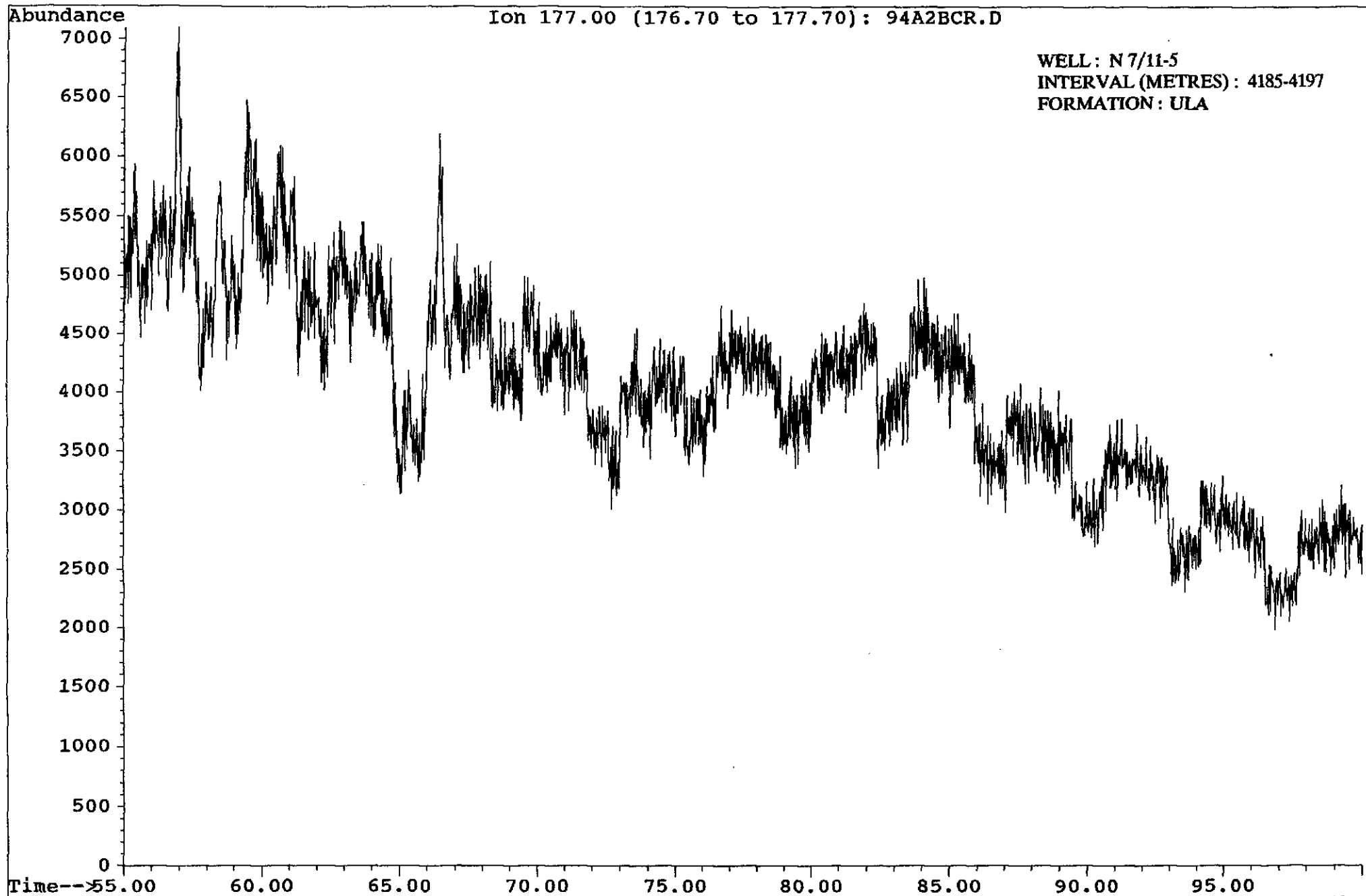


Abundance

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WELL : N7/11-5
INTERVAL (METRES) : 4185-4197
FORMATION : ULA

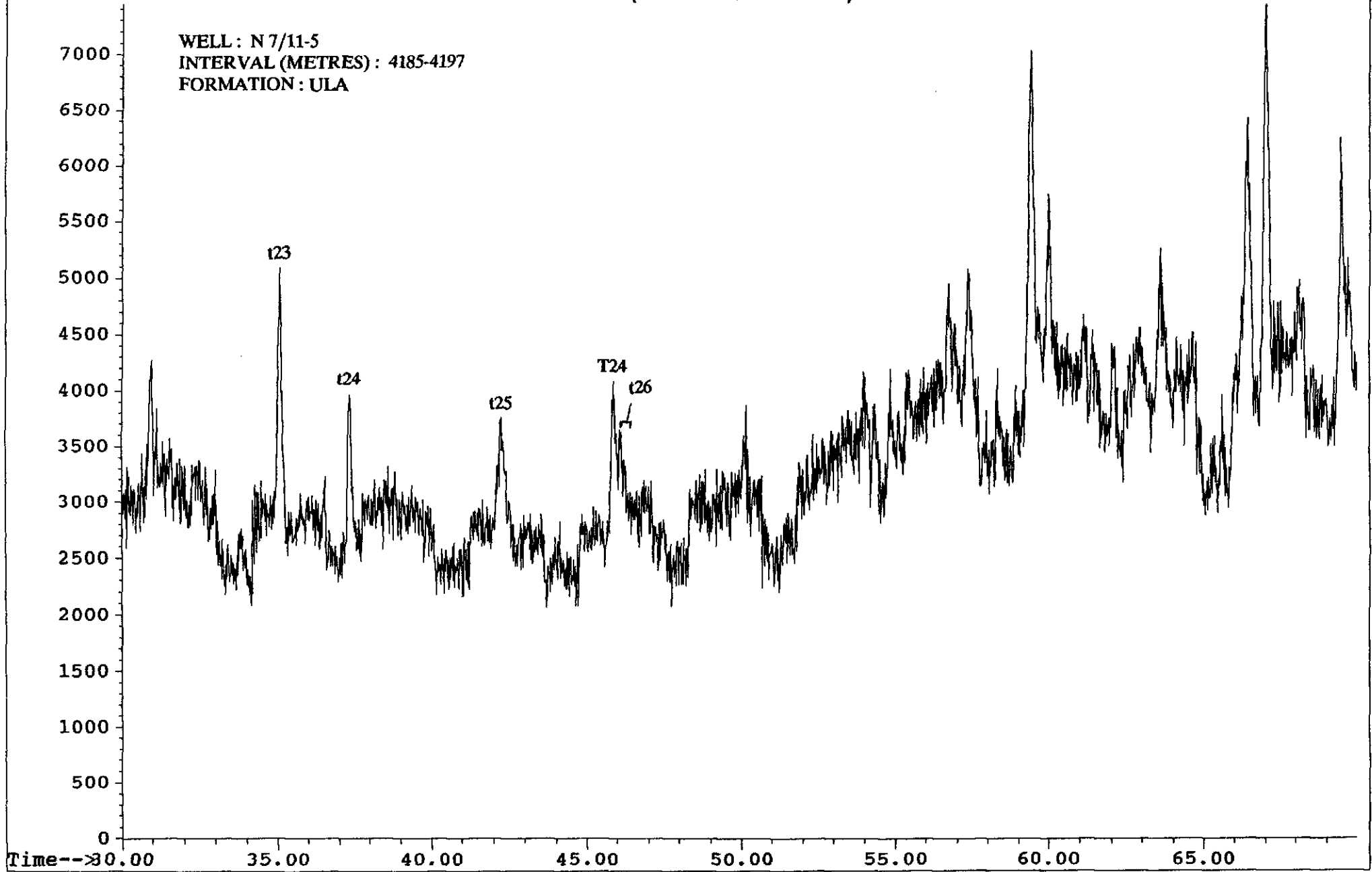




Abundance

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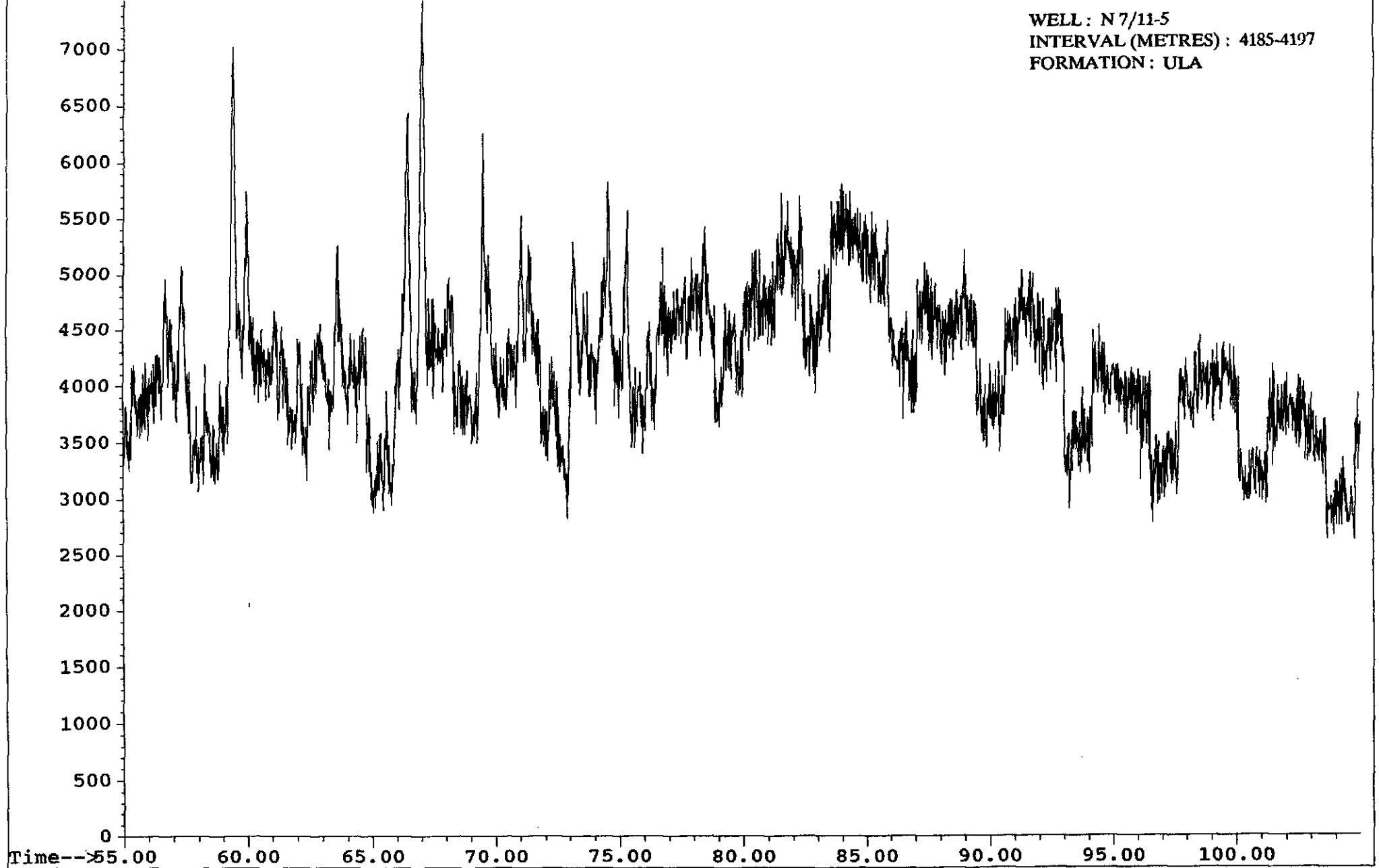
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INTERVAL (METRES) : 4185-4197
FORMATION : ULA

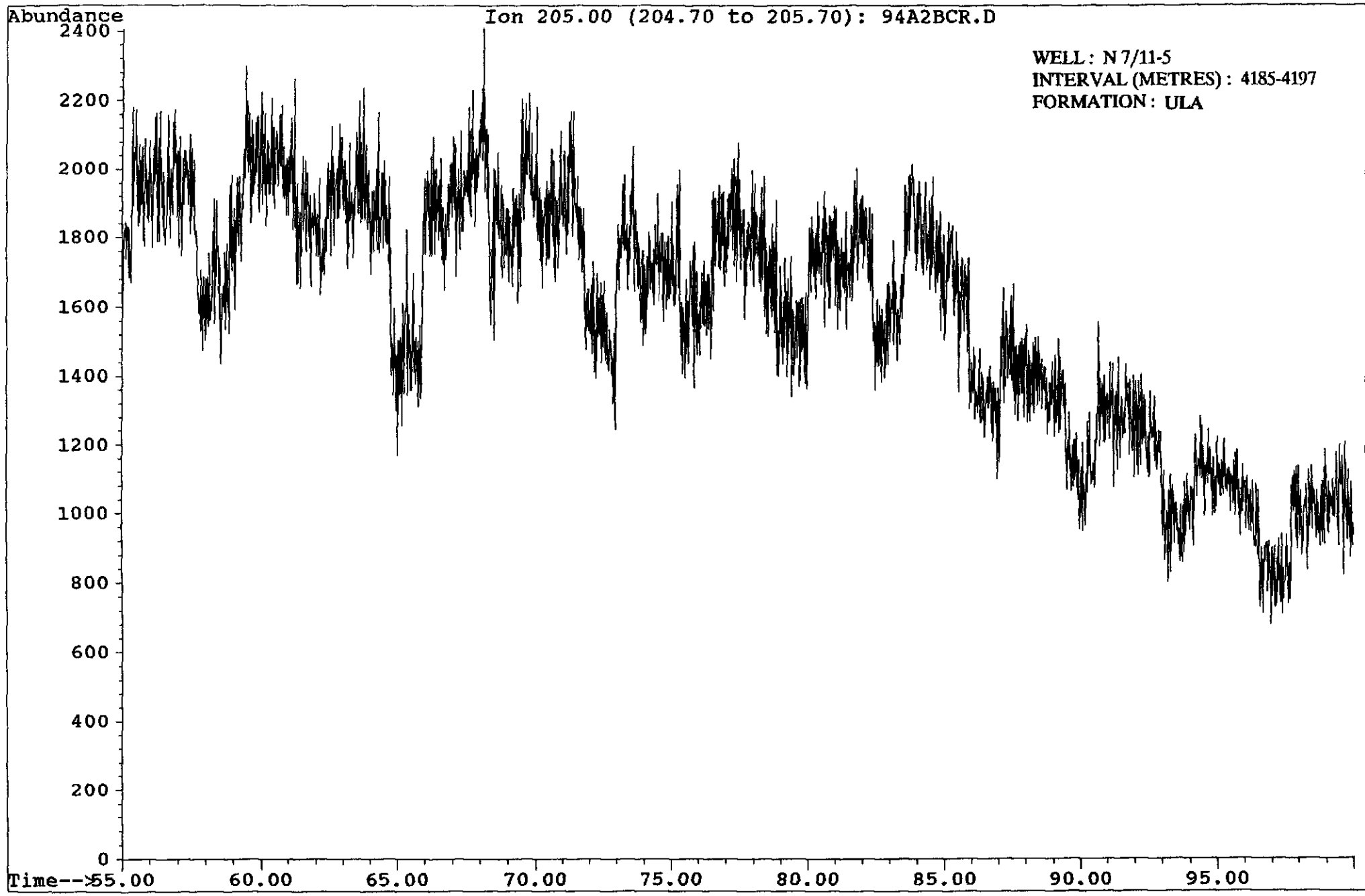


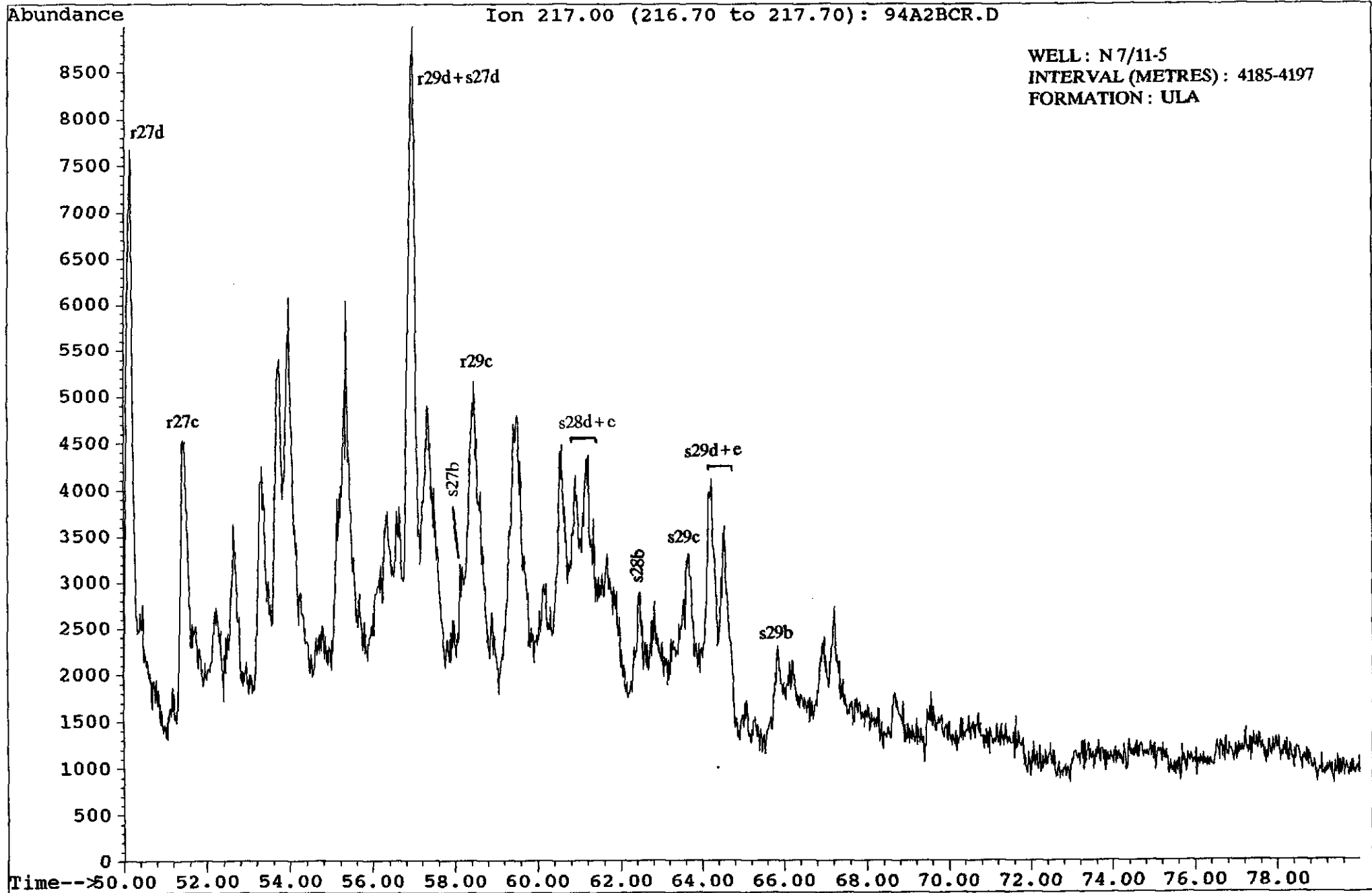
Abundance

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WELL: N7/11-5
INTERVAL (METRES): 4185-4197
FORMATION: ULA



