U-566
U-610

THE ROBERTSON GROUP plc

REPORT NO. 6796/Ic

PETROLEUM GEOCHEMICAL ANALYSIS OF TESTED OILS AND BITUMEN IN CORE SAMPLES, N2/7-20X AND N2/7-21S WELLS, NORWEGIAN NORTH SEA

by

M A BASTOW

PROJECT NO. RGPD/901/Ic/21883

Prepared by:

The Robertson Group plc
Petroleum Division
Llandudno
Gwynedd LL30 1SA
United Kingdom

Prepared for:

Phillips Petroleum Company
Box 200
N 4056 Tananger
Norway

OCTOBER 1990

CONTENTS

Four drill stem test oil samples have been analysed as follows:

WELL	TEST	TESTED INTERVAL (feet)
N2/7-20X	DST-1	13450-13970
N2/7-21S	DST-1	15017-13970
N2/7-21S	DST-2	14588-14825
N2/7-21S	DST-3	14135-14231 + 14588-14825

Detailed well test data were provided by the client in order to aid the interpretation of the geochemical data.

One drill stem test was performed on the N2/7-20X well: DST-1 perforated the interval 13450' to 13970' (drillers depths). The solution gas/oil ratio was 2376 scf/stb and measured reservoir temperatures were 157°C (315°F) at 13170' (flowing) and 152°C (305°F) (shut-in).

Three drill stem tests were performed on the N2/7-21S well, DST-3 being a comingled test of the middle and upper sand intervals. DST-1 perforated the interval 15017' to 15132' (driller's depths) and tested 45°API oil with gas/oil ratio 1600 scf/stb and H_2S and CO_2 contents of 25 ppm and 5.5% respectively. DST-2 perforated the interval 14588' to 14825' (driller's depths) and tested 42°API oil with gas/oil ratio 1800-1850 scf/stb and H_2S and CO_2 contents of 40 ppm and 5% respectively.

DST-3 tested the intervals 14135' to 14231' and 14588' to 14825' (driller's depths). The comingled test flowed 43°API oil with gas/oil ratio 1800-1850 scf/stb and H_2S and CO_2 contents of 20-25 ppm and 5% respectively.

The DST-3 oil sample from the N2/7-21S well was received at the North Wales laboratories of the Robertson Group plc on 25th April 1990 (airway bill number 117 6616 0474). The DST-1 and DST-2 oil samples were received on 17th July 1990 (airway bill number 117 6616 4243).

Based on the results of maturity, source rock and hydrocarbon analyses conducted on core samples from the N2/7-20X and N2/7-21S wells, four core samples have been selected for detailed geochemical analysis as follows:

WELL	DEPTH (feet)	STRATIGRAPHY
N2/7-20X	14753	unassigned sand unit, indeterminate age
N2/7-21S	14267.2	unassigned unit, indeterminate age
N2/7-21S	15281.7	unassigned unit, indeterminate age
N2/7-21S	16521.6	basement, ?Lower Devonian volcanics

During the course of the study the following numbers of analyses have been carried out:

OIL ANALYSIS

Gravity (°API)	:	4
Pour point	:	4
Viscosity (at 20°C, 40°C, 60°C)	:	4
Volatile hydrocarbon content (topping loss)	:	4
Sulphur content	:	4
Nickel content	:	4

Vanadium content	:	4
Asphaltene content	:	4
Wax content	:	4
Whole oil gas chromatography	:	6
Gasoline hydrocarbons	:	4
Column chromatographic fractionation	:	4
Alkane gas chromatography	:	4
Alkane gas chromatography - mass spectrometry	:	4
Carbon isotopes (alkane, aromatic, polar and asphaltene fractions)	:	4

BITUMEN ANALYSIS

Solvent extraction of core samples	:	4
Bitumen isolation by acidification/heavy mineral separation	:	4
Anhydrous pyrolysis of bitumen isolates for 3 days at 300°C	:	4
Solvent extraction of bitumen pyrolysates	:	4
Column chromatographic fractionation of core extracts	:	-
Column chromatographic fractionation of pyrolysate extracts	:	4
Alkane gas chromatography of core extracts	:	4
Alkane gas chromatography of pyrolysate extracts	:	4
Carbon isotopes of core extracts (alkanes, aromatic, polar and asphaltene fractions)	:	4
Alkane gas chromatography - mass spectrometry of core extracts	:	4
Alkane gas chromatography - mass spectrometry of pyrolysate extracts	:	4

The abbreviations used in the analytical data sheets are listed in Appendix 1 of this report. The geochemical analytical procedures and techniques are described briefly in Appendix 2.

COMPANY: PHILLIPS NORWAY WELL: N2/7-20X LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA			
SAMPLE CODE	DST-1		
SAMPLE TYPE	Oil		

GENERAL DATA	OPERATOR DERIVED DATA		
Flow Rate (bopd) , Choke Size (ins)			
°API Gravity			
Gas to Oil Ratio (cu.ft/bbl)	2376		
Reservoir Temp(°C) , Pressure(psi)	160		
Hydrogen Sulphide (ppm)			
Formation { Total (ppm), pH, Cond			
Water { Na, Ca, Mg, (ppm)			
Composition { Cl, SO4, HCO3 (ppm)			

PHYSICAL DATA	ROBERTSON GROUP DATA				
°API Gravity	42.5				
Pour Point (°C)	-50.0				
Viscosity (cSt at 20,40,60 °C)	3.6	2.5	1.2		

BULK CHEMICAL DATA	ROBERTSON GROUP DATA			
Volatile Content (%)	24.50			
Wax Content (%), Water Content (%)	.10			
Sulphur Content (%)	.05			
Nickel, Vanadium Contents (ppm)	1.00	1.00		
Asphaltene Content (%)	1.13			
Gasoline Content (ppm)	67762			
n-Alkane Content (ppm)	0			

COMPOSITION OF OIL FRACTIONS	ColChr(%)	IScan	CIR(‰)DIR	ColChr(%)	IScan	CIR(‰)DIR	ColChr(%)	IScan	CIR(‰)DIR
Alkanes	74.7								
Aromatics	6.2								
Resenes	3.6								
Asphaltenes (non-eluted)	15.5	*							
Whole Oil	*	*							

SELECTED INTERPRETIVE RATIOS	ROBERTSON GROUP DATA				
Nickel(Ni)/Vanadium(V), V/(Ni+V)	1.00	.50			
Pr/Ph, Pr/n-C17, Ph/n-C18	1.35	.57	.50		
CPI(1), CPI(2), Bias	1.05	1.05	2.09		
iso/norm C4, iso/norm C5, Benzene (%)	.25	.53	3.72		
Isoheptane, Heptane, Aromaticity	2.12	36.54	.39		
C5-7 Alkane Composition (n,iso,cyclic)	48	29	24		
C7 Alkane Composition (n,iso,cyclic)	30	24	46		
Alkane/Aromatic Ratios (ColChr & IScan)	12.05				
Terpanes : Ts/Tm,Mor/Hop,C31Hop22S/R					
C29Steranes: %aaa20S,%aββ,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 OIL

TABLE : 1

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA			
SAMPLE CODE	DST-1	DST-2	DST-3
SAMPLE TYPE	Oil	Oil	Oil

GENERAL DATA	OPERATOR DERIVED DATA		
Flow Rate (bopd) , Choke Size (ins)	600 14/64	5000 30/64	8000 48/64
°API Gravity	45.0	42.0	43.0
Gas to Oil Ratio (cu.ft/bbl)	1600	1800	1800
Reservoir Temp(°C) , Pressure(psi)	160	160	160
Hydrogen Sulphide (ppm)	25	40	25
Formation { Total (ppm), pH, Cond			
Water { Na, Ca, Mg, (ppm)			
Composition { Cl, SO4, HCO3 (ppm)			

PHYSICAL DATA	ROBERTSON GROUP DATA								
°API Gravity	43.3			42.2			41.7		
Pour Point (°C)	5.0			5.0			-3.0		
Viscosity (cSt at 20,40,60 °C)	3.3	2.6	1.8	4.1	3.1	2.0	4.0	2.9	*

BULK CHEMICAL DATA	ROBERTSON GROUP DATA								
Volatile Content (%)	24.60			23.30			24.0		
Wax Content (%), Water Content (%)	3.20			2.50			1.17		
Sulphur Content (%)	.04			.05			.07		
Nickel, Vanadium Contents (ppm)	1.00	1.00		1.00	1.00		2.60	1.00	
Asphaltene Content (%)	.33			.09			.30		
Gasoline Content (ppm)	130255			107934			40389		
n-Alkane Content (ppm)	0			0			0		

COMPOSITION OF OIL FRACTIONS	ColChr(%)	IScan	CIR(‰)DIR	ColChr(%)	IScan	CIR(‰)DIR	ColChr(%)	IScan	CIR(‰)DIR
Alkanes	75.7	79.8		71.6	81.5		72.2		
Aromatics	4.7	15.2		5.2	15.5		5.9		
Resenes	1.5	5.0		1.8	3.0		3.7		
Asphaltenes (non-eluted)	18.1	*		21.4	*		18.2	*	
Whole Oil	*	*		*	*		*	*	

SELECTED INTERPRETIVE RATIOS	ROBERTSON GROUP DATA								
Nickel(Ni)/Vanadium(V), V/(Ni+V)	1.00	.50		1.00	.50		2.60	.28	
Pr/Ph, Pr/n-C17, Ph/n-C18	1.16	.55	.56	1.17	.53	.53	1.35	.61	.51
CPI(1), CPI(2), Bias	1.02	1.01	1.90	1.06	1.06	2.15	1.11	1.10	1.99
iso/norm C4, iso/norm C5, Benzene (%)	.29	1.51	1.64	.25	1.39	2.26	.25	1.33	2.65
Isoheptane, Heptane, Aromaticity	2.10	32.63	.59	2.09	33.08	.50	2.06	32.74	.58
C5-7 Alkane Composition (n,iso,cyclic)	51	41	7	51	39	10	51	38	12
C7 Alkane Composition (n,iso,cyclic)	25	20	55	26	20	54	26	20	55
Alkane/Aromatic Ratios (ColChr & IScan)	16.11	5.25		13.77	5.25		12.24		
Terpanes : Ts/Tm,Mor/Hop,C31Hop22S/R									
C29Steranes: %aaa20S,%aββ,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 : 2

TABLE 3

Physical Properties Data for Oils

WELL	TEST	GRAVITY (°API)	POUR POINT (°C)	KINEMATIC VISCOSITY 20°C	40°C	60°C	VOLATILE CONTENT (TOPPING LOSS, %)	SULPHUR (%)	NICKEL (ppm)	VANADIUM (ppm)	ASPHALTENE CONTENT (%)	WAX (%)
N2/7-20X	DST	42.5	-50	3.6	2.5	1.2	24.5	0.05	<1	<1	1.13	<0.1
N2/7-21S	DST-1	43.2	+5	3.3	2.6	1.8	24.6	0.04	<1	<1	0.33	3.2
N2/7-21S	DST-2	42.2	+5	4.1	3.1	2.0	23.3	0.05	<1	<1	0.09	2.5
N2/7-21S	DST-3	41.7	- 3	4.0	2.9	*	24.0	0.07	2.6	<1	0.30	1.17

COMPANY: PHILLIPS NORWAY WELL:N2/7-20X LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE CODE	DST-1					
SAMPLE TYPE	Oil					

COMPONENTS	GASOLINE RANGE COMPONENT ABUNDANCE (ppb)					
i-C4	1104					
n-C4	4404					
i-C5	3415					
n-C5	6477					
2,2,dmb	122					
cp	373					
2,3,dmb	379					
2,mp	2913					
3,mp	2439					
n-C6	9112					
mcp+2,2,dmp	1319					
2,4,dmp	315					
benz	2520					
3,3,dmp	121					
ch	4019					
2,mh	3719					
1,1,dmcp	349					
3,mh	3219					
cis,1,3,dmcp	797					
trans,1,3,dmcp	855					
trans,1,2,dmcp+3,ep	1269					
n-C7	9339					
mch+cis,1,2,dmcp	5262					
ecp	310					
tol	3610					

GENERAL DATA						
Total Abundance(ppb)	67762					
TOC (% of Rock)						
Abundance at 1% TOC	*					
Alkane Composition	48	29	24			
C7Alkane Composition	30	24	46			
Aromatic Composition	9.05					

RATIOS						
i/n-C4	.25					
i/n-C5	.53					
cp / 2,3,dmb	.98					
n-C7 / mch	1.77					
2,mp / 3,mp	1.19					
n-C6 / mcp +2,2,dmp	6.91					
mch / tol	1.46					
Late Mature Index	.48					
Aromaticity Index	.39					
Heptane Index	36.54					
Isoheptane Index	2.12					
Kerogen Type Index	15.34					

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 : 4

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE CODE	DST-1	DST-2	DST-3			
SAMPLE TYPE	Oil	Oil	Oil			

COMPONENTS	GASOLINE RANGE COMPONENT ABUNDANCE (ppm)					
i-C4	6813	3670	1119			
n-C4	23662	14582	4556			
i-C5	37329	29339	9953			
n-C5	24764	21119	7456			
2,2,dmb	133	124	52			
cp	871	790	332			
2,3,dmb	422	395	164			
2,mp	2617	2475	1019			
3,mp	1443	1390	587			
n-C6	12480	12540	5339			
mcp+2,2,dmp	1632	1656	746			
2,4,dmp	207	206	92			
benz	2135	2435	1071			
3,3,dmp	25	37	14			
ch	1813	1963	888			
2,mh	1589	1736	774			
1,1,dmcp	176	199	78			
3,mh	1269	1376	620			
cis,1,3,dmcp	290	315	144			
trans,1,3,dmcp	280	304	142			
trans,1,2,dmcp+3,ep	617	674	312			
n-C7	3870	4386	1958			
mch+cis,1,2,dmcp	3401	3869	1773			
ecp	135	158	73			
tol	2281	2196	1127			

GENERAL DATA						
Total Abundance(ppm)	130255		107934		40389	
TOC (% of Rock)						
Abundance at 1% TOC	*		*		*	
Alkane Composition	51 41 7		51 39 10		51 38 12	
C7Alkane Composition	25 20 55		26 20 54		26 20 55	
Aromatic Composition	3.39		4.29		5.44	

RATIOS						
i/n-C4	.29	.25	.25			
i/n-C5	1.51	1.39	1.33			
cp / 2,3,dmb	2.06	2.00	2.03			
n-C7 / mch	1.14	1.13	1.10			
2,mp / 3,mp	1.81	1.78	1.73			
n-C6 / mcp +2,2,dmp	7.65	7.57	7.16			
mch / tol	1.49	1.76	1.57			
Late Mature Index	.63	.63	.60			
Aromaticity Index	.59	.50	.58			
Heptane Index	32.63	33.08	32.74			
Isoheptane Index	2.10	2.09	2.06			
Kerogen Type Index	13.66	13.94	13.94			

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 : 5

COMPANY: PHILLIPS NORWAY WELL:N2/7-20X LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE CODE	DST-1					
SAMPLE TYPE	Oil					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14	9.73					
n-C15	9.74					
n-C16	8.38					
n-C17	8.59					
n-C18	7.29					
n-C19	7.74					
n-C20	6.04					
n-C21	5.31					
n-C22	4.53					
n-C23	4.47					
n-C24	3.38					
n-C25	2.95					
n-C26	2.43					
n-C27	2.07					
n-C28	1.82					
n-C29	1.60					
n-C30	1.26					
n-C31	1.17					
n-C32	.84					
n-C33	.89					
n-C34	.88					
n-C35	.38					
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	4.89					
i-C20 (Phytane)	3.63					

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	1.05					
CPI-2	1.05					
CPI-3	.97					
Bias	2.09					
i-C19 / n-C17	.57					
i-C20 / n-C18	.50					
i-C19 / i-C20	1.35					

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 6

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE CODE SAMPLE TYPE	DST-1 Oil	DST-2 Oil	DST-3 Oil			

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14	8.11	7.79	10.31			
n-C15	9.23	9.25	9.62			
n-C16	8.55	9.00	8.39			
n-C17	8.40	8.61	7.96			
n-C18	7.13	7.38	7.06			
n-C19	6.82	8.32	7.49			
n-C20	6.28	6.49	5.90			
n-C21	5.65	5.47	5.38			
n-C22	4.67	4.71	4.32			
n-C23	4.98	4.58	4.37			
n-C24	3.67	3.32	3.80			
n-C25	3.38	3.34	3.25			
n-C26	2.91	2.36	2.28			
n-C27	2.29	2.09	1.90			
n-C28	1.88	1.85	1.55			
n-C29	1.59	1.48	1.63			
n-C30	1.36	1.30	1.32			
n-C31	1.08	1.03	1.17			
n-C32	.91	.98	.91			
n-C33	.94	.92	1.13			
n-C34	.87	.77	.95			
n-C35	.67	.52	.79			
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	4.62	4.55	4.89			
i-C20 (Phytane)	3.97	3.90	3.62			

GENERAL DATA						
Total Abundance(%)	100	100	100			
TOC (% of Rock)						
Extract (ppm)						
Hydrocarbons (ppm)						
Hydrocarbon(mg/gTOC)						
Alks(% Hydrocarbons)	84	84				
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	1.02	1.06	1.11			
CPI-2	1.01	1.06	1.10			
CPI-3	.96	.99	.99			
Bias	1.90	2.15	1.99			
i-C19 / n-C17	.55	.53	.61			
i-C20 / n-C18	.56	.53	.51			
i-C19 / i-C20	1.16	1.17	1.35			

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 7

TABLE 8

Column Chromatographic Fractionation Data for Oils

WELL	TEST	ALKANES (%)	AROMATICS (%)	POLARS (%)	NON-ELUTED (%)
N2/7-20X	DST-1	74.7	6.2	3.6	15.5
N2/7-21S	DST-1	75.7	4.7	1.5	18.1
N2/7-21S	DST-2	71.6	5.2	1.8	21.4
N2/7-21S	DST-3	72.2	5.9	3.7	18.2

TABLE 9

Alkane Gas Chromatography - Mass Spectrometry Ratios for Oils

WELL	TEST	1	2	3	4	5	6	7	8	9	10	11
N2/7-20X	DST-1	*	*	*	*	*	*	*	52	54	36:20:44	2.91
N2/7-21S	DST-1	*	*	*	*	0.61	*	0.74	45	56	*	4.34
N2/7-21S	DST-2	*	*	*	*	0.78	*	0.13	47	60	*	4.36
N2/7-21S	DST-3	10.83	*	*	*	0.57	1.55	0.36	43	55	34:21:45	3.71

Explanation of ratios

1 - C_{27} 18α(H)-trisnorneohopane (Ts)/17α(H)-trisnorhopane (Tm) (m/e 191)
2 - C_{30} 17β(H)21α(H)-moretane/17α(H)21β(H)-hopane (m/e 191)
3 - 22S/22R C_{31} 17α(H)21β(H)-homohopanes (m/e 191)
4 - 22S/22R C_{32} 17α(H)21β(H)-bishomohopanes (m/e 191)
5 - C_{29} 17α(H)21β(H)-norhopane/C_{30} 17α(H)21β(H)-hopane + C_{29} 17α(H)21β(H)-norhopane (m/e 191)
6 - C_{28} + C_{29} tricyclic terpanes/C_{30} 17α(H)21β(H)-hopane (m/e 191)
7 - C_{30} 17α(H)21β(H)-hopane (m/e 191)/total C_{29} steranes (m/e 217, 218)
8 - %20S of (20S + 20R) C_{29} 5α(H)14α steranes (m/e 217)
9 - % 5α(H)14β(H)17β(H) (20S + 20R) C_{29} isosteranes (m/e 218) of total C_{29} steranes (m/e 217)
10 - Percentage composition of C_{27}, C_{28} and C_{29} 5α(H)14α(H)17α(H) 20R steranes (m/e 217)
11 - C_{29} 13β(H)17α(H) (20S + 20R) diasteranes/C_{29} 5α(H)14α(H)17α(H) (20S+20R) steranes (m/e 217)
* ratio not determined
ND none detected

TABLE 10

Carbon Isotope Ratios for Oils

WELL	TEST	$\delta^{13}C$ ALKANES	$\delta^{13}C$ AROMATICS	$\delta^{13}C$ POLARS	$\delta^{13}C$ ASPHALTENES
N2/7-20X	DST-1	-27.3	-26.2	-25.8	NDP
N2/7-21S	DST-1	-27.0	-25.7	-25.8	-27.1
N2/7-21S	DST-2	-27.2	-26.6	-26.4	-27.3
N2/7-21S	DST-3	-27.1	-25.8	-26.3	-27.9

COMPANY: PHILLIPS NORWAY WELL: N2/7-20X LOCATION: NORWEGIAN NORTH SEA

GENERAL DATA			MATURITY DATA		KEROGEN COMPOSITION DATA						
SAMPLE DEPTH (Feet)	SAMPLE TYPE	ANALYSED LITHOLOGY	SPORE COLOUR INDEX	VITR. REFL. R oil av %	% (Visual, from microscopy)			% (Calculated)			
					INERTINITE	VITRINITE	SAPROPEL	INERT	VIT	ALG SAP	WXY SAP
14753.00	Core	SST, mod yel-brn+ BIT									
	P	SST, mod yel-brn+ BIT		1.13(29)B 1.62(19)B 2.34(2)B							

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 11

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

GENERAL DATA			MATURITY DATA		KEROGEN COMPOSITION DATA						
SAMPLE DEPTH (Feet)	SAMPLE TYPE	ANALYSED LITHOLOGY	SPORE COLOUR INDEX	VITR. REFL. R oil av %	% (Visual, from microscopy)			% (Calculated)			
					INERTINITE	VITRINITE	SAPROPEL	INERT	VIT	ALG SAP	WXY SAP
14267.20	Core	SST, med gy+ 10% MDST, mod red+ tr BIT									
	P	BIT		.57(2)B 1.05(34)B 1.82(4)B							
15281.70	Core	SST									
	P	SST		1.25(1)B 2.10(1)B							
16521.60	Core	IGN+ 20% BIT									
	P	BIT		.47(1)B 1.29(29)B							

MATURITY AND KEROGEN COMPOSITION DATA

TABLE : 12

COMPANY: PHILLIPS NORWAY WELL: N2/7-20X LOCATION: NORWEGIAN NORTH SEA

GENERAL DATA			CHEMICAL ANALYSIS DATA											
SAMPLE DEPTH (Feet)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	PYROLYSIS					SOLVENT EXTRACTION/FRACTIONATION					
				Tmax °C	HI	OI	PI	POT.YLD. (ppm)	EXTR. (ppm)	HC (ppm)	EXTR. % OC	HC %oOC	HC %EX	ALK. %HC
14753.0	Core	SST, mod yel-brn+ BIT	-						275	165			60	91

SUMMARY OF CHEMICAL ANALYSIS DATA

TABLE : 13

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

GENERAL DATA			CHEMICAL ANALYSIS DATA											
SAMPLE DEPTH (Feet)	SAMPLE TYPE	ANALYSED LITHOLOGY	TOC % OF ROCK	PYROLYSIS					SOLVENT EXTRACTION/FRACTIONATION					
				Tmax °C	HI	OI	PI	POT.YLD. (ppm)	EXTR. (ppm)	HC (ppm)	EXTR. % OC	HC %oOC	HC %EX	ALK. %HC
14267.2	Core	SST, med gy+ 10% MDST, mod red+ tr BIT	-						275	50			18	70
15281.7	Core	SST	-						325	200			61	90
16521.6	Core	IGN+ 20% BIT	-						955	550			58	92