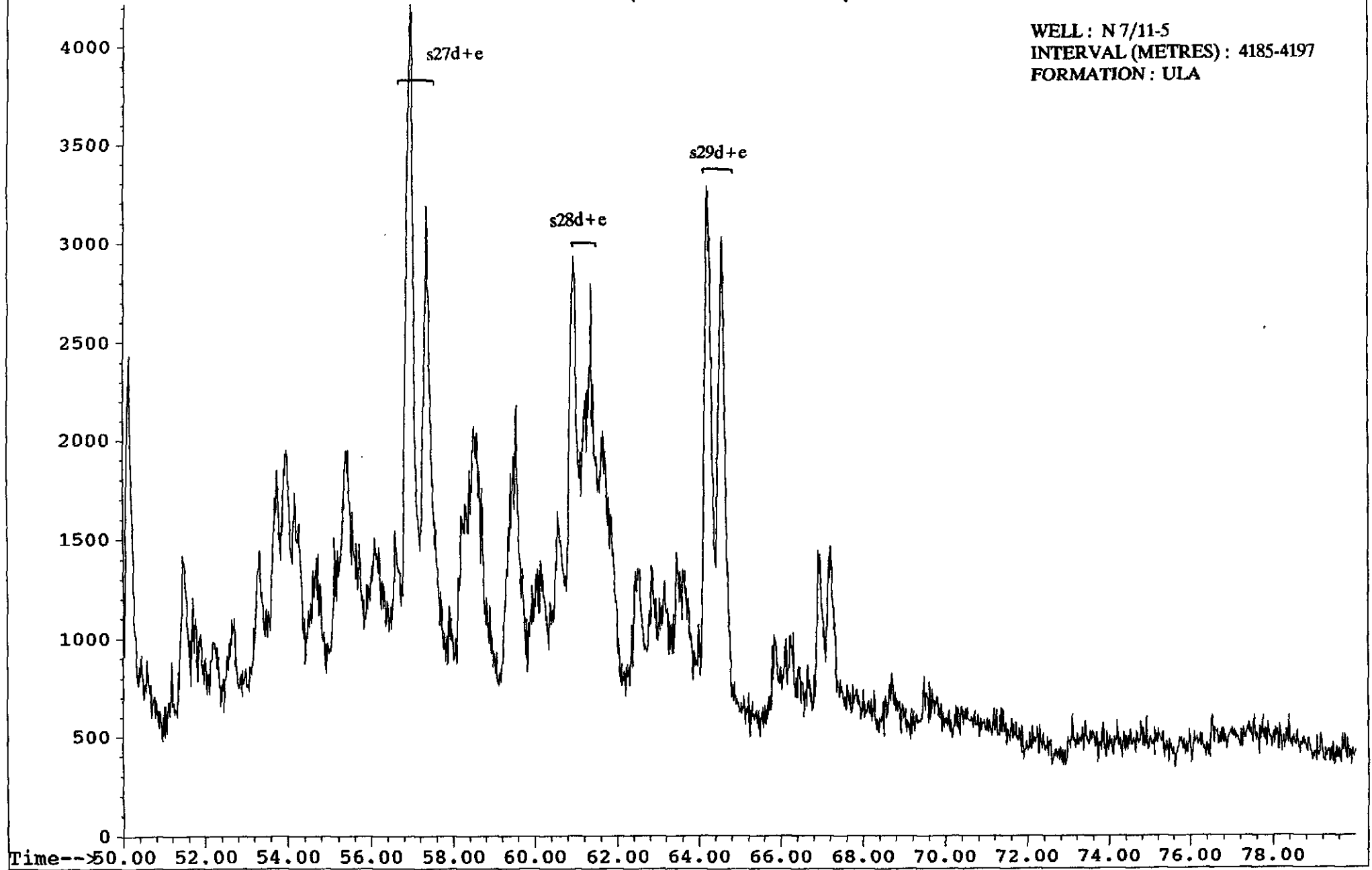


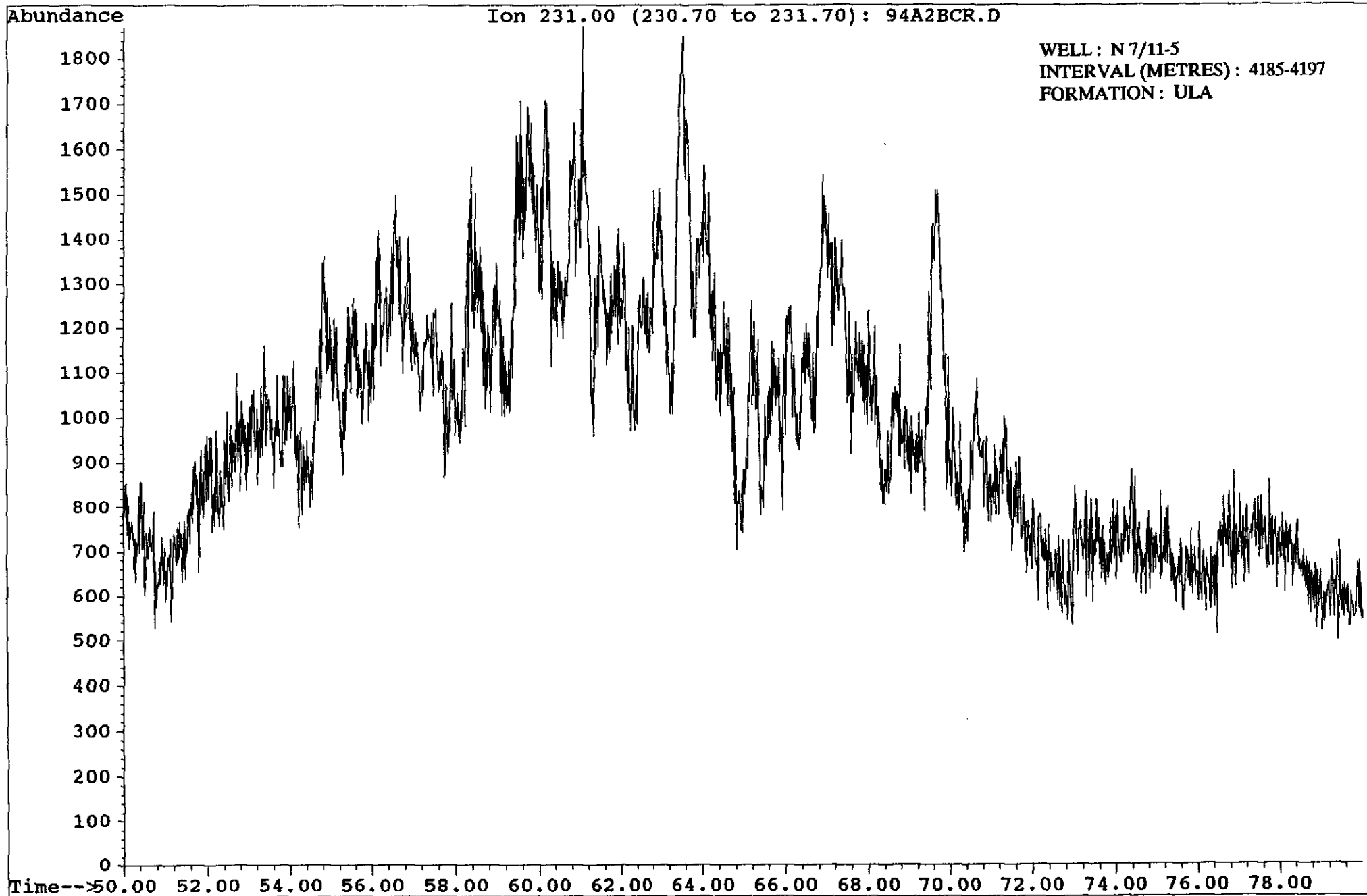


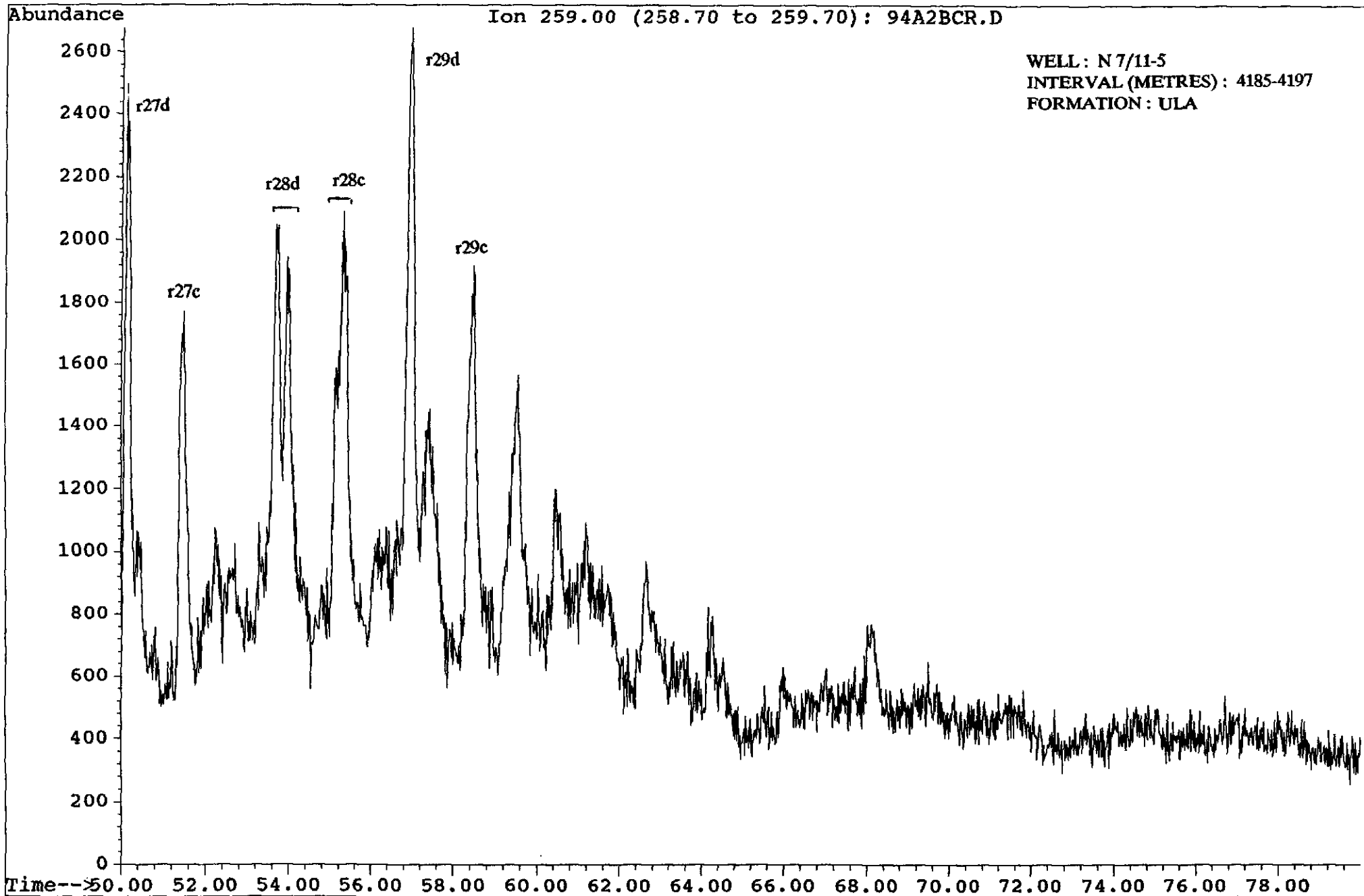
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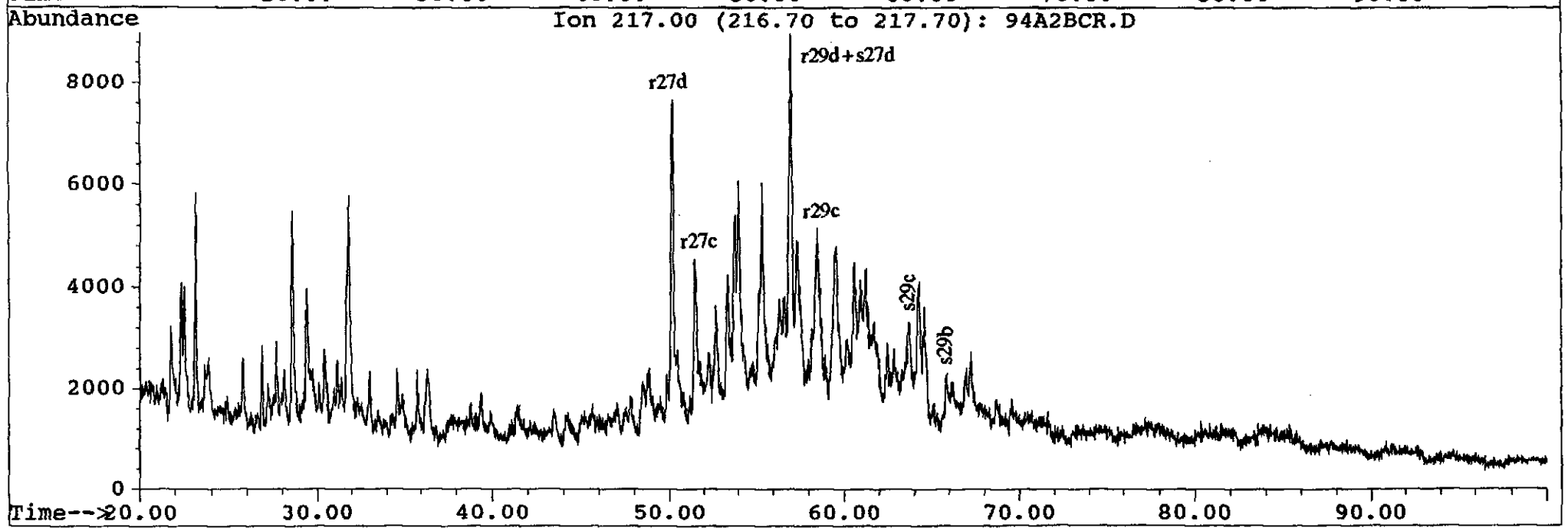
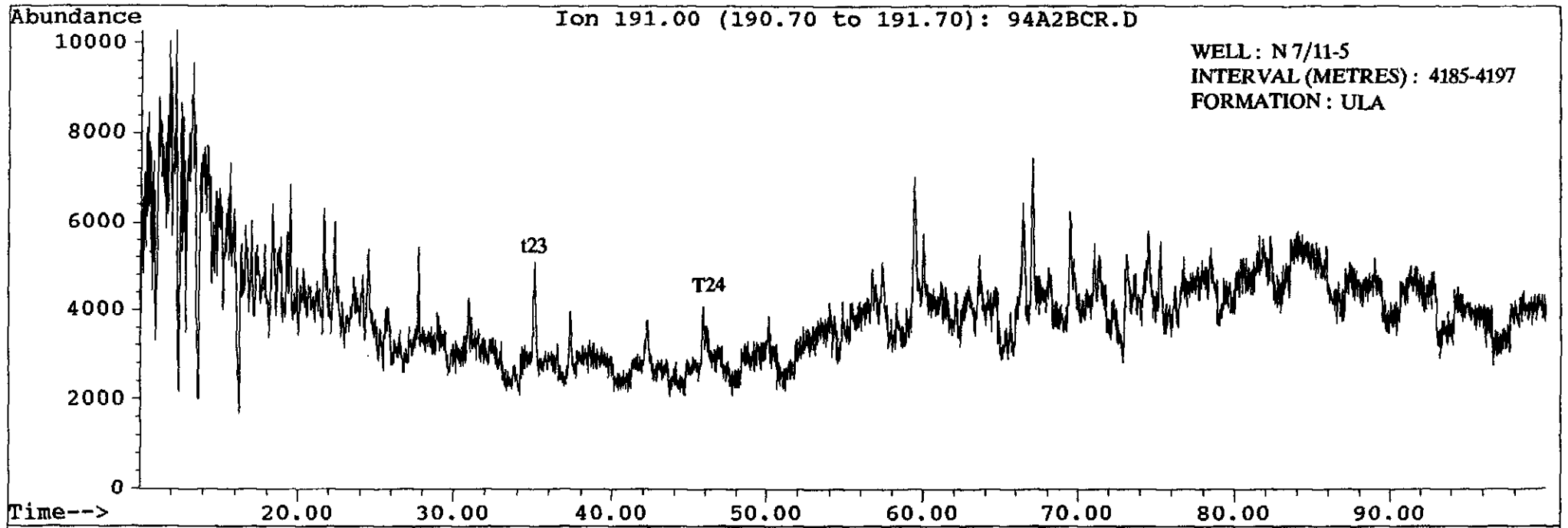
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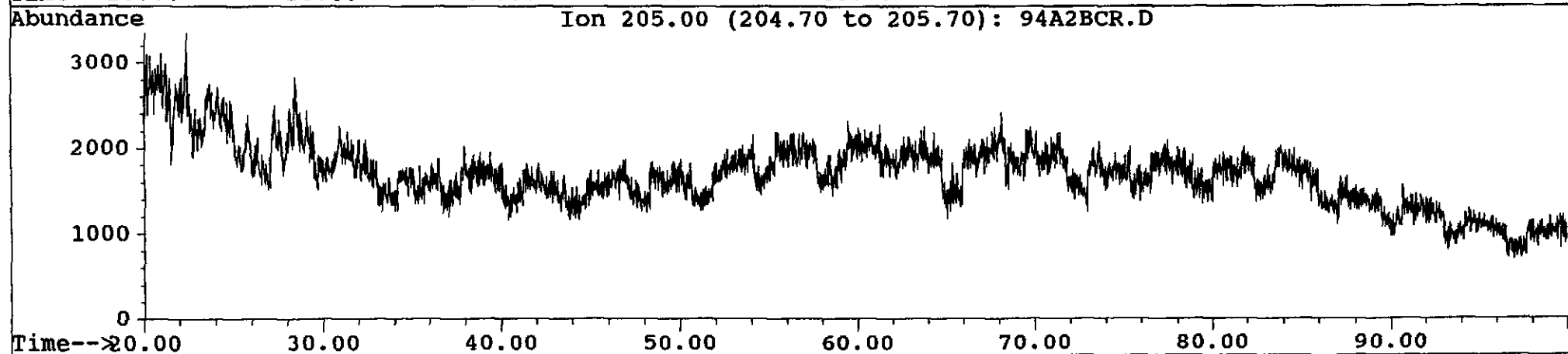
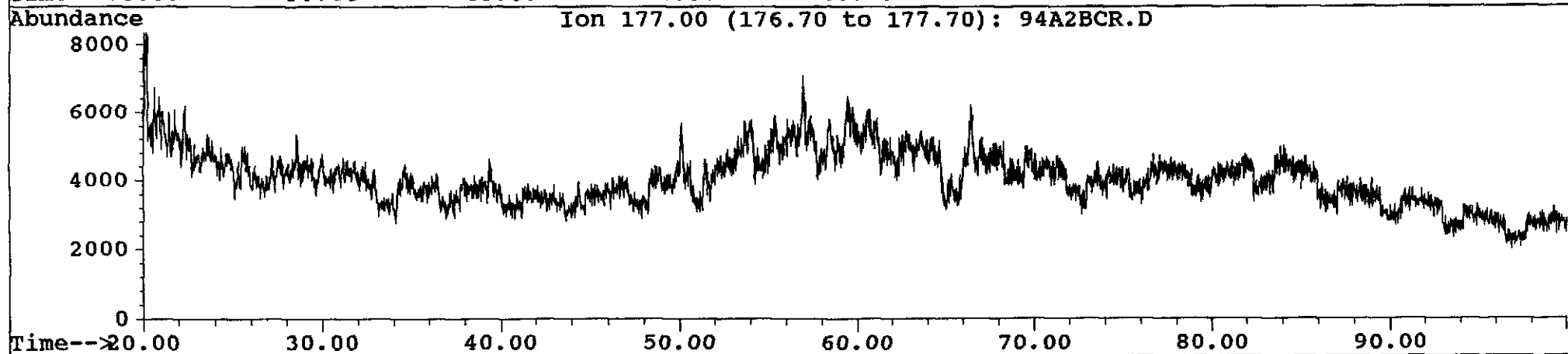
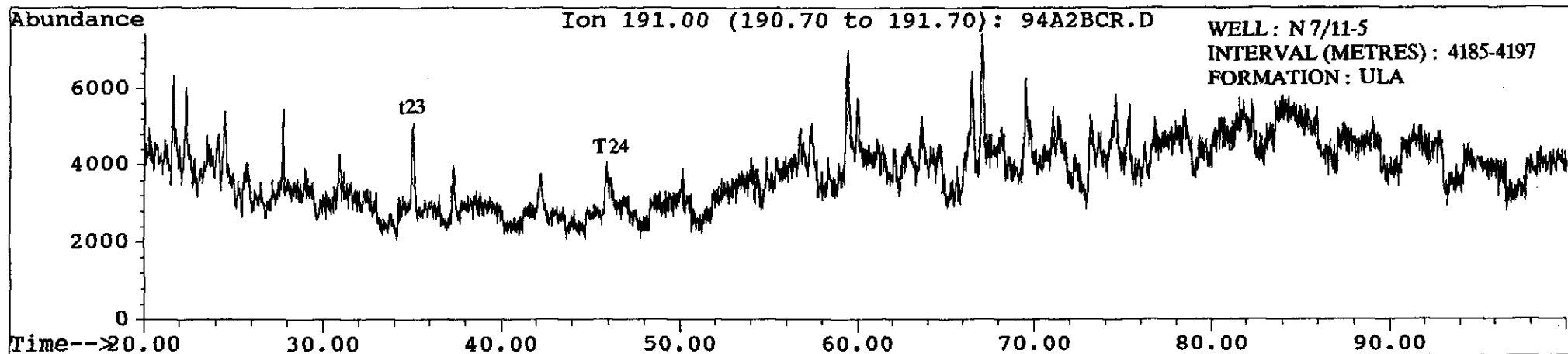
WELL: N 7/11-5
INTERVAL (METRES): 4185-4197
FORMATION: ULA







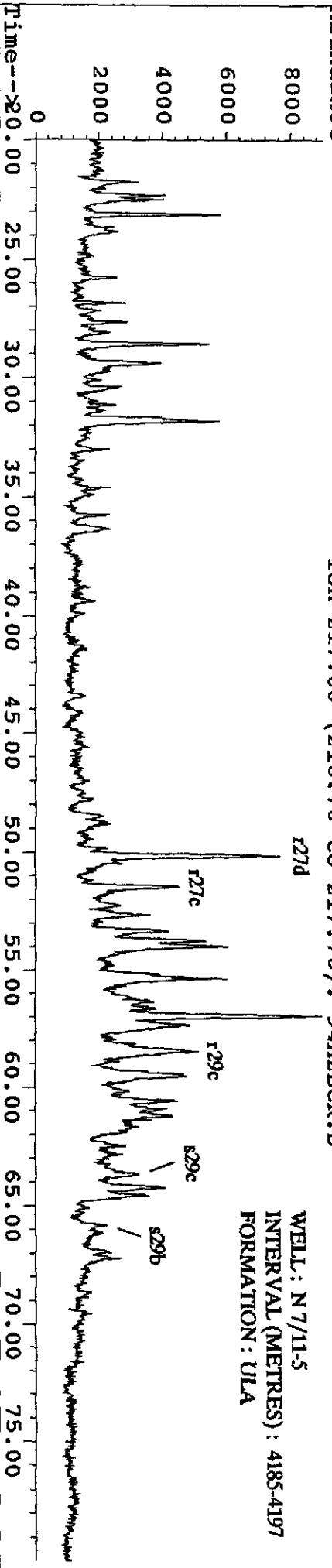




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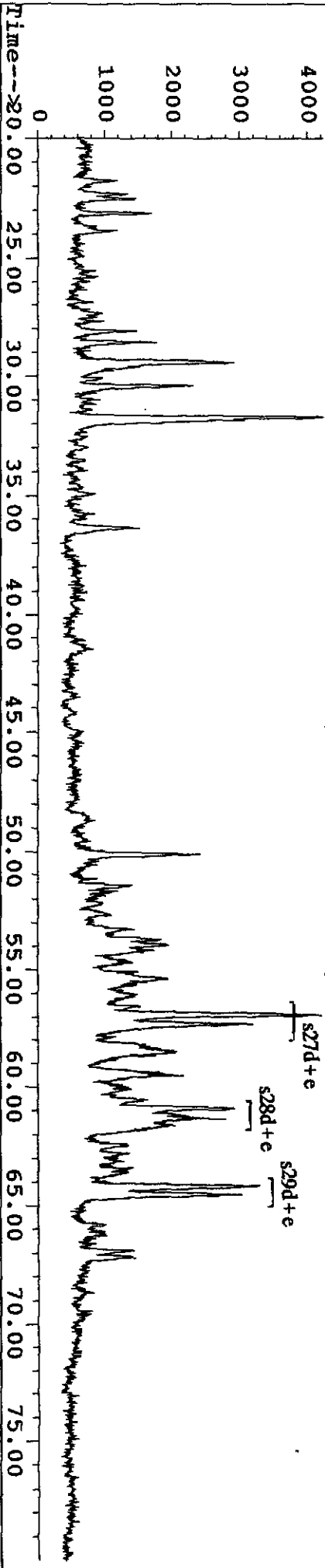
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WELL: N7/11-5
INTERVAL (METRES): 4185-4197
FORMATION: U1A



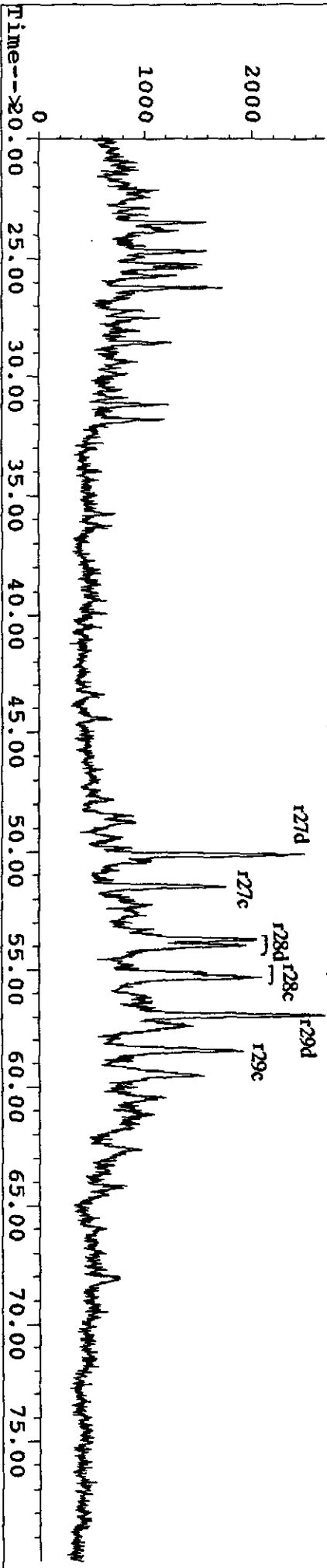
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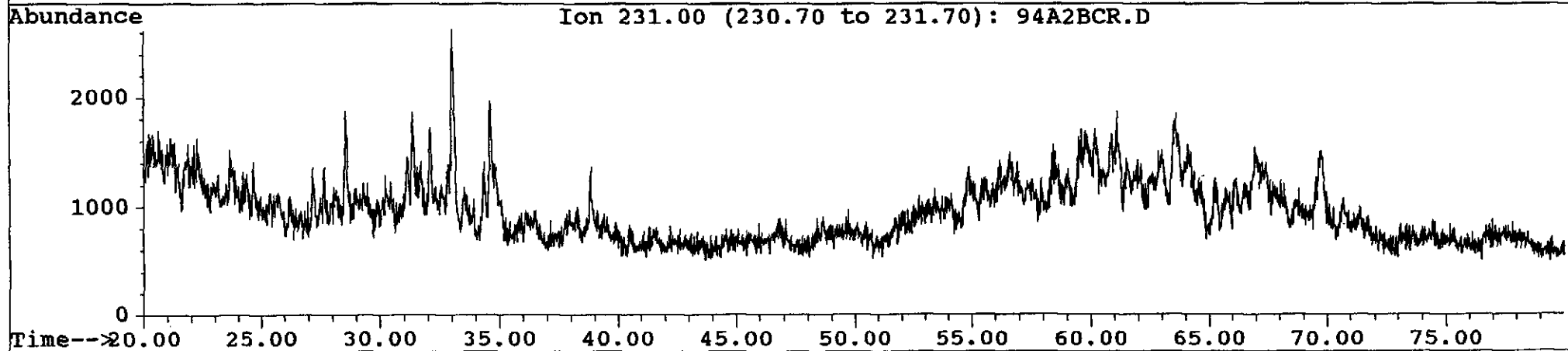
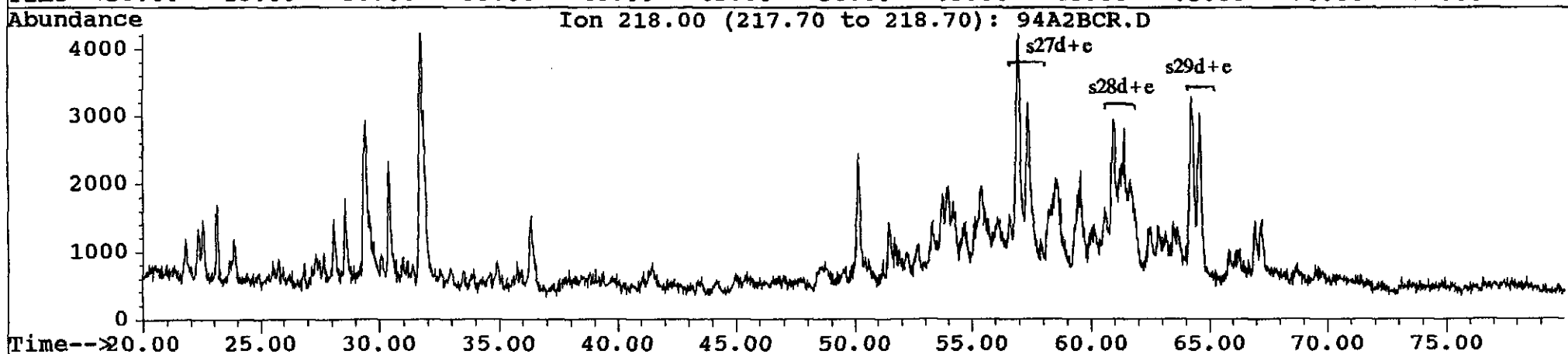
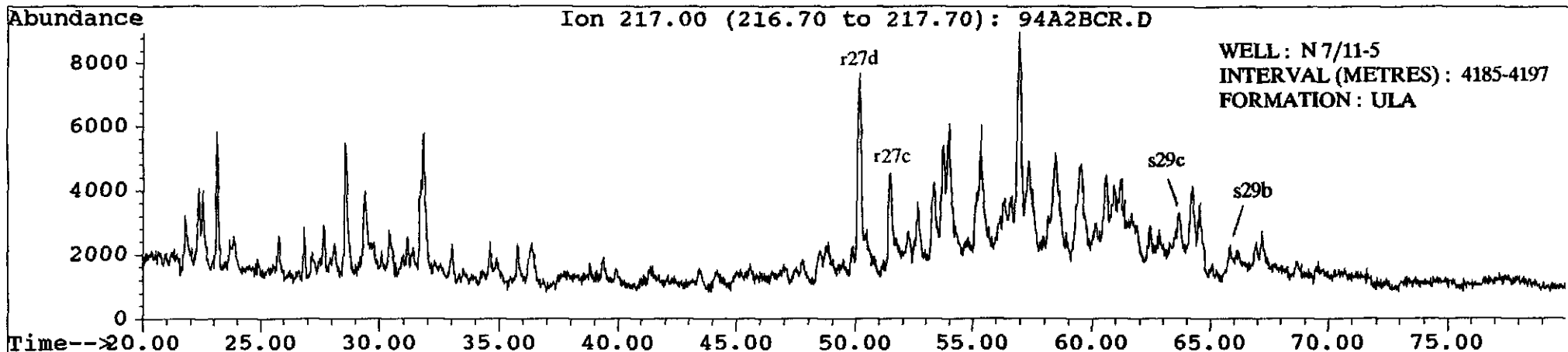
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Abundance

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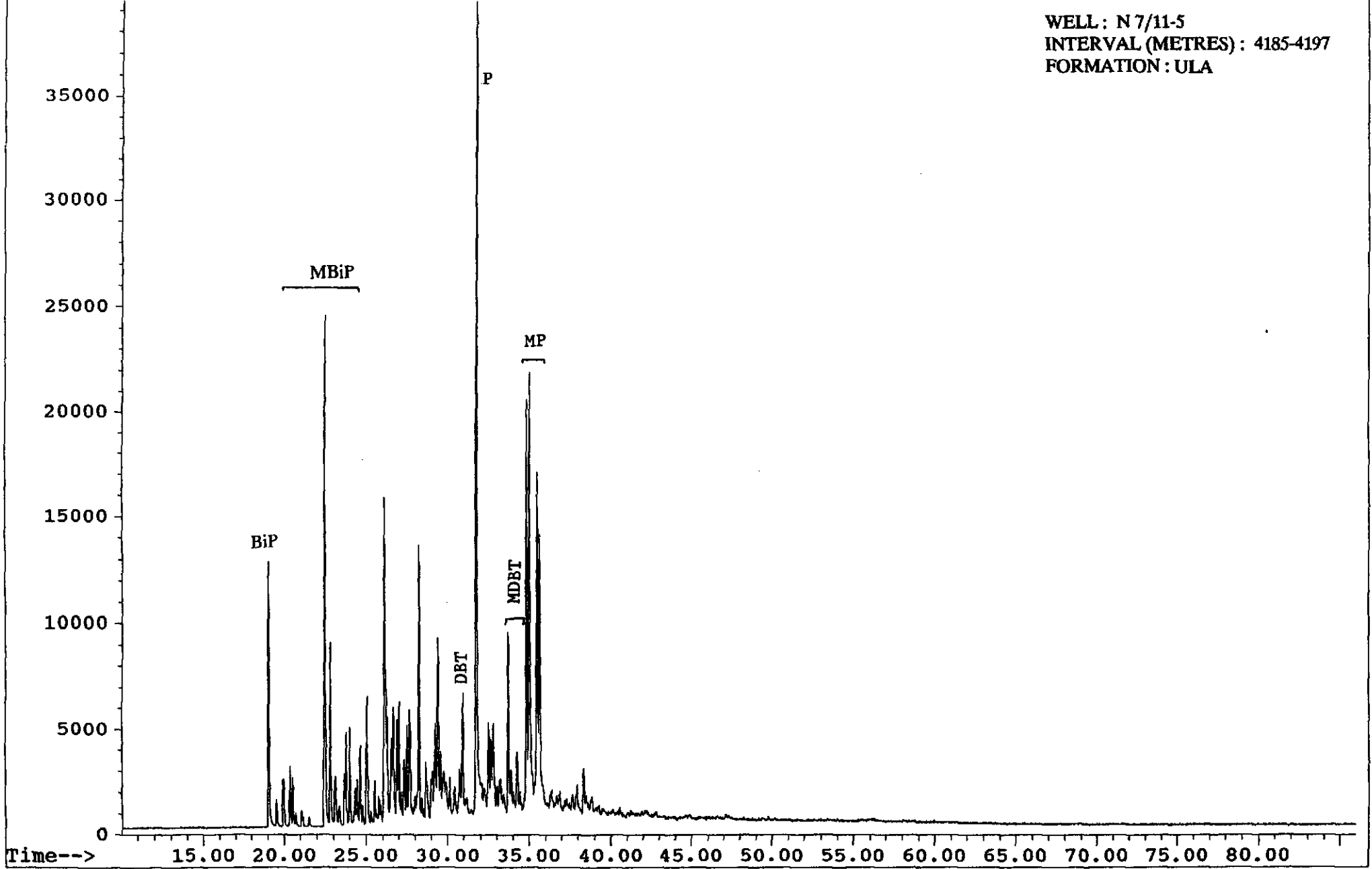


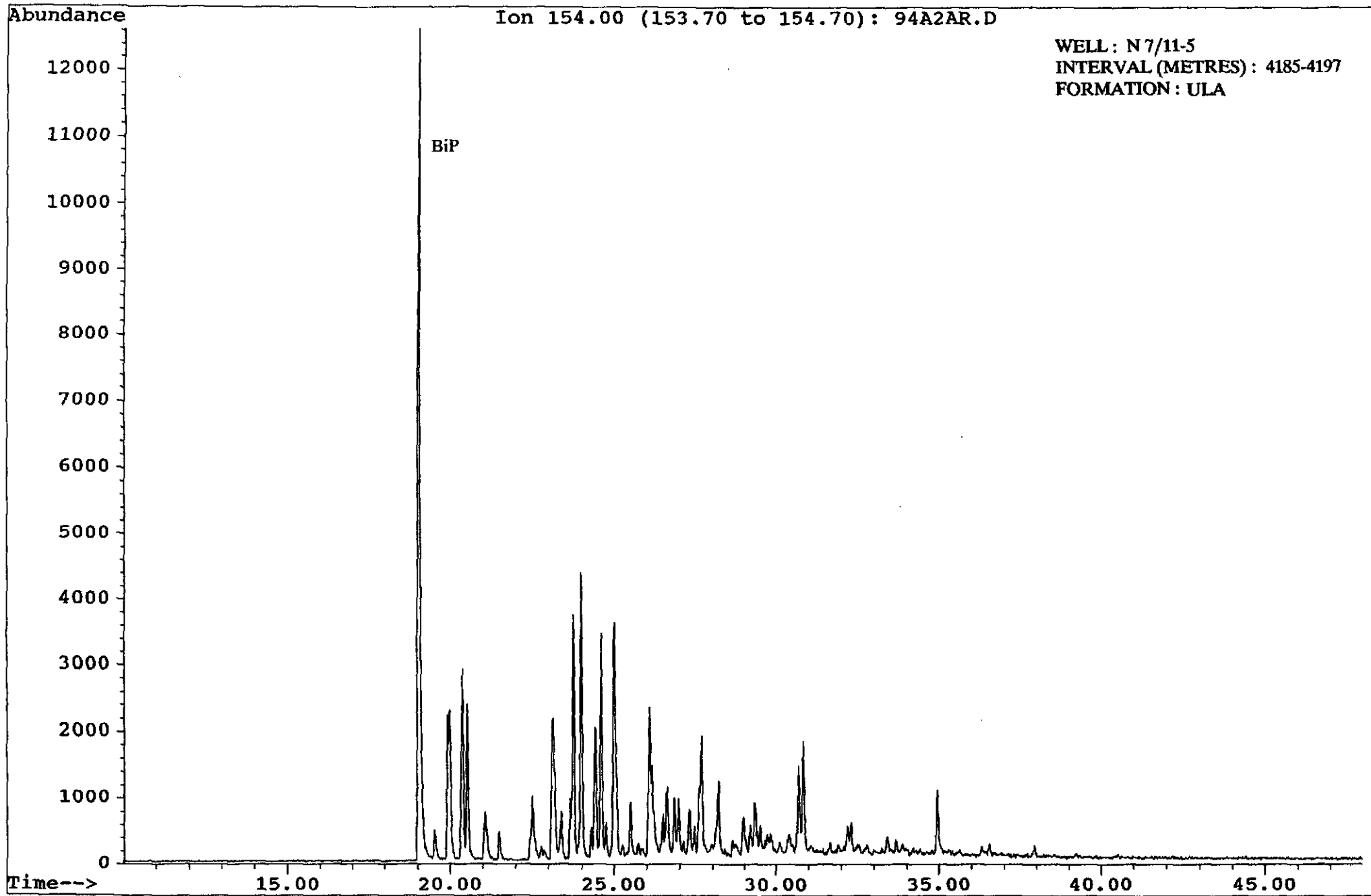


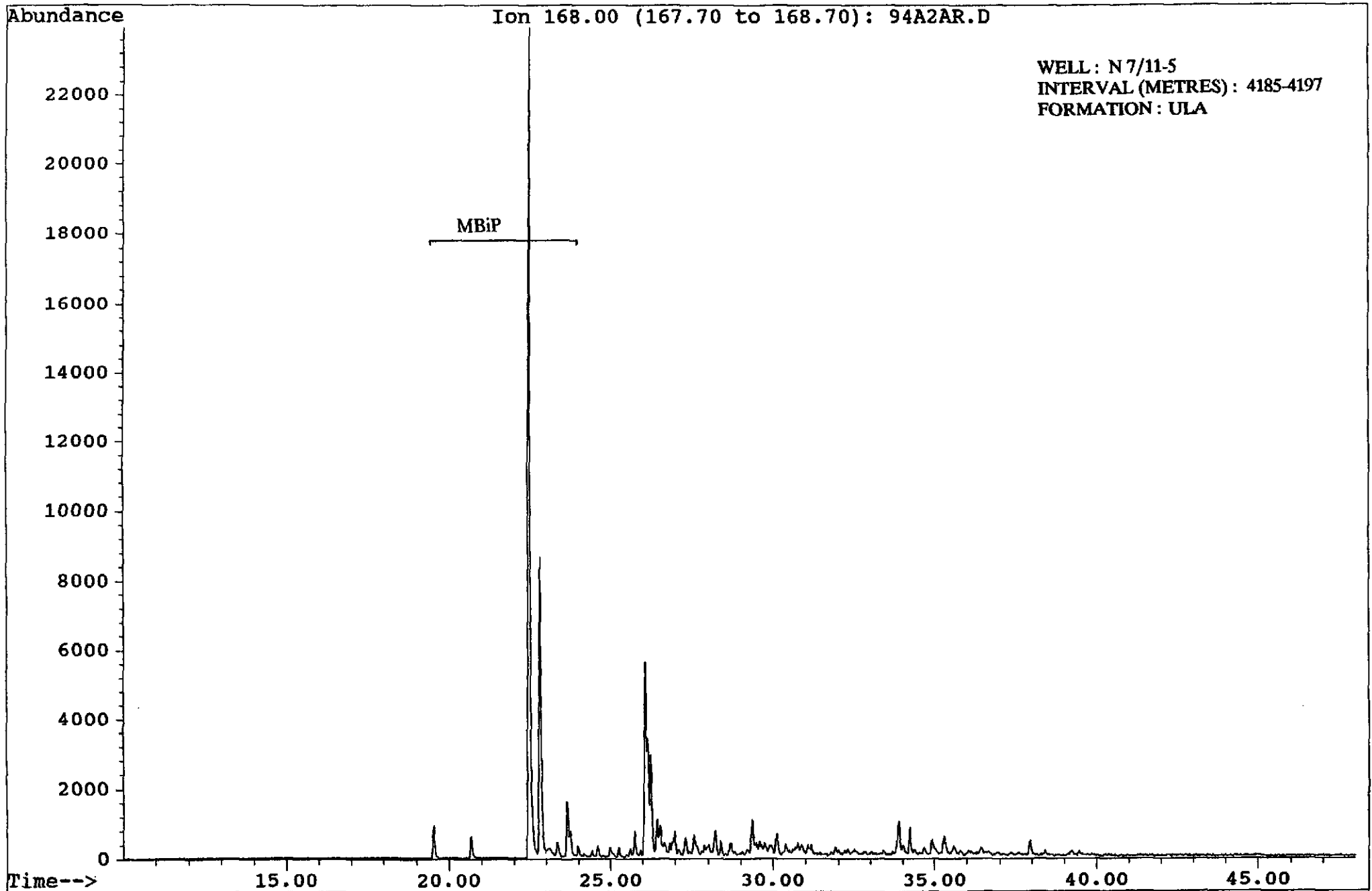
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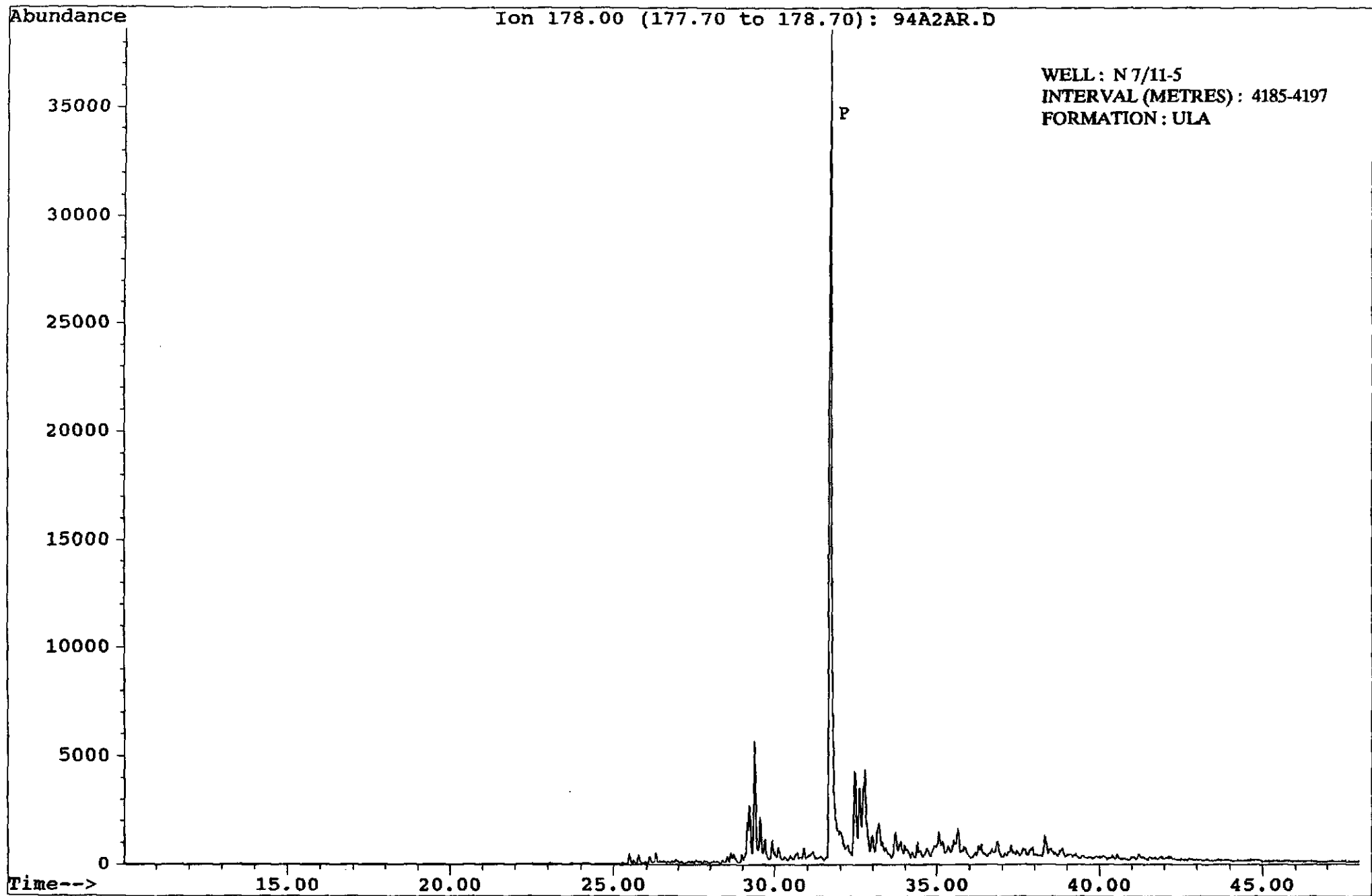
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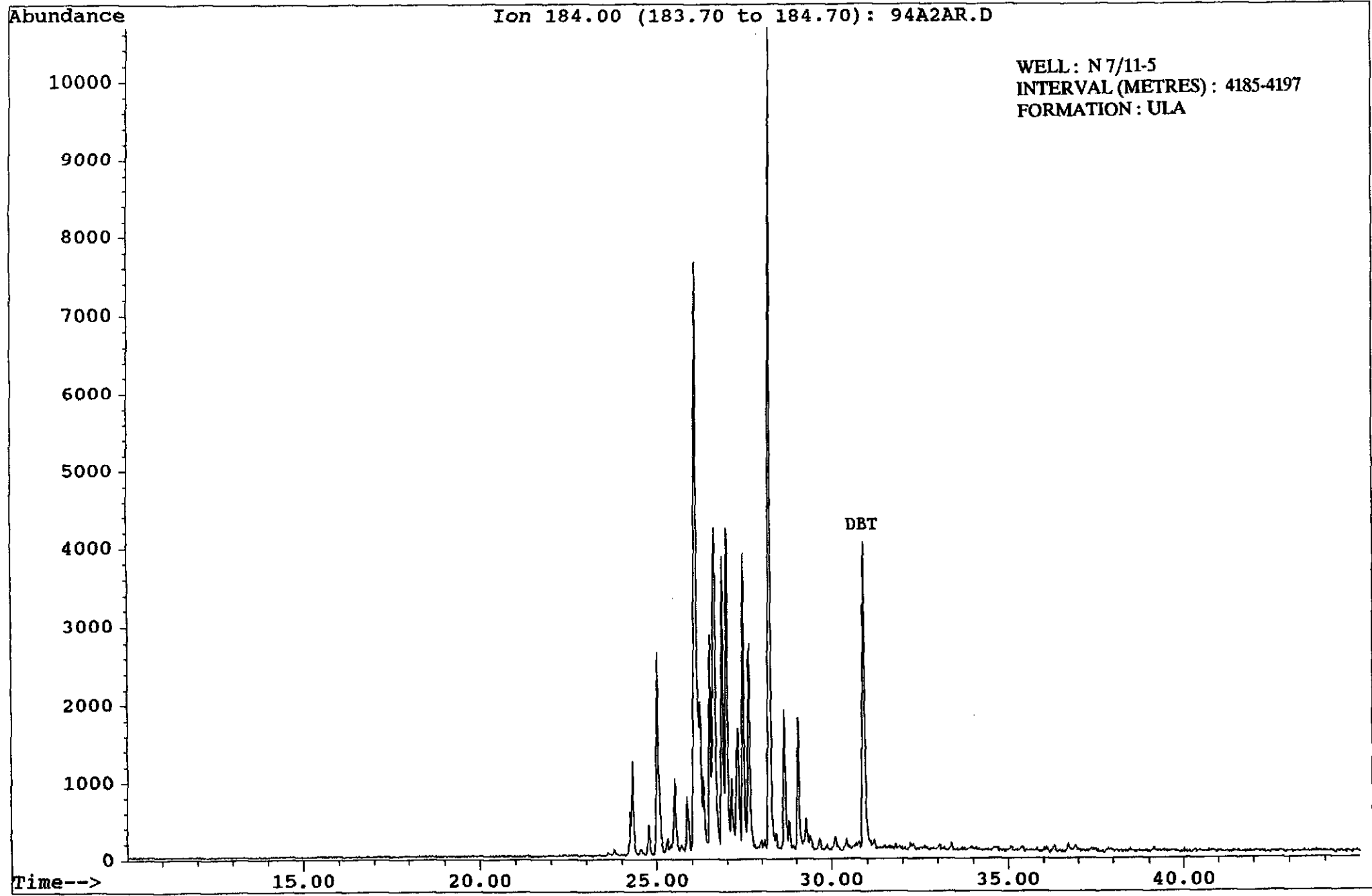
WELL: N 7/11-5
INTERVAL (METRES): 4185-4197
FORMATION: ULA

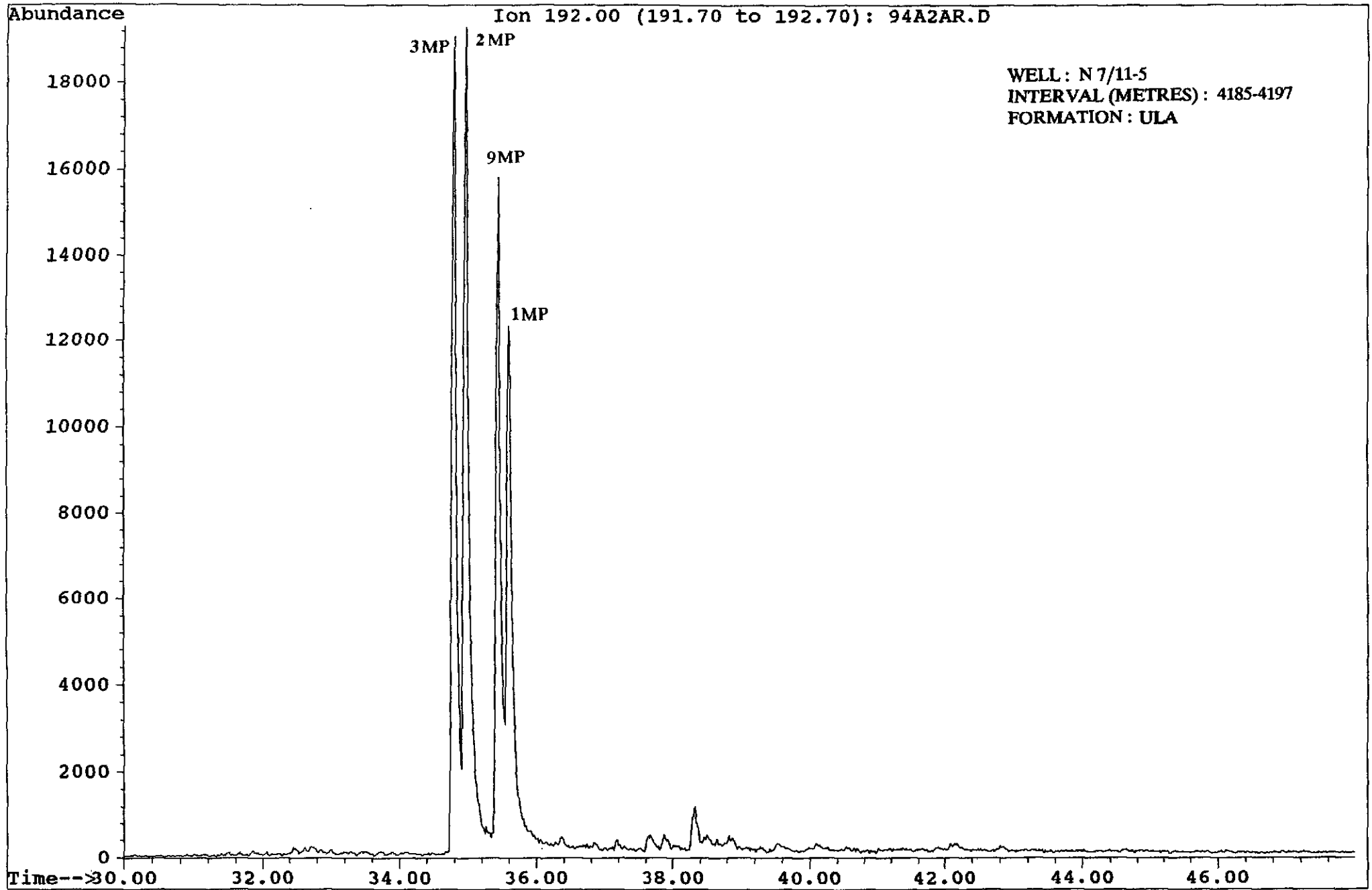


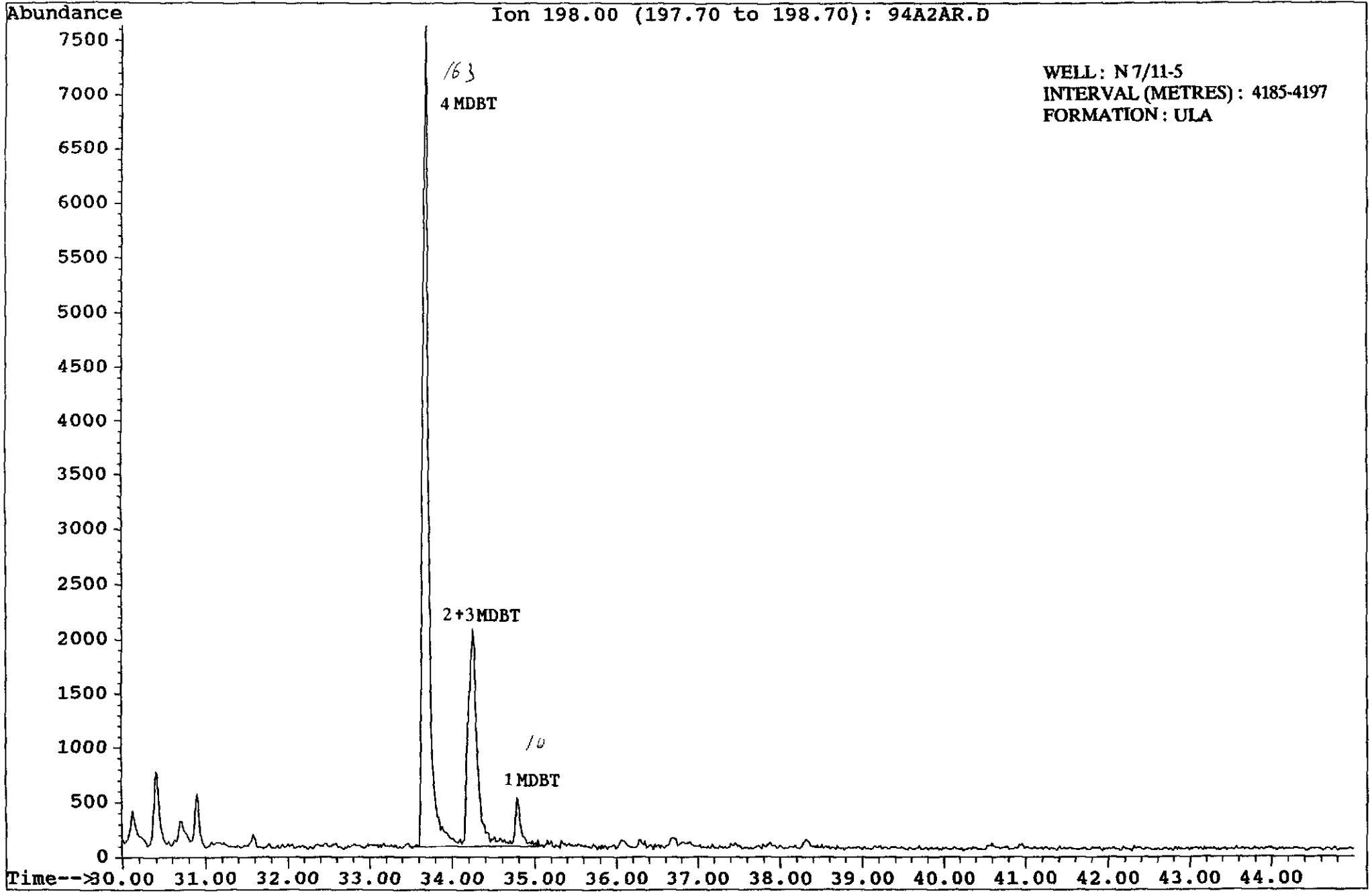


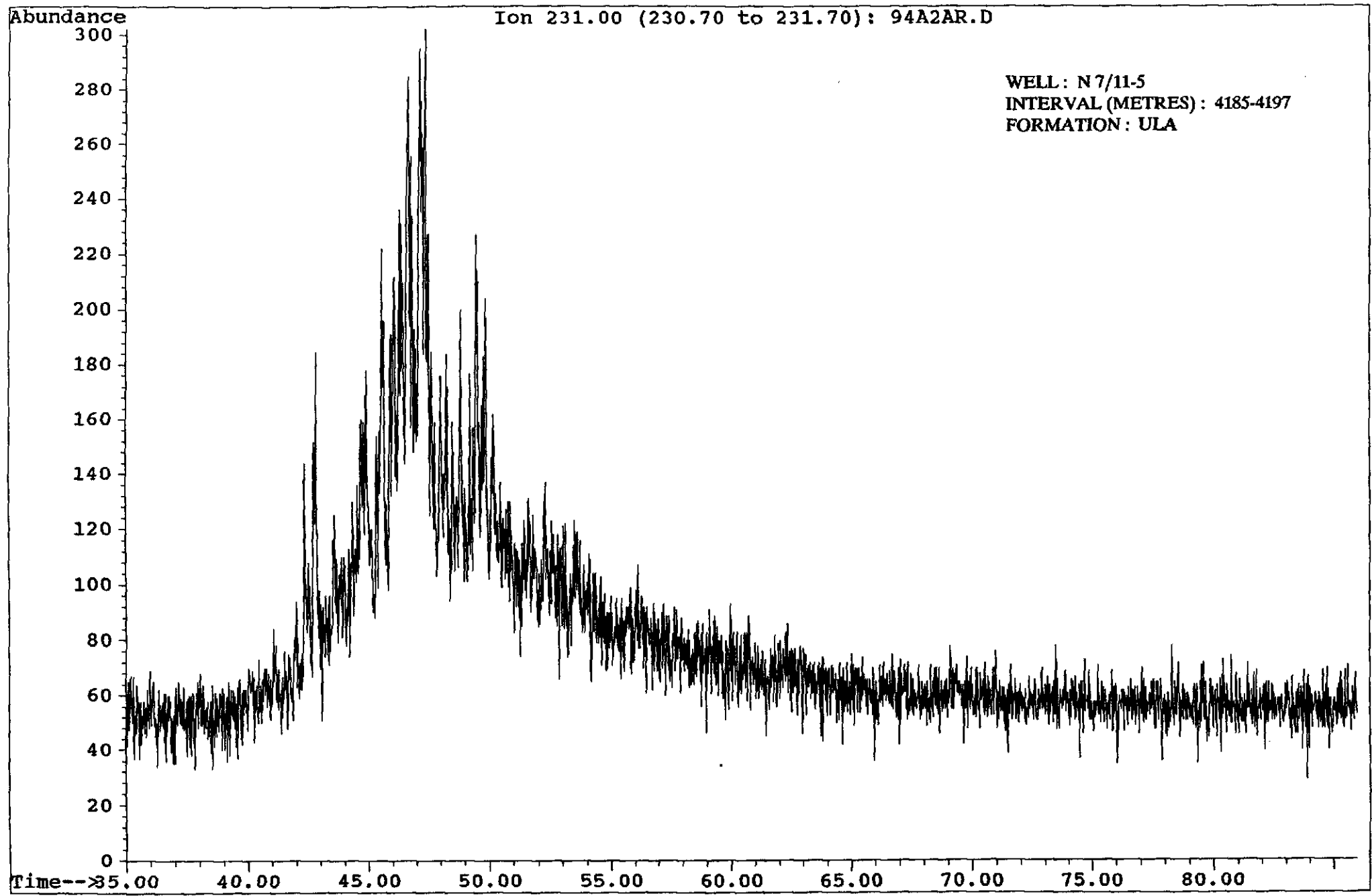


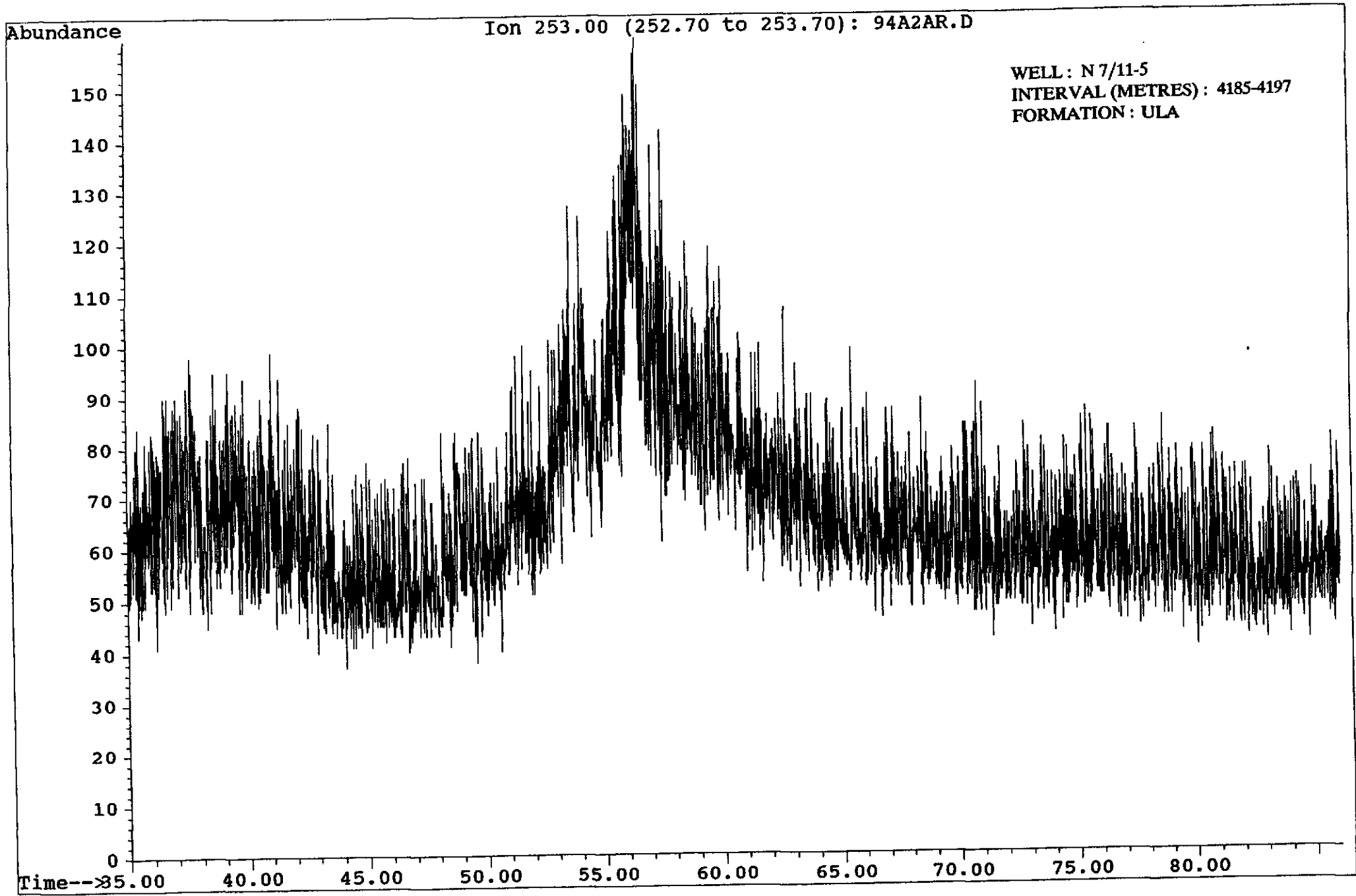












A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7

WELL: N7/11-7
DST: 3
INTERVAL: 14925'-15015'
FORMATION: Smith Bank and Ula

COMPANY: PHILLIPS

WELL: 7/11-7

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA			
SAMPLE DEPTH (Feet)	14925.0-15015.0		
SAMPLE FORMATION	Smith Bank and ULA		

GENERAL DATA		OPERATOR DERIVED DATA	
Flow Rate (bopd) , Choke Size (ins)			
°API Gravity			
Gas to Oil Ratio (cu.ft/bbl)	41		
Reservoir Temp(°C) , Pressure(psi)	182	>11000	
Hydrogen Sulphide (ppm)			
Formation { Total (ppm), pH, Cond			
Water { Na, Ca, Mg, (ppm)			
Composition { Cl, SO ₄ , HCO ₃ (ppm)			

PHYSICAL DATA		ROBERTSON GROUP DATA	
°API Gravity	16.5		
Pour Point (°C)	0.0		
Viscosity (cSt at 20,40,60 °C)			

BULK CHEMICAL DATA		ROBERTSON GROUP DATA	
Volatile Content (%)			
Wax Content (%), Water Content (%)	1.50		
Sulphur Content (%)	.34		
Nickel, Vanadium Contents (ppm)	9.00	1.00	
Asphaltene Content (%)	*		
Gasoline Content (ppm)	*		
n-Alkane Content (ppm)	0		

Elemental analysis, CHN %

COMPOSITION OF OIL FRACTIONS	ColChr(%)IScan	CIR(‰)DIR	ColChr(%)IScan	CIR(‰)DIR	ColChr(%)IScan	CIR(‰)DIR
Alkanes	65.7	-30.0				
Aromatics	15.0	-28.2				
Resenes	2.5	-27.8				
Asphaltenes (non-eluted)	16.8	*				
Whole Oil	*	*	-28.6			
Topped Oil			-28.7			

SELECTED INTERPRETIVE RATIOS	ROBERTSON GROUP DATA			
Nickel(Ni)/Vanadium(V), V/(Ni+V)	9.00	.10		
Pr/Ph, Pr/n-C17, Ph/n-C18	1.00	.59	.68	
CPI(1), CPI(2), Bias	.95	.95	1.97	
iso/norm C ₄ , iso/norm C ₅ , Benzene (%)		.79		
Isoheptane, Heptane, Aromaticity	2.31	25.05	.61	
C ₅ -7 Alkane Composition (n, iso, cyclic)	26	37	36	
C ₇ Alkane Composition (n, iso, cyclic)	19	20	60	
Alkane/Aromatic Ratios (ColChr & IScan)	4.38			
Terpanes : Ts/Tm, Mor/Hop, C31Hop22S/R				
C ₂₉ Steranes: %aaa20S, %aBB, Diast/aaaRS				
Steranes : %C27, %C28, %C29				

LEGEND	
ColChr	: Column Chromatography
IScan	: Iatroscan
CIR	: Carbon Isotope Ratio (% P.D.B.)
DIR	: Deuterium Isotope Ratio (% S.M.O.W.)

GENERAL AND ANALYSED DATA FOR OILS

TABLE : 1

COMPANY: PHILLIPS

WELL: 7/11-7

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	14925.0-15015.0					
SAMPLE FORMATION	Smith Bank and ULA					

COMPONENTS	GASOLINE RANGE COMPONENT ABUNDANCE (%)					
	i-C4	9.680				
n-C4						
i-C5	4.777					
n-C5	6.072					
2,2,dmb	.210					
cp	1.219					
2,3,dmb	.692					
2,mp	4.822					
3,mp	3.077					
n-C6	7.810					
mcp+2,2,dmp	5.685					
2,4,dmp	.689					
benz	1.949					
3,3,dmp	.198					
ch	6.533					
2,mh	5.766					
1,1,dmcp	.200					
3,mh	4.271					
cis,1,3,dmcp	.816					
trans,1,3,dmcp	.694					
trans,1,2,dmcp+3,ep	2.634					
n-C7	10.306					
mch+cis,1,2,dmcp	14.547					
ecp	1.016					
tol	6.336					

GENERAL DATA						
Total Abundance(ppb)	*					
TOC (% of Rock)						
Abundance at 1% TOC	*					
Alkane Composition	26 37 36					
C7Alkane Composition	19 20 60					
Aromatic Composition	8.29					

RATIOS						
i/n-C4						
i/n-C5	.79					
cp / 2,3,dmb	1.76					
n-C7 / mch	.71					
2,mp / 3,mp	1.57					
n-C6 / mcp +2,2,dmp	1.37					
mch / tol	2.30					
Late Mature Index	.13					
Aromaticity Index	.61					
Heptane Index	25.05					
Isoheptane Index	2.31					
Kerogen Type Index	9.11					

LEGEND					
i - iso	c - cyclo	m - methyl	b - butane	h - hexane	tol - toluene
n - normal	d - di	e - ethyl	p - pentane	benz - benzene	
Alkane Composition - % composition of normal, iso and cyclo alkanes					
C7 Alkane Composition - % composition of C7 normal, iso and cyclo alkanes					
Aromatic Composition - % composition of Benzene + Toluene					
For definition of indices - Late Mature, Aromaticity, Heptane, Isoheptane & Kerogen Type - See Appendix 2					

GASOLINE RANGE HYDROCARBON DATA

TABLE : 2

COMPANY: PHILLIPS

WELL: 7/11-7

LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	14925.0-15015.0					
SAMPLE FORMATION	Smith Bank and ULA					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13	4.48					
n-C14	5.85					
n-C15	6.84					
n-C16	7.13					
n-C17	6.82					
n-C18	5.92					
n-C19	7.03					
n-C20	6.40					
n-C21	4.86					
n-C22	4.60					
n-C23	3.61					
n-C24	3.31					
n-C25	3.16					
n-C26	2.95					
n-C27	1.67					
n-C28	1.64					
n-C29	1.34					
n-C30	1.09					
n-C31	.99					
n-C32	.83					
n-C33	1.16					
n-C34	1.45					
n-C35	1.48					
n-C36	1.33					
i-C15 (Farnesane)	1.27					
i-C16	2.38					
i-C18 (Norpristane)	2.42					
i-C19 (Pristane)	4.01					
i-C20 (Phytane)	4.00					

GENERAL DATA						
Total Abundance(%)	100					
TOC (% of Rock)						
Extract (ppm)						
Hydrocarbons (ppm)						
Hydrocarbon(mg/gTDC)						
Alks(% Hydrocarbons)						
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	.95					
CPI-2	.95					
CPI-3	.73					
Bias	1.97					
i-C19 / n-C17	.59					
i-C20 / n-C18	.68					
i-C19 / i-C20	1.00					

LEGEND						
i - isoprenoid	n - normal	For definition of Ratios CPI-1,-2,-3 and Bias - see Appendix 2				

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 3

Company: PHILLIPS

Well: NORTH SEA OIL STUDY

Location: NORTH SEA

Well	DST	Interval	Formation	Peak Area %				Ratios	
				DBT	4MDBT	3+2MDBT	1MDBT	TH-1	TH-2
N7/11-7	3	14925'-15015'	Smith Bank and Ula	16	63	19	1	3.9	63

TH-1 = 4MDBT/DBT
 TH-2 = 4MDBT/1MDBT



TABLE 4 Aromatic GC (FPD) data

Compound	Well: N7/11-7 Depth: 14925'-15015' Formation: Smith Bank & Ula		Terpane Ratios	
	Peak height	Peak area		
m/z 191 t21	-	-	h27s/h27m	1.06
m/z 191 t22	-	-	m30/h30	-
m/z 191 t23	5418	517665	h31S/h31R	1.49
m/z 191 t24	2024	219992	(t23+t24+t25+t26)/h30	0.82
m/z 191 t25	2005	378929	T24/h30%	62
m/z 191 t26	-	-	B/h30%	-
m/z 191 t27	-	-	X/h30%	1
m/z 191 t28	-	-	O/h30%	-
m/z 191 t29	-	-	G/h30%	18
m/z 191 h27s	5320	570005	Sterane Ratios	
m/z 191 h27m	5098	540304	s29c/(s29c+s29b)	0.44
m/z 191 B	-	-	(s29d+s29e)/	
m/z 191 h29	15077	2038093	(s29c+s29d+s29e+s29b)	0.58
m/z 191 X	388	16607	s27b/(s27b+s28b+s29b)%	62
m/z 191 m29	-	-	s28b/(s27b+s28b+s29b)%	7
m/z 191 O	-	-	s29b/(s27b+s28b+s29b)%	31
m/z 191 h30	12458	1364699	s27b/s29b	2.00
m/z 191 m30	-	-	h30/(s29c+s29d+s29e+s29b)	1.39
m/z 191 h31S	6209	668407		
m/z 191 h31R	3975	447451		
m/z 191 G	1812	246186		
m/z 191 h32S	4274	418704		
m/z 191 h32R	2517	245200		
m/z 217 r27d	3899	356909		
m/z 217 r27c	2527	246074		
m/z 217 s27b	2297	281279		
m/z 217 r29c	1987	308986		
m/z 217 s28b	703	31383		
m/z 217 s29c	1527	267752		
m/z 217 s29d	2445	330979		
m/z 217 s29e	1983	243074		
m/z 217 s29b	1269	140359		
m/z 259 r27d	1266	137272		
m/z 259 r27c	885	96633		
m/z 259 r28d	615	46193		
	+494	+42102		
m/z 259 r28c	387	22416		
	+585	+48848		
m/z 259 r29d	826	81935		
m/z 259 r29c	429	25458		

TABLE 5 Alkane GC-MS data and ratios

Compound	Well: N7/11-7 Depth: 14925'-15015'	
	Peak height	Peak area
m/z 154 BiP	12597	607372
m/z 168 1MBiP		
m/z 168 2MBiP		
m/z 168 3MBiP		
m/z 178 P	37393	2131715
m/z 184 DBT	3936	190881
m/z 192 3MP	18635	861243
m/z 192 2MP	18813	1114365
m/z 192 9MP	15289	750999
m/z 192 1MP	12066	823018
m/z 198 4MDBT	7361	362227
m/z 198 2+3MDBT	1952	141337
m/z 198 1MDBT	415	16580
m/z 231 TAS20	-	-
m/z 231 TAS21	-	-
m/z 231 TAS26S	-	-
m/z 231 TAS26R+27S	-	-
m/z 231 TAS28S	-	-
m/z 231 TAS27R	-	-
m/z 231 TAS28R	-	-
m/z 253 MAS21	-	-
m/z 253 MAS22	-	-
m/z 253 MAS29 β 28 α	-	-
m/z 253 MAS29 α	-	-

MPI-1	F1	F2	TAS-1	TAS-2	DBT/P	TH-1	TH-2
0.80	0.56	0.31	-	-	0.09	1.90	21.85

Key:

MPI-1	=	$([3MP+2MP]/[P+9MP+1MP])*1.5$
F1	=	$([3MP+2MP]/[3MP+2MP+9MP+1MP])$
F2	=	$(2MP/[3MP+2MP+9MP+1MP])$
TAS-1	=	$(TAS20+TAS21)/(TAS26+TAS27+TAS28)$
TAS-2	=	$TAS20/TAS28(S+R)$
TH-1	=	$4MDBT/DBT$
TH-2	=	$4MDBT/1MDBT$

NB: Calculations based on peak areas.

TABLE 6 Aromatic GC-MS data and ratios

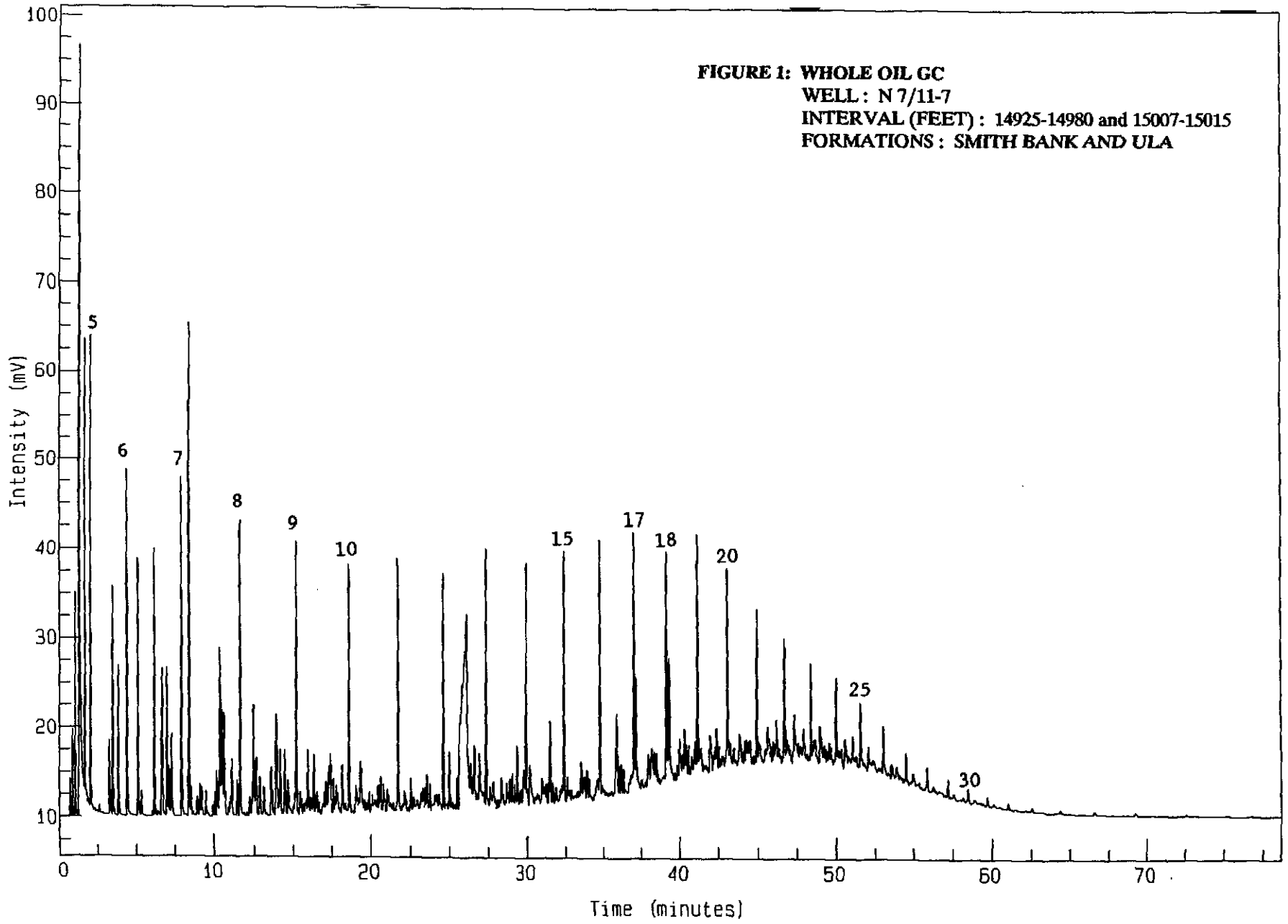


SIMON LABORATORIES

Analysis Name : 9 W94A0001R0, 1, 1.