SUMMARY OF CHEMICAL ANALYSIS DATA

TABLE : 14

COMPANY: PHILLIPS NORWAY WELL: N2/7-20X LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	14753.0					
SAMPLE TYPE	Core					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14						
n-C15	.12					
n-C16	1.36					
n-C17	5.03					
n-C18	7.74					
n-C19	9.80					
n-C20	9.96					
n-C21	8.69					
n-C22	7.77					
n-C23	7.44					
n-C24	5.30					
n-C25	5.43					
n-C26	3.68					
n-C27	3.27					
n-C28	2.81					
n-C29	2.18					
n-C30	2.02					
n-C31	1.64					
n-C32	1.27					
n-C33	1.45					
n-C34	1.19					
n-C35	.84					
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	4.52					
i-C20 (Phytane)	6.48					

GENERAL DATA						
Total Abundance(%)	100					
TOC (% of Rock)						
Extract (ppm)	275					
Hydrocarbons (ppm)	165					
Hydrocarbon(mg/gTOC)						
Alks(% Hydrocarbons)	91					
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	1.10					
CPI-2	1.09					
CPI-3	1.01					
Bias	1.38					
i-C19 / n-C17	.90					
i-C20 / n-C18	.84					
i-C19 / i-C20	.70					

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 15

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	14267.2	15281.7	16521.6			
SAMPLE TYPE	Core	Core	Core			

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14		.58				
n-C15		1.28	.88			
n-C16	.92	4.88	4.44			
n-C17	4.93	10.57	9.72			
n-C18	8.78	10.42	10.86			
n-C19	11.58	9.12	10.34			
n-C20	12.47	8.13	9.58			
n-C21	10.93	7.07	8.20			
n-C22	9.13	5.75	6.71			
n-C23	8.35	5.43	5.84			
n-C24	5.80	3.97	4.10			
n-C25	5.14	3.59	3.65			
n-C26	3.55	2.76	2.80			
n-C27	2.90	2.27	2.28			
n-C28	2.62	2.25	2.35			
n-C29	1.93	1.83	1.67			
n-C30	1.52	1.43	1.24			
n-C31	1.20	1.30	1.05			
n-C32	.79	1.15	.82			
n-C33	.60	1.38	1.02			
n-C34	.36	1.15	.86			
n-C35		.72	.45			
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	2.57	6.80	5.88			
i-C20 (Phytane)	3.93	6.18	5.27			

GENERAL DATA						
Total Abundance(%)	100	100	100			
TOC (% of Rock)						
Extract (ppm)	275	325	955			
Hydrocarbons (ppm)	50	200	550			
Hydrocarbon(mg/gTOC)						
Alks(% Hydrocarbons)	70	90	92			
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	1.08	1.04	1.03			
CPI-2	1.07	1.02	1.01			
CPI-3	.94	.90	.89			
Bias	1.71	2.05	2.23			
i-C19 / n-C17	.52	.64	.60			
i-C20 / n-C18	.45	.59	.49			
i-C19 / i-C20	.65	1.10	1.11			

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 16

TABLE 17

Column Chromatographic Fractionation Data for Core Extracts

WELL	DEPTH (feet)	ALKANES (%)	AROMATICS (%)	POLARS (%)	NON-ELUTED (%)	ASPHALTENE CONTENT (%)
N2/7-20X	14753	62.5	8.3	16.7	12.5	2.44
N2/7-21S	14267.2	38.1	9.5	47.6	4.8	4.88
N2/7-21S	15281.7	55.9	2.9	29.4	11.8	2.04
N2/7-21S	16521.6	76.5	6.1	13.3	4.1	2.80

TABLE 18

Alkane Gas Chromatography - Mass Spectrometry Ratios for Core Extracts

WELL	DEPTH (feet)	1	2	3	4	5	6	7	8	9	10	11
N2/7-20X	14753	1.78	*	1.62	*	0.39	*	1.53	43	54	46:17:37	1.90
N2/7-21S	14267.2	1.75	0.11	1.42	1.48	0.39	0.43	1.72	43	53	35:20:45	1.24
N2/7-21S	15281.7	1.89	0.12	1.39	1.49	0.43	0.32	1.43	47	46	41:16:43	1.56
N2/7-21S	16521.6	1.04	0.09	1.42	1.62	0.40	*	1.47	41	38	35:15:50	0.92

Explanation of ratios

1 - C_{27} 18α(H)-trisnorneohapane (Ts)/17α(H)-trisnorhopane (Tm) (m/e 191)
2 - C_{30} 17β(H)21α(H)-moretane/17α(H)21β(H)-hopane (m/e 191)
3 - 22S/22R C_{31} 17α(H)21β(H)-homohopanes (m/e 191)
4 - 22S/22R C_{32} 17α(H)21β(H)-bishomohopanes (m/e 191)
5 - C_{29} 17α(H)21β(H)-norhopane/C_{30} 17α(H)21β(H)-hopane + C_{29} 17α(H)21β(H)-norhopane (m/e 191)
6 - C_{28} + C_{29} tricyclic terpanes/C_{30} 17α(H)21β(H)-hopane (m/e 191)
7 - C_{30} 17α(H)21β(H)-hopane (m/e 191)/total C_{29} steranes (m/e 217, 218)
8 - %20S of (20S + 20R) C_{29} 5α(H)14α steranes (m/e 217)
9 - % 5α(H)14β(H)17β(H) (20S + 20R) C_{29} isosteranes (m/e 218) of total C_{29} steranes (m/e 217, 218)
10 - Percentage composition of C_{27}, C_{28} and C_{29} 5α(H)14α(H)17α(H) 20R steranes (m/e 217)
11 - C_{29} 13β(H)17α(H) (20S + 20R) diasteranes/C_{29} 5α(H)14α(H)17α(H) (20S+20R) steranes (m/e 217)
* ratio not determined
ND none detected

TABLE 19

Carbon Isotope Ratios for Core Extracts

WELL	DEPTH (feet)	$\delta^{13}C$ ALKANES	$\delta^{13}C$ AROMATICS	$\delta^{13}C$ POLARS	$\delta^{13}C$ ASPHALTENES
N2/7-20X	14753	-26.6	-25.5	-26.4	NDP
N2/7-21S	14267.2	-26.5	-25.4	-26.9	NDP
N2/7-21S	15281.7	-28.4	-26.7	-27.1	NDP
N2/7-21S	16521.6	-27.5	-25.2	-26.0	NDP

COMPANY: PHILLIPS NORWAY WELL: N2/7-20X LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	14753					
SAMPLE TYPE	Core (P)					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14						
n-C15						
n-C16	1.09					
n-C17	5.10					
n-C18	10.92					
n-C19	13.89					
n-C20	12.82					
n-C21	11.62					
n-C22	9.36					
n-C23	7.71					
n-C24	6.19					
n-C25	5.94					
n-C26	3.50					
n-C27	2.63					
n-C28	1.99					
n-C29	1.20					
n-C30	.65					
n-C31						
n-C32						
n-C33						
n-C34						
n-C35						
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	3.03					
i-C20 (Phytane)	2.35					

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

RATIOS						
CPI-1	1.19					
CPI-2	1.19					
CPI-3	.96					
Bias	2.17					
i-C19 / n-C17	.59					
i-C20 / n-C18	.22					
i-C19 / i-C20	1.29					

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 20

COMPANY: PHILLIPS NORWAY WELL: N2/7-21S LOCATION: NORWEGIAN NORTH SEA

SAMPLE DATA						
SAMPLE DEPTH (Feet)	15281.7					
SAMPLE TYPE	Core (P)					

COMPONENTS	QUANTIFIED NORMAL AND ISOPRENOID ALKANE ABUNDANCES (%)					
n-C10						
n-C11						
n-C12						
n-C13						
n-C14	1.77					
n-C15	1.40					
n-C16	5.22					
n-C17	9.99					
n-C18	11.96					
n-C19	13.06					
n-C20	11.31					
n-C21	9.59					
n-C22	7.79					
n-C23	6.31					
n-C24	4.80					
n-C25	3.73					
n-C26	2.78					
n-C27	2.14					
n-C28	1.64					
n-C29	.95					
n-C30	.55					
n-C31						
n-C32						
n-C33						
n-C34						
n-C35						
n-C36						
i-C15 (Farnesane)						
i-C16						
i-C18 (Norpristane)						
i-C19 (Pristane)	4.22					
i-C20 (Phytane)	2.37					

GENERAL DATA						
Total Abundance(%)	100					
TOC (% of Rock)						
Extract (ppm)						
Hydrocarbons (ppm)	10					
Hydrocarbon(mg/gTOC)						
Alks(% Hydrocarbons)						
Rock-Eval HI						
Rock-Eval PI						

RATIOS						
CPI-1	1.03					
CPI-2	1.03					
CPI-3	.97					
Bias	3.01					
i-C19 / n-C17	.42					
i-C20 / n-C18	.20					
i-C19 / i-C20	1.78					

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

ALKANE GAS CHROMATOGRAPHY DATA

TABLE : 21

TABLE 22

Alkane Gas Chromatography - Mass Spectrometry Ratios for Bitumen Pyrolysates

WELL	DEPTH (feet)	1	2	3	4	5	6	7	8	9	10	11
N2/7-20X	14753	*	*	*	*	0.48	*	*	*	*	*	*
N2/7-21S	14267.2	*	*	*	*	*	*	*	*	*	*	*
N2/7-21S	15281.7	1.04	0.15	1.01	*	0.40	*	1.49	*	*	*	1.14
N2/7-21S	16521.6	*	*	*	*	*	*	*	*	*	*	*

Explanation of ratios

1 - C_{27} 18α(H)-trisnorneohopane (Ts)/17α(H)-trisnorhopane (Tm) (m/e 191)
2 - C_{30} 17β(H)21α(H)-moretane/17α(H)21β(H)-hopane (m/e 191)
3 - 22S/22R C_{31} 17α(H)21β(H)-homohopanes (m/e 191)
4 - 22S/22R C_{32} 17α(H)21β(H)-bishomohopanes (m/e 191)
5 - C_{29} 17α(H)21β(H)-norhopane/C_{30} 17α(H)21β(H)-hopane + C_{29} 17α(H)21β(H)-norhopane (m/e 191)
6 - C_{28} + C_{29} tricyclic terpanes/C_{30} 17α(H)21β(H)-hopane (m/e 191)
7 - C_{30} 17α(H)21β(H)-hopane (m/e 191)/total C_{29} steranes (m/e 217, 218)
8 - %20S of (20S + 20R) C_{29} 5α(H)14α steranes (m/e 217)
9 - % 5α(H)14β(H)17β(H) (20S + 20R) C_{29} isosteranes (m/e 218) of total C_{29} steranes (m/e 217, 218)
10 - Percentage composition of C_{27}, C_{28} and C_{29} 5α(H)14α(H)17α(H) 20R steranes (m/e 217)
11 - C_{29} 13β(H)17α(H) (20S + 20R) diasteranes (m/e 259)/C_{29} 5α(H)14α(H)17α(H) (20S+20R) steranes (m/e 217)
* ratio not determined
ND none detected

FIGURE 1.1
WELL : N2/7-20X
DST-1

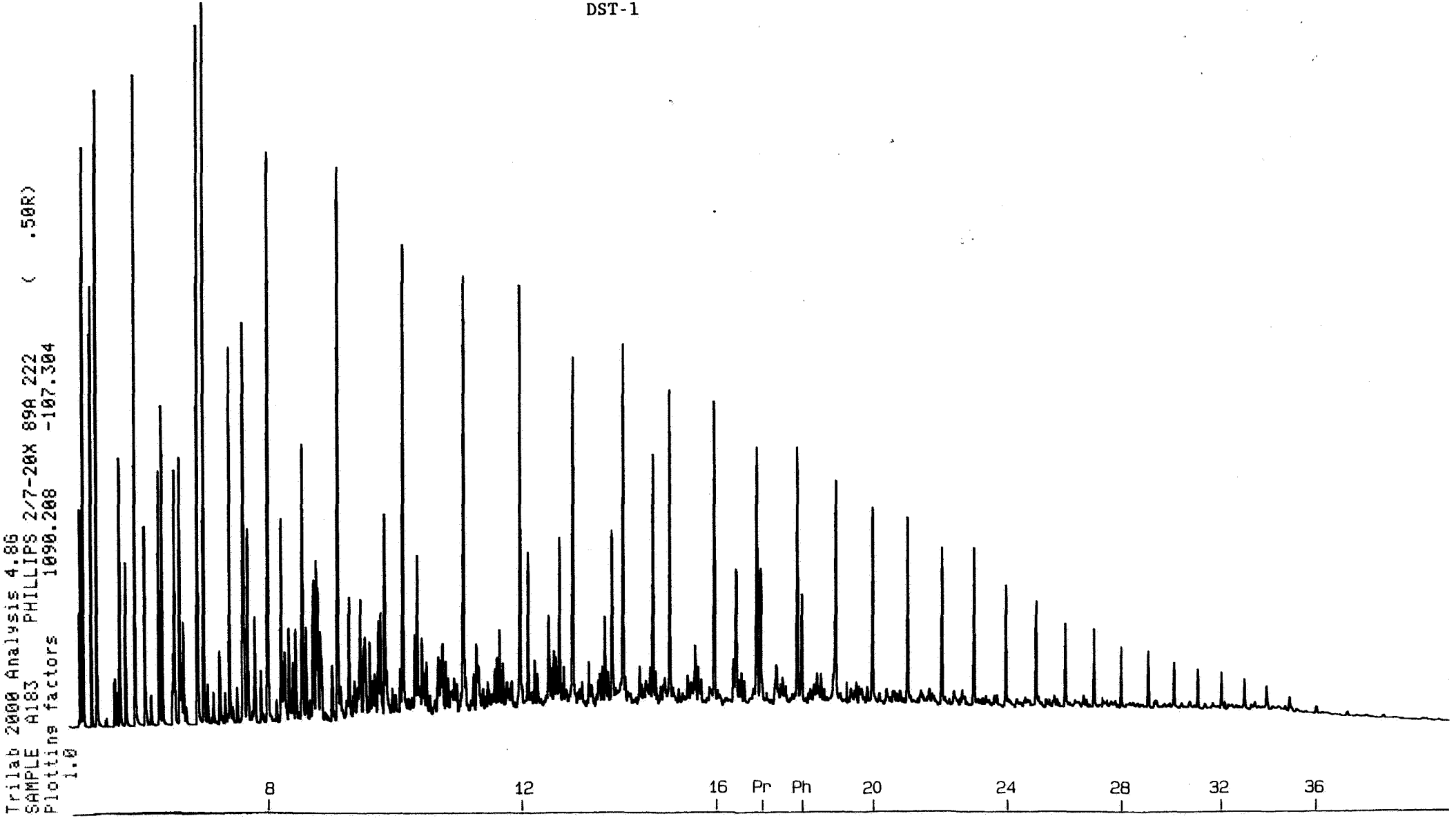


FIGURE 1.2
WELL : N2/7-21S
DST-1 (Sample A)

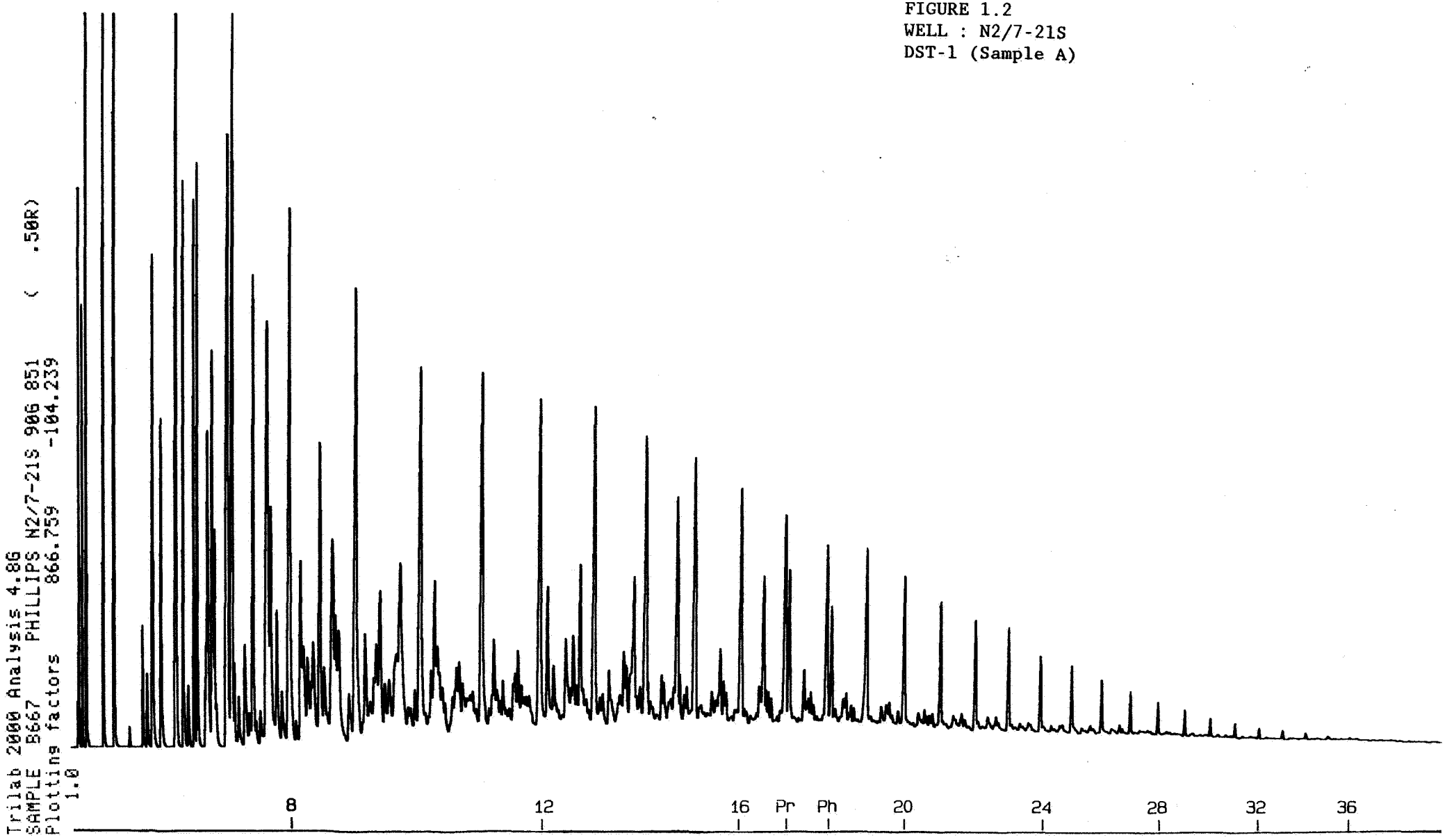


FIGURE 1.3
WELL : N2/7-21S
DST-1 (Sample B)

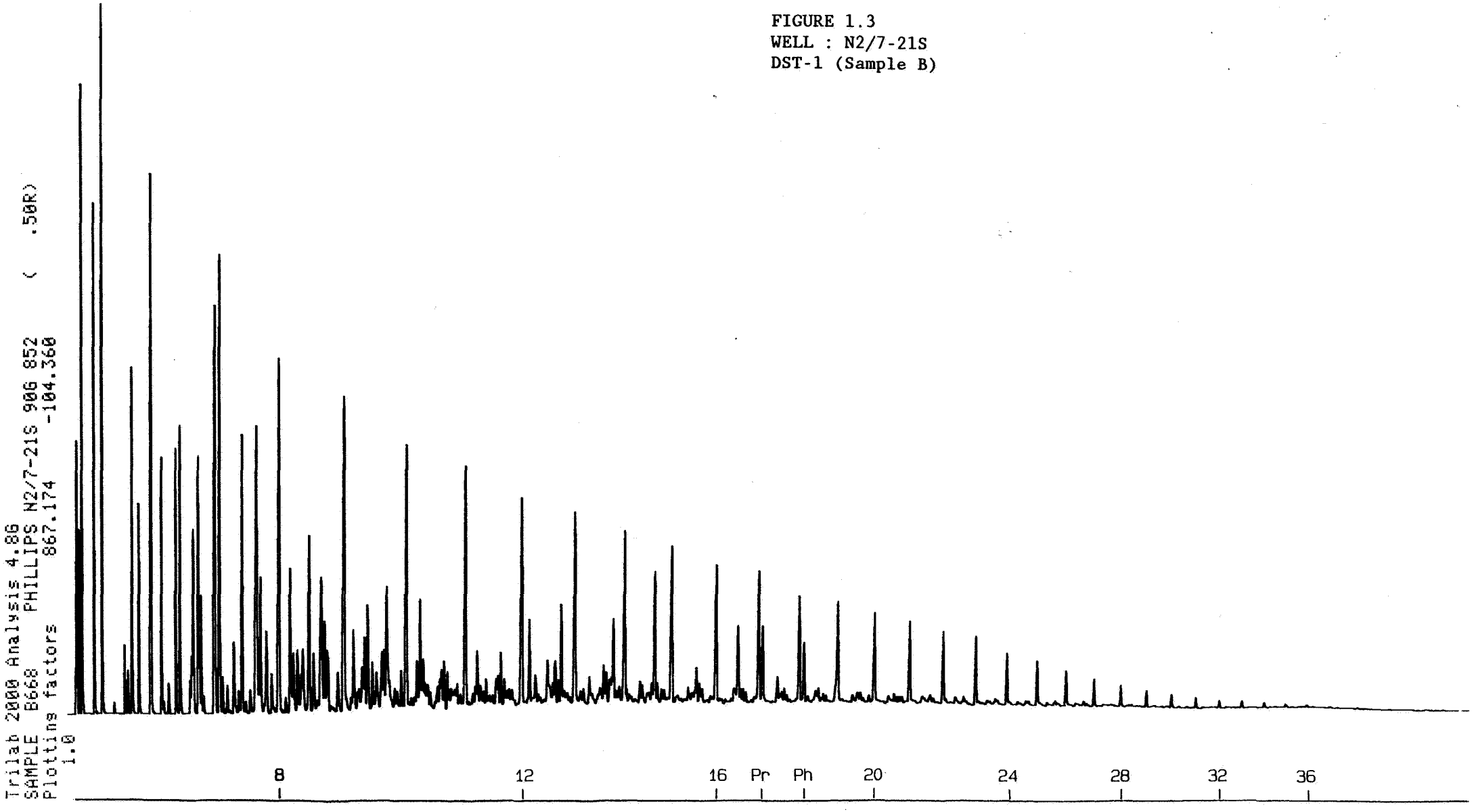


FIGURE 1.4
WELL : N2/7-21S
DST-2 (Sample A)