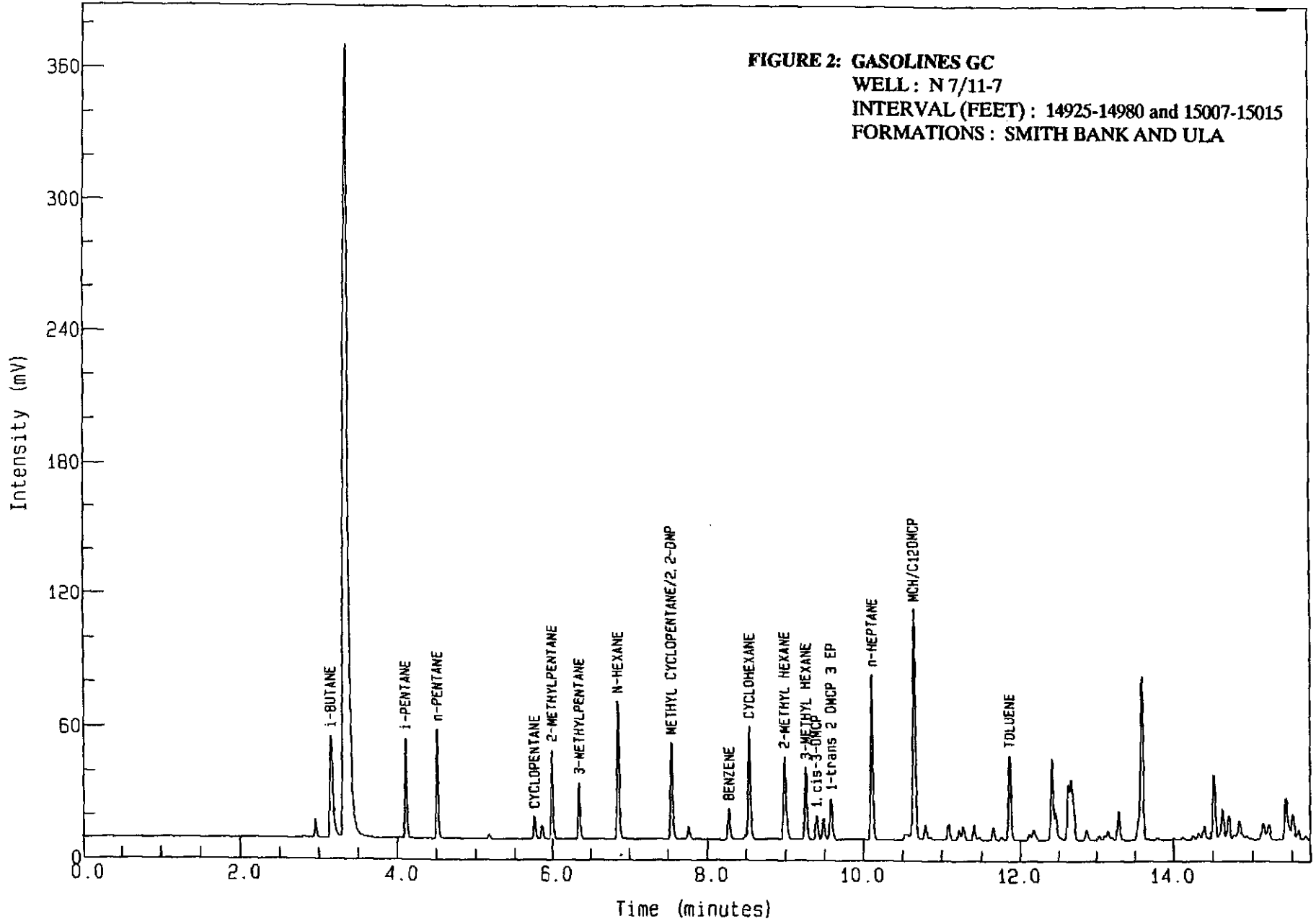
94A 1 PHILLIPS 7/11-7 Amount : 1.000

Whole Oil Gas Chromatography



SIMON LABORATORIES

Analysis Name : 7 694A0001R0, 1, 1.
94A 1 PHILLIPS 7/11-7 Amount : 1.000
Gasoline Gas Chromatography Run On An AMS Model 92



SIMON LABORATORIES

Analysis Name : 5 S94A0001R0, 1, 1.

94A 1 PHILLIPS 7/11-7

Amount : 1.000

SATURATE GC

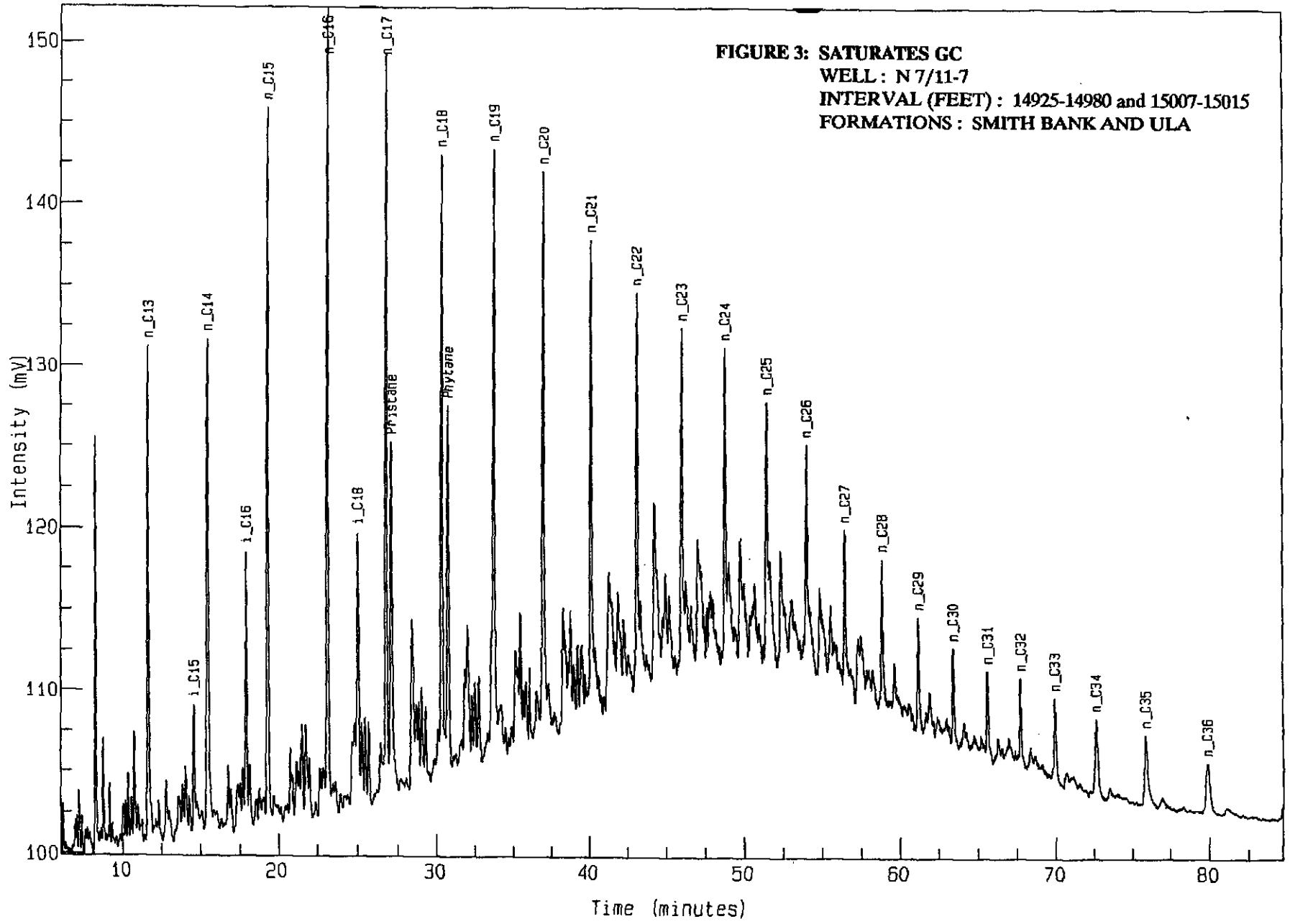


FIGURE 3: SATURATES GC
WELL : N 7/11-7
INTERVAL (FEET) : 14925-14980 and 15007-15015
FORMATIONS : SMITH BANK AND ULA

SIMON LABORATORIES

Analysis Name : 9 A94A0001R1, 1, 1.

94A 1 PHILLIPS 7/11-7 Amount : 1.000

AROMATIC GC

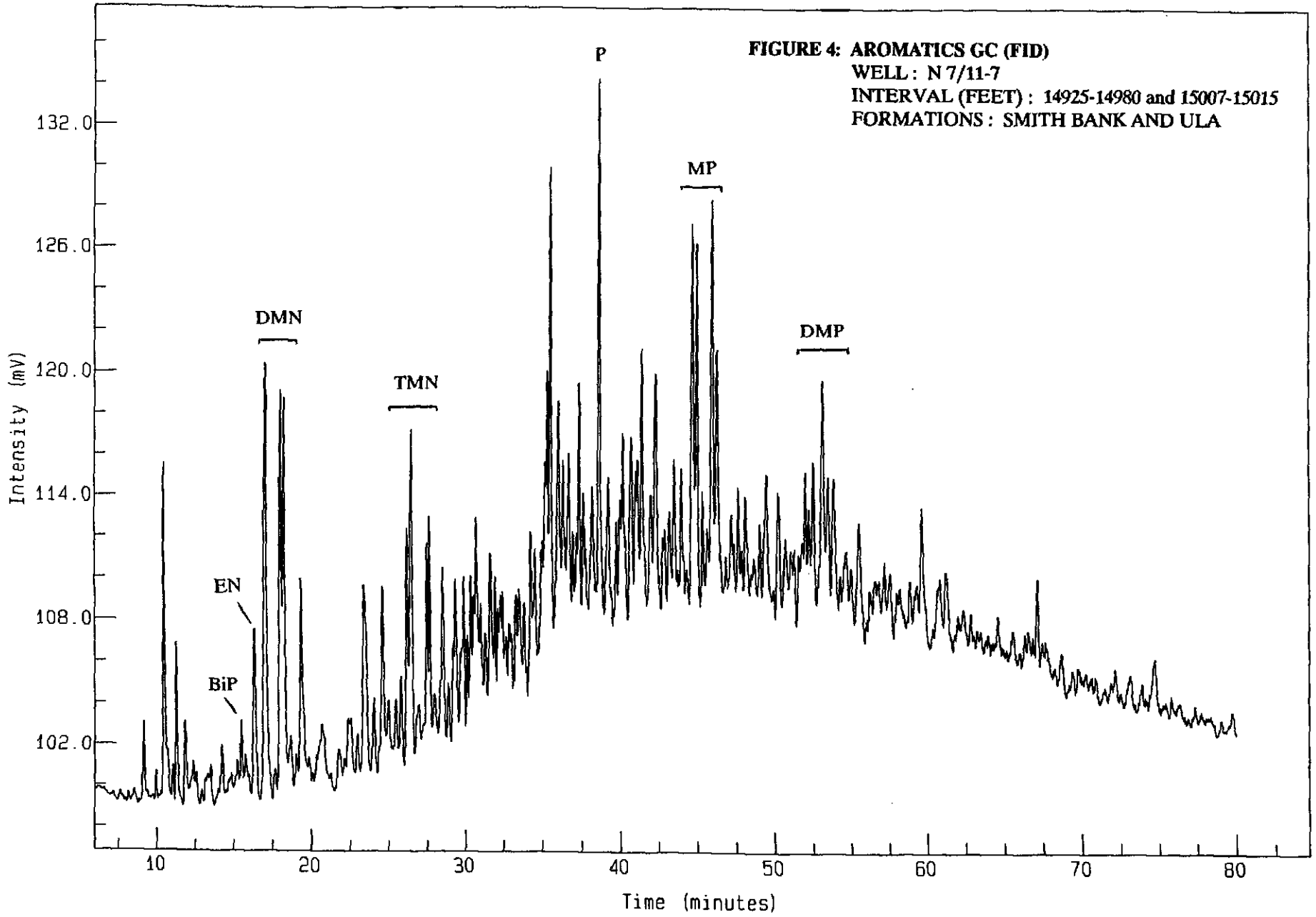


FIGURE 4: AROMATICS GC (FID)

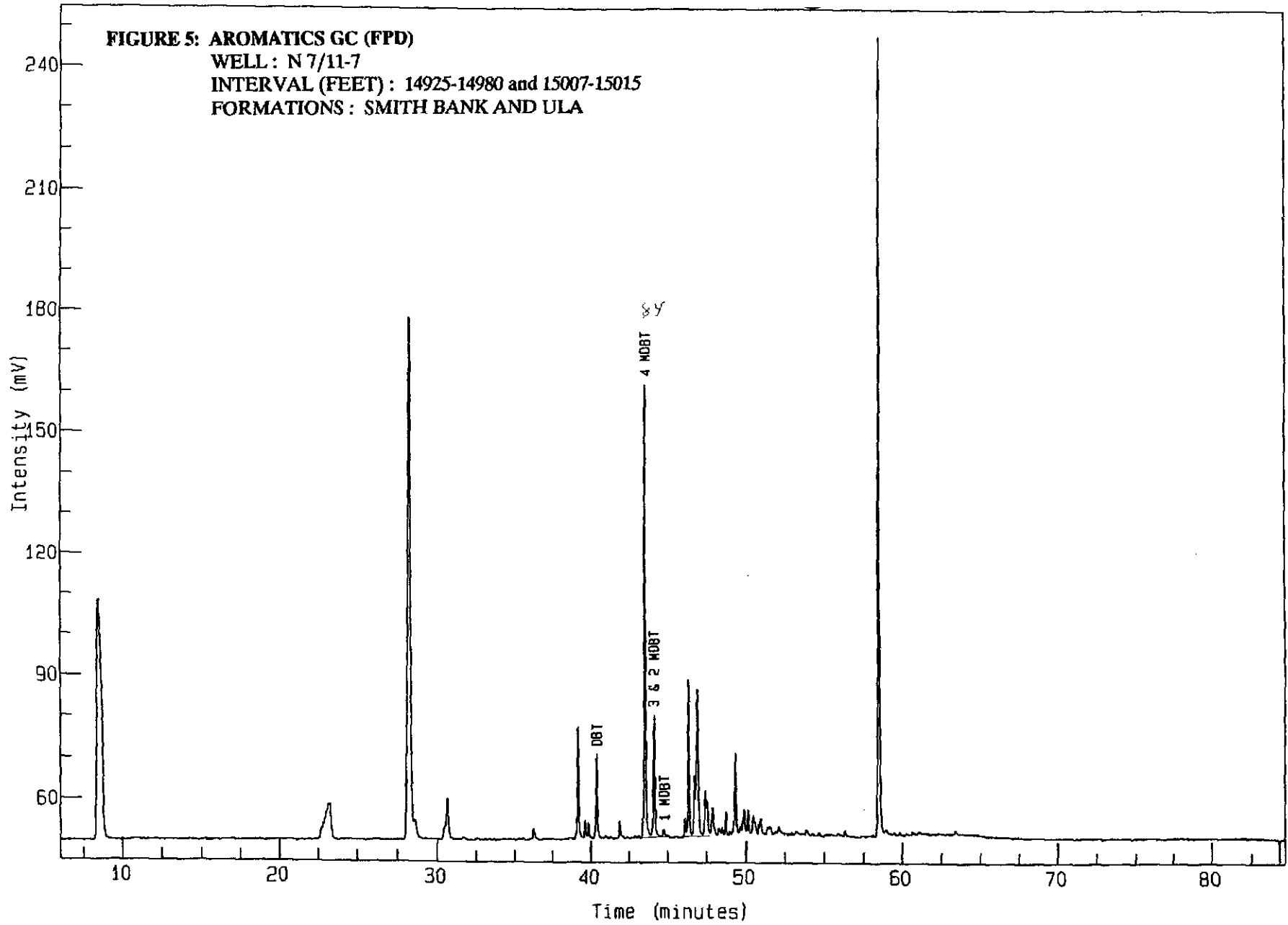
WELL : N 7/11-7

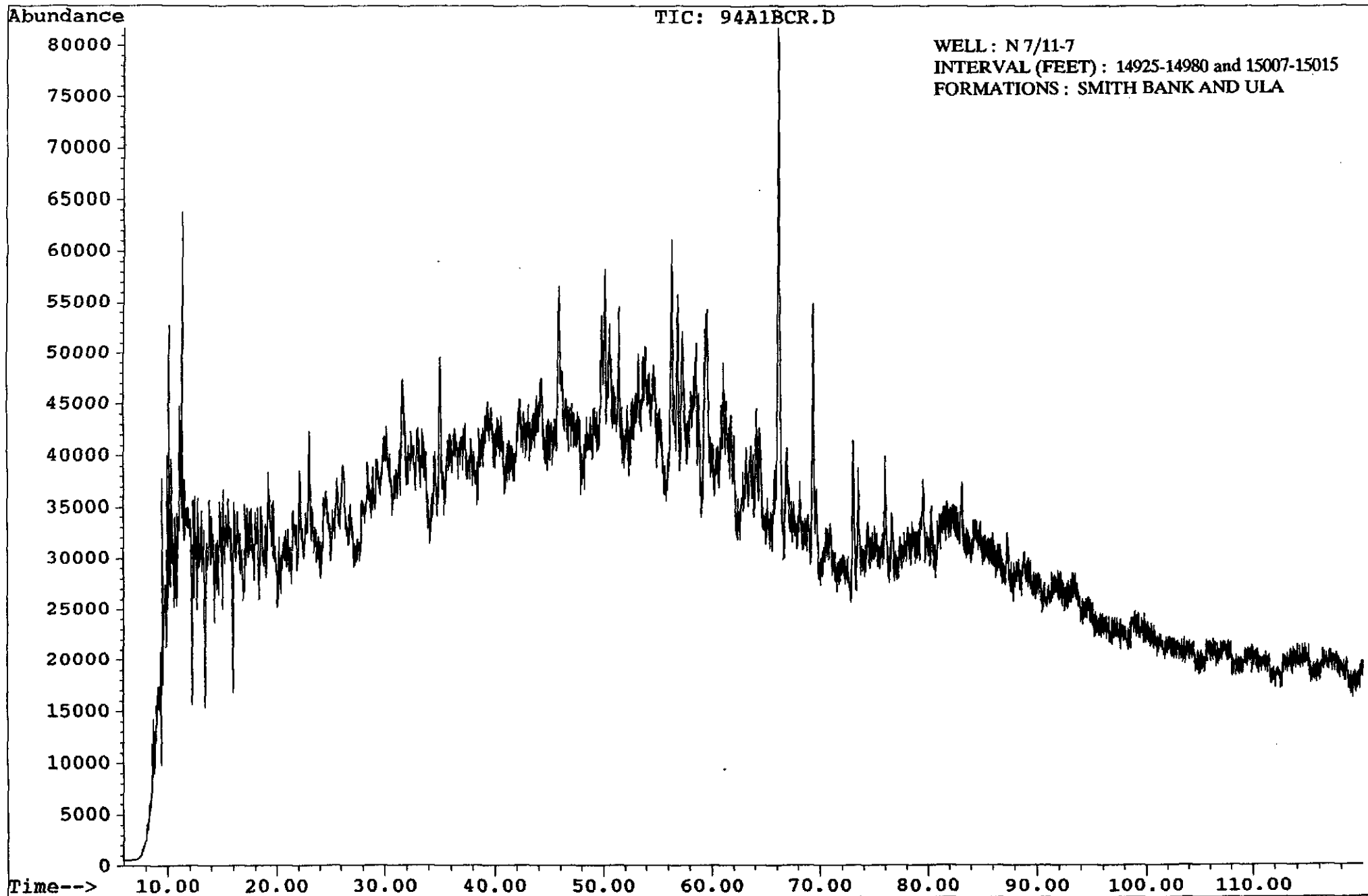
INTERVAL (FEET) : 14925-14980 and 15007-15015

FORMATIONS : SMITH BANK AND ULA

SIMON LABORATORIES

Analysis Name : 12 F94A001R1, 1, 1.
94A001 PHILLIPS OILS Amount : 1.000
AROMATIC GC

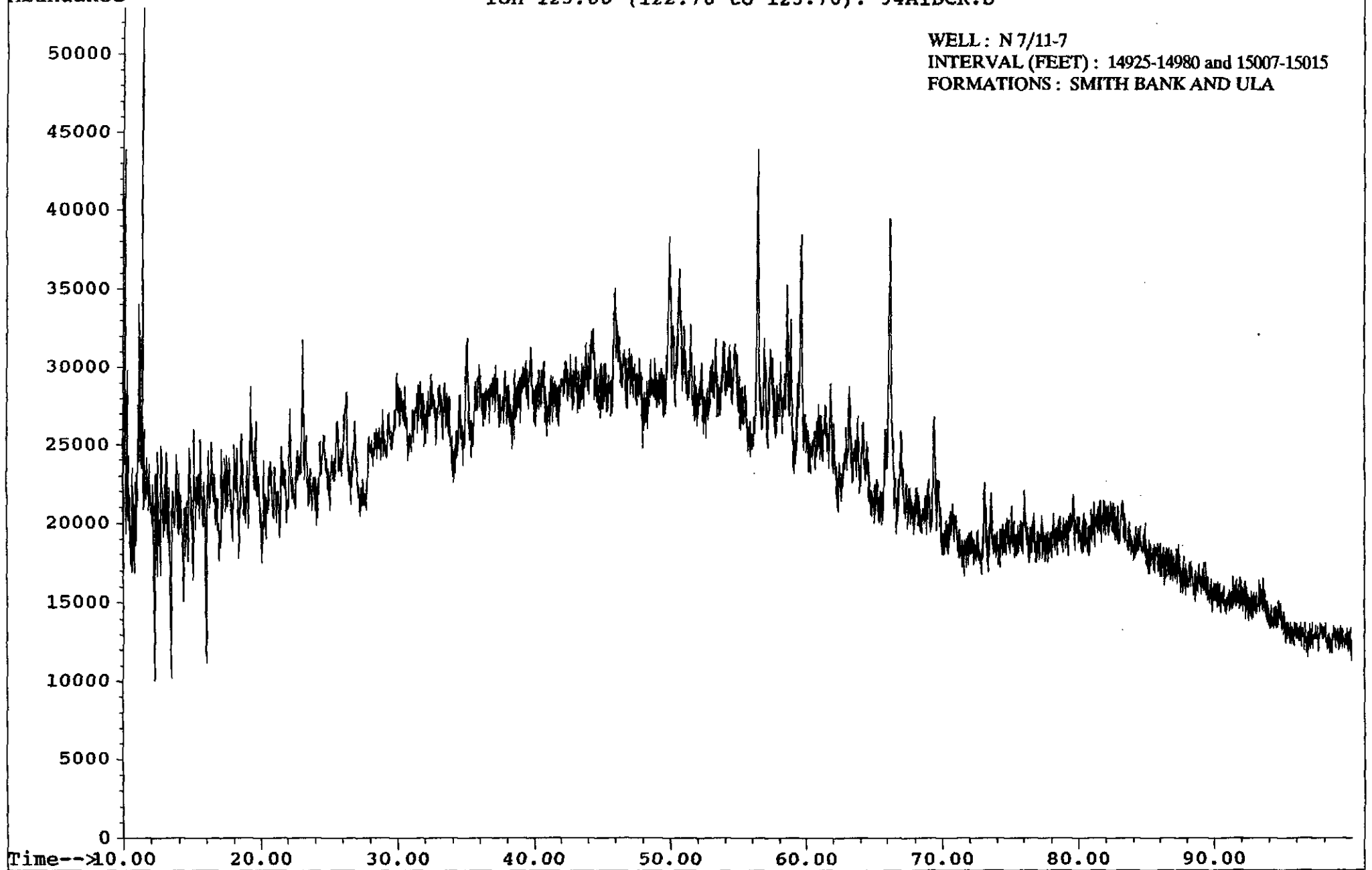




Abundance

Ion 123.00 (122.70 to 123.70): 94A1BCR.D

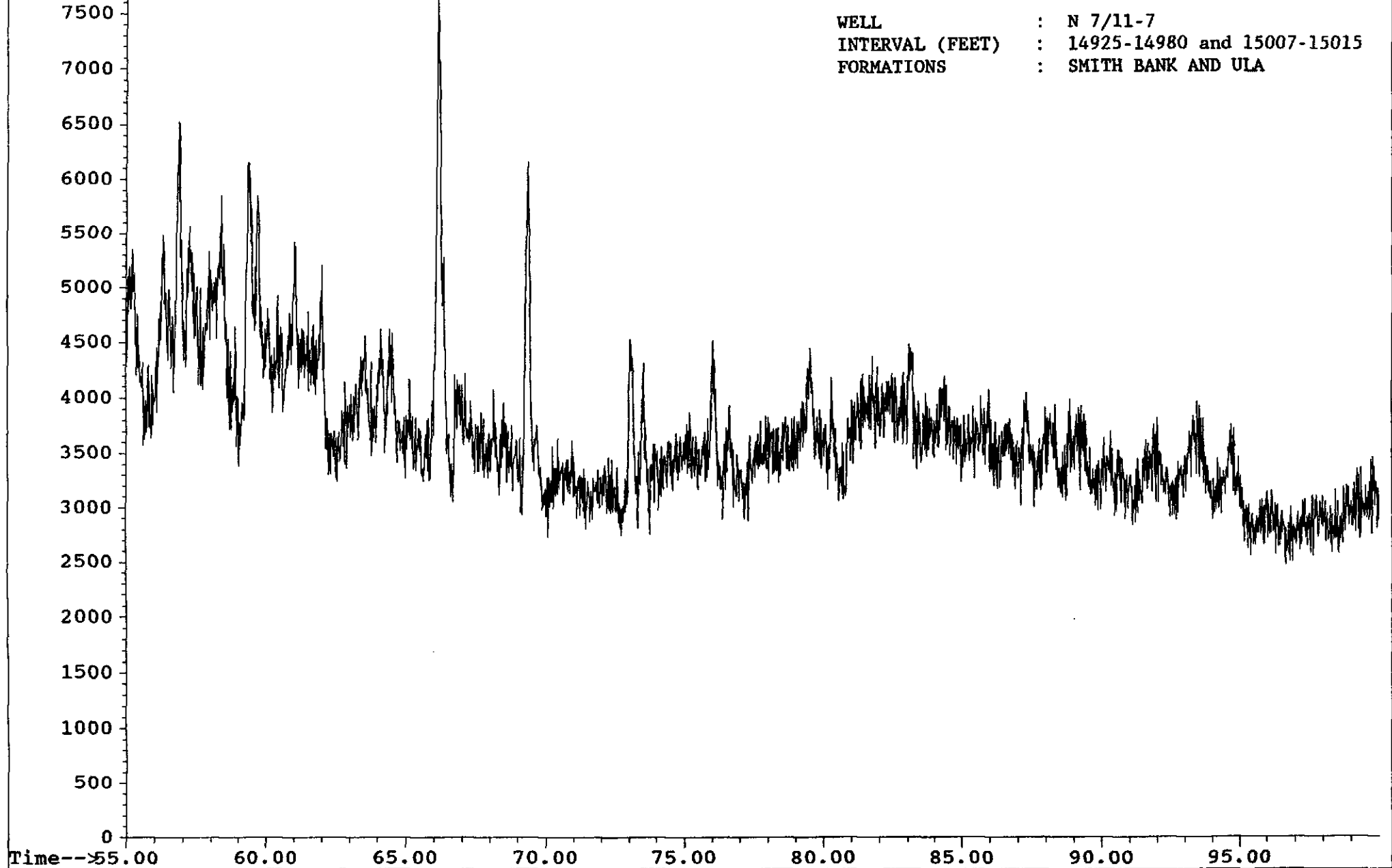
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INTERVAL (FEET): 14925-14980 and 15007-15015
FORMATIONS: SMITH BANK AND ULA

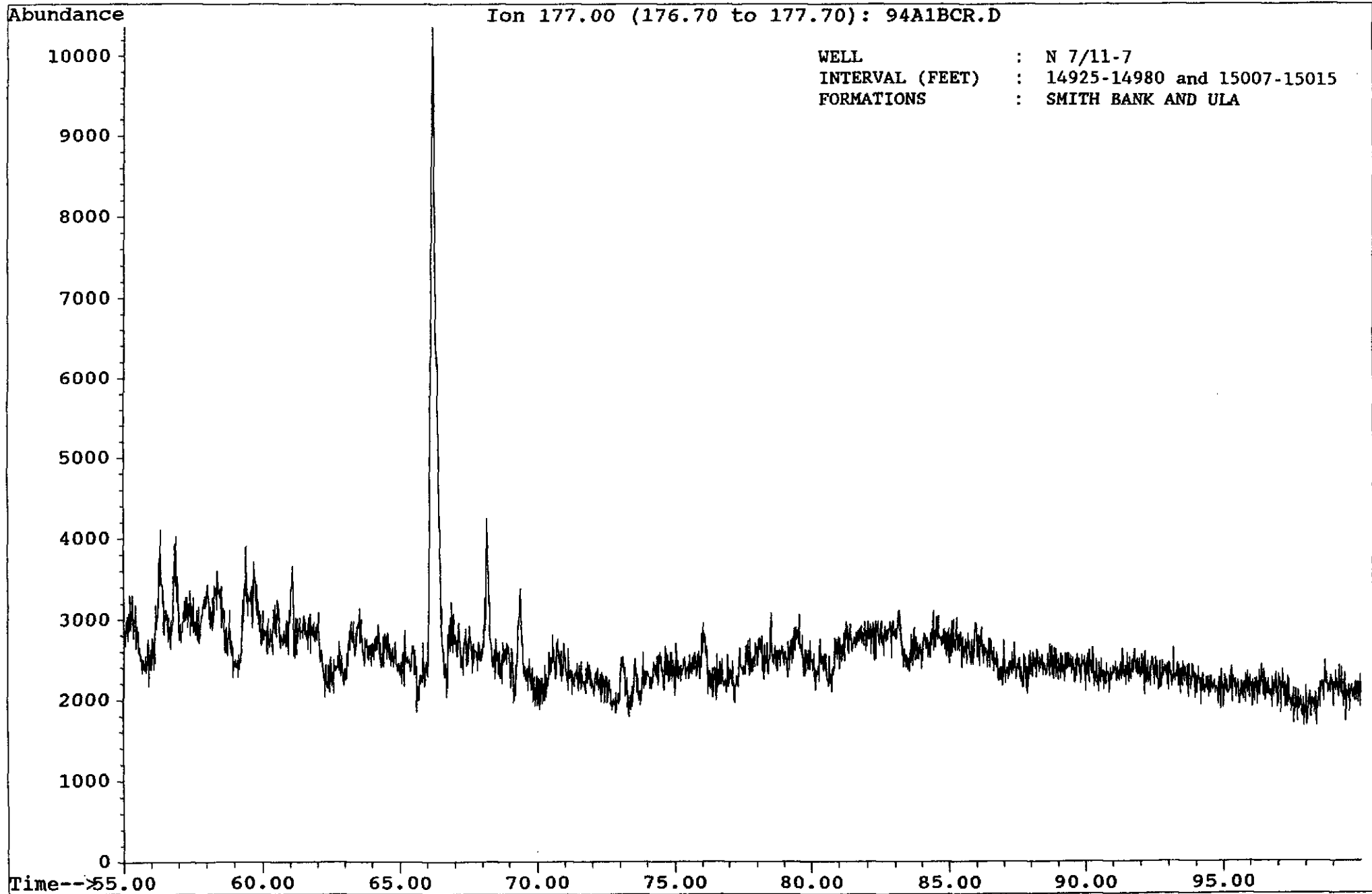


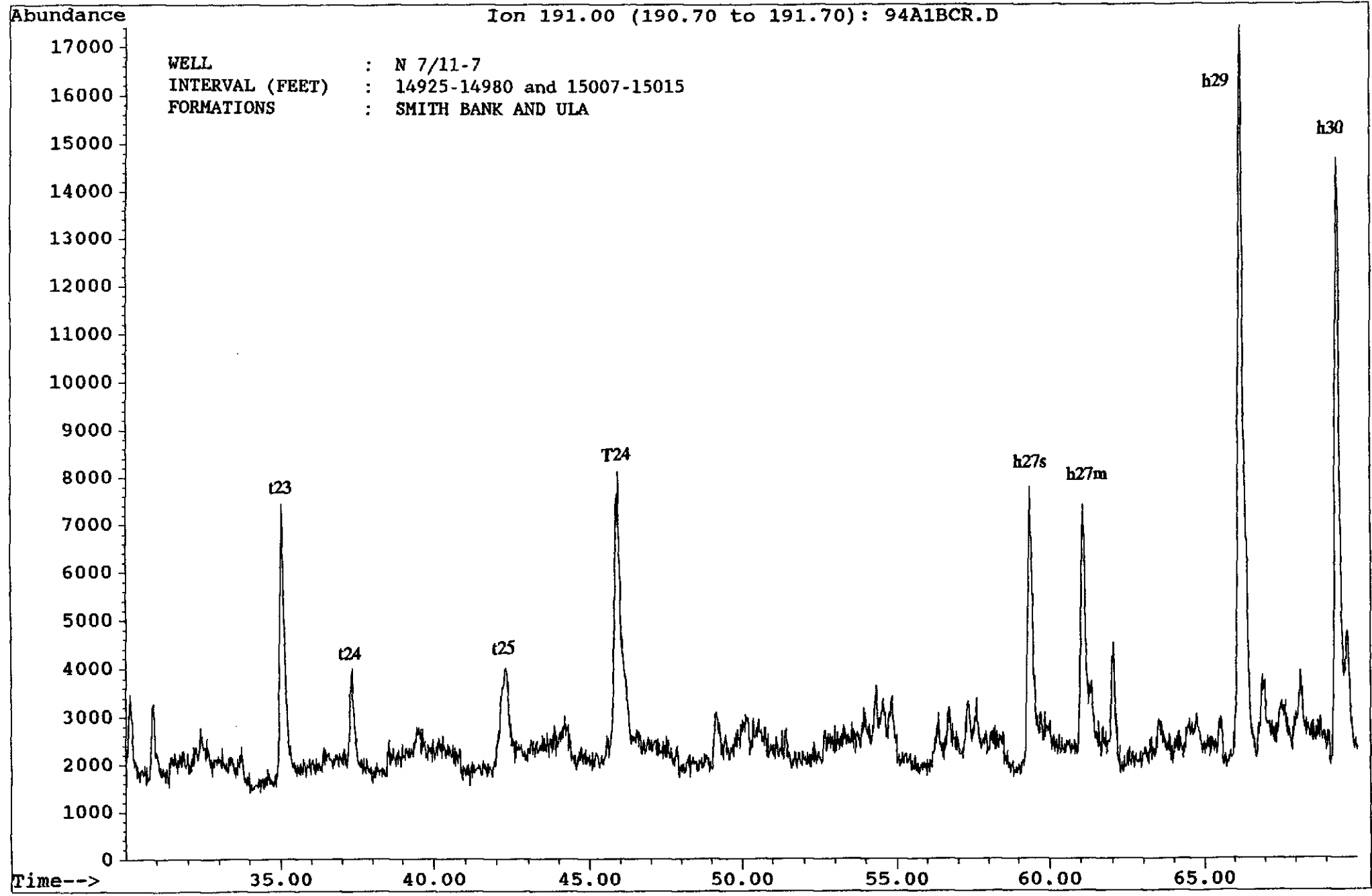
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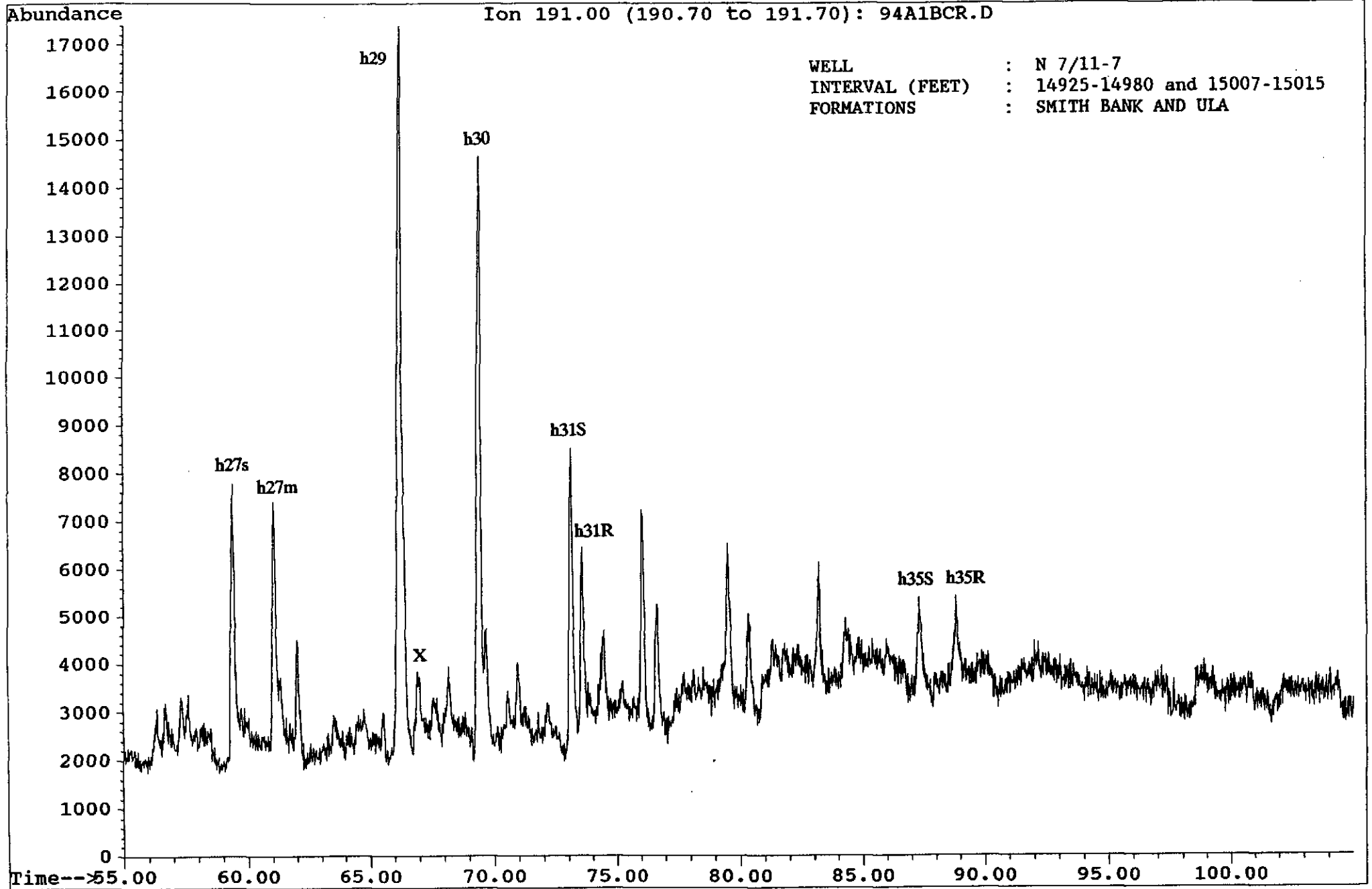
Ion 163.00 (162.70 to 163.70): 94A1BCR.D