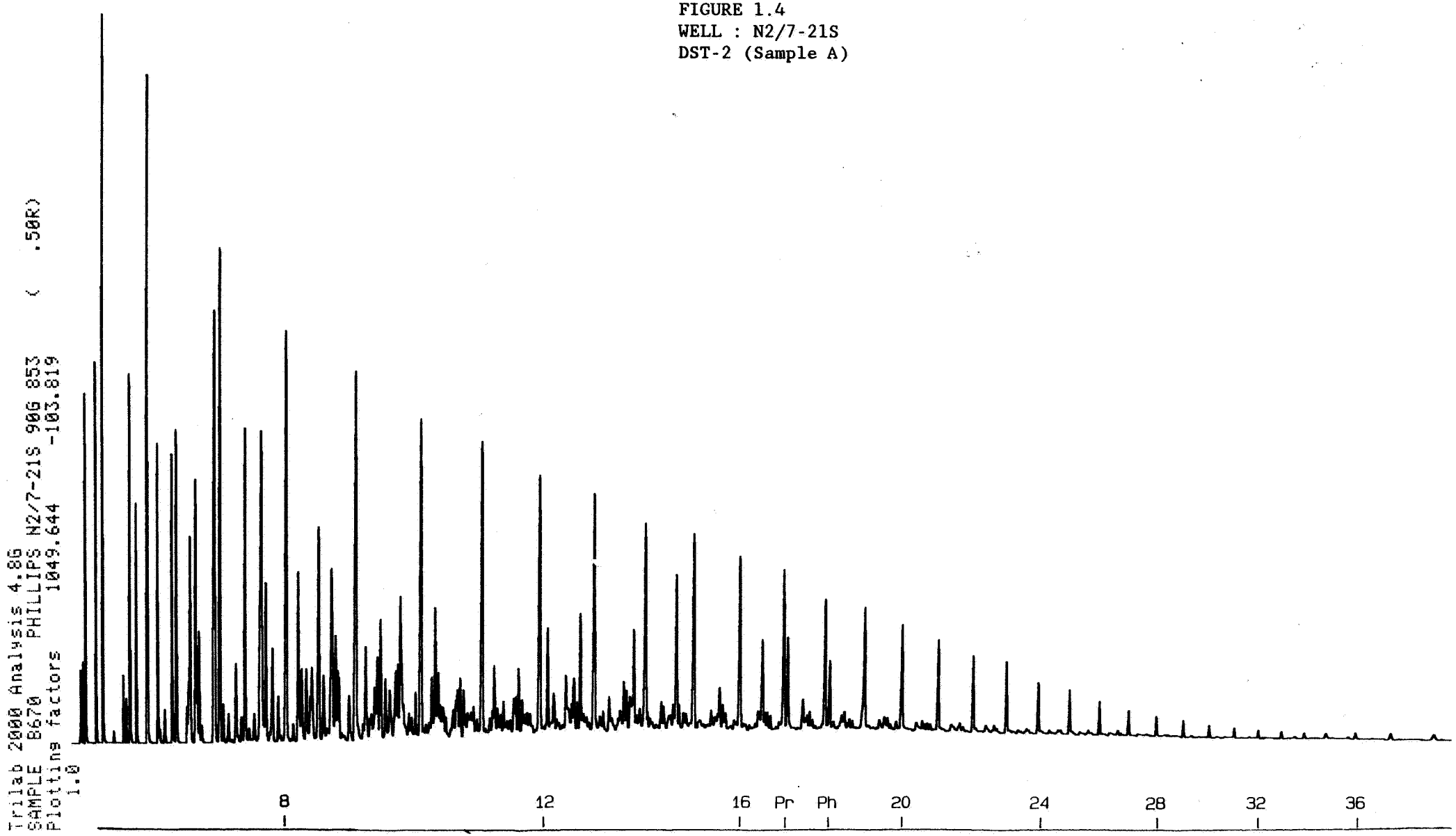


FIGURE 1.5
WELL : N2/7-21S
DST-2 (Sample B)

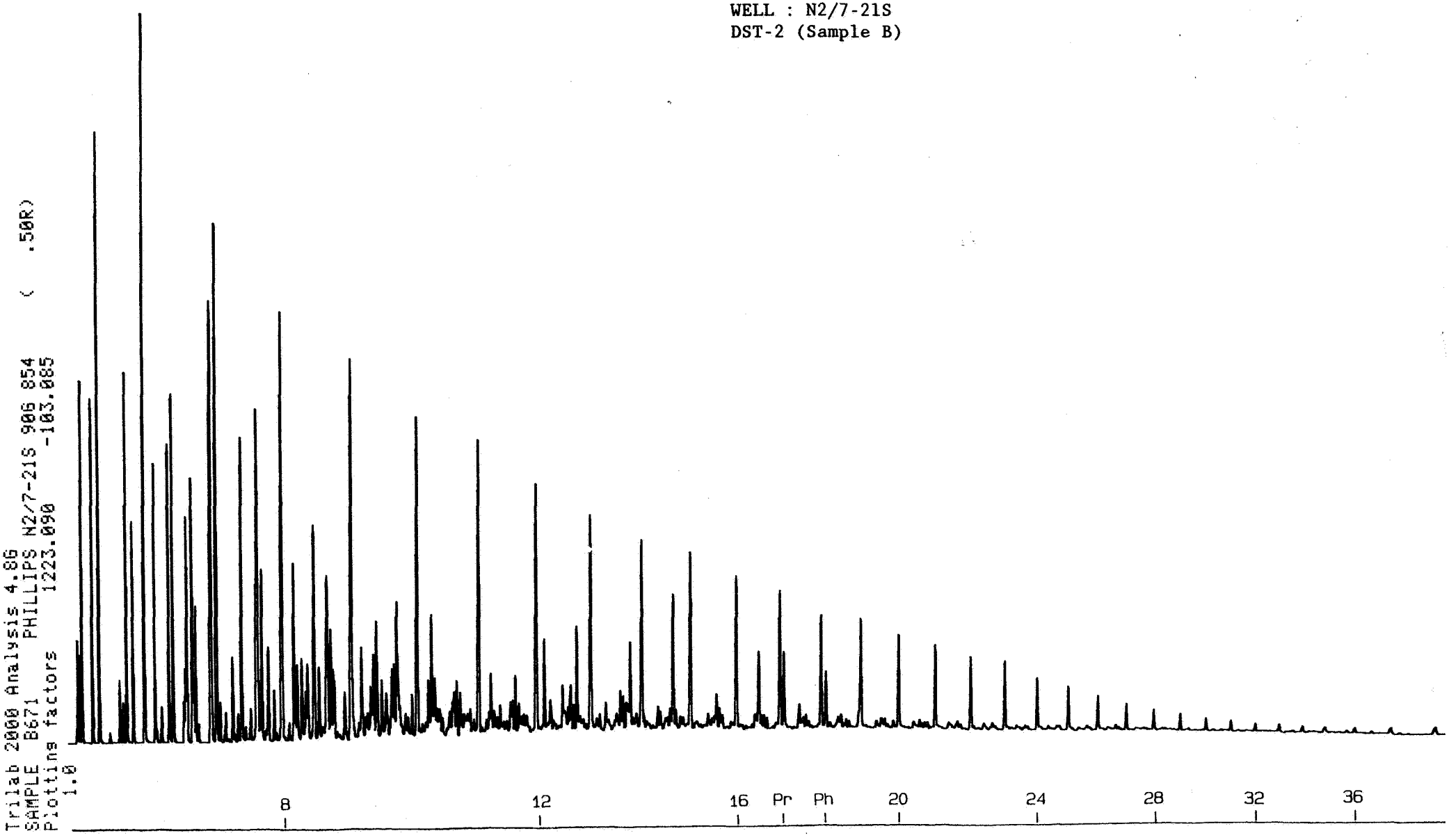
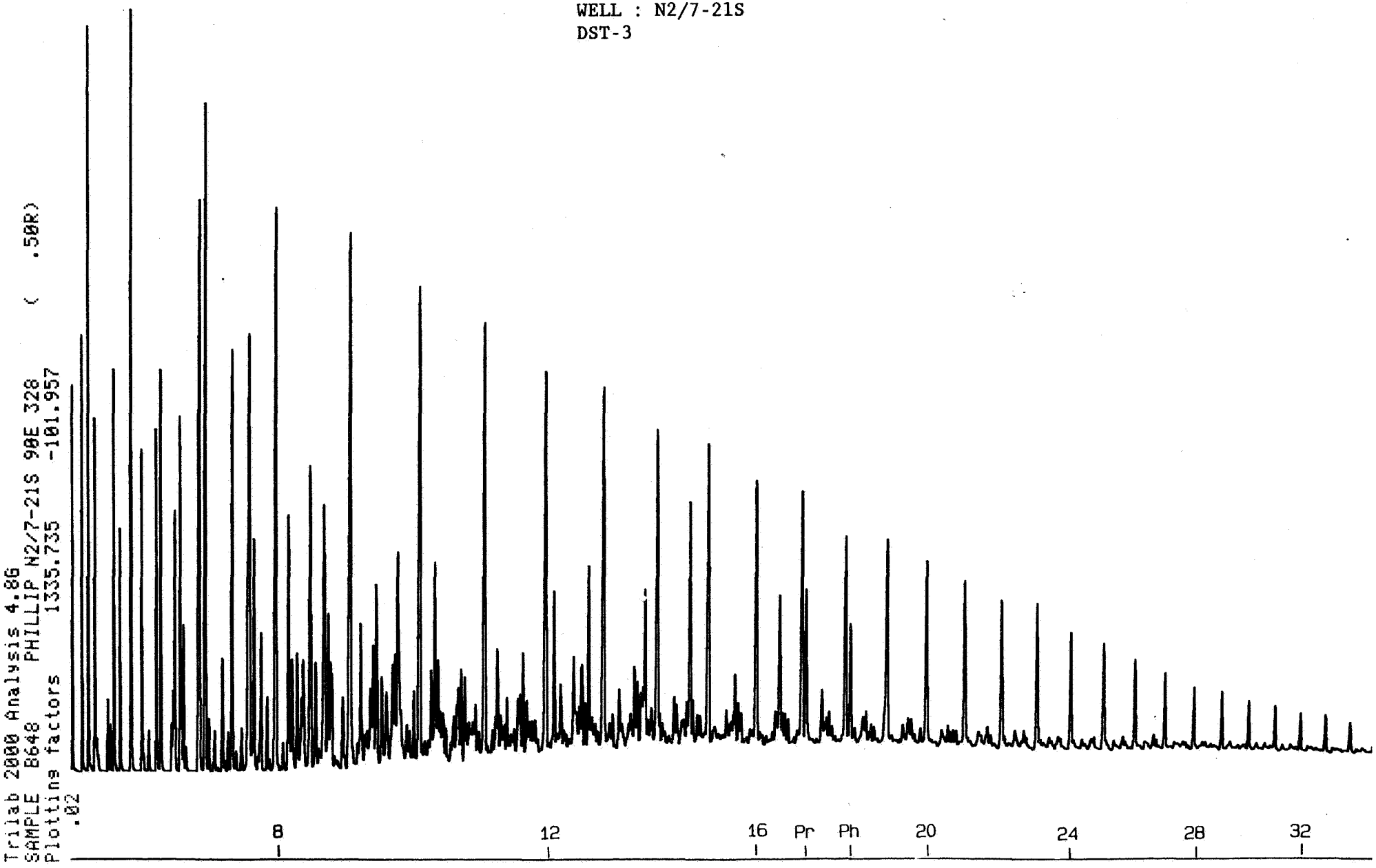


FIGURE 1.6
WELL : N2/7-21S
DST-3



Trilab 2000 Analysis 4.8G
SAMPLE B934 PHILLIPS 2/7-20X 89A 222 (.30R)
Method : GASOLINE

Table No. 9 GASOLINE (Area)

RETN TIME	REL RET	PEAK HT	PEAK AREA	PEAK CONC	%CONC	PEAK NAME
171.3		21.534	31.051	5.527	1.632	IC4
180.9		85.666	123.720	22.017	6.500	NC4
216.3		77.423	119.427	17.067	5.038	IC5
234.6		127.669	210.076	32.369	9.556	NC5
267.0		1.982	4.010	.605	.179	22DMB
299.1		9.765	18.902	1.854	.547	CP
302.1		7.367	13.454	1.897	.560	23DMB
307.2		65.729	119.404	14.567	4.300	2MP
326.1		36.208	70.934	12.182	3.596	3MP
351.0		131.904	255.187	45.544	13.445	N-HEX
390.9		1.816	3.458	.571	.169	MCP
393.6		38.420	85.479	6.025	1.778	22DMP
401.4		5.484	12.534	1.574	.465	24DMP
436.2		38.813	86.370	12.598	3.719	BEN
447.0		1.348	3.128	.602	.178	33DMP
453.9		50.842	105.189	20.096	5.932	C-HEX
472.2		37.499	96.356	18.594	5.489	2MH
480.3		5.215	9.969	1.745	.515	11DMCP
490.5		38.685	83.633	16.098	4.752	3MH
503.7		9.302	22.055	3.989	1.177	C13DMCP
510.9		7.195	23.629	4.273	1.262	T13DMCP
516.0		16.877	37.187	6.345	1.873	T12DMCP3EP
544.5		118.923	224.546	46.691	13.784	N-HEP
587.1		55.671	137.933	26.309	7.767	MCH/C12DMC
613.8		3.381	7.249	1.552	.458	ECP
665.7		27.306	75.361	18.052	5.329	TOL
				338.990		

Trilab 2000 Analysis 4.8G
SAMPLE B934 PHILLIPS 2/7-20X 89A 222 (.30R)
Plotting factors 6709.530 -50.166

FIGURE : 2.1
WELL : N2/7-20X
DST-1

Trilab 2000 Analysis 4.86
SAMPLE C186 PHIL NOR N2/7-21S 90G 852 (.30R)
Method : GASOLINE

Table No.10 GASOLINE (Area)

RETN TIME	REL RET	PEAK HT	PEAK AREA	PEAK CONC	%CONC	PEAK NAME
147.6		2.914	3.859	34.091	5.234	IC4
165.9		10.131	13.393	118.311	18.165	NC4
232.2		6.345	11.214	186.645	28.657	IC5
266.1		10.137	17.944	123.816	19.011	NC5
318.3		.119	.252	.665	.102	22DMB
364.5		.766	1.605	4.355	.669	CP
370.8		.550	1.158	2.109	.324	23DMB
380.7		4.482	9.455	13.086	2.009	2MP
406.8		2.634	5.613	7.218	1.108	3MP
442.5		9.329	19.948	62.399	9.581	N-HEX
491.7		3.124	7.181	8.158	1.253	MCP/22DMP
504.9		.409	.970	1.035	.159	24DMP
541.5		3.093	6.843	10.675	1.639	BEN
555.0		.080	.185	.122	.019	33DMP
559.5		3.688	8.571	9.068	1.392	C-HEX
586.5		3.045	8.383	7.947	1.220	2MH
591.0		.470	1.099	.879	.135	11DMCP
604.2		2.942	6.849	6.342	.974	3MH
614.7		.760	1.813	1.450	.223	C13DMCP
620.4		.753	1.750	1.400	.215	T13DMCP
626.4		1.428	3.390	3.085	.474	T12DMCP3EP
657.9		8.866	21.355	19.348	2.971	N-HEP
694.8		8.051	19.549	17.008	2.611	MCH/C12DMC
721.2		.357	.809	.678	.104	ECP
769.8		6.227	14.510	11.405	1.751	TOL
				1.000		

Trilab 2000 Analysis 4.86
SAMPLE C186 PHIL NOR N2/7-21S 90G 852 (.30R)
Plotting factors 88538.172 563.101

FIGURE : 2.2
WELL : N2/7-21S
DST-1

Trilab 2000 Analysis 4.8G
SAMPLE C187 PHIL NOR N2/7-21S 90G 854 (.30R)
Method : GASOLINE

Table No.10 GASOLINE (Area)

RETN TIME	REL RET	PEAK HT	PEAK AREA	PEAK CONC	%CONC	PEAK NAME
148.5		1.591	2.077	18.348	3.400	IC4
166.8		6.134	8.254	72.920	13.511	NC4
233.1		5.021	8.814	146.697	27.182	IC5
267.0		8.765	15.304	105.596	19.566	NC5
319.5		.113	.235	.620	.115	22DMB
365.1		.716	1.456	3.951	.732	CP
371.7		.487	1.084	1.975	.366	23DMB
381.6		4.234	8.942	12.375	2.293	2MP
407.7		2.577	5.403	6.949	1.288	3MP
443.4		9.329	20.045	62.700	11.618	N-HEX
492.6		3.118	7.287	8.278	1.534	MCP/22DMP
506.1		.406	.964	1.029	.191	24DMP
542.4		3.413	7.806	12.177	2.256	BEN
555.9		.101	.275	.182	.034	33DMP
560.4		3.946	9.280	9.818	1.819	C-HEX
587.4		3.259	9.152	8.676	1.608	2MH
591.9		.499	1.244	.995	.184	11DMCP
605.4		3.218	7.430	6.880	1.275	3MH
615.6		.832	1.972	1.578	.292	C13DMCP
621.3		.832	1.903	1.523	.282	T13DMCP
627.3		1.503	3.700	3.367	.624	T12DMCP3EP
658.8		10.037	24.210	21.934	4.064	N-HEP
696.0		9.322	22.239	19.348	3.585	MCH/C12DMC
722.4		.406	.943	.791	.146	ECP
771.0		5.963	13.970	10.980	2.035	TOL
				536.301		

Trilab 2000 Analysis 4.8G
SAMPLE C187 PHIL NOR N2/7-21S 90G 854 (.30R)
Plotting factors 84810.367 520.599

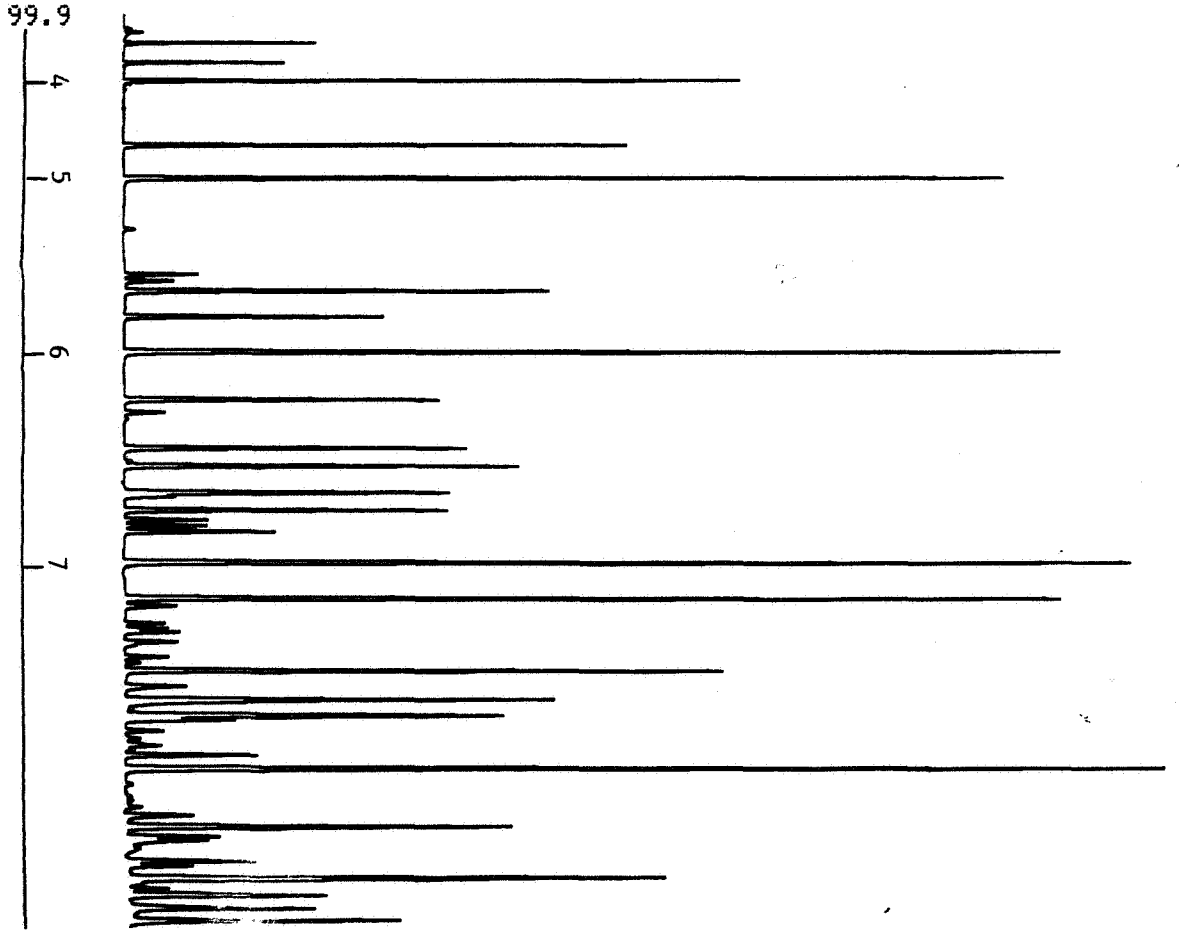


FIGURE : 2.3
WELL : N2/7-21S
DST-2

Trilab 2000 Analysis 4.8G
SAMPLE C170 PHILLIPS N2/7-21S 90E328 (.30R)
Method : GASOLINE

Table No.10 GASOLINE (Area)

RETN TIME	REL RET	PEAK HT	PEAK AREA	PEAK CONC	%CONC	PEAK NAME
147.6		2.390	3.161	27.920	2.765	IC4
165.9		9.252	12.894	113.902	11.282	NC4
231.6		8.568	14.949	248.813	24.645	IC5
265.2		15.502	27.013	186.392	18.462	NC5
317.4		.241	.494	1.304	.129	22DMB
363.0		1.486	3.060	8.306	.823	CP
369.3		1.036	2.248	4.095	.406	23DMB
379.2		8.733	18.396	25.460	2.522	2MP
405.3		5.145	11.415	14.679	1.454	3MP
441.0		19.386	42.672	133.477	13.221	N-HEX
489.9		7.221	16.407	18.638	1.846	MCP/22DMP
503.4		.90	2.162	2.309	.229	24DMP
539.1		7.718	17.154	26.761	2.651	BEN
552.9		.208	.521	.345	.034	33DMP
557.7		9.145	20.990	22.208	2.200	C-HEX
584.4		7.203	20.412	19.350	1.917	2MH
588.9		1.115	2.443	1.954	.194	11DMCP
602.4		7.021	16.731	15.493	1.535	3MH
612.6		1.932	4.505	3.604	.357	C13DMCP
618.3		1.855	4.427	3.542	.351	T13DMCP
624.3		3.583	8.568	7.797	.772	T12DMCP3EP
655.8		24.129	54.020	48.942	4.848	N-HEP
693.0		20.325	50.941	44.318	4.390	MCH/C12DMC
719.1		.936	2.170	1.818	.180	ECP
767.4		15.176	35.847	28.176	2.791	TOL
				1000.000		

Trilab 2000 Analysis 4.8G
SAMPLE C170 PHILLIPS N2/7-21S 90E328 (.30R)
Plotting factors 37270.371 154.261

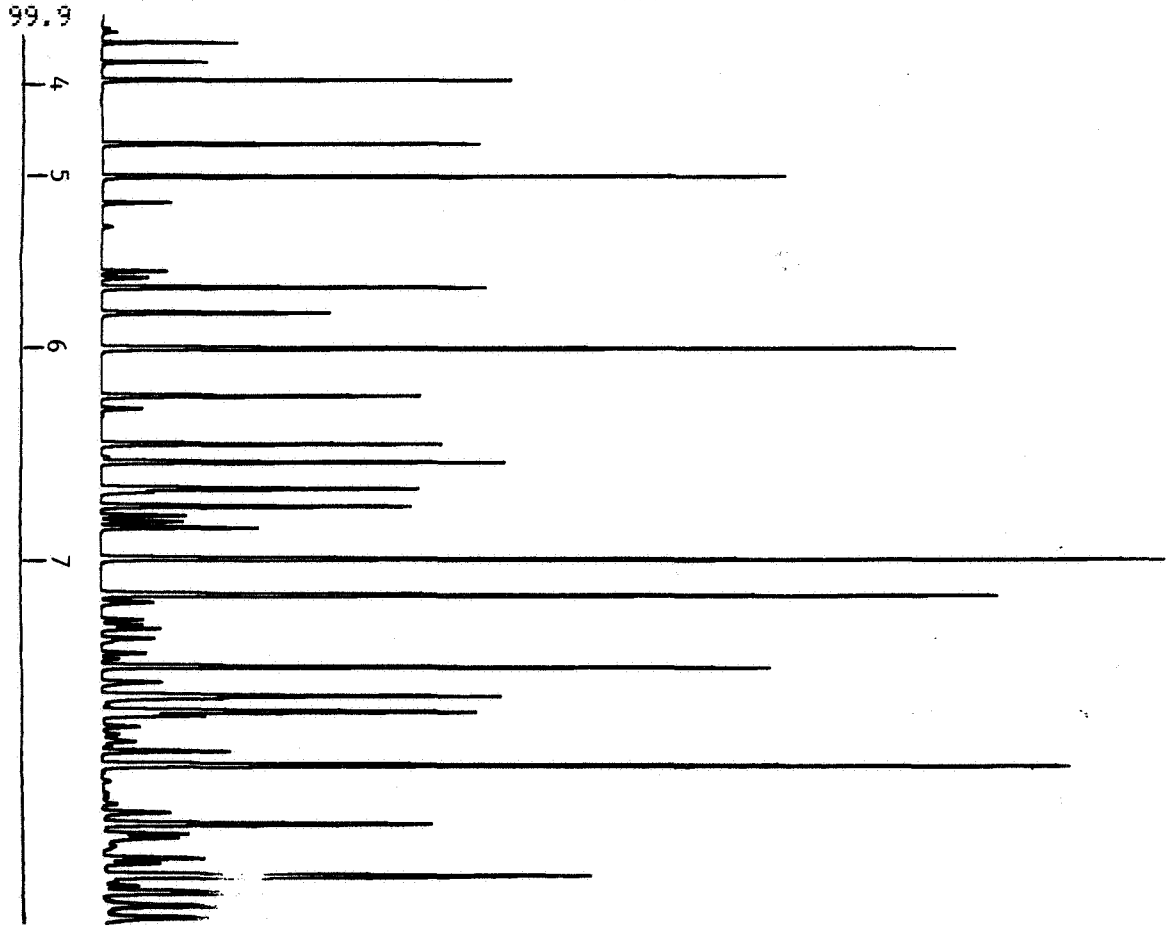


FIGURE : 2.4
WELL : N2/7-21S
DST-3

FIGURE 3.1
WELL : N2/7-20X
DST-1

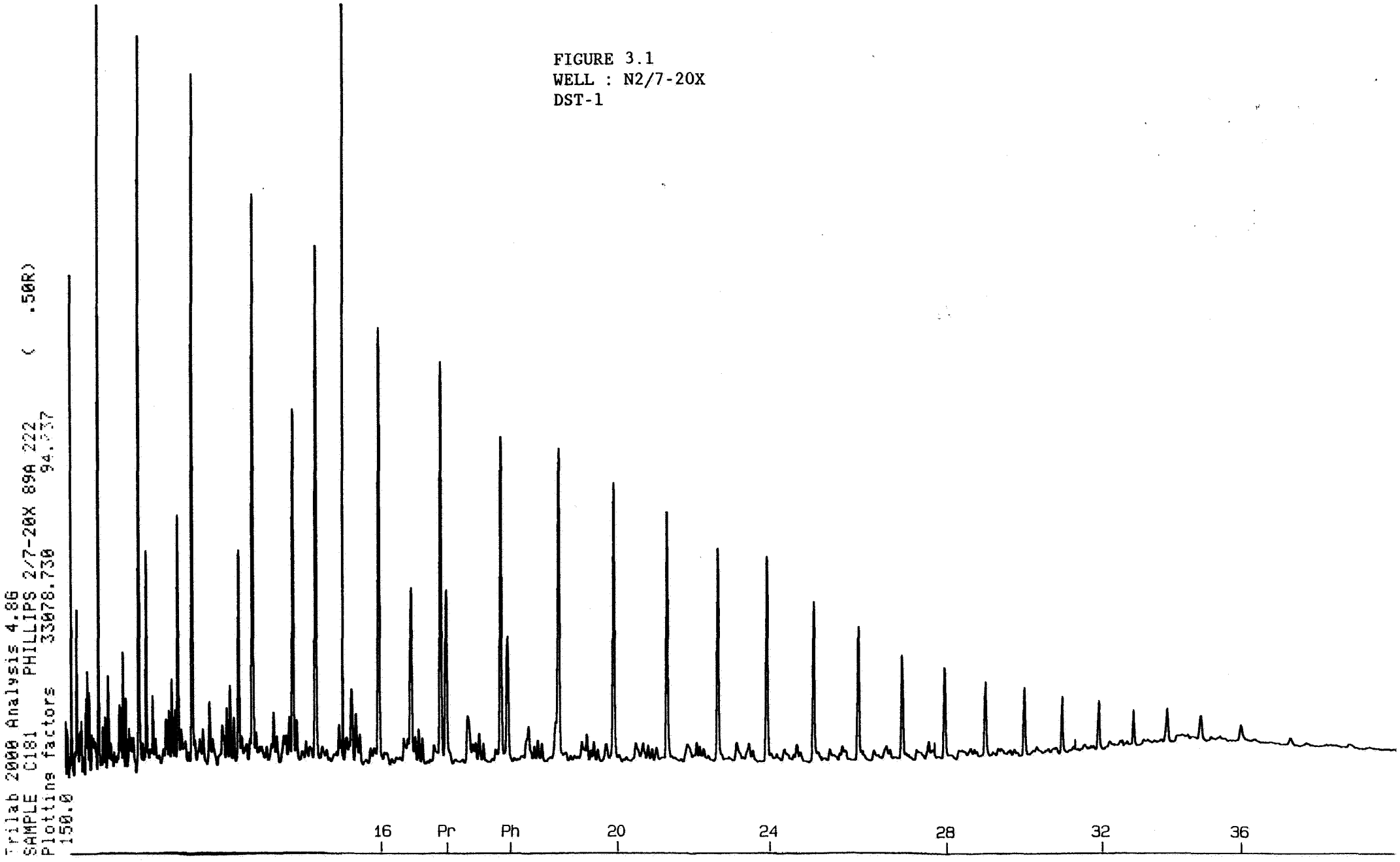


FIGURE : 3.2
WELL : N2/7-21S
DST-1

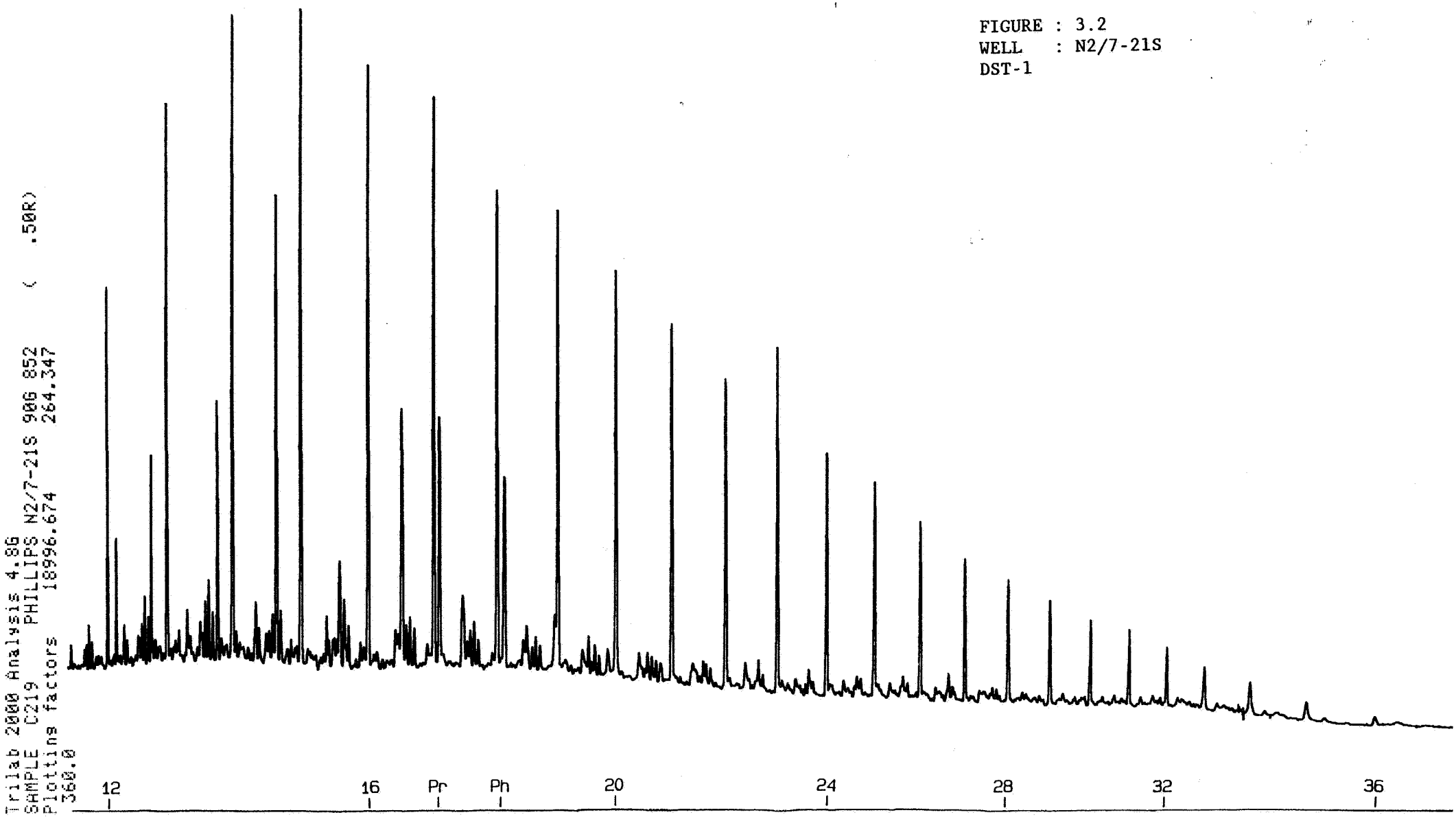


FIGURE : 3.3
WELL : N2/7-21S
DST-2

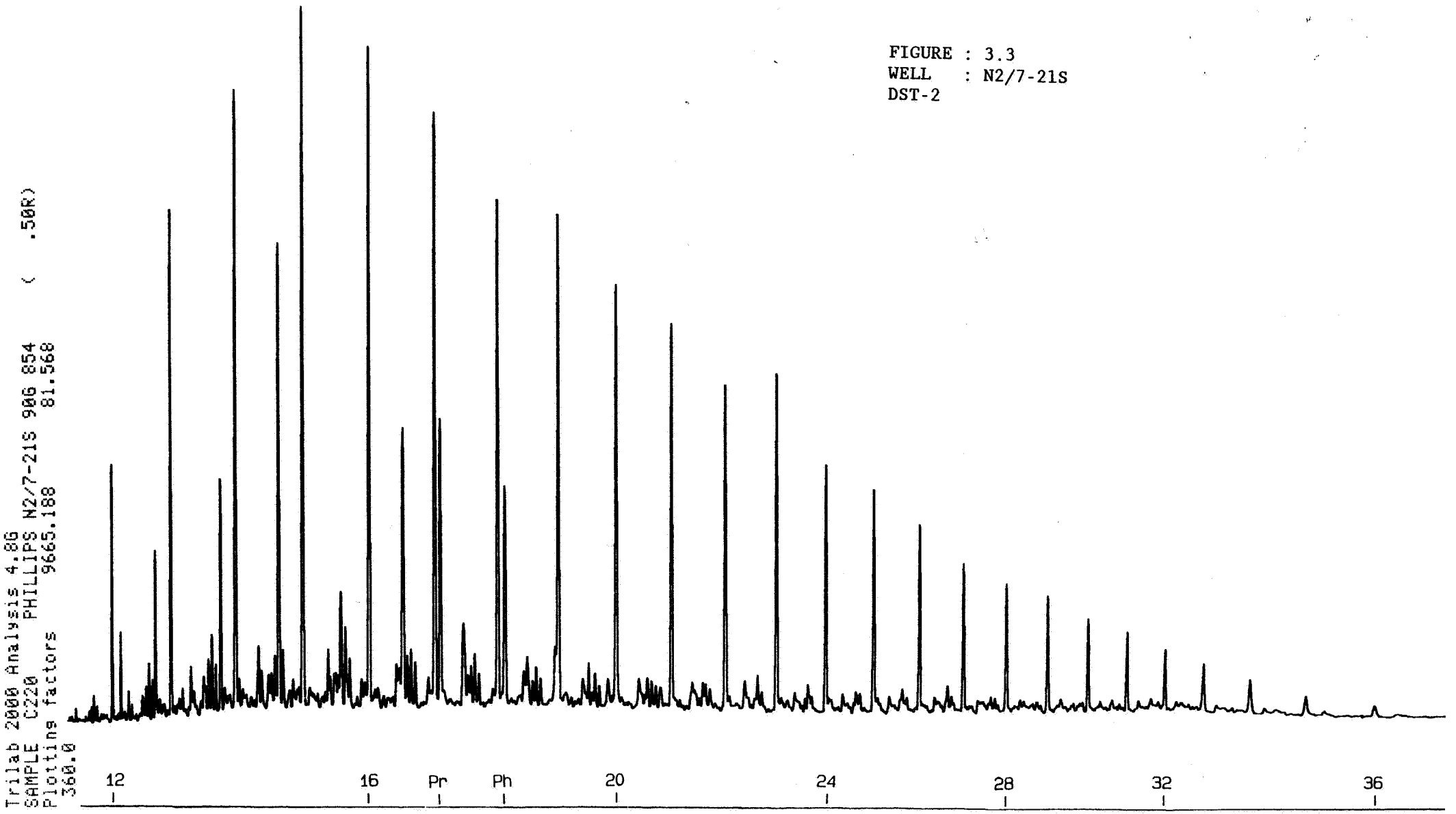
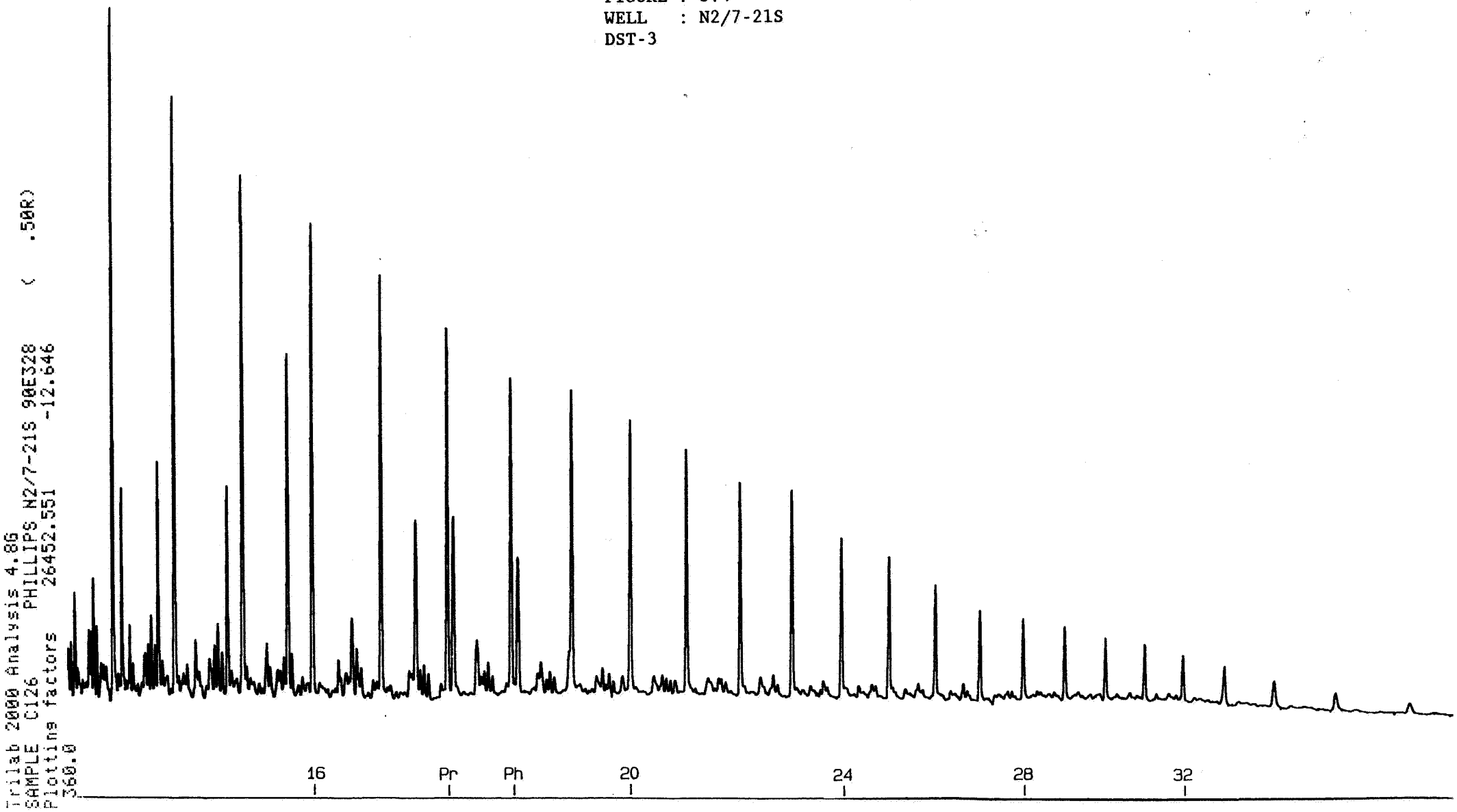