WELL : N 7/11-7
INTERVAL (FEET) : 14925-14980 and 15007-15015
FORMATIONS : SMITH BANK AND ULA





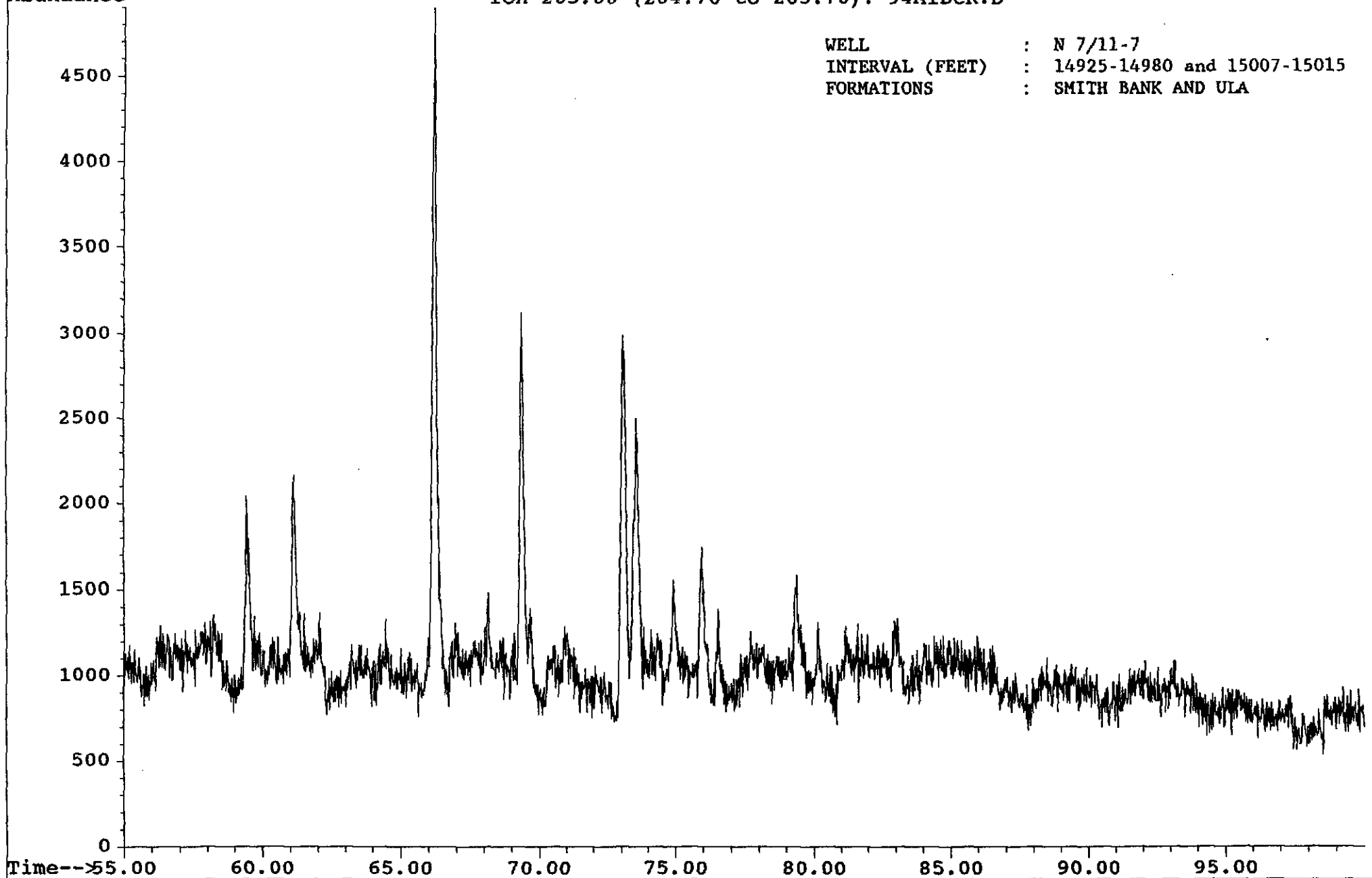


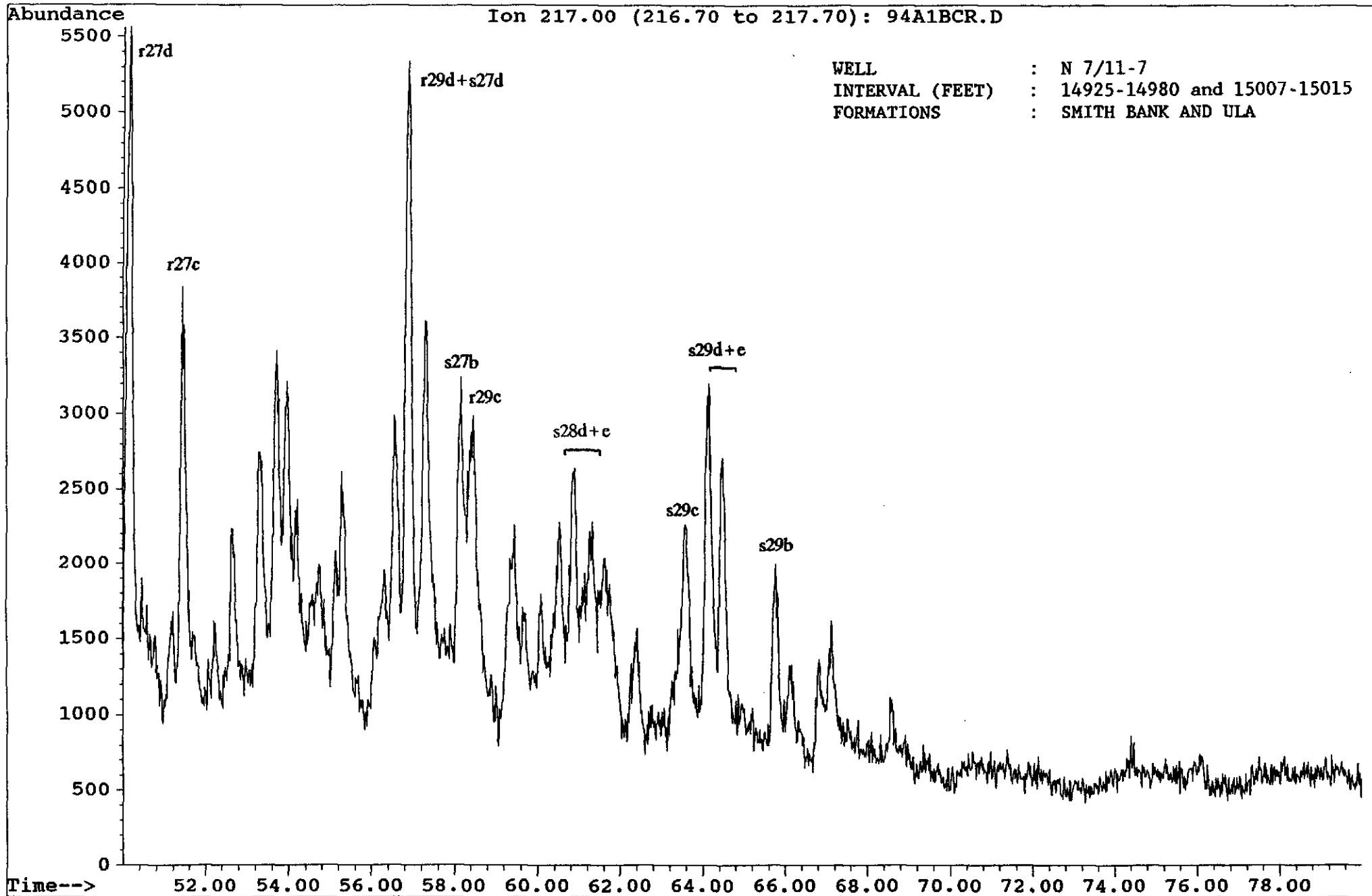


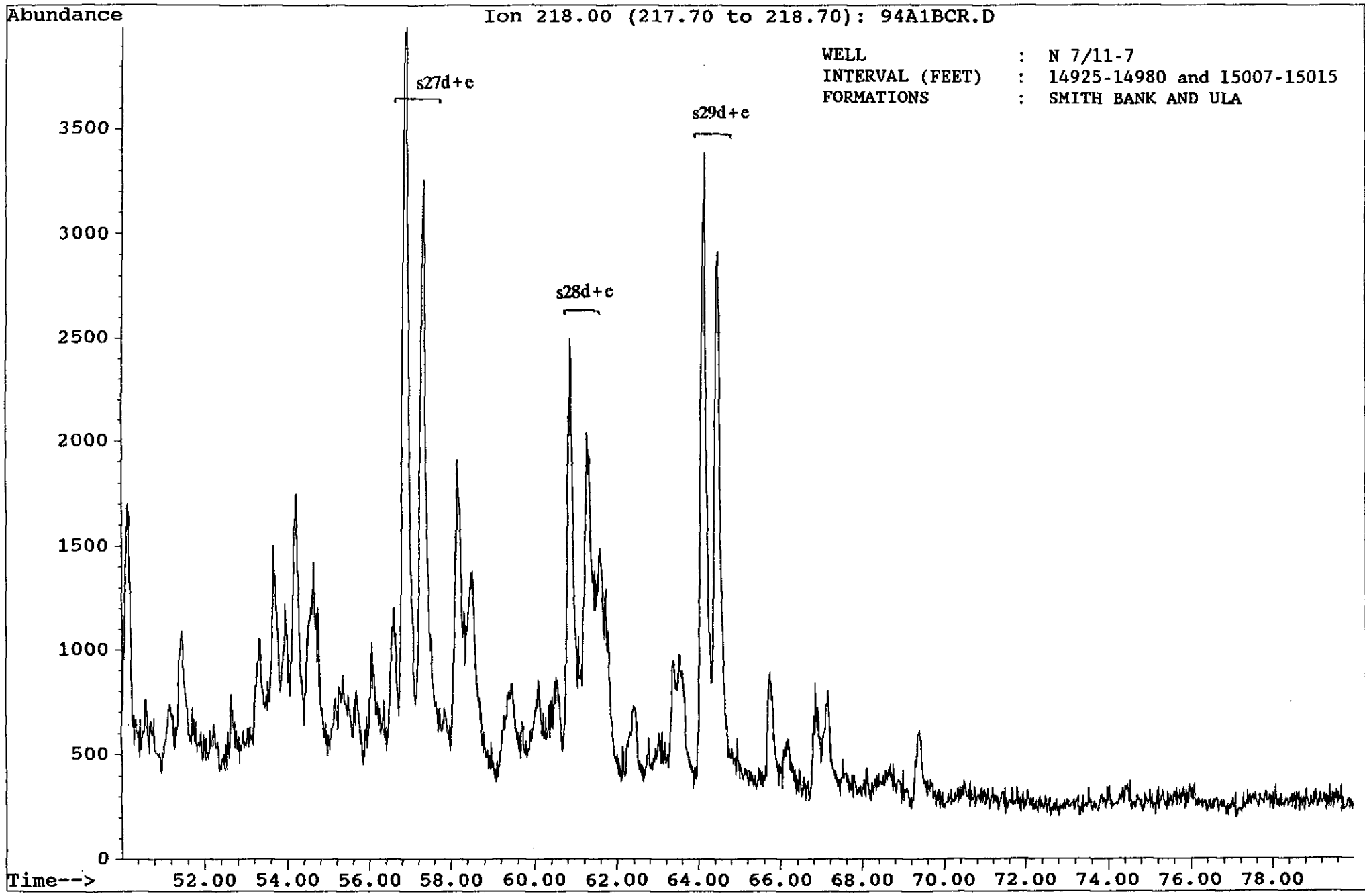
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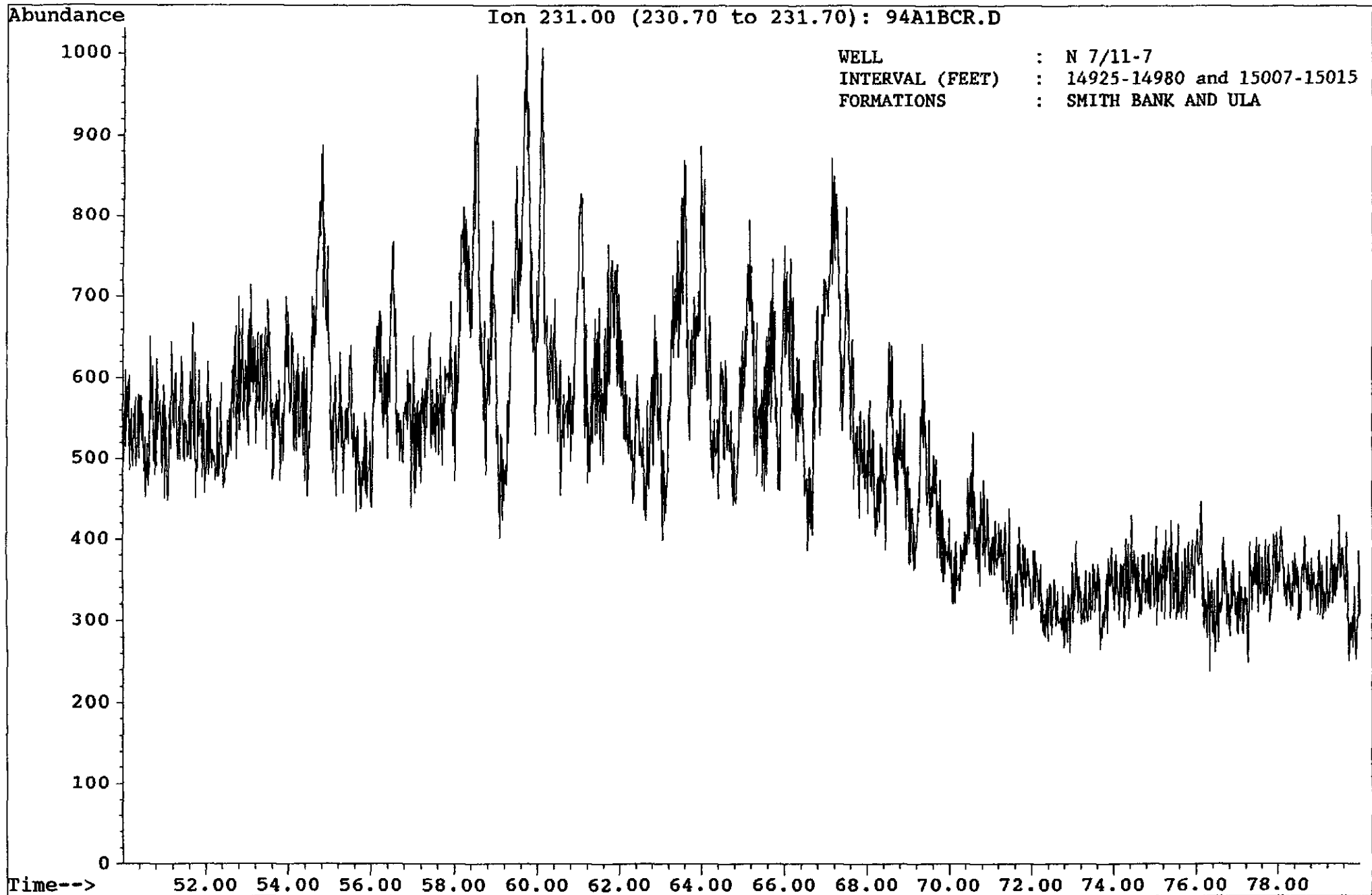
Ion 205.00 (204.70 to 205.70): 94A1BCR.D

WELL : N 7/11-7
INTERVAL (FEET) : 14925-14980 and 15007-15015
FORMATIONS : SMITH BANK AND ULA





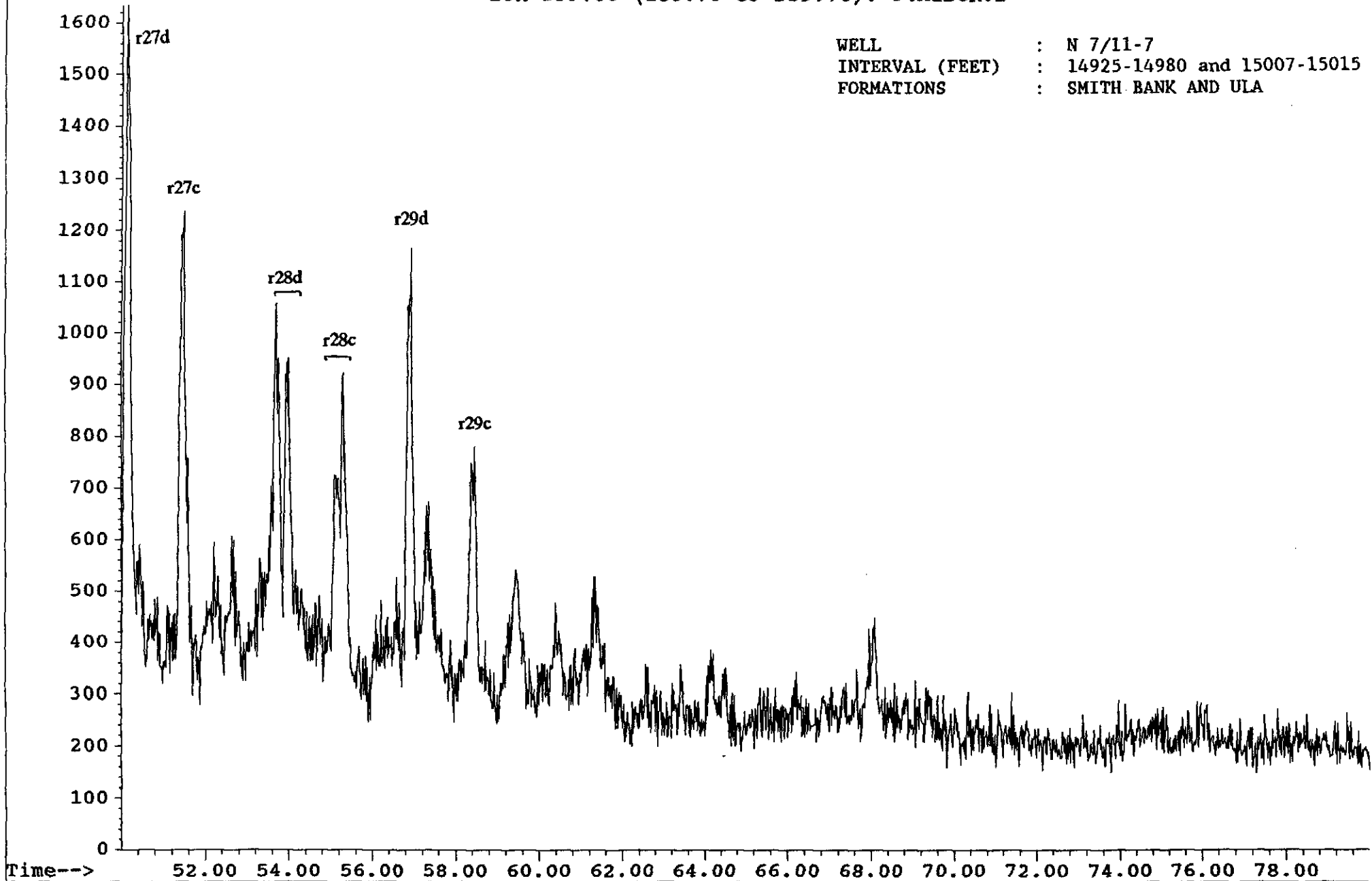


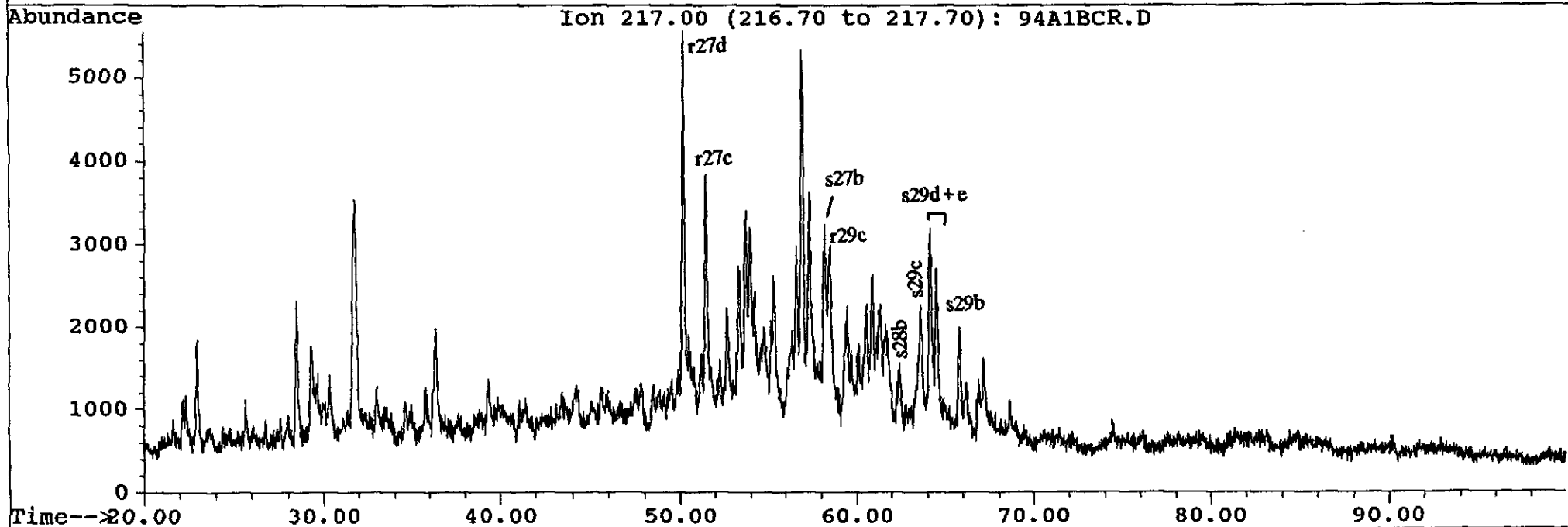
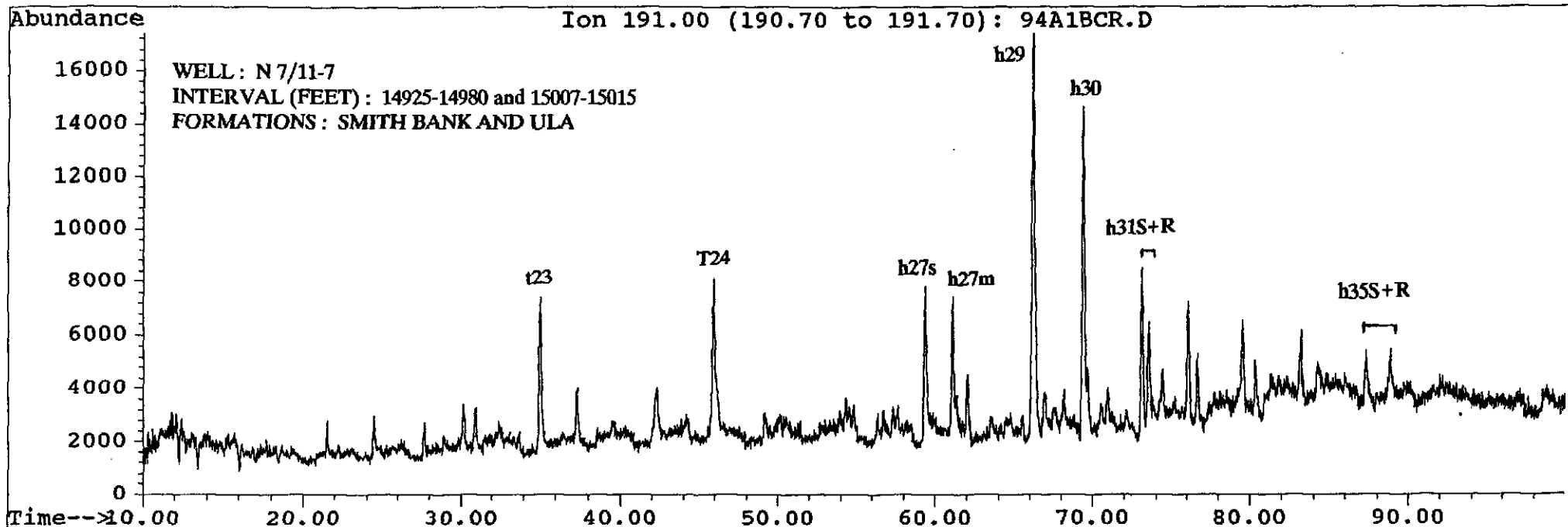