FIGURE : 3.4
WELL : N2/7-21S
DST-3



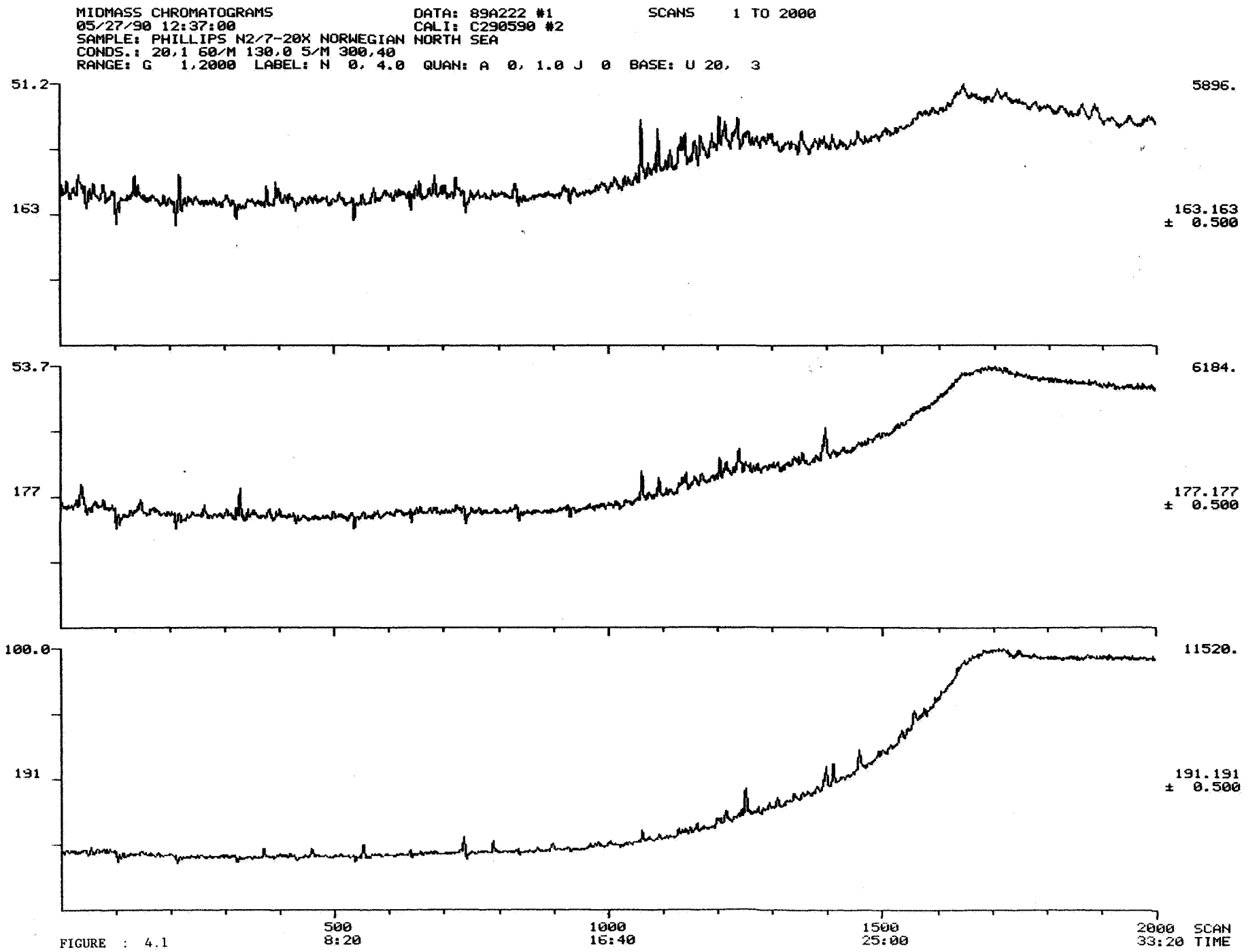


FIGURE : 4.1
WELL : N2/7-20X
DST-1

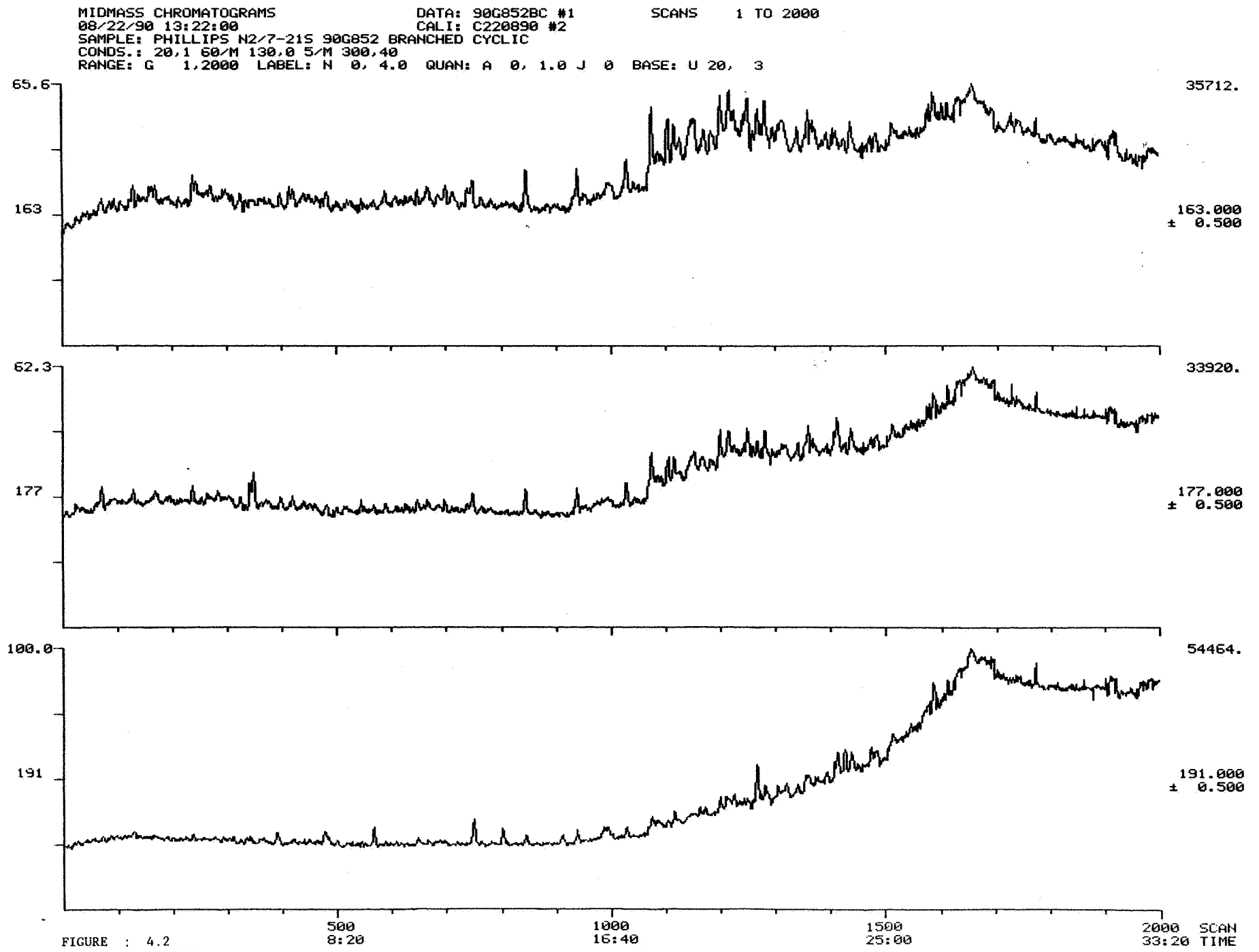


FIGURE : 4.2
WELL : N2/7-21S
DST-1

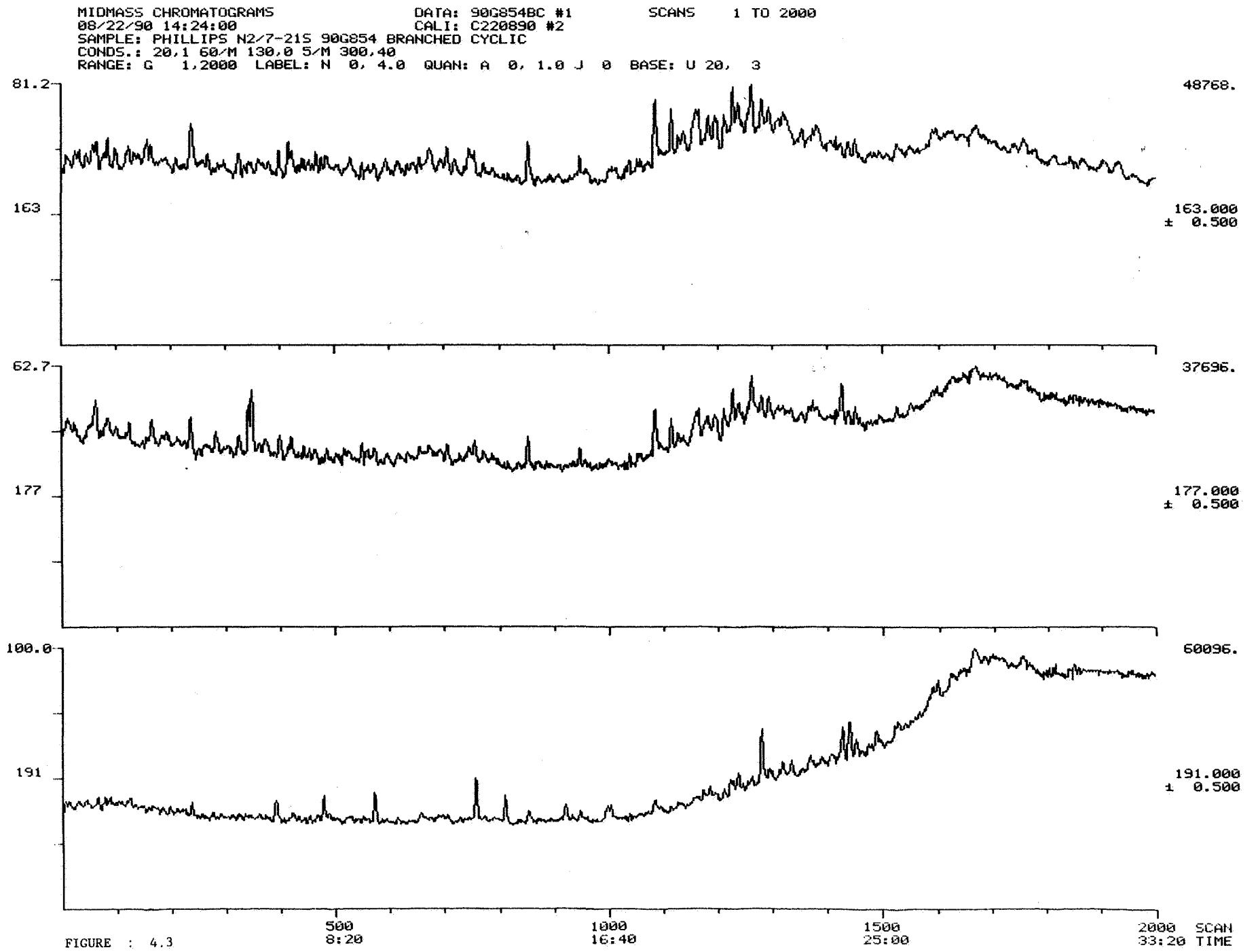


FIGURE : 4.3
WELL : N2/7-21S
DST-2

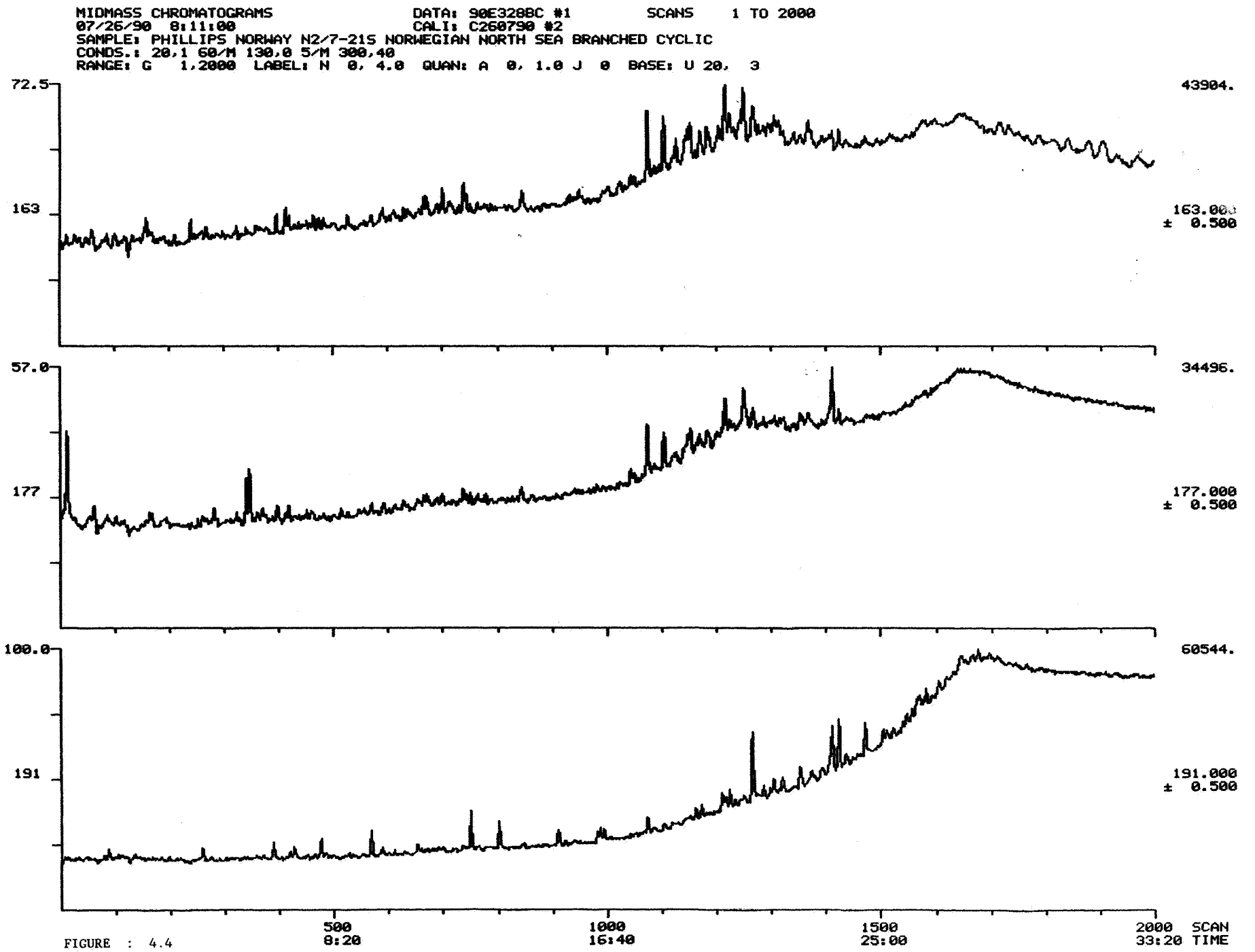


FIGURE : 4.4
WELL : N2/7-21S
DST-3

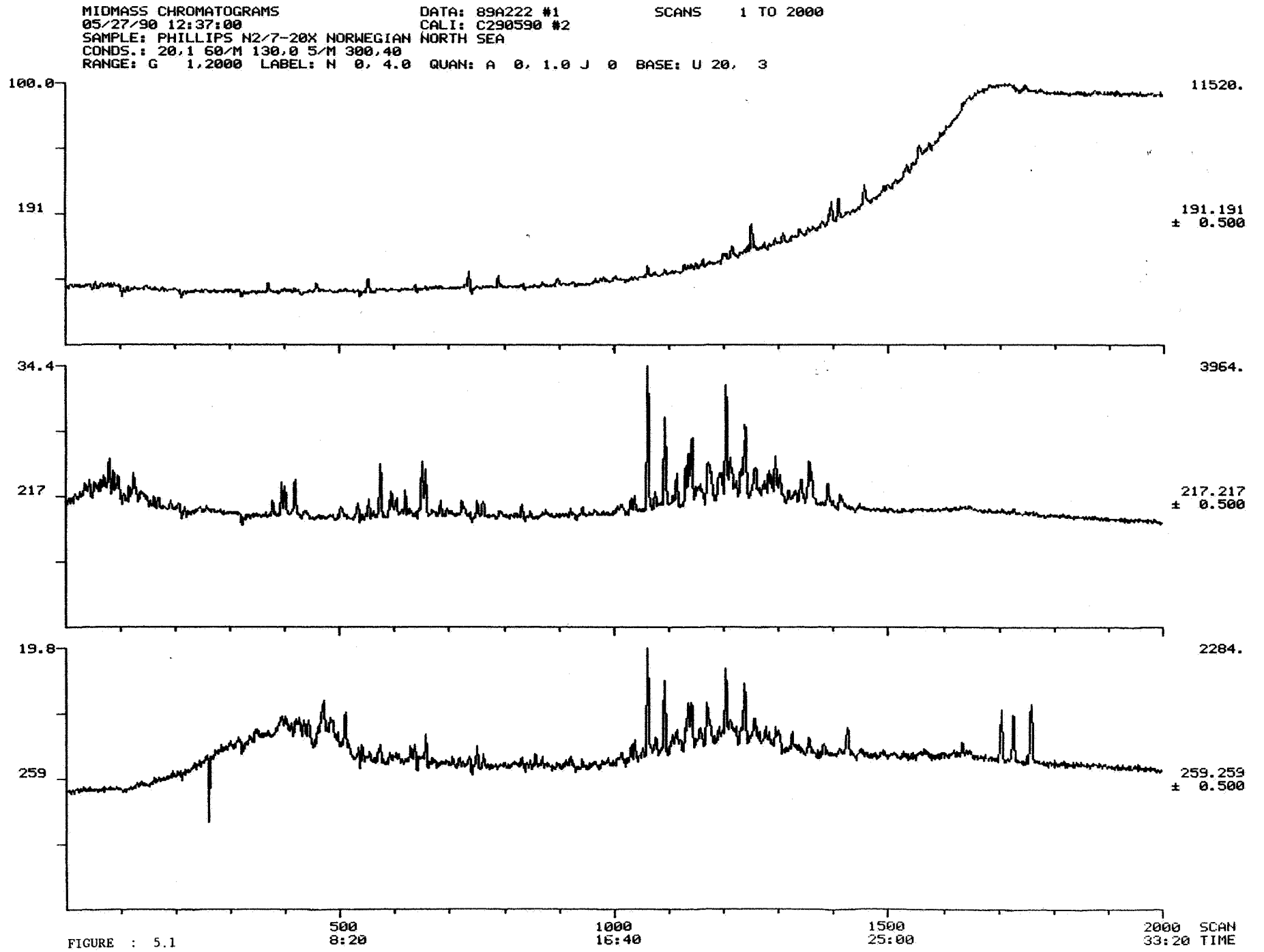


FIGURE : 5.1
WELL : N2/7-20X
DST-1

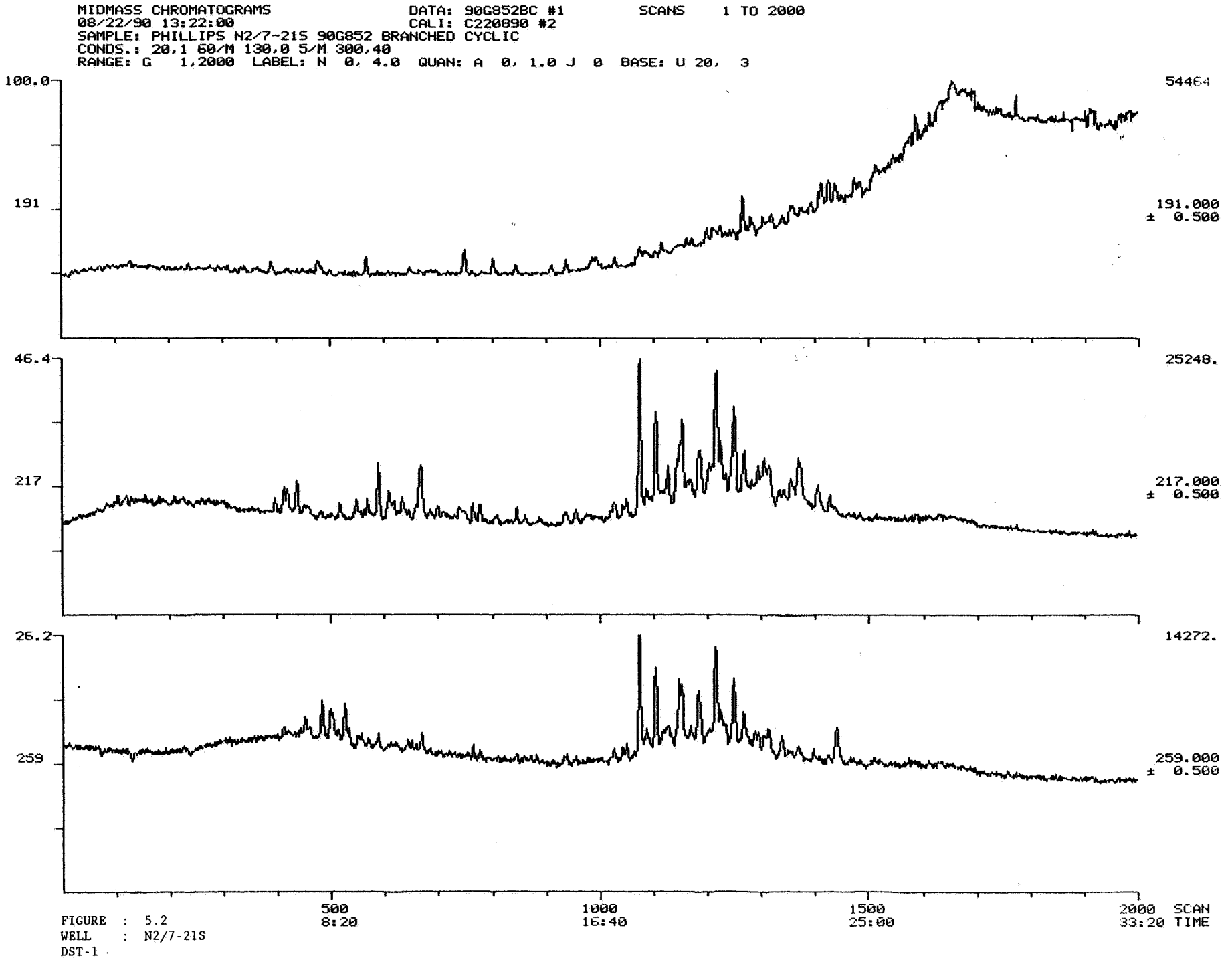


FIGURE : 5.2
WELL : N2/7-21S
DST-1

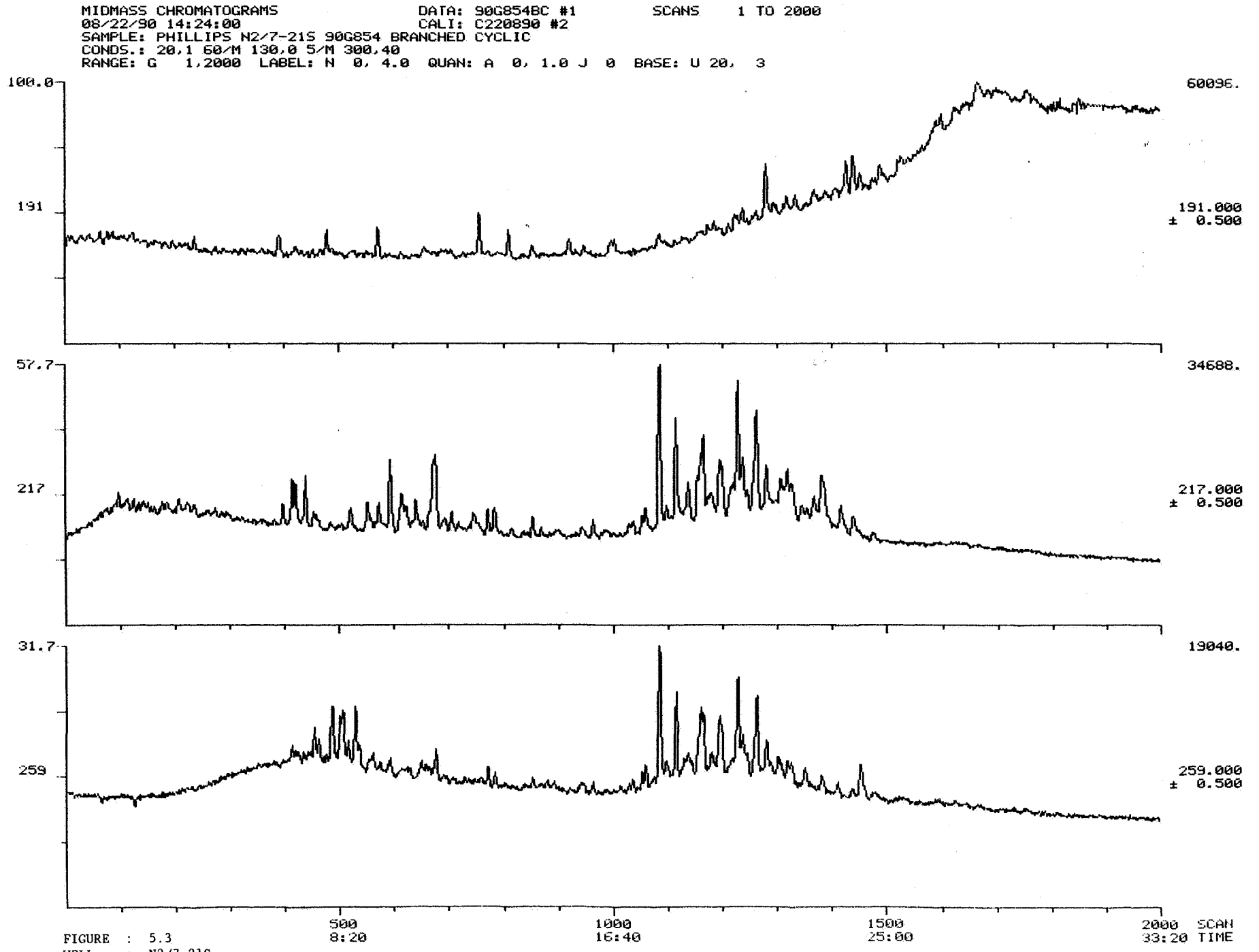


FIGURE : 5.3
WELL : N2/7-21S
DST-2

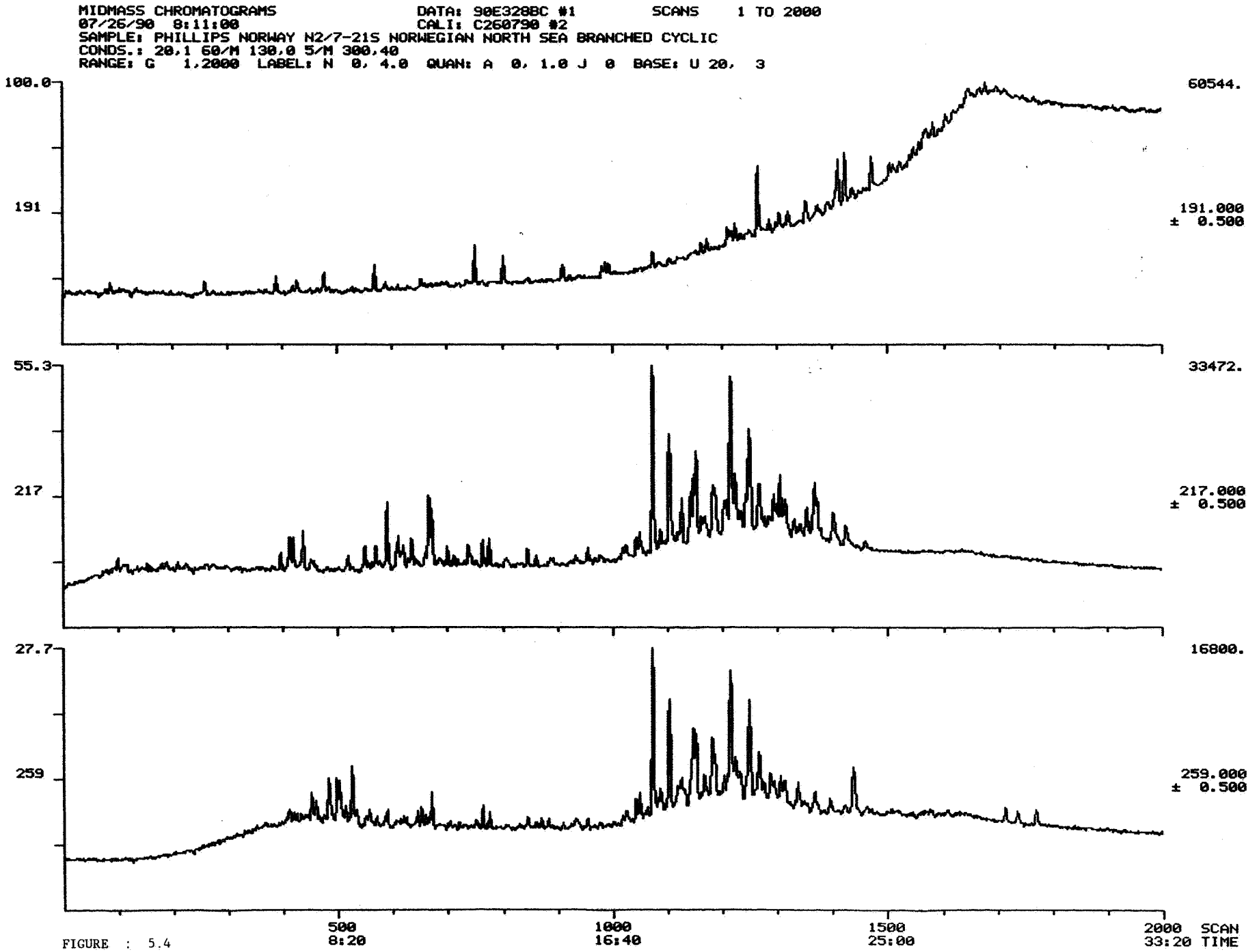


FIGURE : 5.4
WELL : N2/7-21S
DST-3

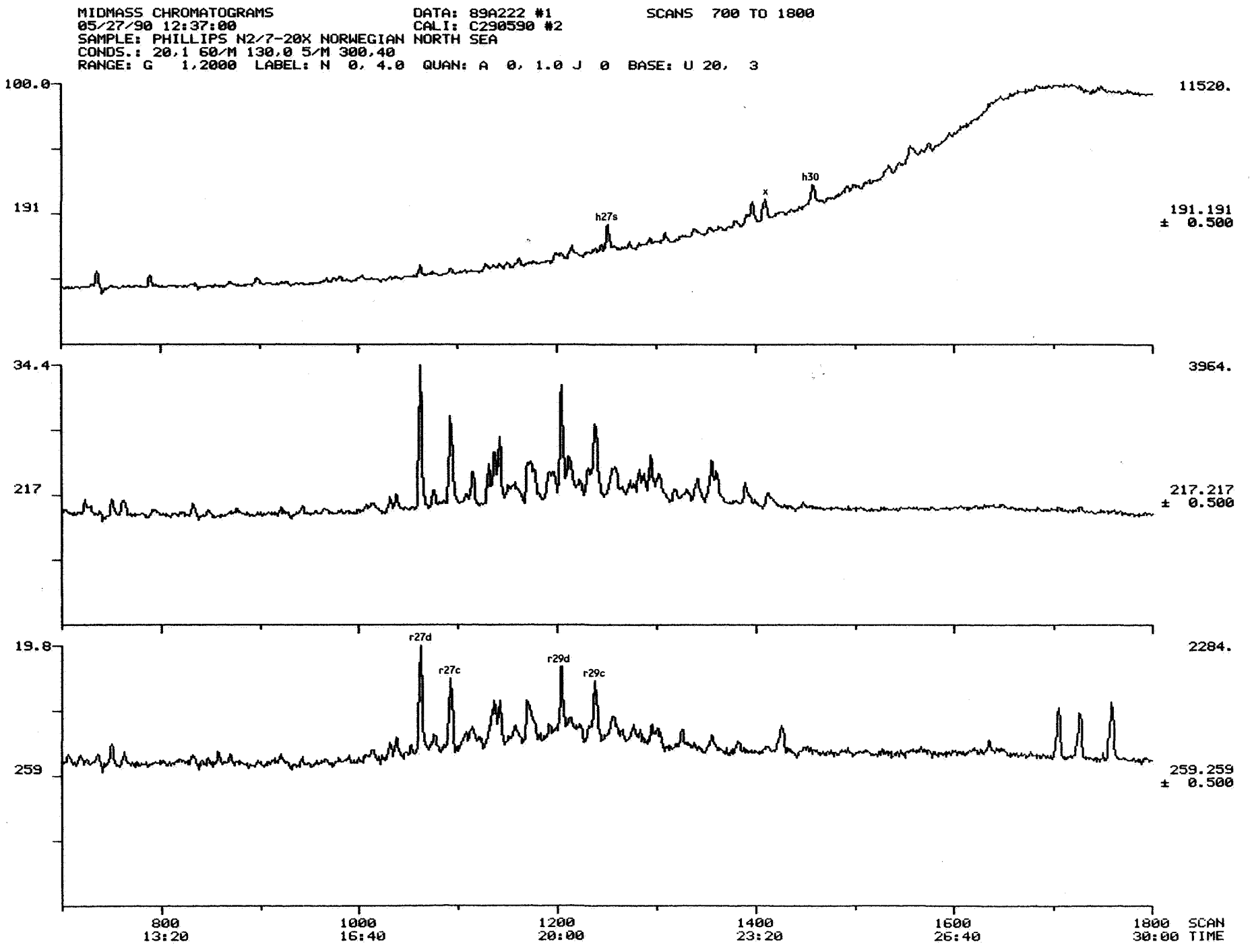


FIGURE : 6.1
WELL : N2/7-20X

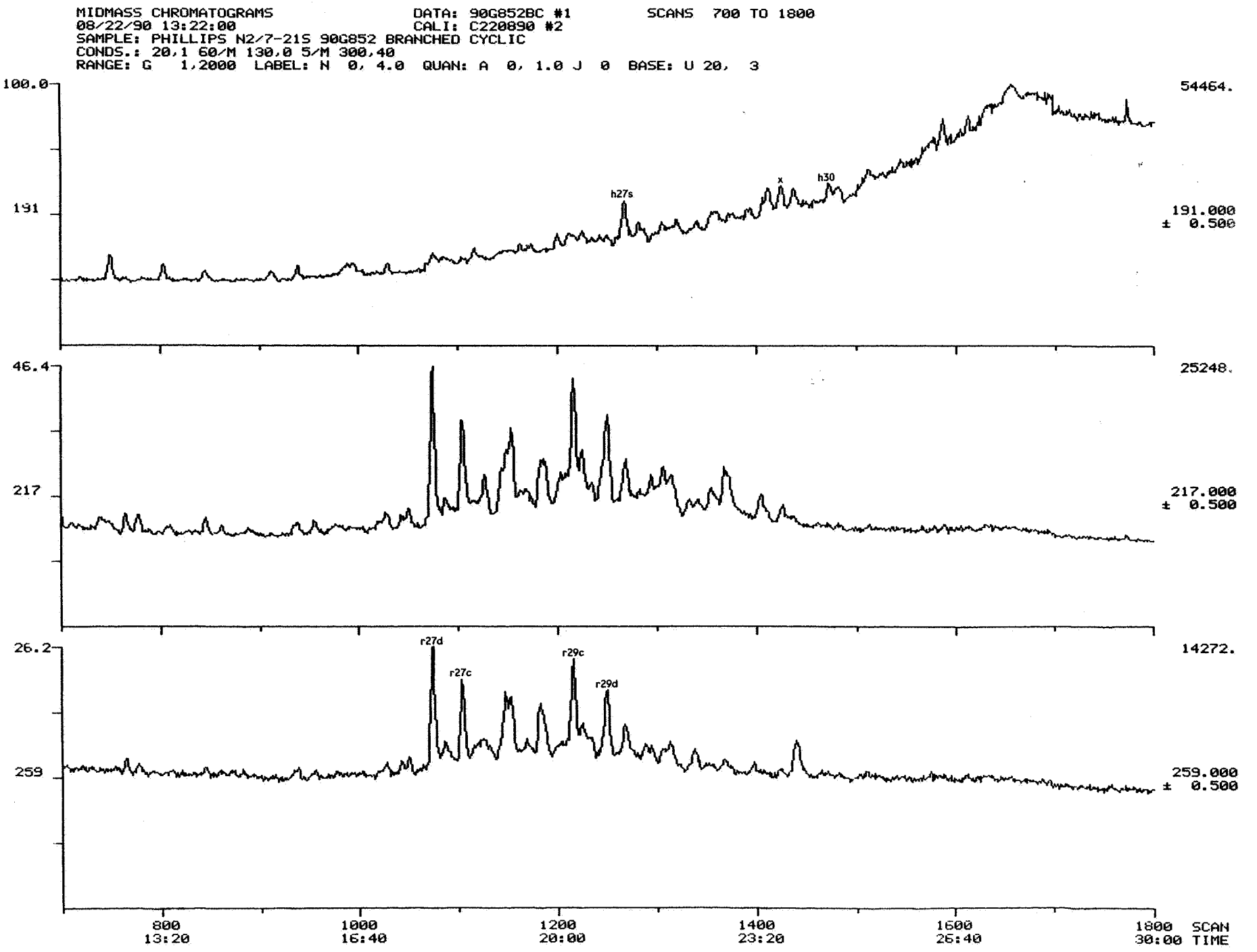


FIGURE : 6.2
WELL : N2/7-21S
DST-1

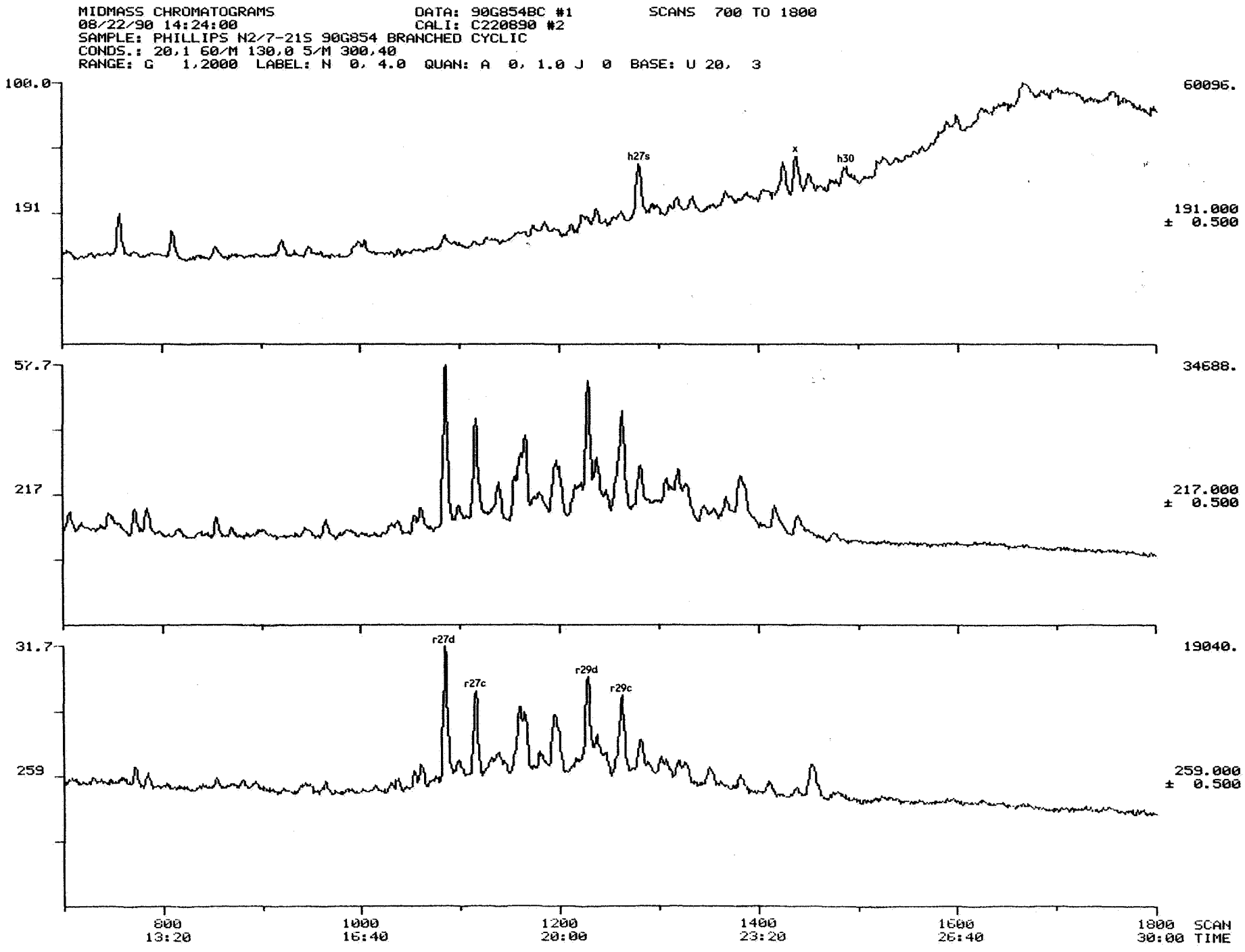


FIGURE : 6.3
WELL : N2/7-21S
DST-2

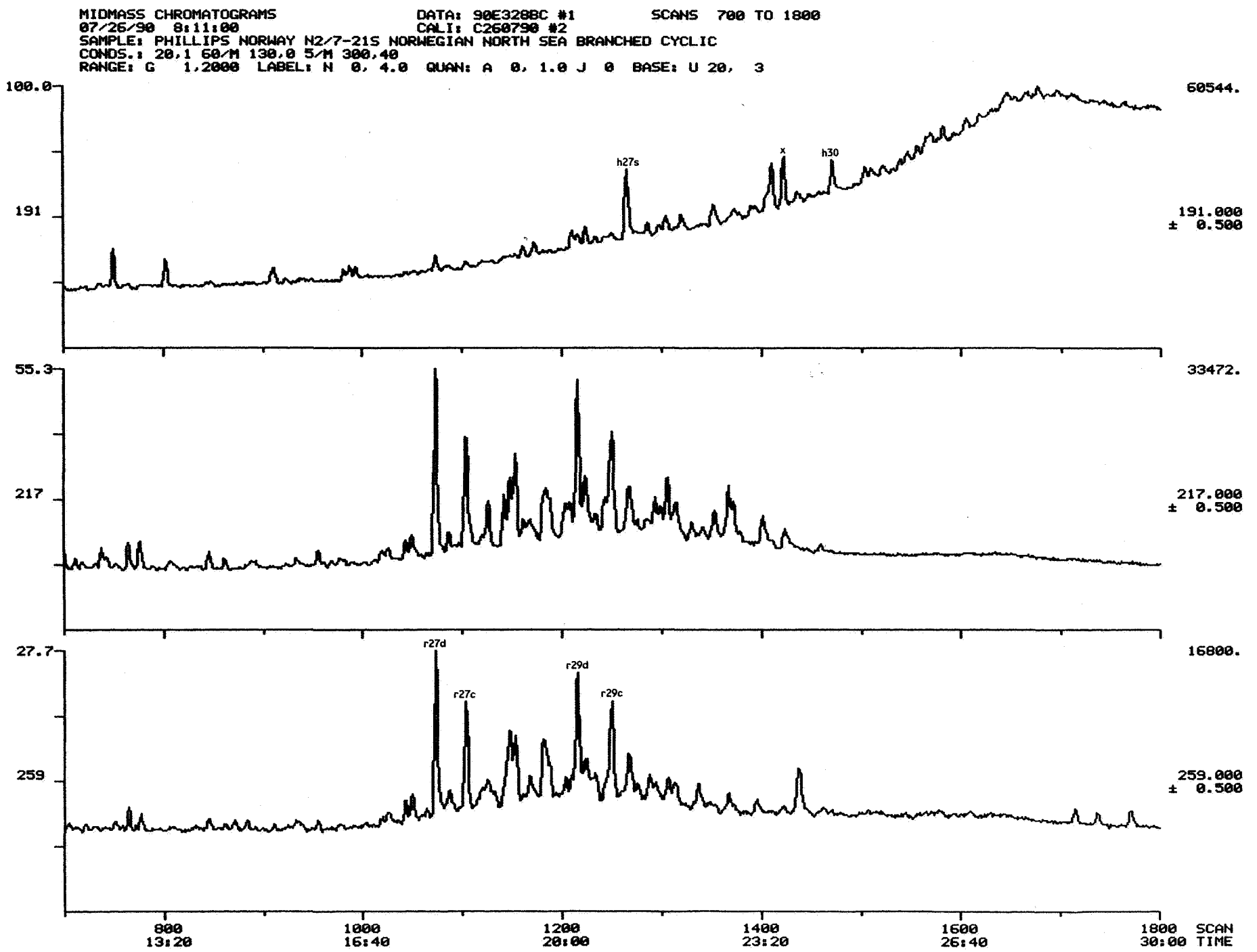


FIGURE : 6.4
WELL : N2/7-21S

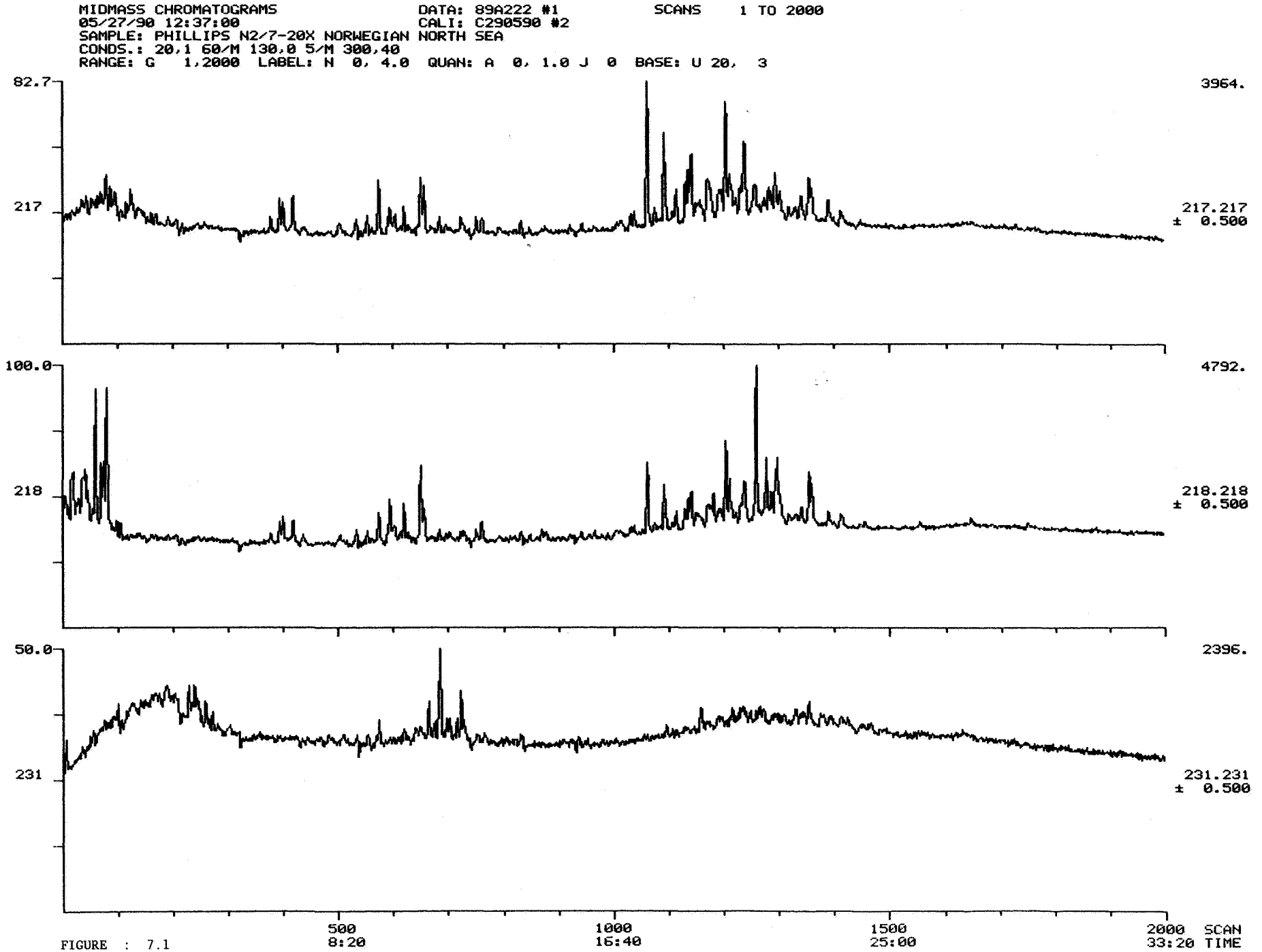


FIGURE : 7.1
WELL : N2/7-20X
DST-1

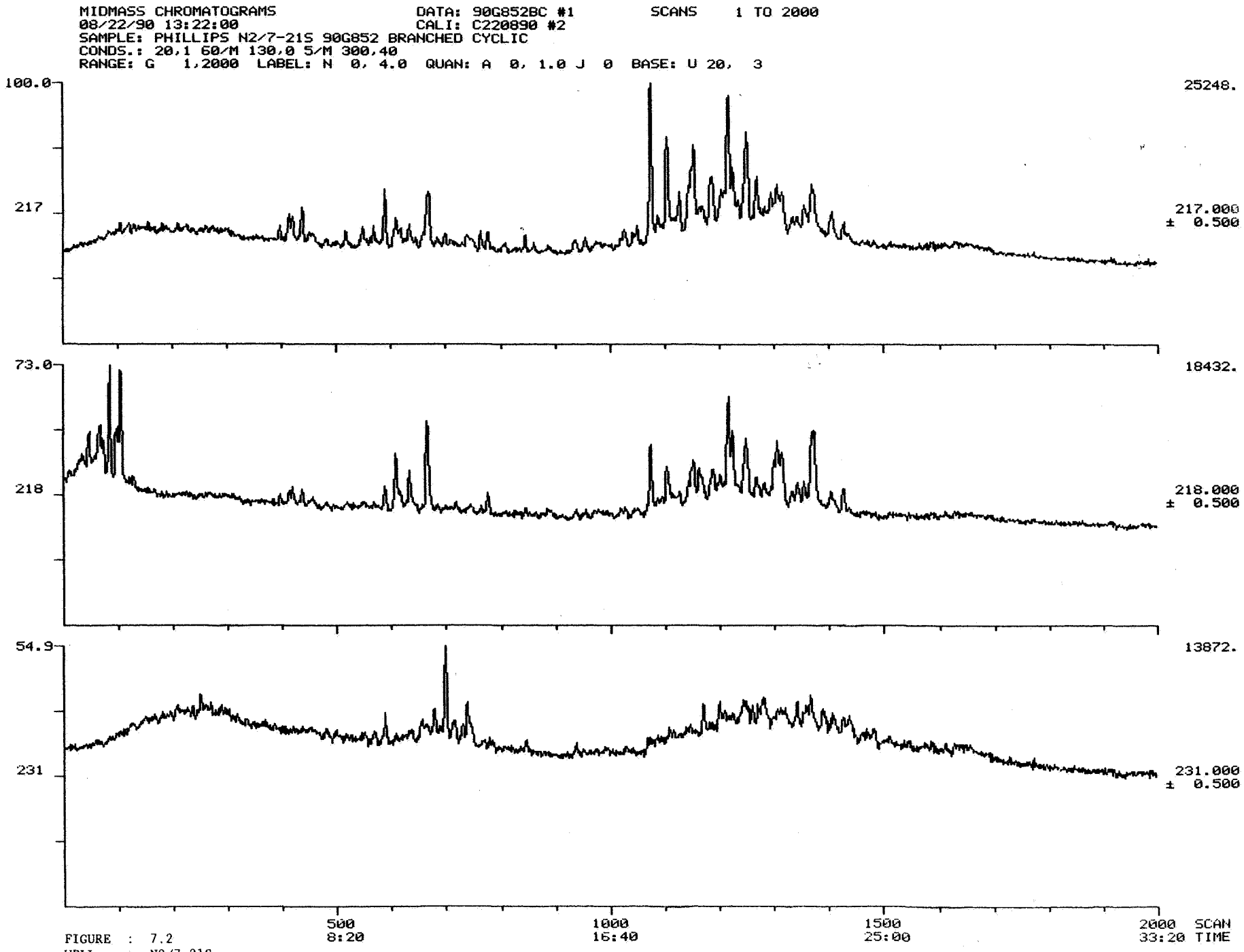