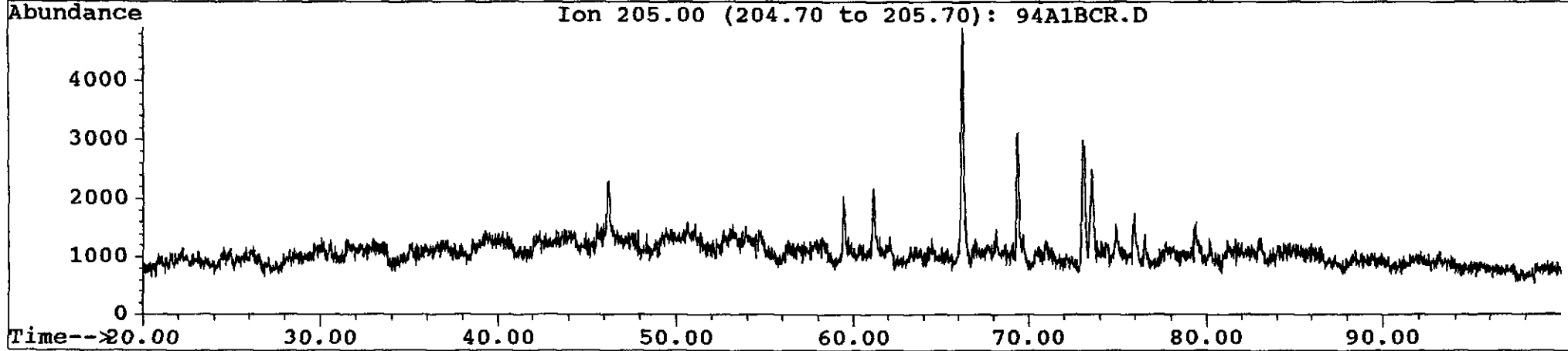
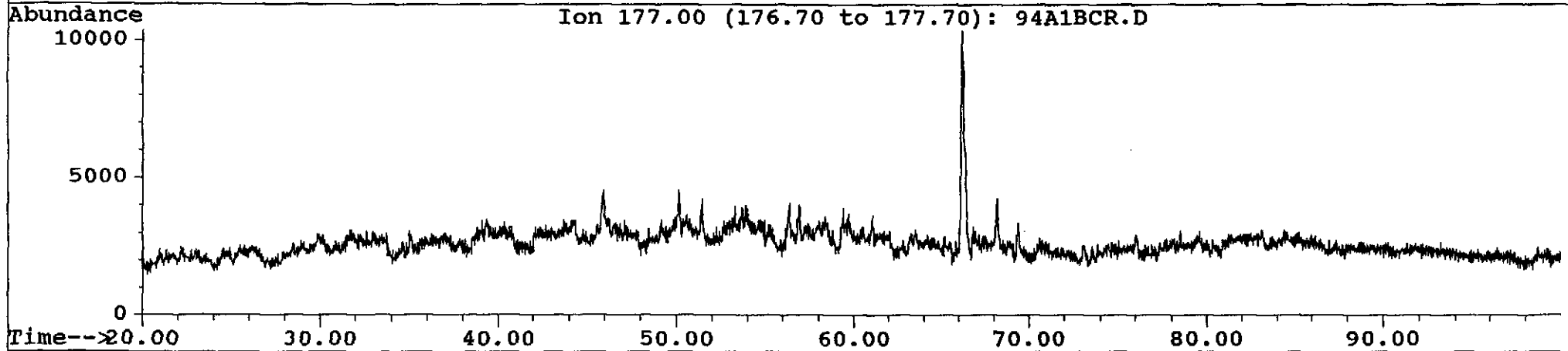
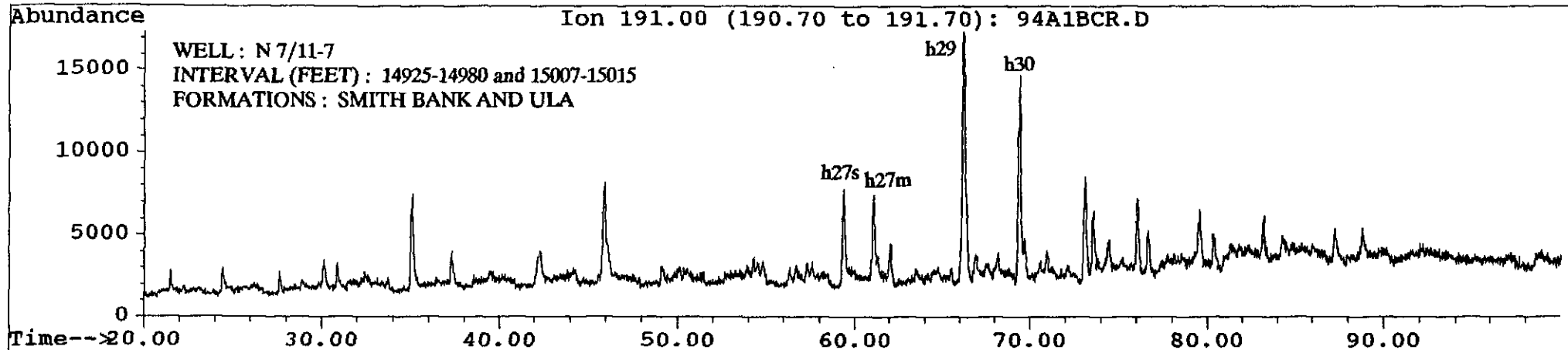
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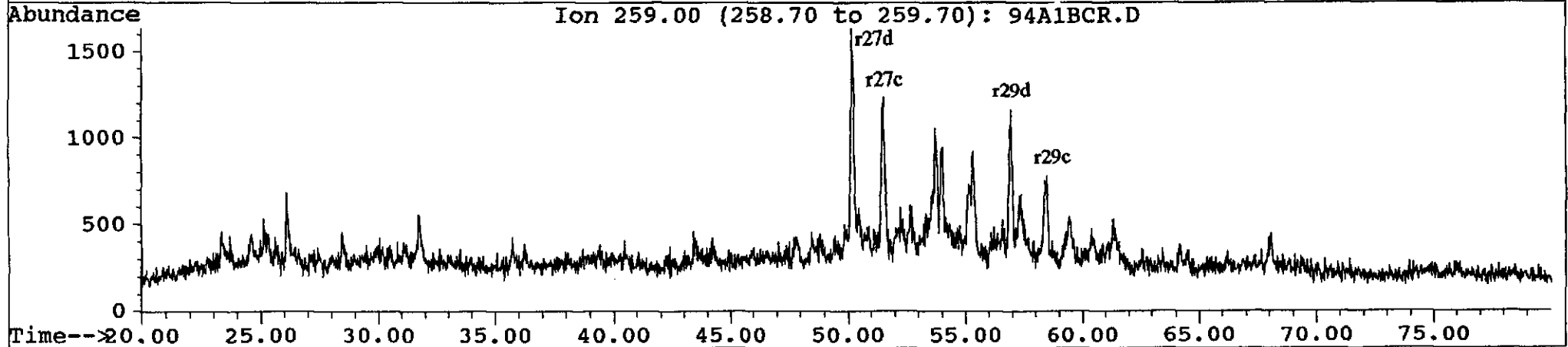
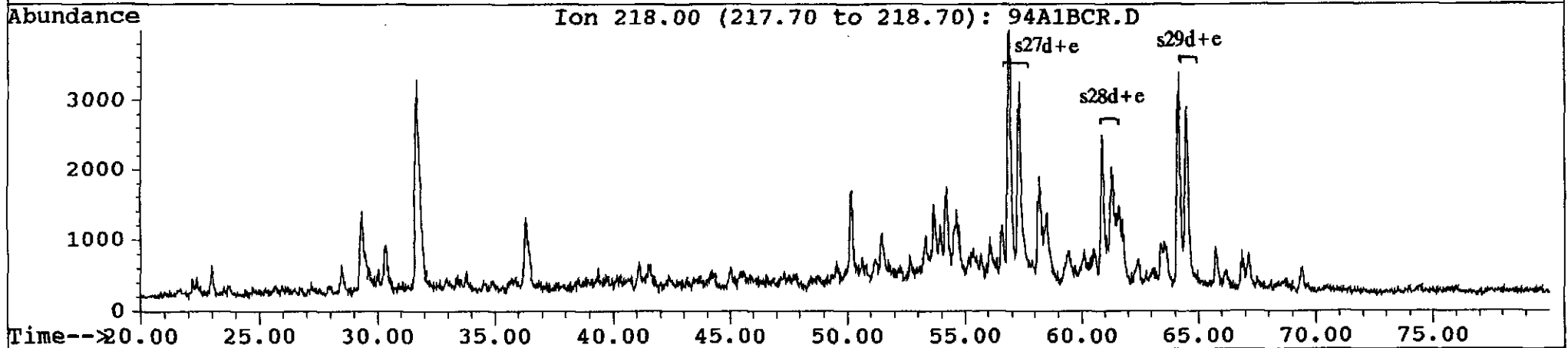
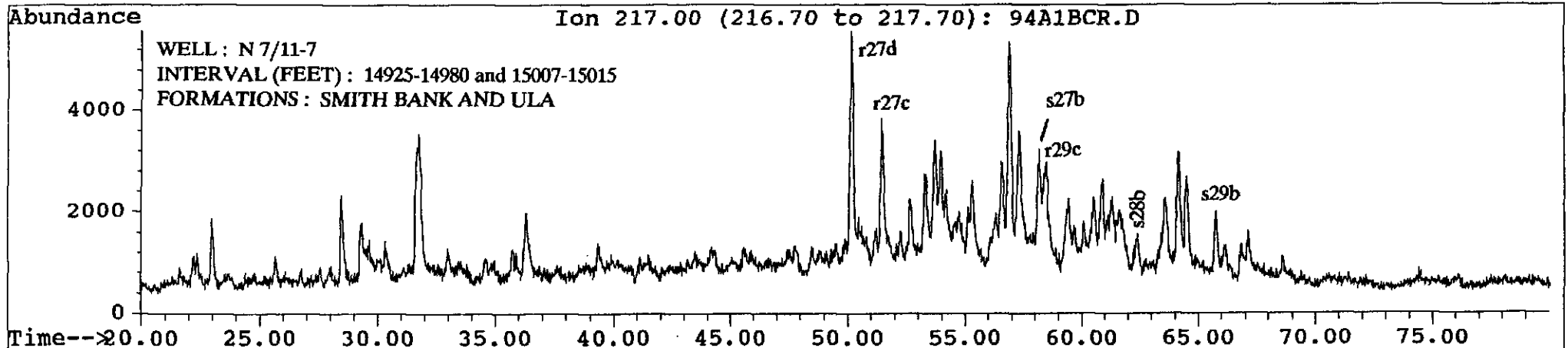
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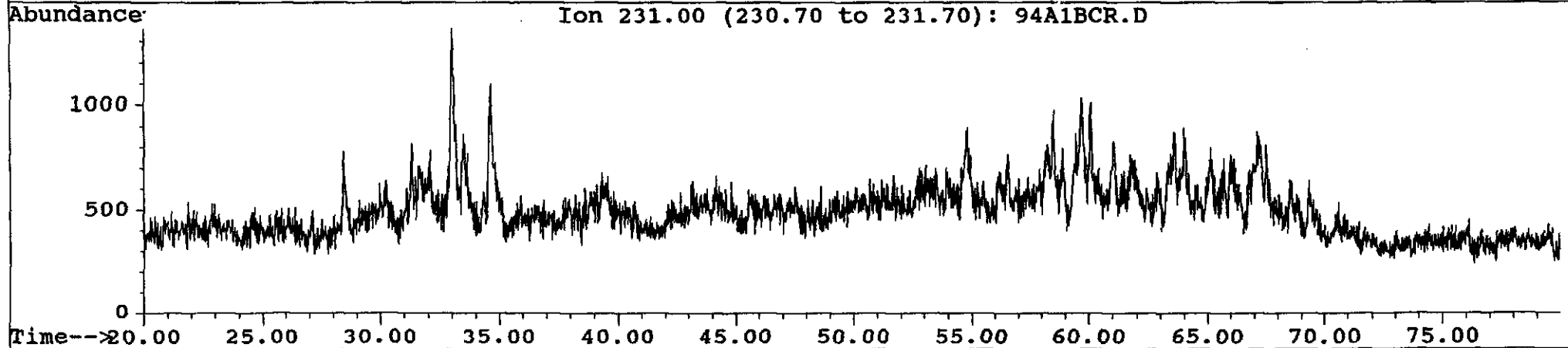
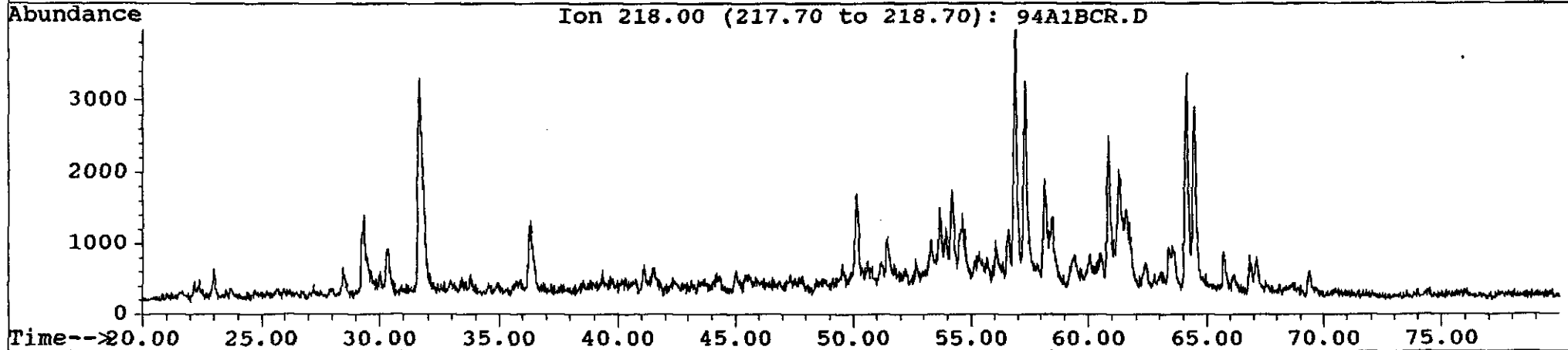
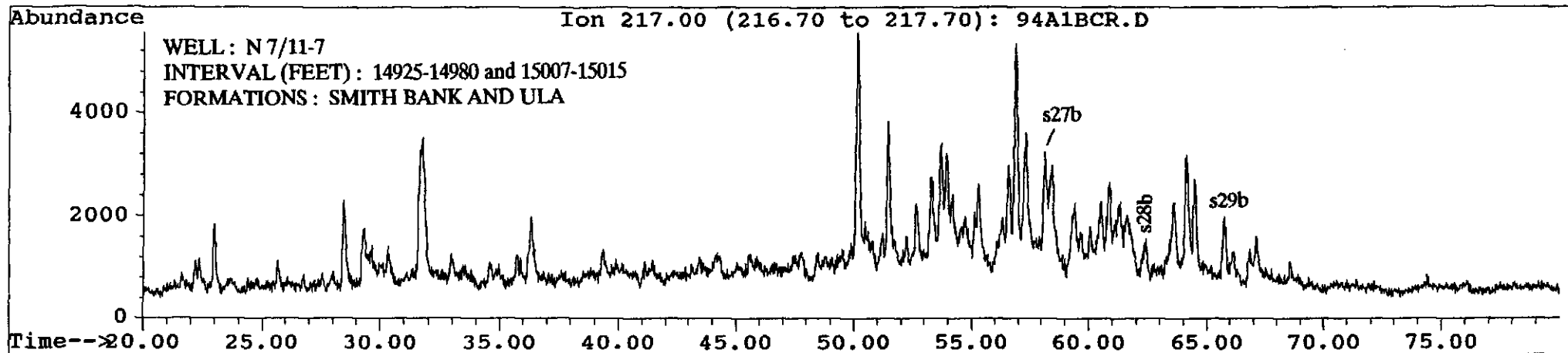
WELL : N 7/11-7
INTERVAL (FEET) : 14925-14980 and 15007-15015
FORMATIONS : SMITH BANK AND ULA