FIGURE : 7.2
WELL : N2/7-21S
DST-1

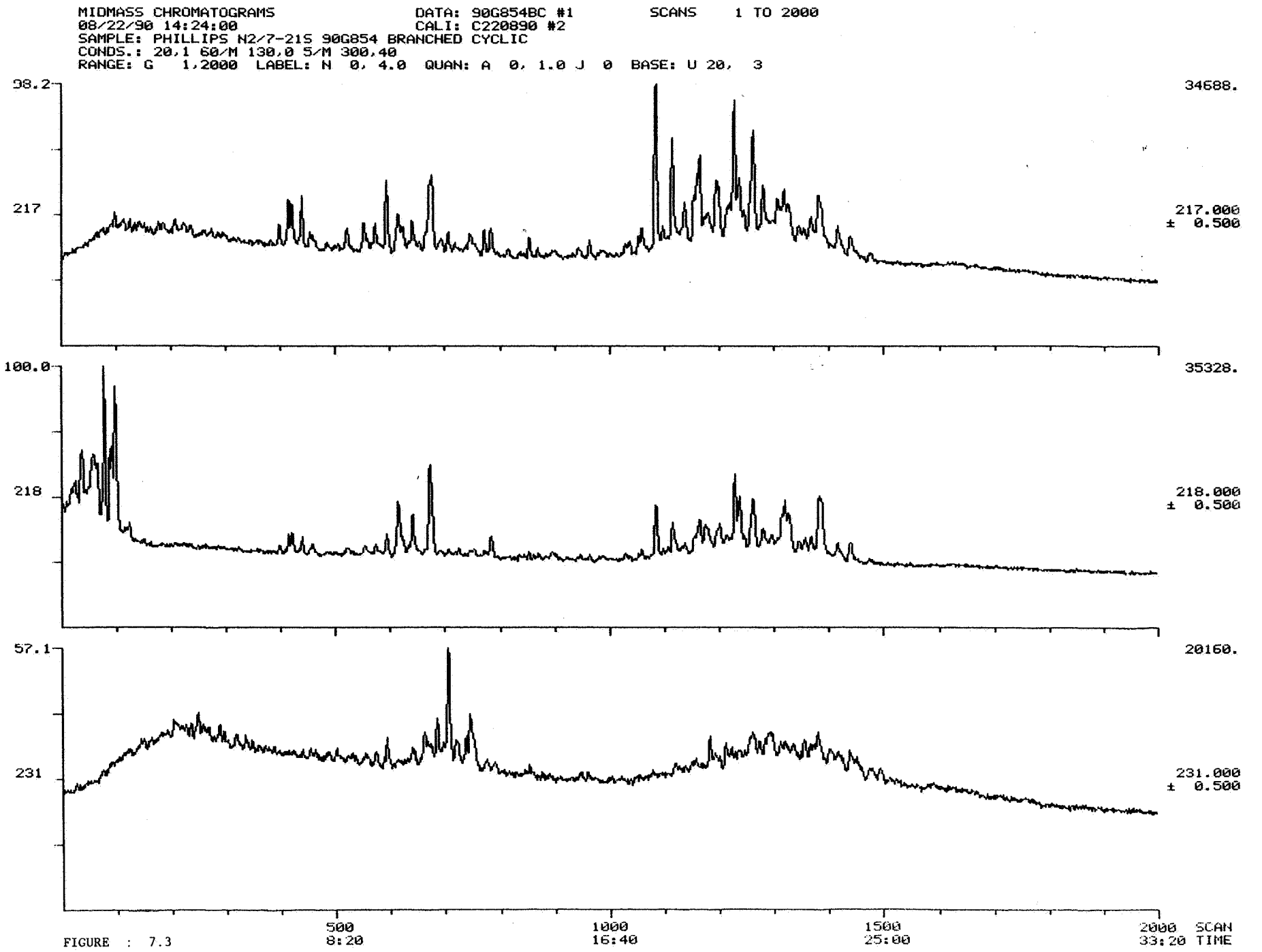


FIGURE : 7.3
WELL : N2/7-21S
DST-2

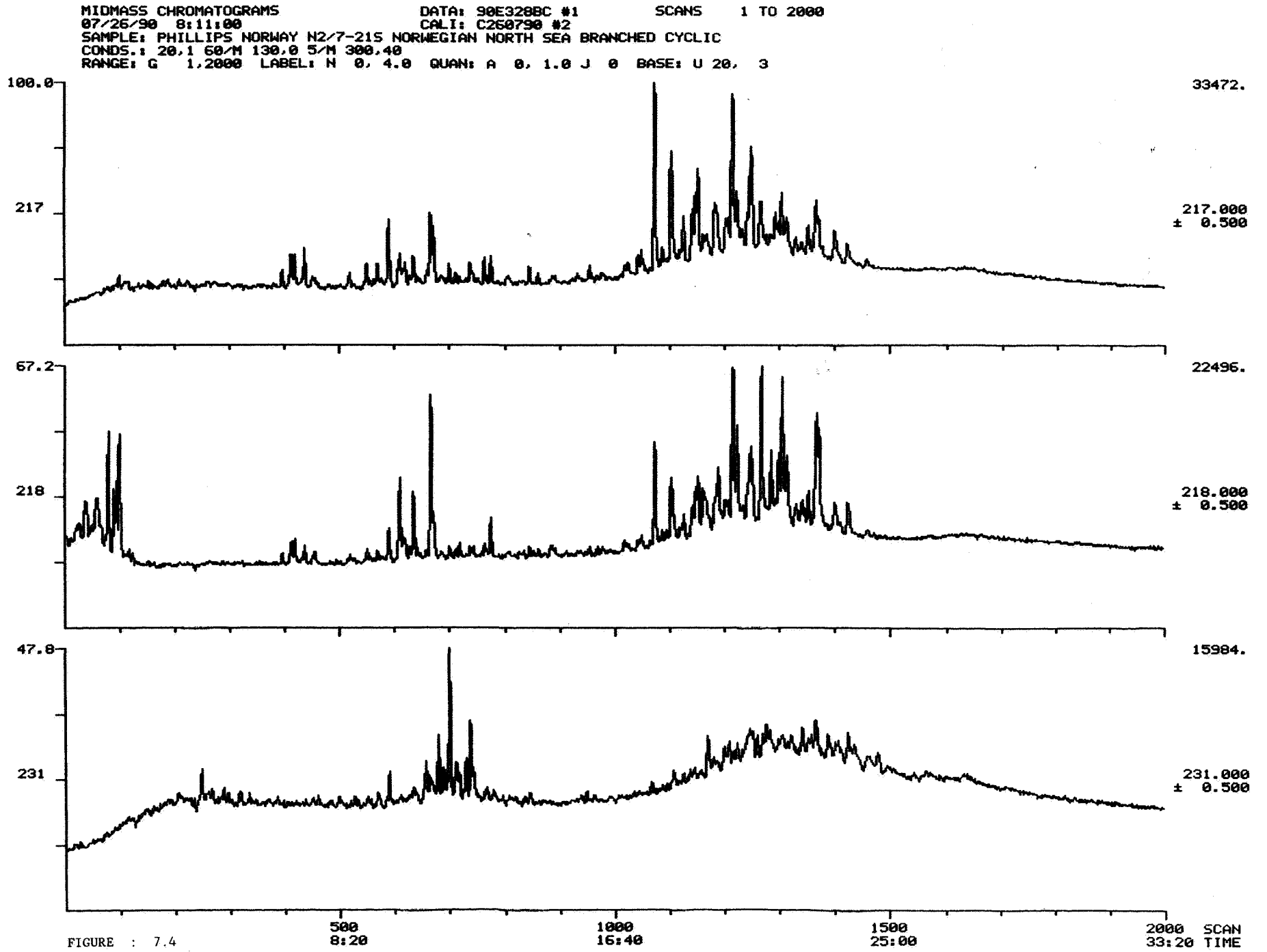


FIGURE : 7.4
WELL : N2/7-21S
DST-3

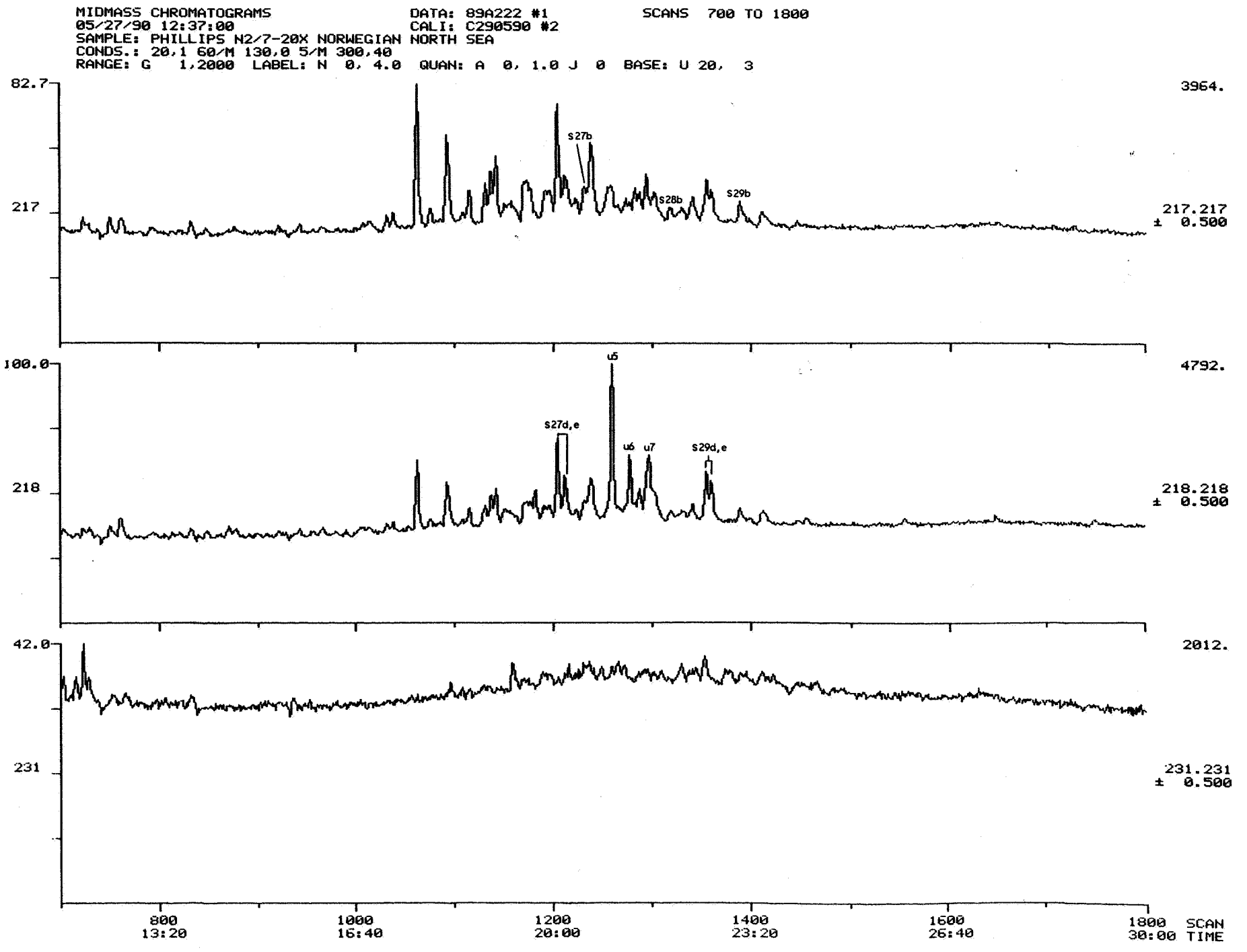


FIGURE : 8.1
WELL : N2/7-20X

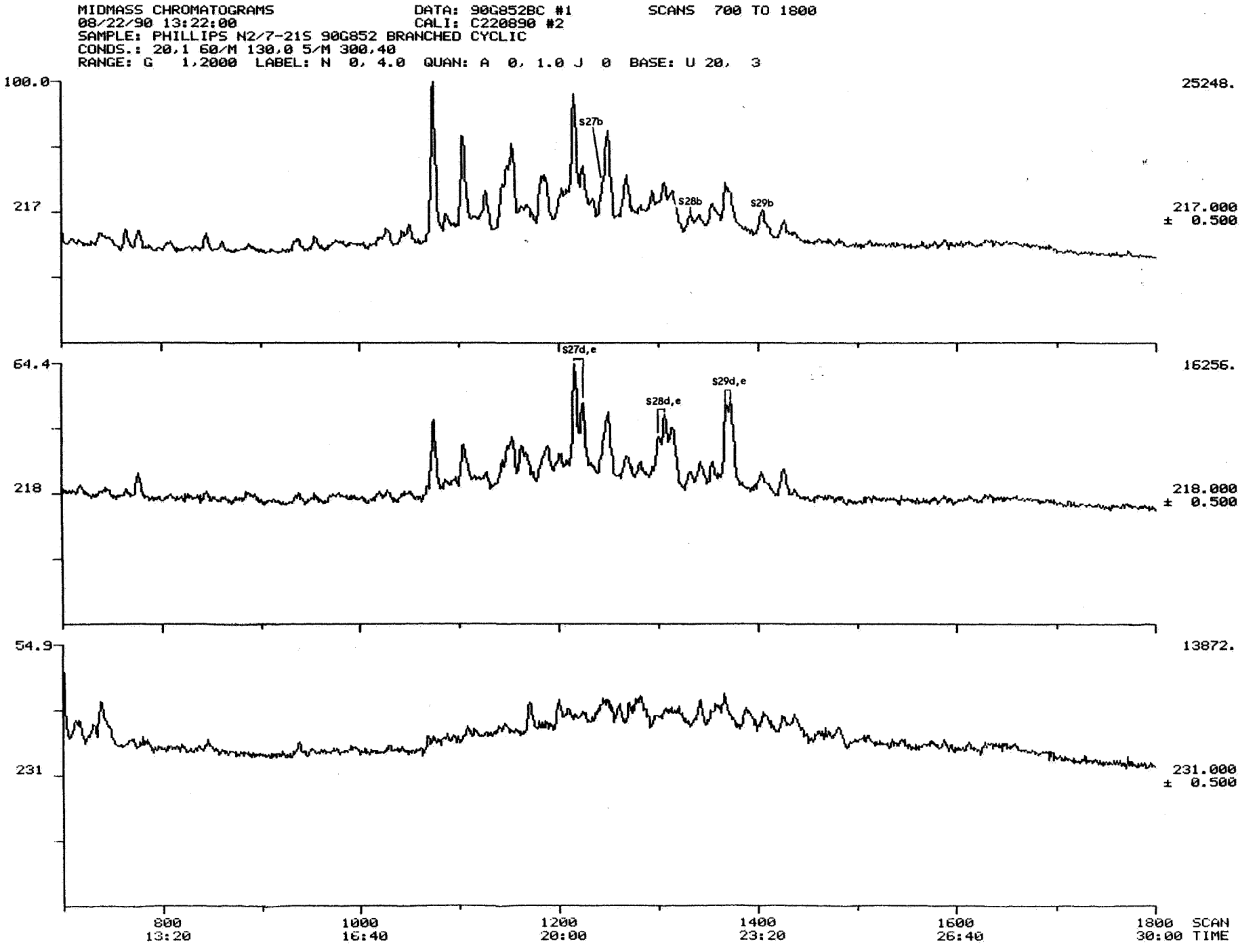


FIGURE : 8.2
WELL : N2/7-21S
DST-1

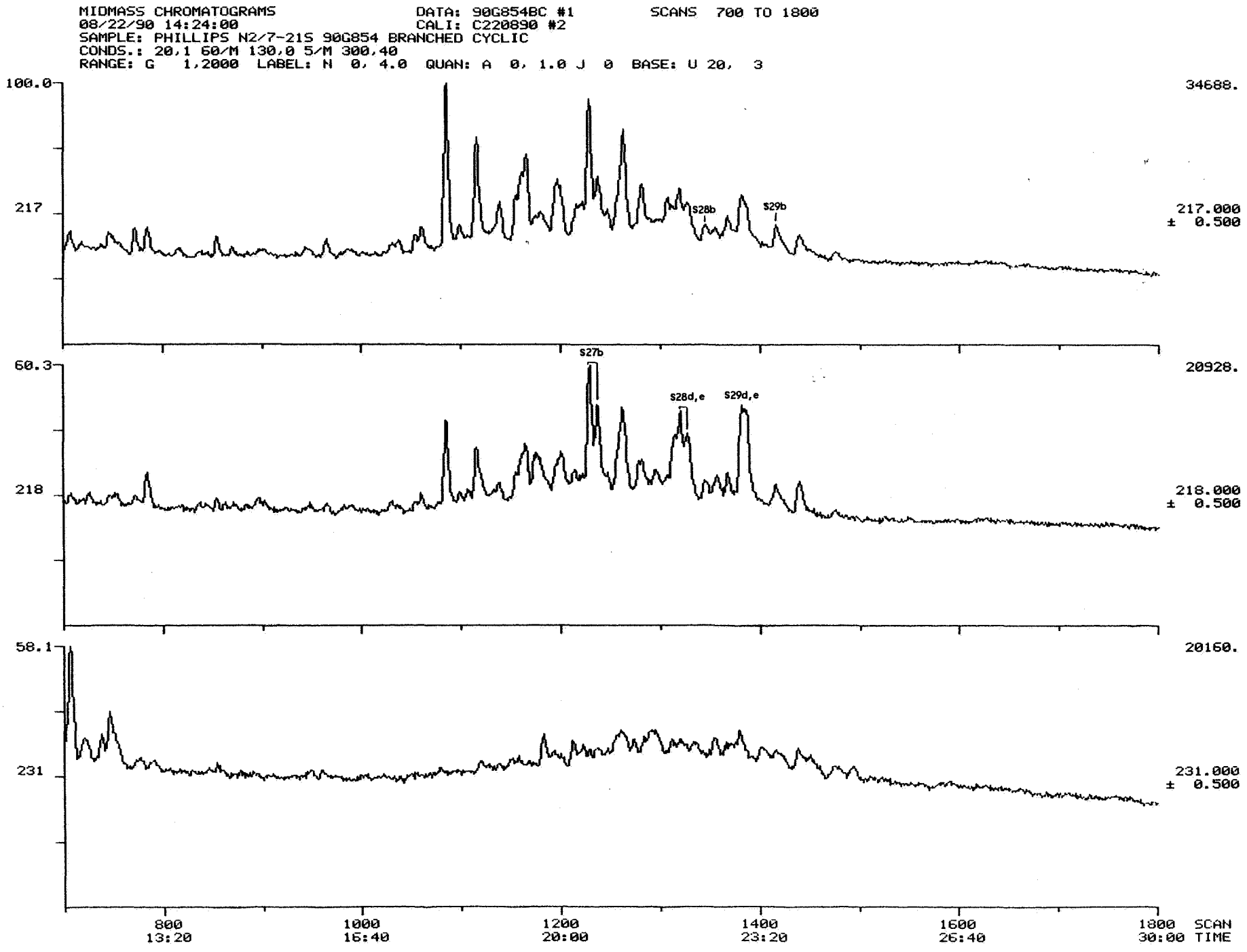


FIGURE : 8.3
WELL : N2/7-21S
DST-2

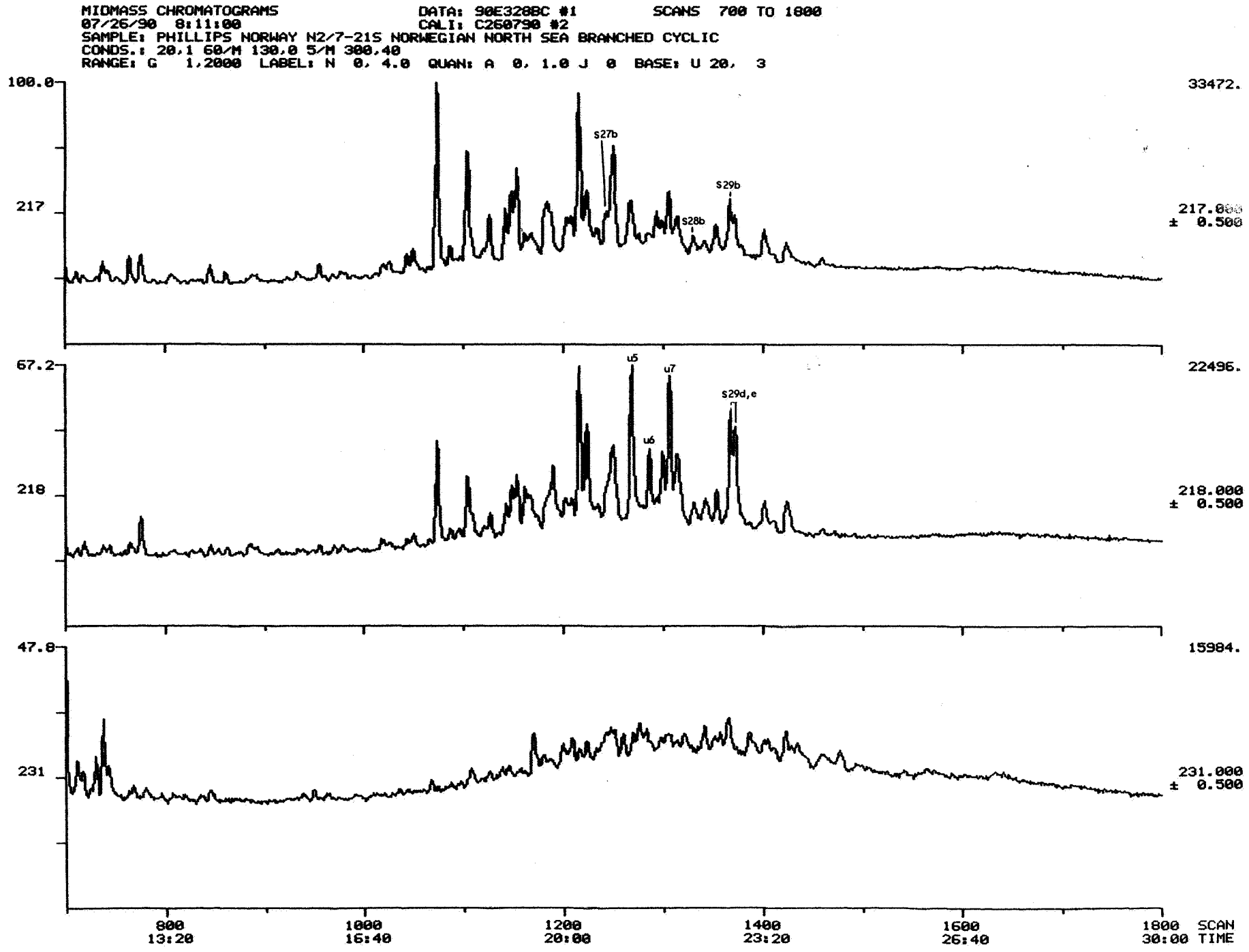


FIGURE : 8.4
WELL : N2/7-21S

FIGURE : 9.1
Well : N2/7-20X
Depth : 14753.0'