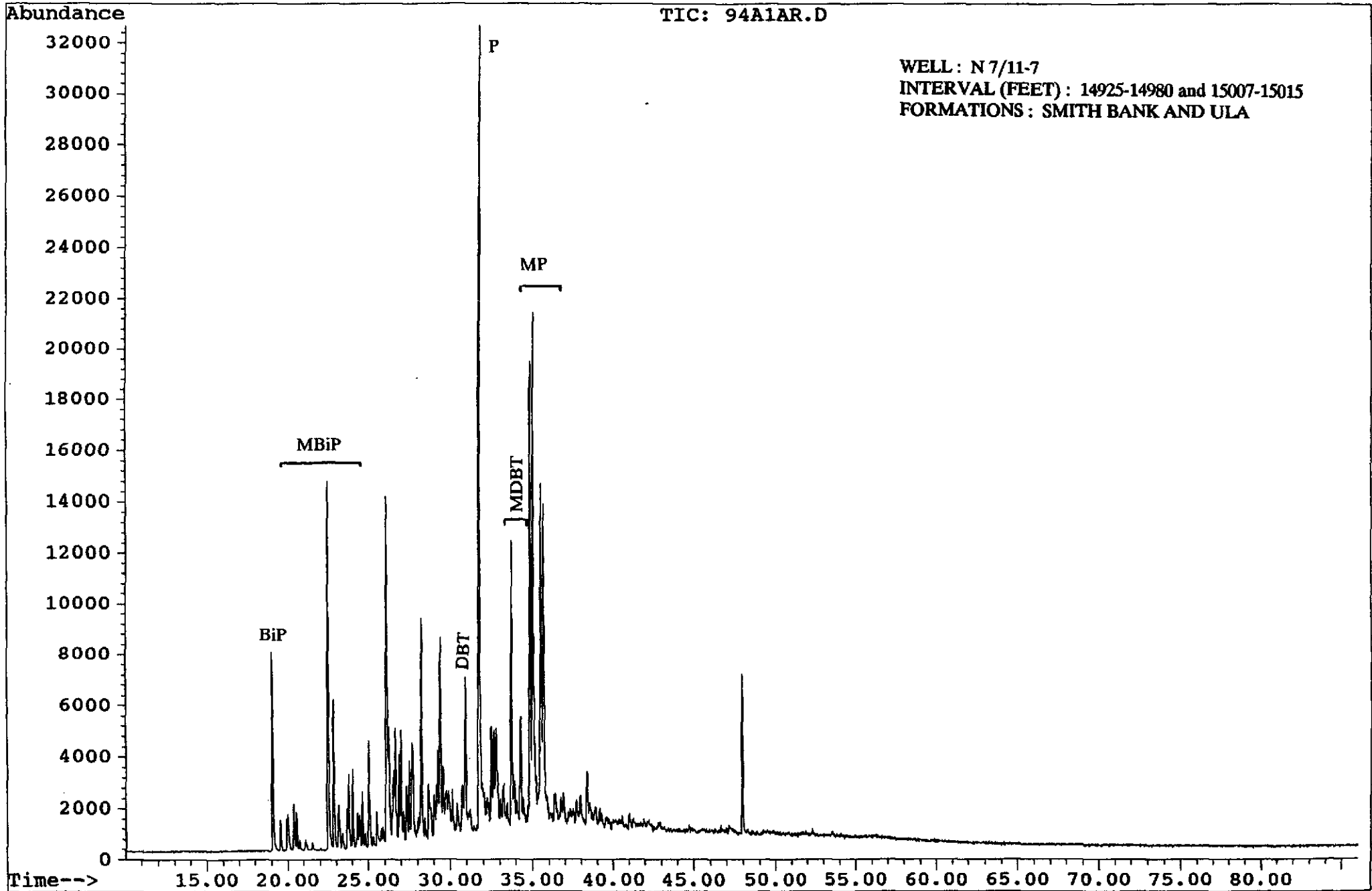


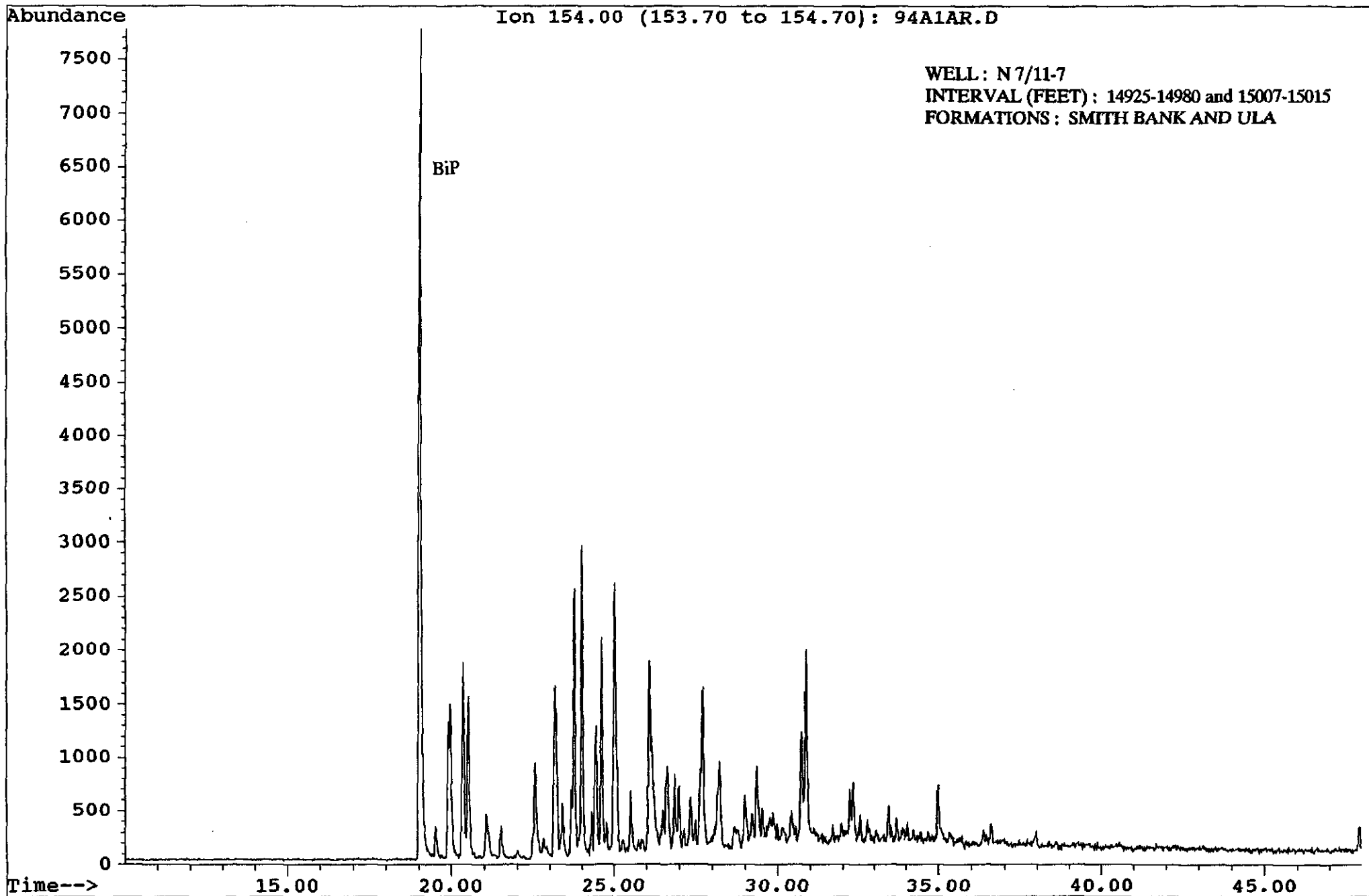


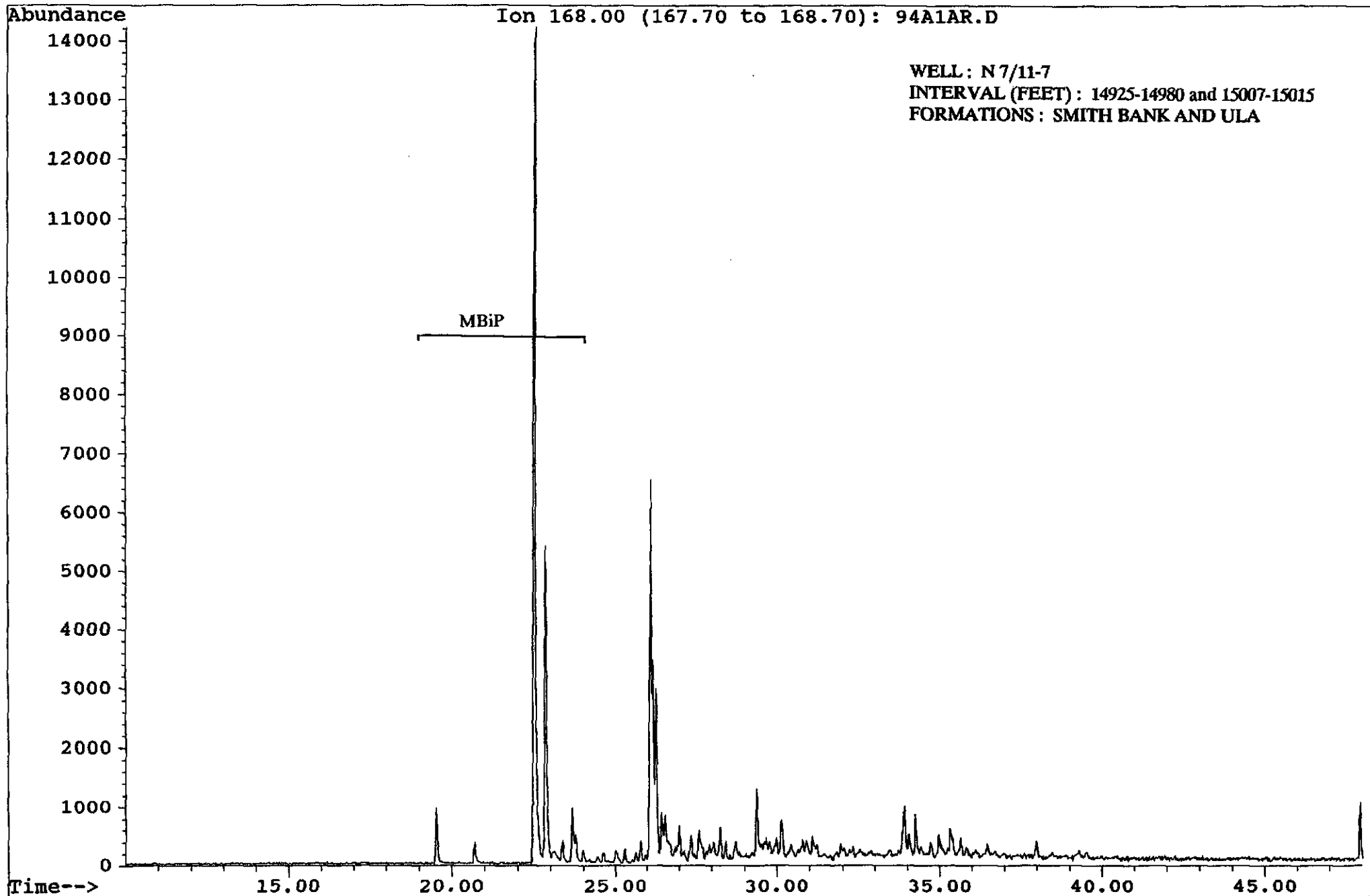


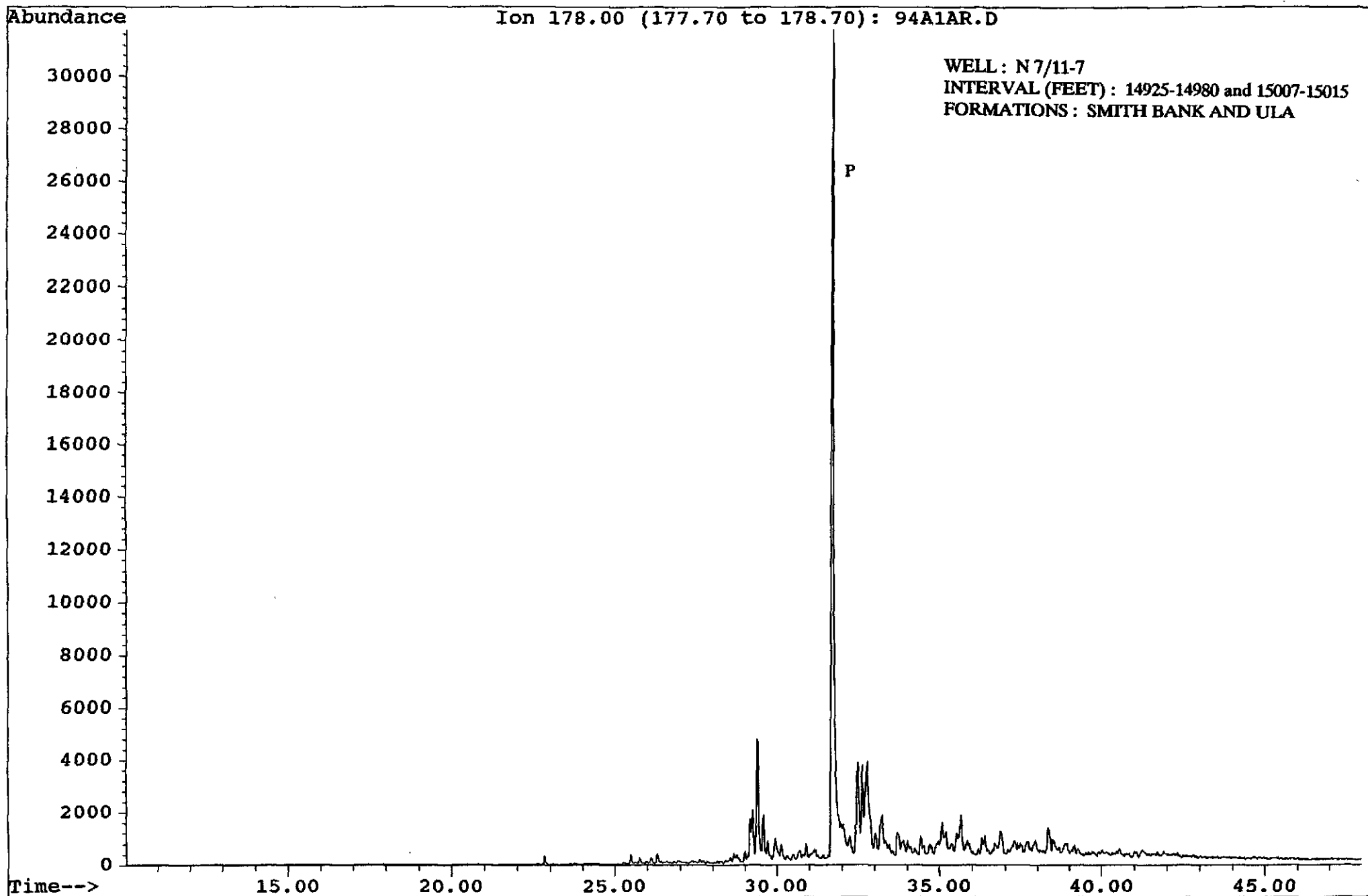


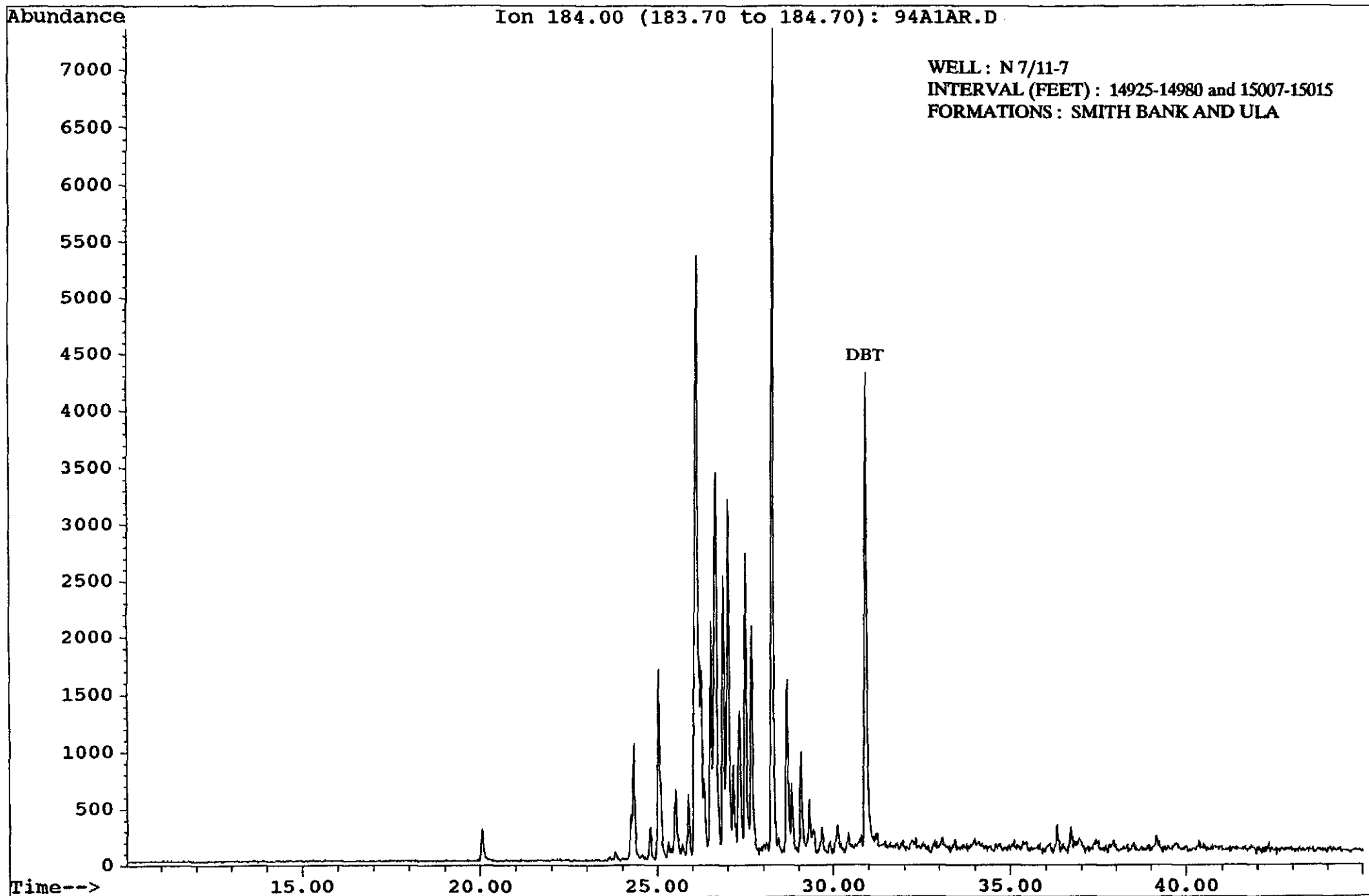


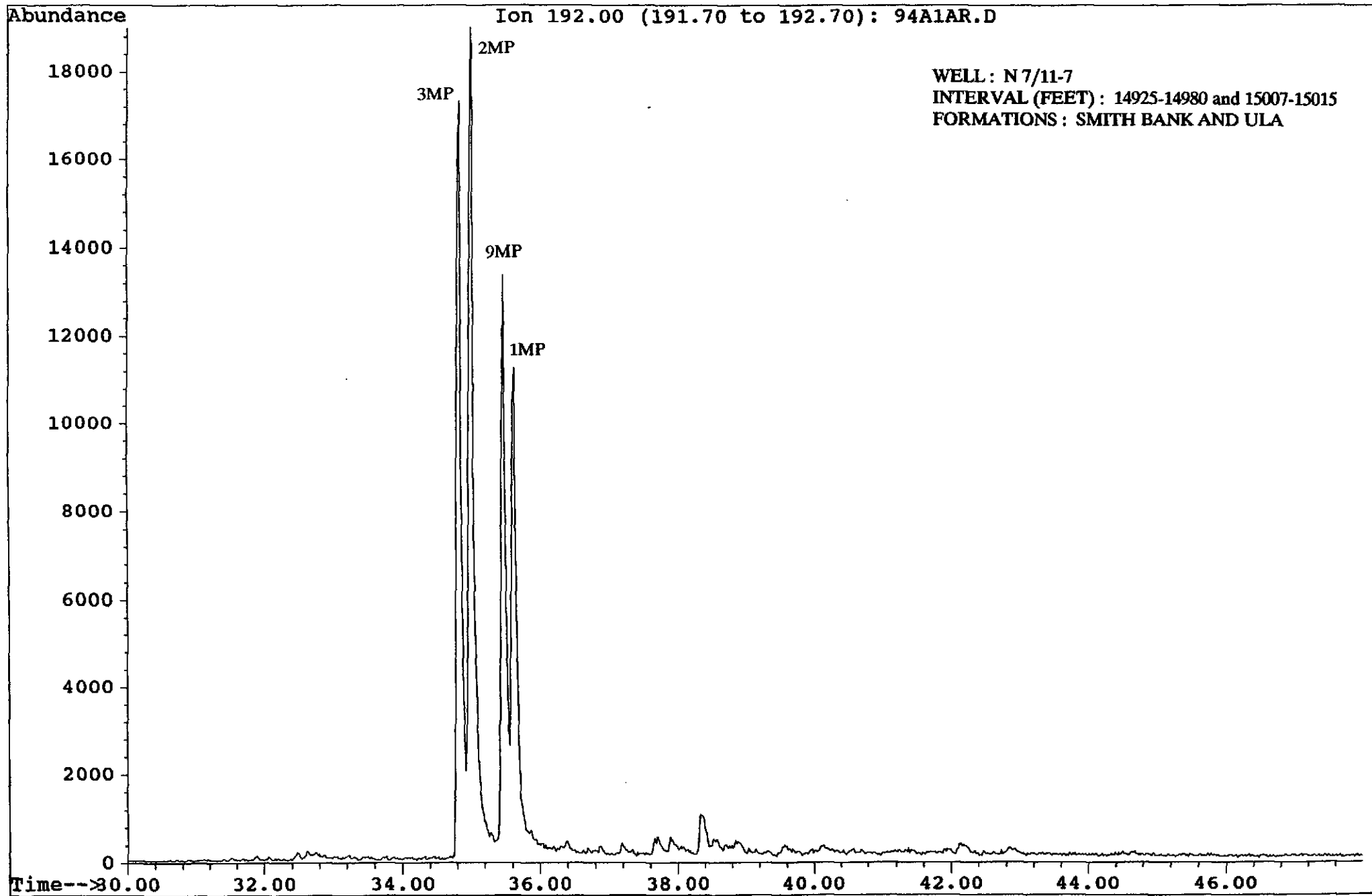


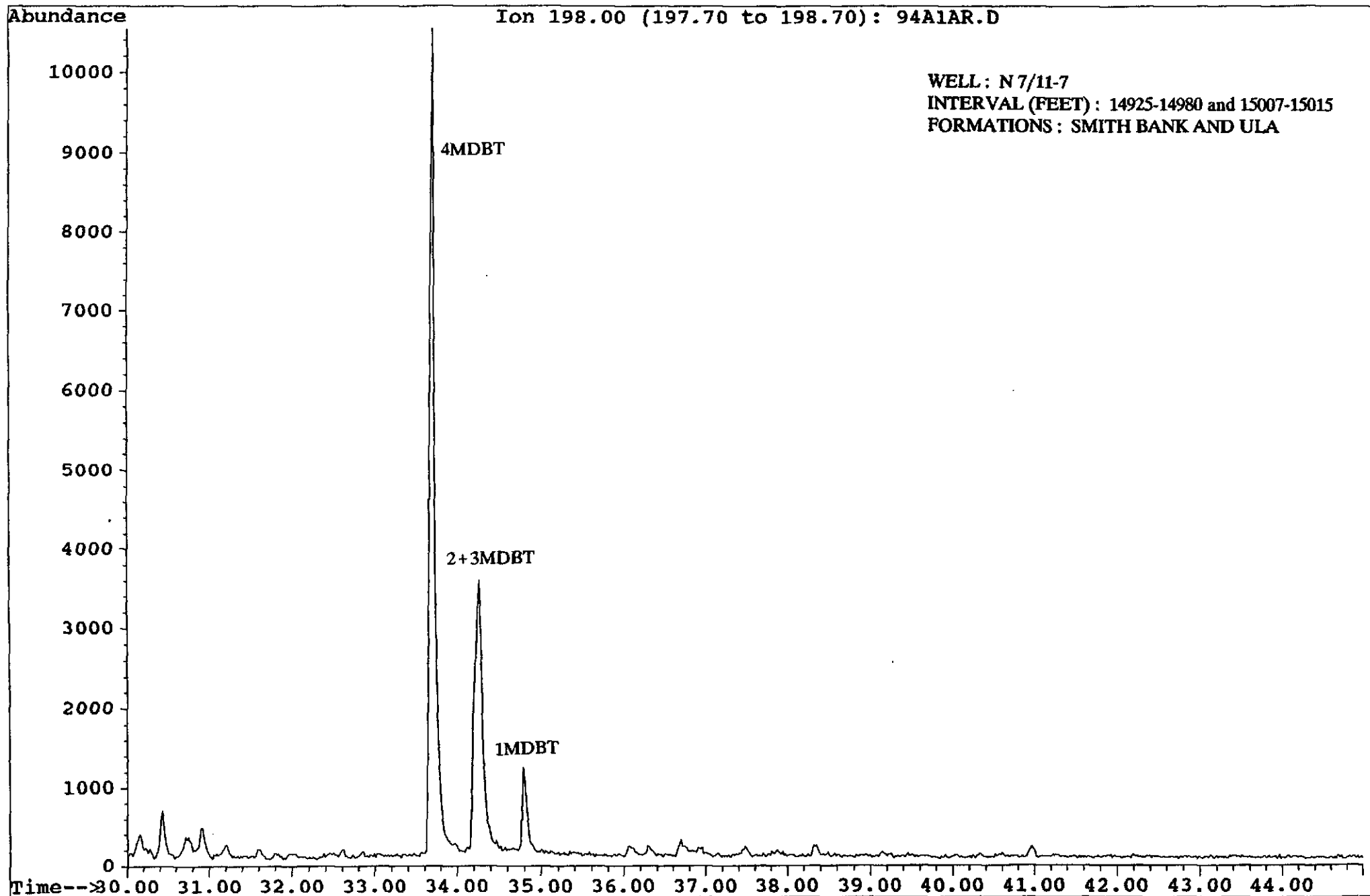


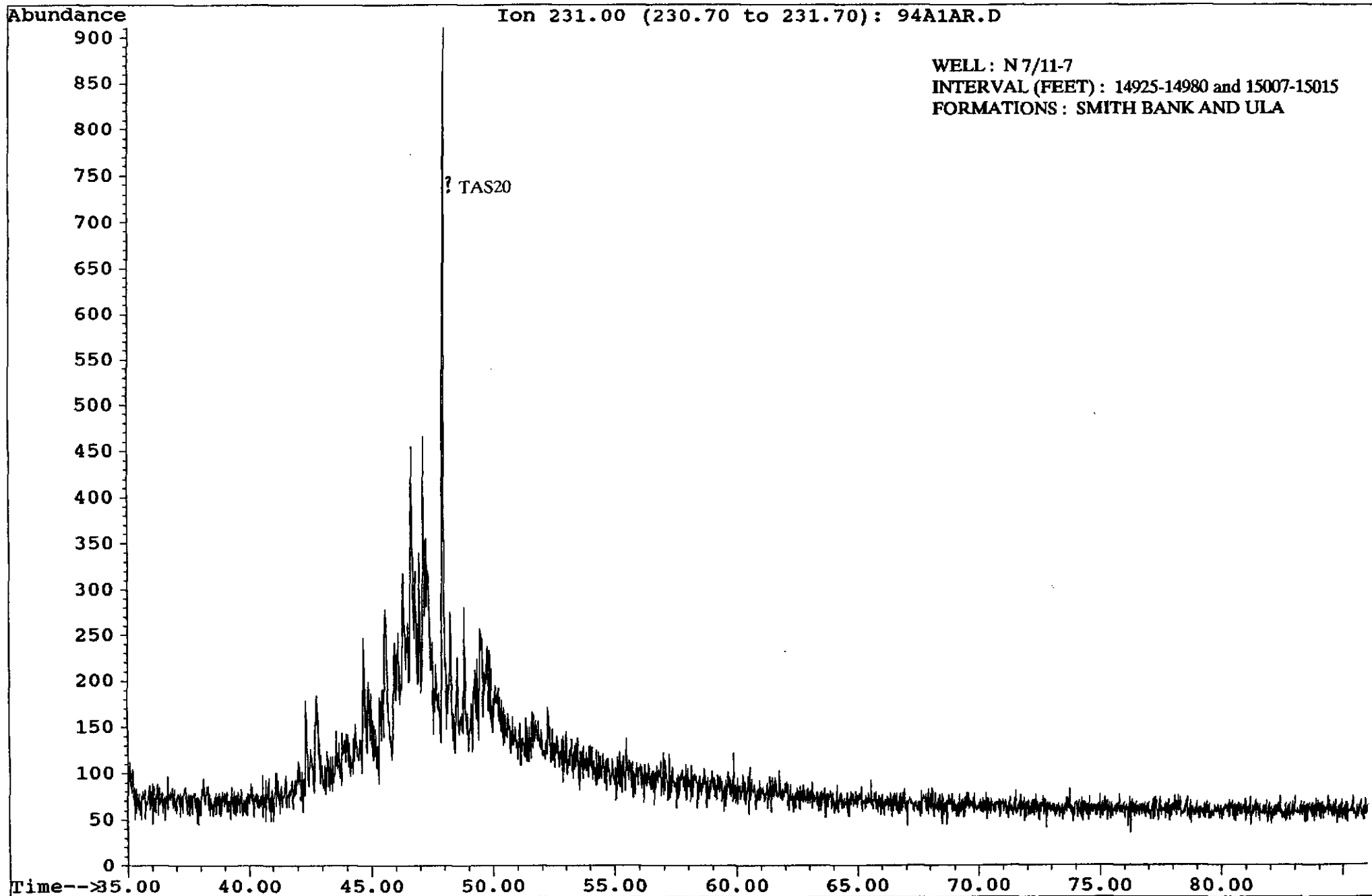












Abundance

Ion 253.00 (252.70 to 253.70): 94A1AR.D

WELL: N7/11-7
INTERVAL (FEET): 14925-14980 and 15007-15015
FORMATIONS: SMITH BANK AND ULA

? MAS21

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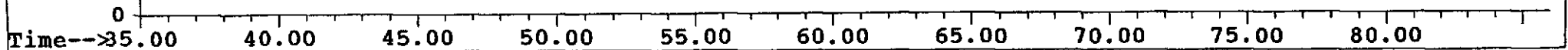
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65.00

70.00

75.00

80.00



APPENDIX 1

LIST OF ABBREVIATIONS

a/a	-	as above	min	-	mineral
Ac	-	acritarchs	mnr	-	minor
ADD	-	mud additive	mod	-	moderate
Al	-	algae	n-	-	normal
ALKS	-	alkanes	NA	-	not available
A	-	amorphous	NS	-	no sample
ANH	-	anhydrite	OC	-	organic carbon
aren	-	arenaceous	occ	-	occasional
arg	-	argillaceous	OI	-	oxygen index
AROMS	-	aromatics	ol	-	olive
B(IT)	-	bitumen/bituminous	ool	-	oolitic
bl	-	blue	orng	-	orange
bld	-	bleached	OS	-	oil stain
blk	-	black	P	-	picked lithology, pale (bleached)
brn	-	brown	pal	-	pale
calc	-	calcareous	PDB	-	Fee Dee Belemnite
CALT	-	calcite	Ph	-	phytane
carb	-	carbonaceous	PI	-	production index
CGL	-	conglomerate	pnk	-	pink
CHK	-	chalk	por	-	porous/porosity
CHT	-	chert	pp	-	purple
CLYST	-	claystone	ppt	-	parts per thousand
CMT	-	cement (from casing)	ppm	-	parts per million
CPI	-	carbon preference index	ppb	-	parts per billion (10 ⁹)
crs	-	coarse	Pr	-	pristane
CSG	-	casing point/shoe	pred	-	predominantly
cSt	-	centistokes	prt	-	present
Ctgs	-	ditch cuttings	Py	-	pyrolysis
Cu	-	cuticle	PY	-	potential yield
C(vd)	-	caved	PYR/pyr	-	pyrite/pyritic
decarb	-	decarbonated	QTZ(T)	-	quartz(ite)
Di	-	dinocysts	Re	-	resin
dk	-	dark	R(ew)	-	reworked, reworked or high reflecting vitrinite/semifusinite
DOL/dol	-	dolomite/dolomitic	Ro	-	reflectance in oil
dsk	-	dusky	Sap	-	sapropel
EPOC	-	extract percent OC	SCI	-	spore colour index
E(XTR)	-	extract	SD	-	standard deviation
Ex	-	exinite	Sf	-	semifusinite
f	-	fine	st	-	soft
fer	-	ferruginous	SH	-	shale
FID	-	flame ionisation detector	shly	-	shaly
flu	-	fluorescence	sil	-	siliceous
fm	-	formation	sks	-	slickenside surface
foss	-	fossils/fossiliferous	SLA	-	slate
FPD	-	flame photometric detector	SLT(ST)	-	silt(stone)
Fu	-	fusinite	sly	-	silty
GC	-	gas chromatogram (graph)	SMOW	-	standard mean oceanic water
GLC/glc	-	glaucinite/glaucinitic	SND	-	sand
GC-MS	-	gas chromatography - mass spectrometry	s(t)	-	stained
gn	-	green	sndy	-	sandy
grns	-	grains	Sp	-	spores
gy	-	grey	SST	-	sandstone
GYP	-	gypsum	sg	-	strong
HAL	-	halite	str	-	structured
HC	-	hydrocarbons	SWC	-	sidewall core
hd	-	hard	TAI	-	thermal alteration index
HI	-	hydrogen index	TD	-	total depth
i-	-	iso-	TOC	-	total organic carbon
i/b	-	interbedded	tr	-	trace(s)
IGN	-	igneous rocks	v	-	very
indet	-	indeterminate	Vit	-	vitrinite
indig	-	indigenous	vn	-	vein
Inert	-	inertinite	VR	-	vitrinite reflectivity
lam	-	laminae/laminated	wht	-	white
LCM	-	lost circulation material	wk	-	weak
LIG/Lig	-	lignite/lignitic	wxy	-	waxy
L(RV)	-	low reflecting vitrinite	xln	-	crystalline
LST	-	limestone	yel	-	yellow
lt	-	light	-	-	no analysis carried out
MDST	-	mudstone	*	-	analysed but no data obtained
med	-	medium	gy-gn	-	greyish green
MET	-	metamorphic rocks	gy/gn	-	grey-green (gradation)
mic	-	mica/micaceous	gn-gy	-	greenish grey
micr	-	micritic			

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

APPENDIX 2

ANALYTICAL PROCEDURES AND TECHNIQUES

This appendix summarises the main steps in the organic geochemical analyses carried out in Simon Petroleum Technology (Simon-Robertson) and Simon Laboratory Services. Analytical pathways are shown on the flow chart (Appendix Figure 1) and details of laboratory procedures and techniques are given in the following tables. The laboratories are NAMAS accredited and details of standards, frequency of use, etc. are included. The OLS numbers given in Sections 2 and 3 refer to the documented in-house methods specified in our NAMAS accreditation schedule. Interpretation guidelines are given although it must be emphasised that numerous factors may affect the assessment of any one data set, and such guidelines may not always be applicable. The presentation and interpretation of GC-MS data are the subjects of a separate appendix.

1 Sample Preparation

General

Samples are received into the laboratories in the forms of wellsite canned ditch cuttings; bagged ditch cuttings in various stages of preparation from wet, unwashed to dried, washed; sidewall cores; conventional cores; outcrop samples; crude oil samples and gas samples. Each sample is assigned a number which is entered into a computer system to monitor sample selection and progress. Preparation techniques are directed towards obtaining clean samples, free of drilling mud and mud additives, obvious caving contamination and indeterminate fine material. Washing with cold water is standard but further washing with solvent (dichloromethane, DCM) is carried out if oil-based mud is present, after which samples are dried, described and individual lithologies hand picked where practicable. Samples are rough crushed to approximately pea-sized fragments for kerogen preparation or finely milled for chemical analysis.

Kerogen Preparation

Kerogen concentrates for microscopic examination and elemental analysis are prepared using standard palynological procedures but omitting oxidation or acetolysis. Acid maceration involves the use of hot hydrochloric acid (HCl) to remove carbonates and hot 60% hydrofluoric acid (HF) to remove or break down silicates. Mineral residues are separated from the kerogen by a combination of ultrasonic vibration and zinc bromide flotation. Kerogen samples for spore colour and kerogen typing are mounted on glass slides in glycerin jelly, those for vitrinite reflectivity are dried and mounted in epoxy resin. Kerogen residues are stored in methanol.

2 Simon Laboratories - Geochemical Standards (November 1992)

OLS Number	Analysis	Standard	Frequency	Average Value	Standard Deviation	No. of Runs	Comments	
1	TOC	Leco steel ring	Every 10 samples	To manufacturer's specifications				
		Calcium carbonate	Daily	11.79 wt%	0.16	91	Expected value 12.0	
		In-house rock std	3 per batch	2.27 wt%	0.06	321		
		Traceable British Standard Steel	Weekly	0.509 wt%	0.004	70	Quoted value 0.51	
5	Rock-Eval pyrolysis	IFP standard	Weekly	To manufacturer's specifications				
		In-house rock std	Every 5 samples					
		S_1		0.68 mg/g	0.07	76)	In-house standard	
		S_2		6.65 mg/g	0.35	76)	values based on	
		S_3		0.38 mg/g	0.05	76)	weekly run	
T_{max}		438 deg C	2.32	76)	against IFP standard			
11	Headspace gas C_1-C_4	Traceable standard calibration gas	Daily	To manufacturer's specifications				
12	Headspace gas C_1-C_{6+}	Traceable standard calibration gas	Daily	To manufacturer's specifications				
13	Occluded gas C_1-C_4	Traceable standard calibration gas	Daily	To manufacturer's specifications				
14	Occluded gas C_1-C_{6+}	Traceable standard calibration gas	Daily	To manufacturer's specifications				
8	Solvent extraction	In-house rock std	Every 30 samples	1467 ppm	138	74		
23	Fractionation by Introscan	In-house standard oil	Daily					
				Alkane	35.7 wt%	1.0	41	
				Aromatic	32.1 wt%	0.7	41	
		Polars	32.2 wt%	0.9	41			
15	Gasoline GC	Mixed multicomponent standard	After maintenance					
16	C_{13+} alkane GC	In-house standard oil	Daily	16872 ppm	1820	59		
		In-house standard oil (alk fract.)	Every 30 samples	CPI-1=0.91	0.03	50		
17	Aromatic GC (FID)	5 component standard	Every 20 working days					
		In-house aromatic fraction	Every 30 samples					
21	Whole oil/extract	5 component standard	Every 20 working days					
		In-house standard oil	Every 30 samples					
22	Pyrolysis-GC	5 component standard	Every 20 working days					
		In-house pyrolysis - GC standard	Daily	C_1/C_{10} ratio = 8.5	2.6	46		
27	GC-MS	In-house standard oil (alk fract.)	Every 30 samples					
		Blank	Every 60 samples					

3 Instrumentation

Analysis (OLS Number)	Instrument Type	Minimum Sample Requirement	Standard	Comments
TOC (1)	Leco CS-125	1 g	Leco ring C/S/steel, #, *	Duplicate analysis run on 1 in 3 samples and on all samples submitted for Rock-Eval or extraction
Screening pyrolysis (5) Pyrolysis (5)	Rock-Eval II Rock-Eval II	1 g 1 g	IFF, #, * IFF, #, *	Cycle 1, omitting CO ₂ Cycle 1, 300°-550° at 25°C/min
Headspace (airspace) gas C ₁ -C ₄ (11)	Shimadzu GC-8A	15 ml headspace; sample ctgs in sealed can	4 component mixture	Isothermal, 90°C
C ₁ -C ₆ (12)	Perkin Elmer Sigma 3	20 ml headspace; sample ctgs in sealed can	9 component mixture	Isothermal, 110°C
Cuttings gas C ₁ -C ₄ (13) C ₁ -C ₆ (14)	Shimadzu GC-8A Perkin Elmer Sigma 3	25 g wet sample 25 g wet sample	4 component mixture 9 component mixture	Isothermal, 90°C Isothermal, 110°C
Solvent extraction (8)	Soxtec System 1043	10 g	#	40-60 min boil/80-120 min rinse
Extract fractionation (23)	Iatroscan TH-10 MKIII Column	2 mg 100 mg	# (standard oil) #	TLC/FID method Long column packed with silica/alumina
Branched/cyclic alkane separation	Urea adduction			Preparation for GC-MS
Gas chromatography- Gasolines, C ₁ -C ₄ (15)	Hewlett Packard 5890	25 g wet sample	Multi-component mixture and standard oil (#)	-10°C to 170°C at 6°C per minute
Whole oil/extracts (21)	AMS 92	2 mg	# and mixed 5 component standard	-30°C to 270°C at 5°C per minute
C ₁₅ alkanes (16)	Hewlett Packard 5890	2 mg	#, squalane	50°C to 70°C at 30°C per minute 70°C to 270°C at 3°C per minute Hold at 270°C for 30 minutes
Aromatics (17)	Hewlett Packard 5890	2 mg		50°C to 300°C @ 7.5°C per minute Hold at 300°C for 20 minutes
GC by FPD (18)	AMS 92	2 mg	Standard oil #	50°C to 70°C at 30°C per minute 70°C to 270°C at 3°C per minute 270°C to 290°C at 30°C per minute 290°C for 10 minutes
Extended ('wax') GC Thermal extraction Pyrolysis-GC (22))) Perkin Elmer F17)	2 mg 2 mg 2 mg	C ₃₄ std # #	60°C to 460°C at 10°C per minute -30°C to 270°C at 7.5°C per minute Pyroprobe burn-off: Thermal extraction, 300°C Pyrolysis-GC, 600°C
GC-MS	Finnegan 4000	2 mg	#, mass calibration by FC43 Quantitative peak calibration by deuterated choles- tane standard	20°C for 1 minute, 30°C per minute to 150°C 5°C per minute to 300°, 300° for 20 minutes Start acquisition at 60°C
Carbon isotopes	VG 602 stable isotope mass spectrometer, with dual inlet	2 mg	#, standard oil against NBS 22 at -29.81‰ PDB	
Oils - API gravity	Method IP60	5 ml minimum but 100 ml preferred	# standard oil	
viscosity	Method IP71	2 ml	# standard oil	
pour point	Method IP15	10 ml	# standard oil	
topping	Thermal flat bed	10g for one hour (or until equilibrium)	# standard oil	

N ₂ , V sulphur	ICP Labex, X-ray fluorescence		# standard oil # standard oil	
Gases - total content HC content) AMS 92) see C ₁ -C ₄ ASG	5 ml at STP	Standard calibration gas	C ₁ , C ₂ , C ₂ H ₆ , CO, CO ₂ , O ₂ , N ₂ , C ₂ H ₂ , H ₂
UV fluorescence - 2D (28) UV fluorescence - 3D (29)	Perkin Elmer LS-5	10 mg	Plastic block and standard oils #	
Vitrinite reflectance	Leitz Orthoplan/MPV compact. Zeiss	5 g	Glasses and gemstones in range 0.2% to 5.1% Ro	Kerogen sieved at 10 µm unless low recovery, in which case total kerogen mounted. Whole rocks crushed to pass 1 mm but not 5 mm mesh
Spore colouration	Leitz Dialux/Laborlux standard palynological microscopes	5 g	SPT 1-10 SCI standard reference slides (19 single grain mounts) #	Carried out on 10 µm sieved fraction of kerogen or on total kerogen if recovery low
Kerogen typing	Leitz Dialux/Laborlux as above	5 g	See Appendix Figure 2	Carried out on total kerogen in transmitted light
Kerogen fluorescence	Leitz Ploemopak 50W Hg	5 g		Qualitative

Note :

- # in-house primary standard
- * in-house secondary standard

4 Interpretation

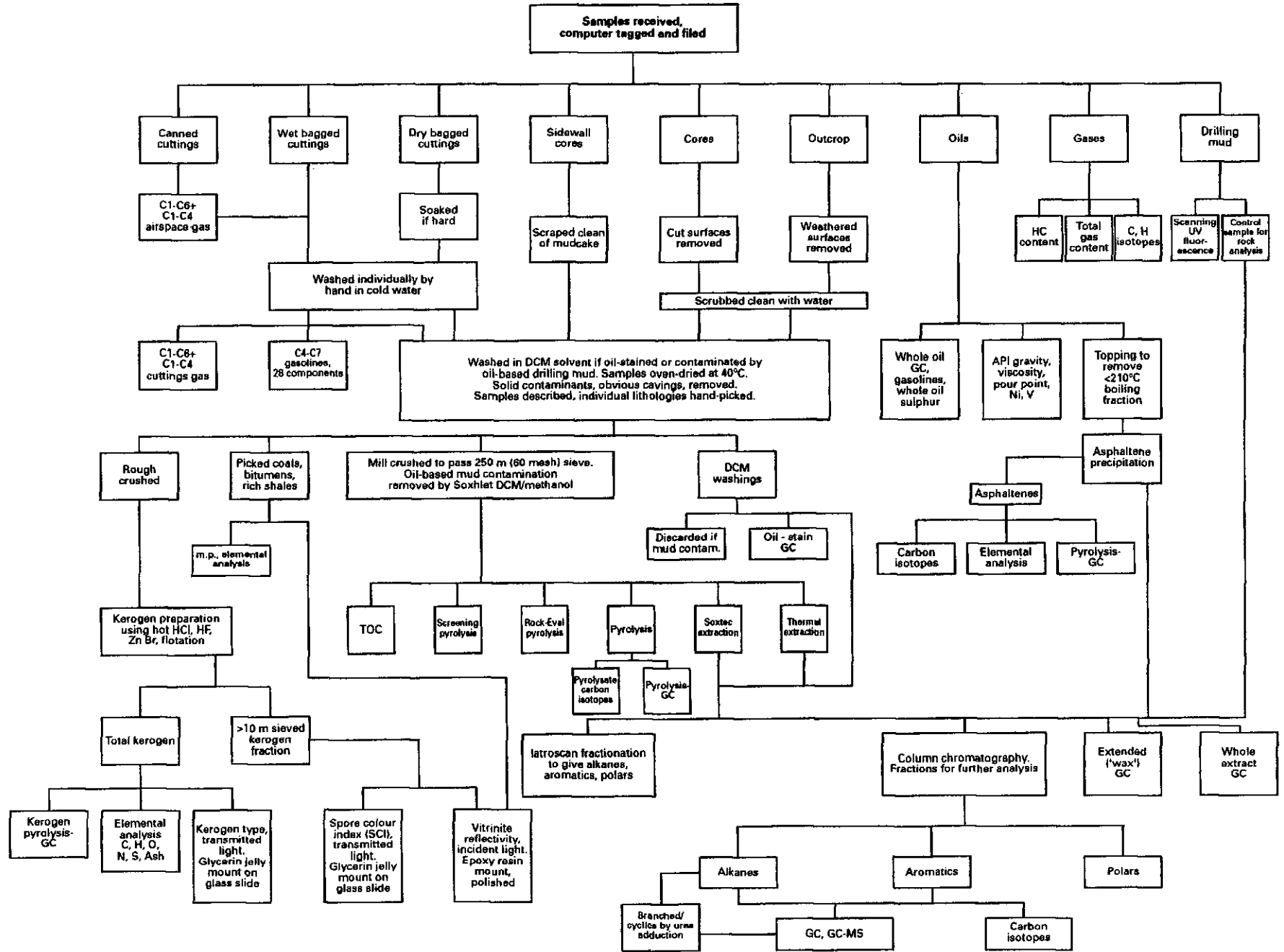
Analysis	Purpose SR = Source rock MAT = Maturity	Parameters/Units/Ratios	Interpretation	Application	Limitations
TOC	SR quality and screening	% wt. of rock	0-0.3% non-source 0.3-1% marginal source 1% + possible source	Defines basis for SR quality assessment	Does not assess source type
Rock-Eval pyrolysis	SR quality and MAT	Tmax, °C	400°-430° immature 430°-435° early mature 435°-450° middle mature 450°-470° late mature 470° + post-mature		Kerogen type dependent, strongly affected by presence of LCM, oil, oil-based mud contamination, etc.
		HI - hydrogen index S ₁ /TOC (mgHC/gOC)	0-200 gas-prone or mature oil prone 200-400 mature, oil-prone 400+ immature, oil-prone	Measures HC generation potential and defines source type	Maturity dependent; bulk samples only
		OI - oxygen index S ₂ /TOC (mgCO ₂ /gOC)	Low in oil-prone or over mature source rocks High in gas-prone source rocks	Defines source type	Often enhanced by presence of metastable carbonates or LCM
		PI - production index S ₁ /(S ₁ +S ₂)	0-0.15 immature to mature source rocks 0.15-1.0 presence of oil or contaminants	Screen for oil-stain	Affected by oil-based mud contamination
		PY - potential yield S ₂ (ppm, mg/g, kg/tonne)	0-2000 ppm poor potential 2000-6000 ppm fair potential 6000-20000 ppm good potential 20000 ppm very good potential	Measures total remaining yield of SR	Maturity dependent

Headspace (air-space) gas C_1-C_6 and C_1-C_4	MAT, migrant HCs	Abundance - ppm of HC in headspace on volume/volume basis		Rapid screening of samples direct from well-site. Measures HC generation directly	May be kerogen type dependent. Samples must be canned and sealed with bactericide at well-site
		C_1-C_4/C_1-C_4 % gives gas wetness	0-5% wet gas - immature or post mature 5%-15% - early mature 15%+ - middle/late mature		
		<i>i/n</i> -butane ratio	> 1.0 immature/early mature < 1.0 mature		
Solvent extraction	SR quality, MAT and migrant HCs	Total extract (about C_{12}) in ppm of weight of rock	0-200 ppm lean 200-1000 ppm fair 1000-2000 ppm good > 2000 ppm rich/oil stained	Essential starting point for analysis of free HC in source rocks and oil stained cgs/core. Used to remove oil-based mud contamination	
		Extract % organic carbon (EPOC)	10%-15% - suspect oil-stain or contamination > 15% - probable oil-stain or contamination		
Extract fractionation	SR quality, MAT and migrant HCs	% alkanes, aromatics and polars of total extract	See Extract Composition Diagram (triangular plot). Alkanes increase with maturity but overall proportions characteristic of source type	MAT progression with respect to oil composition	Requires maturity of host rock for interpretation Separation of hydrocarbons into alkanes and aromatics fractions depends on technique employed, because of differing response of mixed molecules
		HC ppm	Increase with source quality or oil-stain		
		$HC^\circ / \infty OC$ (or HC mg per g OC)	< 100 immature or poor SR > 100 fair/good SR		
		HC % extract	> 20% in oil window. Oil-stain gives high value (> 50%)		
		Alkanes % HC and alkanes:aromatics ratio	Increases through oil window and defines paraffinic or aromatic sources		
Gas Chromatography	SR quality and type, MAT and migrant HCs. Oil-SR comparisons	Total abundance (ppm or ppb) or normalised to 100%. Individual compounds expressed as ppm, ppb or % total	Numerous ratios available by comparison of peak areas	Provides basic fingerprint of HC types; indicates alteration processes; indicates kerogen type and maturity	
1. Gasolines	SR quality and type, MAT and migrant HCs by examination of light (C_1-C_6) HCs	See also Gasoline Range Hydrocarbon Data table			
		Abundance - ppm of HC in oil	High in light, live oils, low in heavy, degraded oils		
		Abundance - ppb of HC per weight of wet rock	Increases with maturity and source rock quality		
		Late mature index - Benzene: methyl cyclohexane	Increases with maturity but may be reduced by water-washing		
		Aromaticity index - Toluene: <i>n</i> -heptane	As above		
		Heptane index - <i>n</i> -heptane: all C_7 compounds (%)	Increases with maturity and discriminates between paraffinic and non-paraffinic source rocks		
		Isoheptane index - methyl hexanes (non-cyclic): dimethyl cyclopentanes	A/a - see fields on heptane index/isoheptane index cross-plot		
		Kerogen type index - (heptane index - 4): isoheptane index	Liptinitic sources > 12, humic sources < 6		

2. Whole oils	Oil type and source by examination of C ₁ -C ₃₀ HCs	Bias towards light or heavy HCs	High bias (see below) and presence of light HCs indicate light, live oil		
		Baseline hump, lack of n-alkane peaks	Biodegradation		
3. C ₁₃₊ alkanes	SR type and maturity, oil type and source	Baseline hump, lack of n-alkane peaks	Biodegradation		
		Bias = $\frac{C_{16} + C_{17} + \dots + C_{22}}{C_{23} + C_{24} + \dots + C_{29}}$	Increases with maturity, decreases with terrestrial input to source kerogen		
		CPI 1 $\frac{1}{2} \times \left[\frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{26} + C_{28} + C_{30} + C_{32} + C_{34}} + \frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{26} + C_{28} + C_{30} + C_{32} + C_{34}} \right]$			
		CPI 2 $\frac{1}{2} \times \left[\frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{26} + C_{28} + C_{30} + C_{32}} + \frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{26} + C_{28} + C_{30} + C_{32}} \right]$			
		CPI 3 $\frac{2 \times C_{27}}{C_{26} + C_{28}}$			
		CPI values converge to 1.0 with increasing maturity. Values > 1.0 indicate immaturity and/or terrestrial kerogen. Values < 0.9 suggest rapid deposition into an anoxic environment and are often associated with carbonate SRs			
		Pristane (i-C ₁₉): Phytane (i-C ₂₀)	< 1.0 - highly anoxic environment > 1.5 - terrestrial source		
		Prn-C ₁₇ and Phn-C ₁₈	Decrease with maturity but are also source kerogen dependent (see cross-plot)		
4. C ₁₃₊ aromatics	SR type and MAT, oil type and source	Methyl phenanthrene index MPI-1 = 1.5 (2-mp + 3-mp) $\frac{p + (1-mp + 9-mp)}{m}$ m - methyl p - phenanthrene	Gives approximate vitrinite reflectance equivalent at the time of generation (oils)	Gives a value for source rock maturity at time of generation. Sulphur aromatic ratios are source dependent	
Pyrolysis - gas chromatography (Py-GC)	SR type and MAT		Doublet peaks comprise alkene-alkane pairs, with the elution order dependent on column type. Chromatograms range from C ₁ to C ₃₀ or above with gas-prone kerogen cracking to give a limited molecular weight range of products, concentrated towards the light ends, whereas oil-prone kerogen gives more prominent alkene-alkane doublets in the C ₁₂ -C ₂₀ region. The largest peak from both types is usually methane	Gives a direct chemical finger-print of source type. Pyrolysate may be used in isotope studies	Pyrolysis products not like natural petroleum (more unsaturated)
Stable carbon isotopes	Correlation of oils and gases to source. Differentiation of biogenic and thermogenic gases	Alkane, aromatic, asphaltene fractions of oils or source rock extracts, and kerogens from source rocks analysed to give deviation from PDB standard. Results expressed as δ ¹³ C PDB in parts per thousand (parts per mil; ‰). Value of NBS 22 taken as -29.81‰	Negative deviations from PDB standard are normal in oils and source rock organic matter and indicate impoverishment of ¹³ C with respect to ¹² C. Oils and source rock extracts and kerogens give values in the range -20 ‰ to -32 ‰ with ¹³ C enrichment in the order: kerogen-asphaltenes-aromatics-alkanes. Oils tend to be about 1 ‰ enriched in ¹³ C (less negative ratios) than their sources.	Little affected by maturity	Oil-source comparisons made within relatively narrow range of values. Different sources may have similar values

			Comparisons generally made by alkane-aromatic cross-plot. For gases, $\delta^{13}\text{C}_1$ more negative than -60, biogenic; less negative than -50, thermogenic		
Stable isotope of hydrogen (deuterium)	Differentiation of biogenic and thermogenic gases	Results expressed as δD SMOW in parts per thousand (parts per mil; ‰)	Characteristic values for marine biogenic methane: -150 to -190 ‰, for non-marine biogenic methane: -200 to -250 ‰. Gases become less depleted in deuterium with increasing source maturity, e.g. -200 to -250 ‰ at early maturity to about -150 ‰ at the end of the oil window		
Stable isotope of sulphur (^{34}S)	Investigation of H_2S formation, timing of anhydrite formation, oil-oil and oil-source rock correlations	Results expressed as $\delta^{34}\text{S}$ CDT (Canyon Diablo Troilite) in parts per thousand (parts per mil; ‰)	$\delta^{34}\text{S}$ of oils and source rocks are highly variable with respect to age/type, but correlate on value	$\delta^{34}\text{S}$ of anhydrites are age dependent	
Elemental analysis	SR type and MAT	Results quoted as % weight of elements C,H,O,N,S and ash in coals or kerogens	Atomic ratios H/C and O/C plotted on van Krevelen diagram with fields and maturity	Gives chemical composition of kerogen directly	Difficult to remove pyrite, other minerals and water completely
Oil analysis (whole oil)	Typing of oils using physical and chemical properties	*API gravity:- 141.5 oil specific grav. at 60°F	10°-25° heavy and degraded oils 25°-45° medium gravity oils 45°-50° light oils > 50° condensates		
		Pour point (°C)	Most mobile oils < 0°C Waxy oils may be over 20°C		
		Kinematic viscosity (centistokes, cSt)	Decreases with temperature and API gravity		
		Sulphur (%S)	High sulphur crudes (> 2%S) usually associated with heavy oils from carbonate sources		
		Water, wax, asphaltene contents (%)	Typing of oil		
		Nickel, vanadium content (ppm)	Medium and light oils usually < 10 ppm, heavy oil > 10 ppm	Ni/V ratio is specific to oils and may be used (with %S) in correlations	
		Topping (wt%)	Equivalent to removal of < 210°C boiling fraction	Gives a more standardised product for comparison of liquid and gas chromatography results, and CIR analysis	
Gas analysis	Gas type and source	HC gases C_1 to C_4 collected from wellsite in sealed containers or desorbed from canned, wet ditch cuttings samples. Results quoted as % weight (with or without non-HC gases)	Check for wetness, butane ratio as for airspace gas		
Solid bitumen analysis	Tarmat studies, oil emplacement and degradation histories	Differentiation into solid bitumen group: ozocerite - asphalt - gilsonite - glance pitch - grahamite - wurtzilite - albertite - impsponites by solubility, fusibility, reflectivity etc.		Time-temperature changes produce known sequences of bitumen types from which information on maturity, source and reservoir effects may be deduced	

Ultra-violet fluorescence scanning	Distinction of crude oils in oil-based drilling muds.	Plotted results include a conventional emission spectrum at a single excitation frequency of 265 nm, a synchronous scan at 23 nm separation, '3-D' isometric plot and contoured plot. Ratios of 3-ring to 2-ring aromatics	Spectra and other plots used for fingerprinting. Direct comparison of 3-ring to 2-ring aromatic ratios may be applied to crudes and mud base oils		
Spore colouration (Spore Colour Index, SCI)	MAT	Colours of spores matched against SCI 1-10 scale standard reference slides and expressed as SCI units to ± 0.5 May be applied, with modification, to acritarch colours	SCI 1-3.5 - immature 3.5-5.0 - early mature 5.0-7.0 - middle mature 7.0-8.5 - late mature 8.5-10.0 - post-mature	Rapid maturity measurement. Grains may be stratigraphically diagnostic to minimise caving or reworking problems. Sporopollenin close to oil generation kerogen types	Plethora of scales in industry use. Spores may be oxidised or pigmented to give anomalously low ('bleached') or high ('stained') values of SCI. Eye-ball method of measurement
Liptinite UV fluorescence	MAT; SR quality by distinguishing oil- and gas-prone organic matter	Qualitative use only. Colour and brightness reported	Oil-prone organic matter is fluorescent at maturities up to late or post-mature levels. Spores respond: yellow - immature to early mature yellow-orange - early to middle mature orange - middle mature brown - late mature	May be used on transmitted or reflected light preparations. Rapid check on broad maturity range	Qualitative use only. Different organic matter types have different response
Vitrinite reflectivity	MAT	Results expressed as average of n mean (random) reflectance values, measured in oil immersion i.e. R_o % ave. (n)	$R_o = 0.2-0.5\%$ - immature to early mature $0.5-1.3\%$ - middle and late mature $> 1.3\%$ - post-mature (oil) $> 1.0\%$ - mature (gas) The kinetics of oil generating kerogen may be different from those governing the development of reflectivity. The generation thresholds above must be taken as a general guide only	Widely used method of maturity measurement with easily obtained standards. Precise measurement of reflectance electronically	Subjective selection of grains for measurement or selection of population. No direct control on differentiation of caved, reworked vitrinite. High and low reflecting particles may interfere
Kerogen typing (visual)	SR quality and type	Percentages of up to 5 main categories given (to nearest 5% or 10%)	See Appendix Figure 2.	Composition of mixtures seen directly (cf. bulk chemical methods)	Measures relative kerogen amounts. Fine material may not be easily identified



General type	Liptinitic		Humic		Inertinitic	INDETERMINATE AMORPHOUS
Source potential	Oil-prone		Gas-prone		Inert	
Chemical type	I	II	IIIA		IIIB	
Summary chart code	[Solid black]		[Diagonal lines]		[Dotted]	
Major component classification	LIPTINITE		VITRINITE		INERTINITE	
	AMORPHOUS	EXINITE	AMORPHOUS	STRUCTURED		
Response in UV/ blue light	Fluorescent		Non or weakly fluorescent		Non-fluorescent	
Description and origin	Typical oil-prone, sapropelic kerogen of algal/bacterial origin. Degraded spores, algae	Algae, resin, spores, pollen, cuticle, dinocysts	Amorphous of probable humic origin by gel precipitation or degradation of structured plant tissue	Woody tissues, red-brown becoming black at high maturity	Woody tissues, dark brown to black or opaque	Amorphous kerogen of all types at high maturity levels
Miscellaneous 'kerogen' components in approximately equivalent categories	Soft bitumens. Grease contamination		Solid bitumen, brown, often with crystal imprints	Microforaminifera tests, chitinozoa, graptolitic fragments, spores etc. at high maturity	Solid bitumen, black or opaque	
NPD guidelines equivalent category	AM - FA	HE,AL	AM - HA	WO	CO	
Mud additives	Additives may fall into all categories					

APPENDIX Figure 2 Kerogen typing scheme for transmitted white and incident UV/blue light

A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7

APPENDIX 3

Index of Alkane Molecular Biomarker Gas Chromatography-Mass Spectrometry Peak Assignments

STERANES

$5\beta(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ and $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ C_{27} , C_{28} and C_{29} regular (normal) steranes and $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ C_{27} , C_{28} and C_{29} isosteranes

Peak	Assignment	NPD Codes
S27a	C_{27} $5\beta(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	
S27c	C_{27} $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20S cholestane	27 $\alpha\alpha$ S
S27d	C_{27} $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20R isocholestane	27BBR
S27e	C_{27} $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20S isocholestane	27BBS
S27b	C_{27} $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	27 $\alpha\alpha$ R
S28a	C_{28} 24-methyl- $5\beta(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	
S28c	C_{28} 24-methyl- $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20S cholestane	28 $\alpha\alpha$ S
S28d	C_{28} 24-methyl- $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20R isocholestane	28BBR
S28e	C_{28} 24-methyl- $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20S isocholestane	28BBS
S28b	C_{28} 24-methyl- $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	28 $\alpha\alpha$ R
S29a	C_{29} 24-ethyl- $5\beta(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	
S29c	C_{29} 24-ethyl- $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20S cholestane	29 $\alpha\alpha$ S
S29d	C_{29} 24-ethyl- $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20R isocholestane	29BBR
S29e	C_{29} 24-ethyl- $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20S isocholestane	29BBS
S29b	C_{29} 24-ethyl- $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R cholestane	29 $\alpha\alpha$ R

Configurations:

- a $5\beta(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R (immature or biological configuration)
- b $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20R (regular or normal sterane)
- c $5\alpha(\text{H})14\alpha(\text{H})17\alpha(\text{H})$ 20S (regular or normal sterane)
- d $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20R (isosterane)
- e $5\alpha(\text{H})14\beta(\text{H})17\beta(\text{H})$ 20S (isosterane)

Notes:

All steranes listed are likely to be 24R and 24S epimers which cannot be separated with the chromatography conditions used.

The elution sequence of normal and isosteranes for each of the C₂₇, C₂₈ and C₂₉ groups is as shown in the above listing: 5 α (H)14 α (H)17 α (H) 20S, 5 α (H)14 β (H)17 β (H) 20R, 5 α (H)14 β (H)17 β (H) 20S, 5 α (H)14 α (H)17 α (H) 20R. The C₂₇, C₂₈ and C₂₉ 5 β (H)14 α (H)17 α (H) 20R steranes approximately coelute with the respective C₂₇, C₂₈ and C₂₉ 5 α (H)14 β (H)17 β (H) 20R isosteranes. The order of thermal stability of the steranes is 5 α (H) > 5 β (H), 5 α (H) 20S > 5 α (H) 20R and 14 β (H)17 β (H) > 14 α (H)17 α (H).

4-desmethylsteranes have been identified and are considered to be biological markers for marine organic material; however, these compounds cannot be differentiated from C₃₀ 4-methylsteranes without metastable ion monitoring (GC-MS-MS). C₃₀ 4-desmethylsteranes occur with 5 α (H)14 α (H)17 α (H) 20R and 20S and 5 α (H)14 β (H)17 β (H) 20R and 20S (isosterane) configurations. C₂₆ steranes have also been identified (Shi Ji-Yang *et al.*, 1982) but are rare.

METHYLSTERANES

4 α (H) and 4 β (H) C₂₈, C₂₉ and C₃₀ methylsteranes

Peak	Assignment
ms28d	C ₂₈ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20S cholestane
ms28b	C ₂₈ 4 α (H)-methyl-5 β (H)14 α (H)17 α (H) 20R cholestane
ms28e	C ₂₈ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20R cholestane
ms28f	C ₂₈ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20S cholestane
ms28c	C ₂₈ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20R cholestane
ms28a	C ₂₈ 4 β (H)-methyl-5 α (H)14 α (H)17 α (H) 20R cholestane
ms29d	C ₂₉ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20S methylcholestane
ms29b	C ₂₉ 4 α (H)-methyl-5 β (H)14 α (H)17 α (H) 20R methylcholestane
ms29e	C ₂₉ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20R methylcholestane
ms29f	C ₂₉ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20S methylcholestane
ms29c	C ₂₉ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20R methylcholestane
ms29a	C ₂₉ 4 β (H)-methyl-5 α (H)14 α (H)17 α (H) 20R methylcholestane
ms30d	C ₃₀ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20S ethylcholestane
ms30b	C ₃₀ 4 α (H)-methyl-5 β (H)14 α (H)17 α (H) 20R ethylcholestane
ms30e	C ₃₀ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20R ethylcholestane
ms30f	C ₃₀ 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20S ethylcholestane
ms30c	C ₃₀ 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20R ethylcholestane
ms30a	C ₃₀ 4 β (H)-methyl-5 α (H)14 α (H)17 α (H) 20R ethylcholestane

Configurations:

- a 4 β (H)5 α (H)14 α (H)17 α (H) 20R (immature)
- b 4 α (H)5 β (H)14 α (H)17 α (H) 20R (immature)
- c 4 α (H)5 α (H)14 α (H)17 α (H) 20R (regular or normal methylsterane)
- d 4 α (H)5 α (H)14 α (H)17 α (H) 20S (regular or normal methylsterane)
- e 4 α (H)5 α (H)14 β (H)17 β (H) 20R (isomethylsterane)
- f 4 α (H)5 α (H)14 β (H)17 β (H) 20S (isomethylsterane)

Notes:

The full stereochemistry of the methylsteranes, that is, either the 23,24-dimethyl (dinosterane) or the 24-ethyl configuration, cannot be determined without full scan GC-MS analysis and examination of mass spectra. Mass spectra of 23,24-dimethylsteranes (dinosteranes) show a significant ion at m/e 198 (Goodwin *et al.*, 1988). The elution sequence of the C₂₈, C₂₉ and C₃₀ 4-methyl-14 α (H)17 α (H) 20R steranes is 4 α (H)5 β (H), 4 α (H)5 α (H) and 4 β (H)5 α (H). In synthetic mixtures of 4-methylsteranes, the 4 β (H)5 β (H) isomer elutes between the 4 α (H)5 β (H) and 4 α (H)5 α (H) (Goodwin *et al.*, 1988), but does not appear to occur naturally.

The order of thermal stability of the naturally occurring 4-methylsteranes is 4 α (H) > 4 β (H) and 4 α (H)5 α (H) > 4 α (H)5 β (H) (Wolff *et al.*, 1986). The elution sequence of 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) and 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) steranes for each of the C₂₇, C₂₈ and C₂₉ groups is similar to the desmethyl steranes and is as shown in the above listing: 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20S, 4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20R,

4 α (H)-methyl-5 α (H)14 β (H)17 β (H) 20S, 4 α (H)-methyl-5 α (H)14 α (H)17 α (H) 20R. The order of thermal stability is presumed to be comparable to the desmethyl steranes.

Compounds identified as methylsteranes, but substituted at a position other than at C-4 on the A-ring, have been reported (Fowler and Douglas, 1987; Summons and Powell, 1987; Summons *et al.*, 1987) but appear to be rare.

REARRANGED STERANES (DIASTERANES)

13 β (H)17 α (H) and 13 α (H)17 β (H) C₂₇, C₂₈ and C₂₉ rearranged steranes

Peak	Assignment	NPD Codes
r27d	C ₂₇ 13 β (H)17 α (H) 20S diacholestane	27d δ S
r27c	C ₂₇ 13 β (H)17 α (H) 20R diacholestane	27d δ R
r27b	C ₂₇ 13 α (H)17 β (H) 20S diacholestane	27d α S
r27a	C ₂₇ 13 α (H)17 β (H) 20R diacholestane	27d α R
r28d	C ₂₈ 24-methyl-13 β (H)17 α (H) 20S diacholestane	28d δ S
r28c	C ₂₈ 24-methyl-13 β (H)17 α (H) 20R diacholestane	28d δ R
r28b	C ₂₈ 24-methyl-13 α (H)17 β (H) 20S diacholestane	28d α S
r28a	C ₂₈ 24-methyl-13 α (H)17 β (H) 20R diacholestane	28d α R
r29d	C ₂₉ 24-ethyl-13 β (H)17 α (H) 20S diacholestane	29d δ S
r29c	C ₂₉ 24-ethyl-13 β (H)17 α (H) 20R diacholestane	29d δ R
r29b	C ₂₉ 24-ethyl-13 α (H)17 β (H) 20S diacholestane	29d α S
r29a	C ₂₉ 24-ethyl-13 α (H)17 β (H) 20R diacholestane	29d α R

Configurations:

- a 13 α (H)17 β (H) 20R
- b 13 α (H)17 β (H) 20S
- c 13 β (H)17 α (H) 20R
- d 13 β (H)17 α (H) 20S

Notes:

All rearranged steranes listed are likely to be 24R and 24S epimers which, with the exception of C₂₈ 24-methyl-13 β (H)17 α (H) diacholestanes, cannot normally be separated with the chromatography conditions used.

The C₂₉ 24-ethyl-13 β (H)17 α (H) 20S diacholestane co-elutes with the C₂₇ 5 α (H)14 β (H)17 β (H) 20R isocholestane and the C₂₉ 24-ethyl-13 α (H)17 β (H) 20R diacholestane co-elutes with the C₂₈ 24-methyl-5 α (H)14 β (H)17 β (H) 20R isocholestane under normal chromatography conditions. The 13 α (H)17 β (H) configuration is less thermally stable than 13 β (H)17 α (H).

C₃₀ rearranged steranes also occur, with 13 β (H)17 α (H) 20R and 20S and 13 α (H)17 β (H) 20R and 20S configurations.

BICYCLIC SESQUITERPANES

Peak	Assignment
DM	8 β (H)-drimane
HD	8 β (H)-homodrimane
ED	4 β (H)-eudesmane

TRICYCLIC TERPANES

Peak	Assignment	NPD Codes
t19	C ₁₉ tricyclic terpane	
t20	C ₂₀ tricyclic terpane	
t21	C ₂₁ tricyclic terpane	
t22	C ₂₂ tricyclic terpane	
t23	C ₂₃ tricyclic terpane	23/3
t24	C ₂₄ tricyclic terpane	24/3
t25	C ₂₅ tricyclic terpane	25/3
t26	C ₂₆ tricyclic terpanes	26/3
t27	C ₂₇ tricyclic terpanes	
t28	C ₂₈ tricyclic terpanes	
t29	C ₂₉ tricyclic terpanes	
t30	C ₃₀ tricyclic terpanes	

Notes:

C₂₆, C₂₈, C₂₉ and C₃₀ tricyclic terpanes occur as isomeric (at C-22) C₂₂ and C₂₇ tricyclic terpanes are generally less abundant, suggesting branching at these positions. Tricyclic terpanes of higher molecular weight, up to C₄₀ and higher, have been identified (Moldowan *et al.*, 1983), but are unusual. Mello *et al.* (1988) identified C₃₁, C₃₃, C₃₄ and C₃₅ tricyclic terpanes in Brazilian oils.

TETRACYCLIC TERPANES

Seco-17,21-hopanes

Peak	Assignment	NPD Code
T24	C ₂₄ tetracyclic terpane	24/4
T26	C ₂₆ tetracyclic terpane	

Notes:

The tetracyclic terpanes are hopane related compounds and have the structure seco-17,21-hopane.

PENTACYCLIC TRITERPANES

C_{27} and C_{29} to C_{35} $17\alpha(H)21\beta(H)$ and $17\beta(H)21\beta(H)$ hopane and $17\beta(H)21\alpha(H)$ moretane series.

C_{27} and C_{29} to C_{35} $17\alpha(H)21\beta(H)$ hopane series:

Peak	Assignment	NPD Codes
h27s	C_{27} $18\alpha(H)-22,29,30$ -trisorneohopane (Ts)	27Ts
h27m	C_{27} $17\alpha(H)$ -trisorhopane (Tm)	27Tm
h29	C_{29} $17\alpha(H)21\beta(H)$ -30-norhopane	29 $\alpha\beta$
h30	C_{30} $17\alpha(H)21\beta(H)$ -30-hopane	30 $\alpha\beta$
h31s	C_{31} $17\alpha(H)21\beta(H)$ -30,31-homohopane 22S	31 $\alpha\beta$ S
h31R	C_{31} $17\alpha(H)21\beta(H)$ -30,31-homohopane 22R	31 $\alpha\beta$ R
h32S	C_{32} $17\alpha(H)21\beta(H)$ -30,31-bishomohopane 22S	32 $\alpha\beta$ S
h32R	C_{32} $17\alpha(H)21\beta(H)$ -30,31-bishomohopane 22R	32 $\alpha\beta$ R
h33S	C_{33} $17\alpha(H)21\beta(H)$ -30,31-trishomohopane 22S	33 $\alpha\beta$ S
h33R	C_{33} $17\alpha(H)21\beta(H)$ -30,31-trishomohopane 22R	33 $\alpha\beta$ R
h34S	C_{34} $17\alpha(H)21\beta(H)$ -30,31-tetrakishomohopane 22S	34 $\alpha\beta$ S
h34R	C_{34} $17\alpha(H)21\beta(H)$ -30,31-tetrakishomohopane 22R	34 $\alpha\beta$ R
h35S	C_{35} $17\alpha(H)21\beta(H)$ -30,31-pentakishomohopane 22S	35 $\alpha\beta$ S
h35R	C_{35} $17\alpha(H)21\beta(H)$ -30,31-pentakishomohopane 22R	35 $\alpha\beta$ R

C_{27} and C_{29} to C_{35} $17\beta(H)21\alpha(H)$ moretane series

Peak	Assignment	NPD Codes
m29	C_{29} $17\beta(H)21\alpha(H)$ -30-normoretane	29 $\beta\alpha$
m30	C_{30} $17\beta(H)21\alpha(H)$ -30-moretane	30 $\beta\alpha$
m31	C_{31} $17\beta(H)21\alpha(H)$ -homomoretane	
m32	C_{32} $17\beta(H)21\alpha(H)$ -bishomomoretane	

C_{27} $17\beta(H)$ and C_{29} to C_{35} $17\beta(H)21\beta(H)$ hopanees

Peak	Assignment
b27	C_{27} $17\beta(H)$ trisorhopane
b29	C_{29} $17\beta(H)21\beta(H)$ norhopane 22R
b30	C_{30} $17\beta(H)21\beta(H)$ hopane 22R
b31	C_{31} $17\beta(H)21\beta(H)$ homohopane 22R
b32	C_{32} $17\beta(H)21\beta(H)$ -30,31-bishomohopane 22R
b33	C_{33} $17\beta(H)21\beta(H)$ -30,31-trishomohopane 22R
b34	C_{34} $17\beta(H)21\beta(H)$ -30,31-tetrakishomohopane 22R
b35	C_{35} $17\beta(H)21\beta(H)$ -30,31-pentakishomohopane 22R

Notes:

The C_{29} to C_{35} pentacyclic triterpane (hopane) series of compounds have been identified with $17\alpha(H)21\beta(H)$ (hopane), $17\beta(H)21\alpha(H)$ (moretane) and $17\beta(H)21\beta(H)$ (hopane) configurations. C_{27} trisnorhopanes have no side-chain at C-21 and have either the $17\alpha(H)$ or $17\beta(H)$ configuration, the former being the more thermally stable and the latter form generally present in immature samples only. The C_{27} $18\alpha(H)$ -trisnorhopane (T_1) is more thermally stable than C_{27} $17\alpha(H)$ -trisnorhopane (T_m). 3-methylhopanes are rarely present and may be detected by use of m/e 205 mass chromatograms (McEvoy and Giger, 1986).

UNSATURATED PENTACYCLIC TRITERPENOIDS

Peak	Assignment
uh1	C ₂₇ 22,29,30-trisnorneohop-13(18)-ene
uh2	C ₂₇ trisnorhop-17-ene
uh3	C ₂₉ norhop-17(21)-ene
uh4	C ₂₉ 30-neonor-13(18)-ene
uh5	C ₃₀ hop-17(21)-ene
uh6	C ₃₀ neohop-13(18)-ene
uh7	C ₃₁ homohop-17(21)-ene (22R and 22S)

Notes:

Unsaturated pentacyclic compounds usually occur only in thermally immature samples.

OTHER PENTACYCLIC TRITERPENOIDS

Peak	Assignment	NPD Codes
T	C ₂₇ 17 α (H)18 α (H)21 β (H)-25,28,30-trisnorhopane	25 nor 28 $\alpha\beta$
Tm	C ₂₇ 17 β (H)18 α (H)21 α (H)-25,28,30-trisnormoretane	
B	C ₂₈ 17 α (H)18 α (H)21 β (H)-28,30-bisnorhopane	28 $\alpha\beta$
Bnm	C ₂₈ 17 β (H)18 α (H)21 α (H)-28,30-bisnormoretane	
G	C ₃₀ gammacerane	30G
O	C ₃₀ 18 α (H) oleanane	30O
J	C ₃₀ 18 β (H) oleanane ('compound J')	
L	C ₃₀ lupane	
BL	C ₂₈ bisnorlupane	
d28	C ₂₈ diahopane	
X	C ₃₀ diahopane	30d

Notes:

The C₃₀ 18 α (H) oleanane and 18 β (H) oleanane (formerly 'compound J' of Grantham *et al.*, 1983) coelute on standard GC columns. The 18 β (H) oleanane is less thermally stable than 18 α (H) oleanane (Riva *et al.*, 1988).

The C₃₀ and C₂₈ diahopanes were formerly identified as the structurally elucidated pentacyclic triterpanes X and Y, respectively, of Philp and Gilbert (1986).

DEMETHYLATED HOPANES AND DEMETHYLATED MORETANESC₂₆ and C₂₈ to C₃₄ 17 α (H)21 β (H)-25-norhopanes and 17 β (H)21 α (H)-25-normoretanes

Peak	Assignment	NPD Codes
dh26S	C ₂₆ 18 α (H)-22,25,29,30-tetrakisnorneohopane	
dh26m	C ₂₆ 17 α (H)-22,25,28,30-tetrakishnorhopane	
dh28	C ₂₈ 17 α (H)21 β (H)-25,30-bisnorhopane	
dm28	C ₂₈ 17 β (H)21 α (H)-25,30-bisnormoretane	
dh29	C ₂₉ 17 α (H)21 β (H)-25-norhopane	25nor30 $\alpha\beta$
dm29	C ₂₉ 17 β (H)21 α (H)-25-normoretane	
dh30S	C ₃₀ 17 α (H)21 β (H)-25-norhomohopane 22S	
dh30R	C ₃₀ 17 α (H)21 β (H)-25-norhomohopane 22R	
dh31S	C ₃₁ 17 α (H)21 β (H)-25-norbishomohopane 22S	
dh31R	C ₃₁ 17 β (H)21 β (H)-25-norbishomohopane 22R	
dh32S	C ₃₂ 17 α (H)21 β (H)-25-nortrishomohopane 22S	
dh32R	C ₃₂ 17 α (H)21 β (H)-25-nortrishomohopane 22R	
dh33S	C ₃₃ 17 α (H)21 β (H)-25-nortetrakishomohopane 22S	
dh33R	C ₃₃ 17 α (H)21 β (H)-25-nortetrakishomohopane 22R	
dh34S	C ₃₄ 17 α (H)21 β (H)-25-norpentakishomohopane 22S	
dh34R	C ₃₄ 17 α (H)21 β (H)-25-norpentakishomohopane 22R	

Notes:

Nuclear demethylated hopanes are biological markers for severe bacterial degradation (Volkman *et al.*, 1983a and b). Demethylation involves the loss of the C-25 methyl group from the C-10 position on the A-ring (Rullkotter and Wendisch, 1982).

DEMETHYLATED TRICYCLIC TERPANES

Peak	Assignment
dt18	C ₁₈ tricyclic terpane
dt19	C ₁₉ tricyclic terpane
dt20	C ₂₀ tricyclic terpane
dt21	C ₂₁ tricyclic terpane
dt22	C ₂₂ tricyclic terpane
dt23	C ₂₃ tricyclic terpane
dt24	C ₂₄ tricyclic terpane
dt25	C ₂₅ tricyclic terpanes
dt26	C ₂₆ tricyclic terpanes
dt27	C ₂₇ tricyclic terpanes
dt28	C ₂₈ tricyclic terpanes
dt29	C ₂₉ tricyclic terpanes

Notes:

These compounds are relatively unusual and are indicative of the severest levels of biodegradation (Howell *et al.*, 1984). C₂₅, C₂₇, C₂₈ and C₂₉ demethylated tricyclic terpanes occur as isomeric (at C-22) pairs.

SECOHOPANES

Seco-8,14-hopanes

Peak	Assignment
sh1	C ₂₇ seco-8,14-hopane
sh2	C ₂₉ seco-8,14-hopane
sh3	C ₃₀ seco-8,14-hopane

Notes:

Tetracyclic terpanes in degraded oil stains from the Morondava Basin of Madagascar have been identified as Ring-C opened seco-8,14-hopanes by Rullkotter and Wendisch (1982). Stereochemistry at C-8 and C-14 gives rise to several isomers and higher and lower carbon numbers may also be present. Minor amounts of secohopanes were detected in Brazilian oils by Mello *et al.* (1988).

OTHER COMPOUNDS

Peak	Assignment
BC	C ₃₄ botryococcane
S	C ₃₀ squalane
βC	β-carotane
γC	γ-carotane

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A Geochemical Analysis of 2 North Sea Oils From Wells N7/11-5 and N7/11-7

APPENDIX 4

**Index of Aromatic Molecular Biomarker
Gas Chromatography-Mass Spectrometry Peak Assignments****SUBSTITUTED NAPHTHALENES****Methylnaphthalenes**

Peak	Assignment
2MN	2-methylnaphthalene
1MN	1-methylnaphthalene

Ethylnaphthalenes

Peak	Assignment
2EN	2-ethylnaphthalene
1EN	1-ethylnaphthalene

Dimethylnaphthalenes

Peak	Assignment
26DMN	2,6-dimethylnaphthalene
27DMN	2,7-dimethylnaphthalene
13DMN	1,3-dimethylnaphthalene
17DMN	1,7-dimethylnaphthalene
16DMN	1,6-dimethylnaphthalene
23DMN	2,3-dimethylnaphthalene
14DMN	1,4-dimethylnaphthalene
15DMN	1,5-dimethylnaphthalene
12DMN	1,2-dimethylnaphthalene

Notes:

Methylnaphthalene and ethylnaphthalene isomers identified after Volkman *et al.* (1984). Dimethylnaphthalene isomers identified after Volkman *et al.* (1984), Hall *et al.* (1985), Radke *et al.* (1986) and Rowland *et al.* (1986).

Trimethylnaphthalenes

Peak	Assignment
137TMN	1,3,7-trimethylnaphthalene
136TMN	1,3,6-trimethylnaphthalene
146TMN	1,4,6-trimethylnaphthalene
135TMN	1,3,5-trimethylnaphthalene
236TMN	2,3,6-trimethylnaphthalene
127TMN	1,2,7-trimethylnaphthalene
167TMN	1,6,7-trimethylnaphthalene
126TMN	1,2,6-trimethylnaphthalene
124TMN	1,2,4-trimethylnaphthalene
125TMN	1,2,5-trimethylnaphthalene

Notes:

Trimethylnaphthalene isomers identified after Rowland *et al.* (1986) and Strachan *et al.* (1988). Heating rate effects on dimethylnaphthalene and trimethylnaphthalene maturity parameters are discussed in Alexander *et al.* (1986).

PHENANTHRENE AND SUBSTITUTED PHENANTHRENES

Peak	Assignment
P	phenanthrene
3MP	3-methylphenanthrene
2MP	2-methylphenanthrene
9MP	9-methylphenanthrene
1MP	1-methylphenanthrene
DMP	dimethylphenanthrene
TMP	

Notes:

Methylphenanthrene maturation parameters, and empirical correlations with vitrinite reflectance, are discussed by Radke and Welte (1983), Radke *et al.* (1984, 1986), Kvalheim *et al.* (1987), Boreham *et al.* (1988) and Radke (1988). Ethylphenanthrene and dimethylphenanthrene isomers are identified by Radke *et al.* (1986).

MONOAROMATIC STEROIDS (C-ring)

Peak	Assignment	NPD Codes
MAS21	C ₂₁ monoaromatic steroid	A1
MAS22	C ₂₂ monoaromatic steroid	B1
MAS27	C ₂₇ monoaromatic steroid	D1
MAS29β28α	5β(H)C ₂₉ + 5α(H)C ₂₈ monoaromatic steroid (20R)	H1 I1
MAS29α	5α(H)C ₂₉ monoaromatic steroid (20R)	

TRIAMOMATIC STEROIDS

Peak	Assignment	NPD Codes
TAS20	C ₂₀ triaromatic steroid	a1
TAS21	C ₂₁ triaromatic steroid	b1
TAS26S	C ₂₆ triaromatic steroid 20S	c1
TAS26R	C ₂₆ triaromatic steroid 20R	d1
TAS27S	C ₂₇ triaromatic steroid 20S	
TAS27R	C ₂₇ triaromatic steroid 20R	f1
TAS28S	C ₂₈ triaromatic steroid 20S	e1
TAS28R	C ₂₈ triaromatic steroid 20R	g1

Notes:

Identification of monoaromatic and triaromatic steroids from Mackenzie *et al.* (1981), Seifert *et al.* (1983), Wardroper *et al.* (1984), Killops and Readman (1985), Riolo *et al.* (1986) and Williams *et al.* (1986).

THIOPHENIC-SULPHUR COMPOUNDS

Peak	Assignment
2BT	C ₂ -benzothiophene
3BT	C ₃ -benzothiophene
4BT	C ₄ -benzothiophene
DBT	dibenzothiophene
4MDBT	4-methyldibenzothiophene
3MDBT	3-methyldibenzothiophene
2MDBT	2-methyldibenzothiophene
1MDBT	1-methyldibenzothiophene
DMDBT	dimethyldibenzothiophenes
TMDBT	trimethyldibenzothiophenes
BNT	benzonaphthothiophenes

Notes:

2-methyldibenzothiophene and 3-methyldibenzothiophene coelute. See Hughes (1983), Leythauser *et al.* (1988) and Schou and Myhr (1988) for identification and significance of benzothiophenes, dibenzothiophene and substituted dibenzothiophenes.

OTHER AROMATIC COMPOUNDS

Peak	Assignment
A	Anthracene
MA	Methylantracene
F	Fluorene
MF	Methylfluorene
C	Chrysene
MC	Methylchrysene
PY	Pyrene
MPY	Methylpyrene
Ca	Cadalene (1,6-dimethyl-4-isopropylnaphthalene)
Eu	Eudalene (1-methyl-7-isopropylnaphthalene)
BH	Benzohopanes
MBH	Methylbenzohopanes

Notes:

For benzohopane identification see Belayouni and Trichet (1984) and Hussler *et al.* (1984).

Methylantracene identified in Williams *et al.* (1986).

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