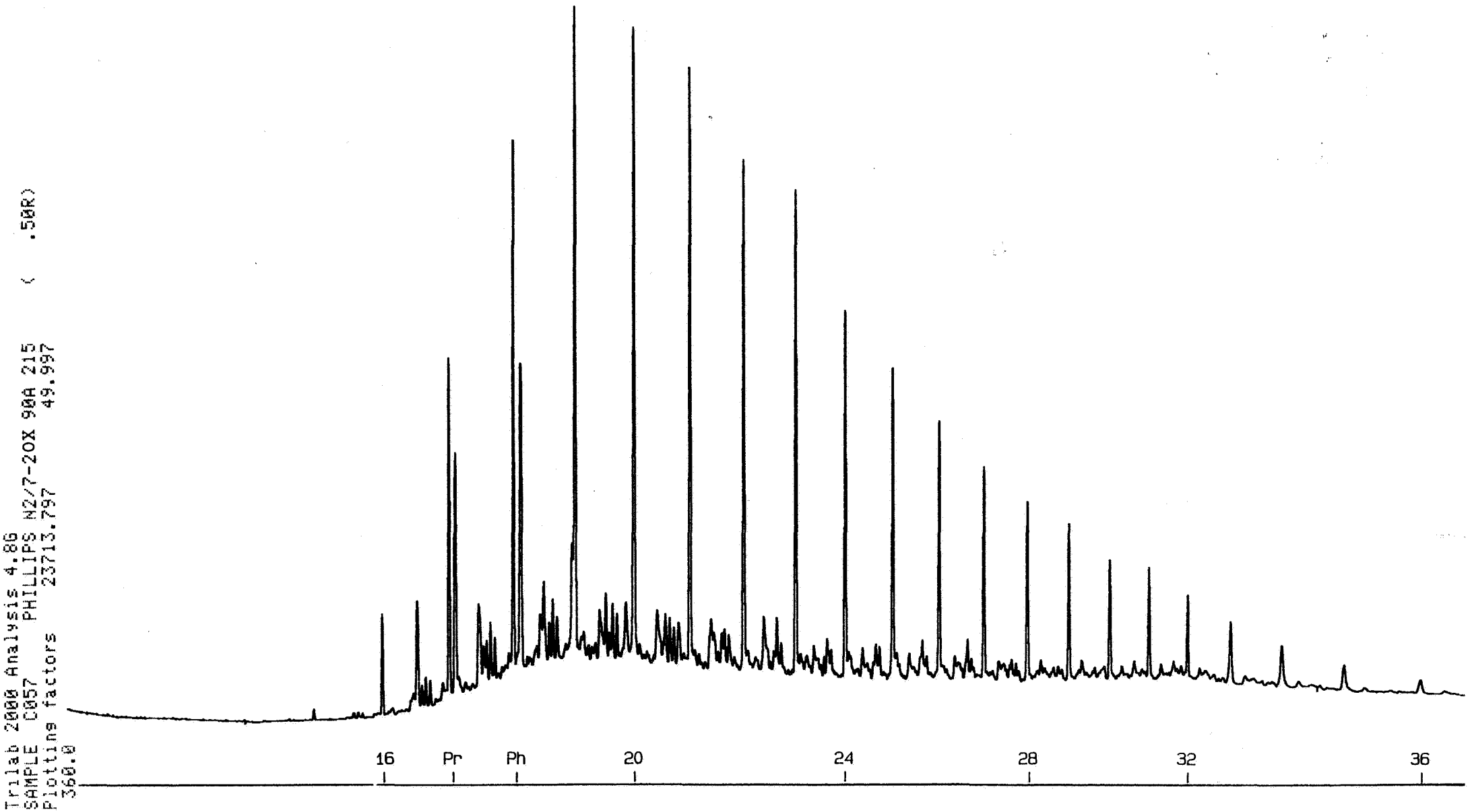


FIGURE : 9.2
Well : N2/7-21S
Depth : 14267.2'

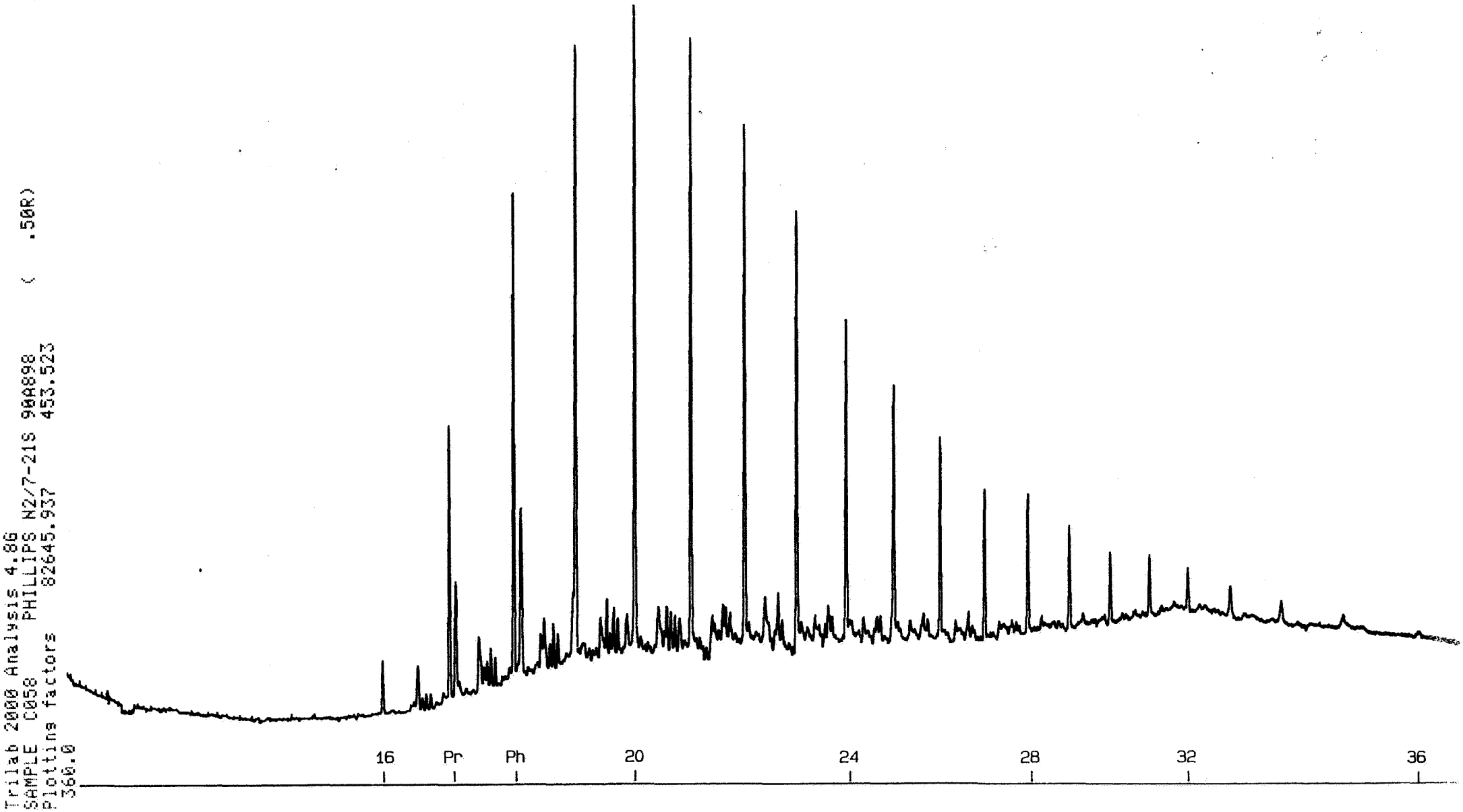


FIGURE : 9.3
Well : N2/7-21S
Depth : 15281.7'

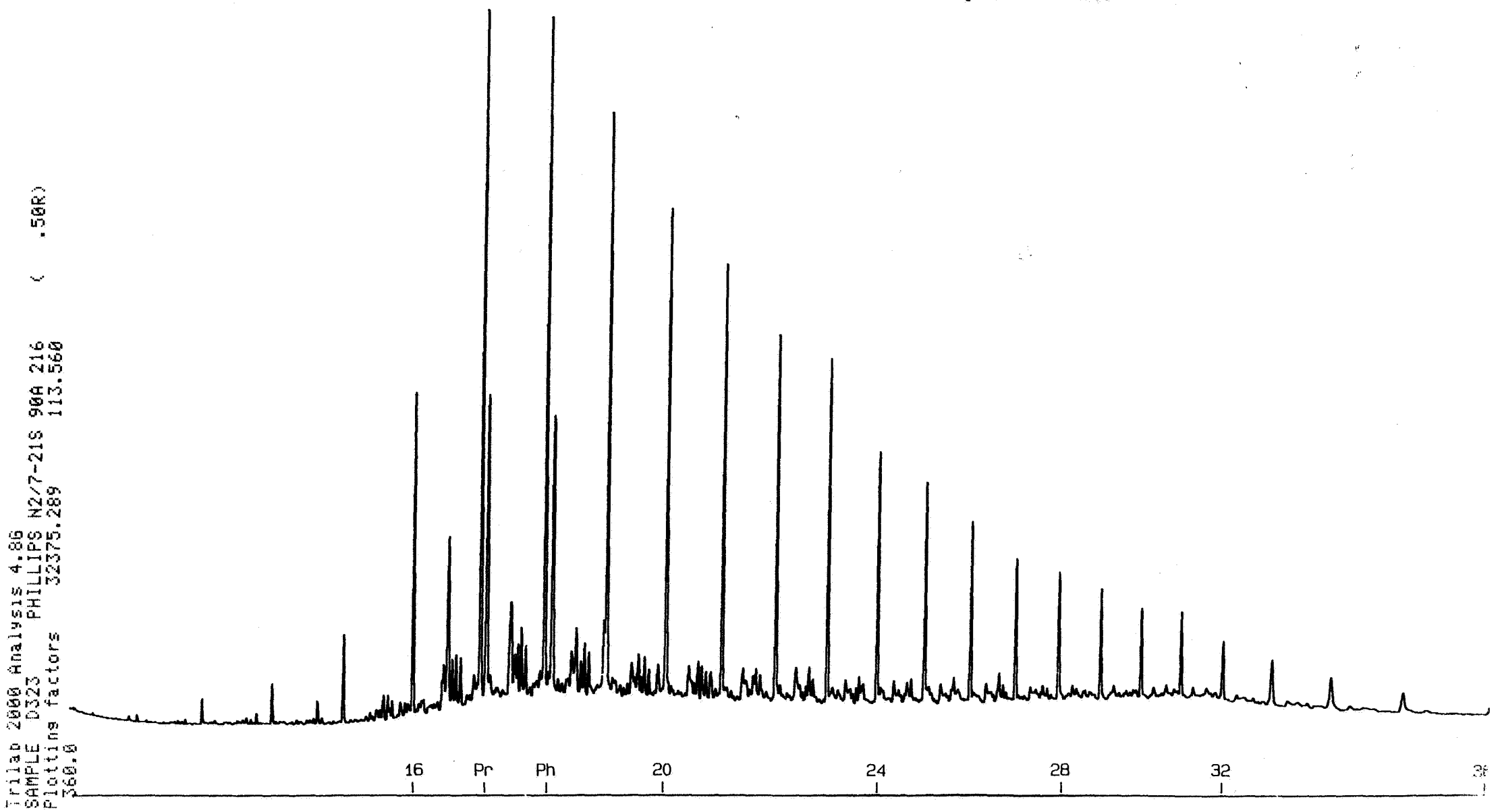
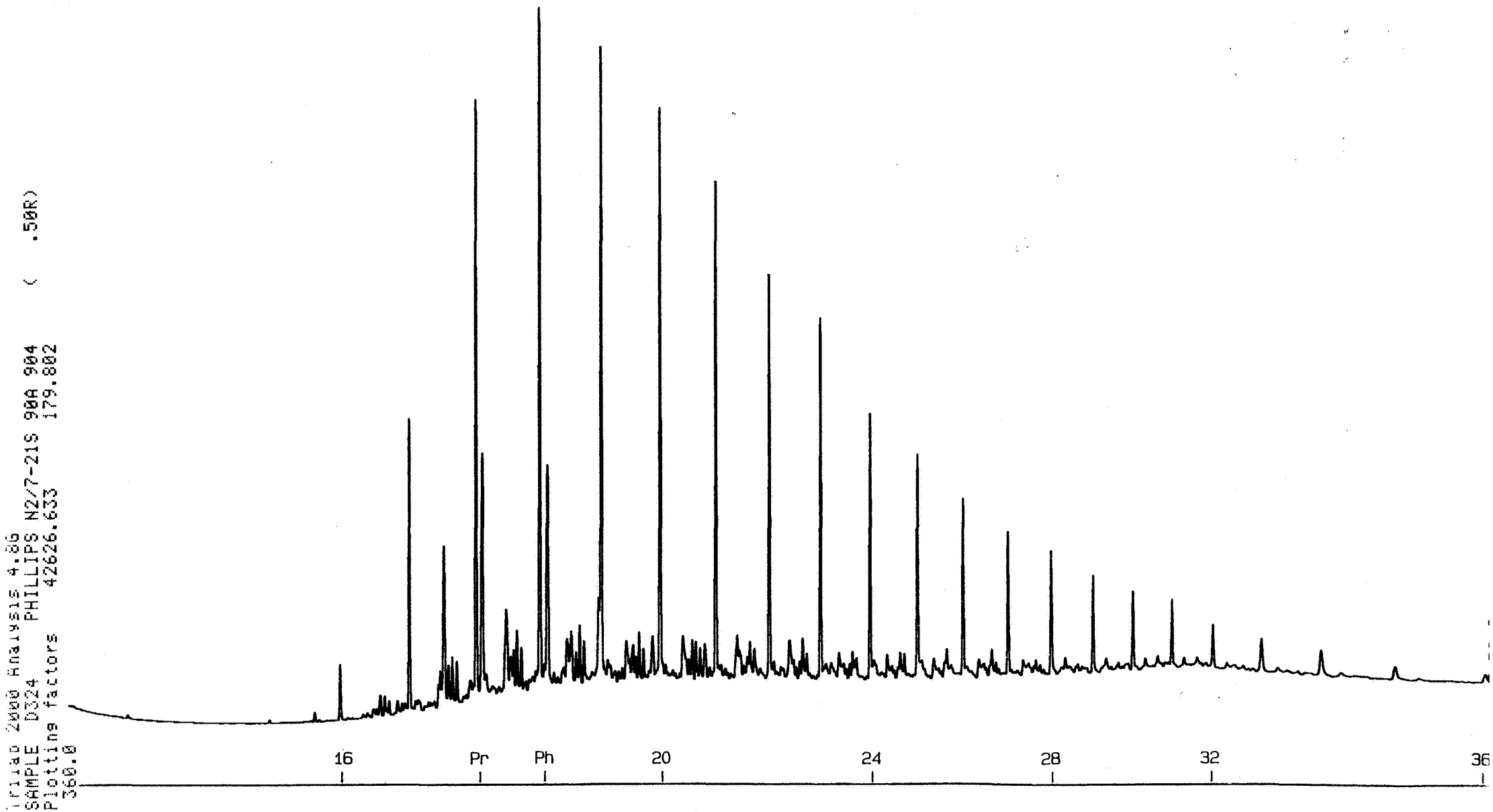


FIGURE : 9.4
Well : N2/7-21S
Depth : 16521.6'



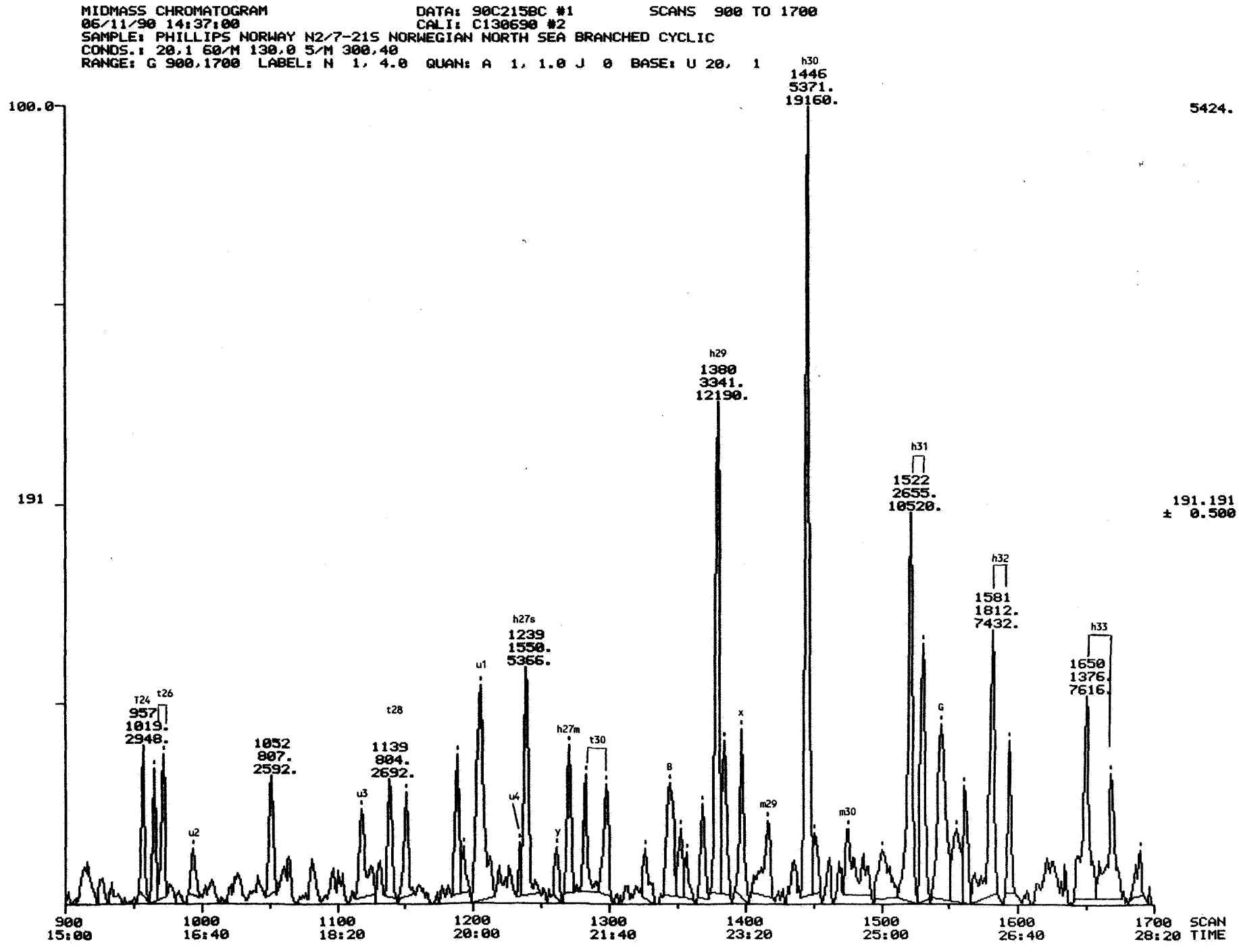


FIGURE : 10.1
WELL : N2/7-20X
DEPTH : 14753'

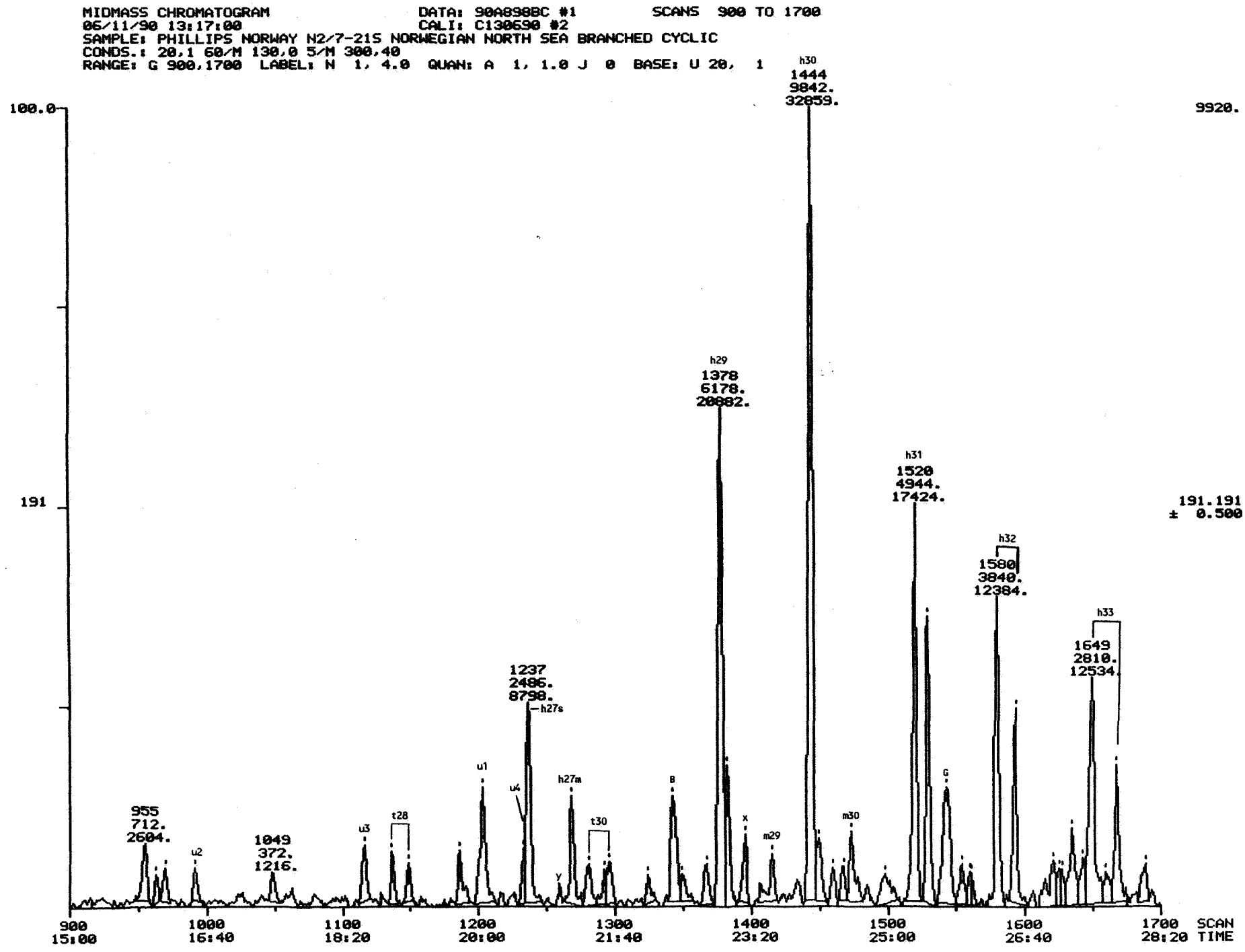


FIGURE : 10.2
WELL : N2/7-21S

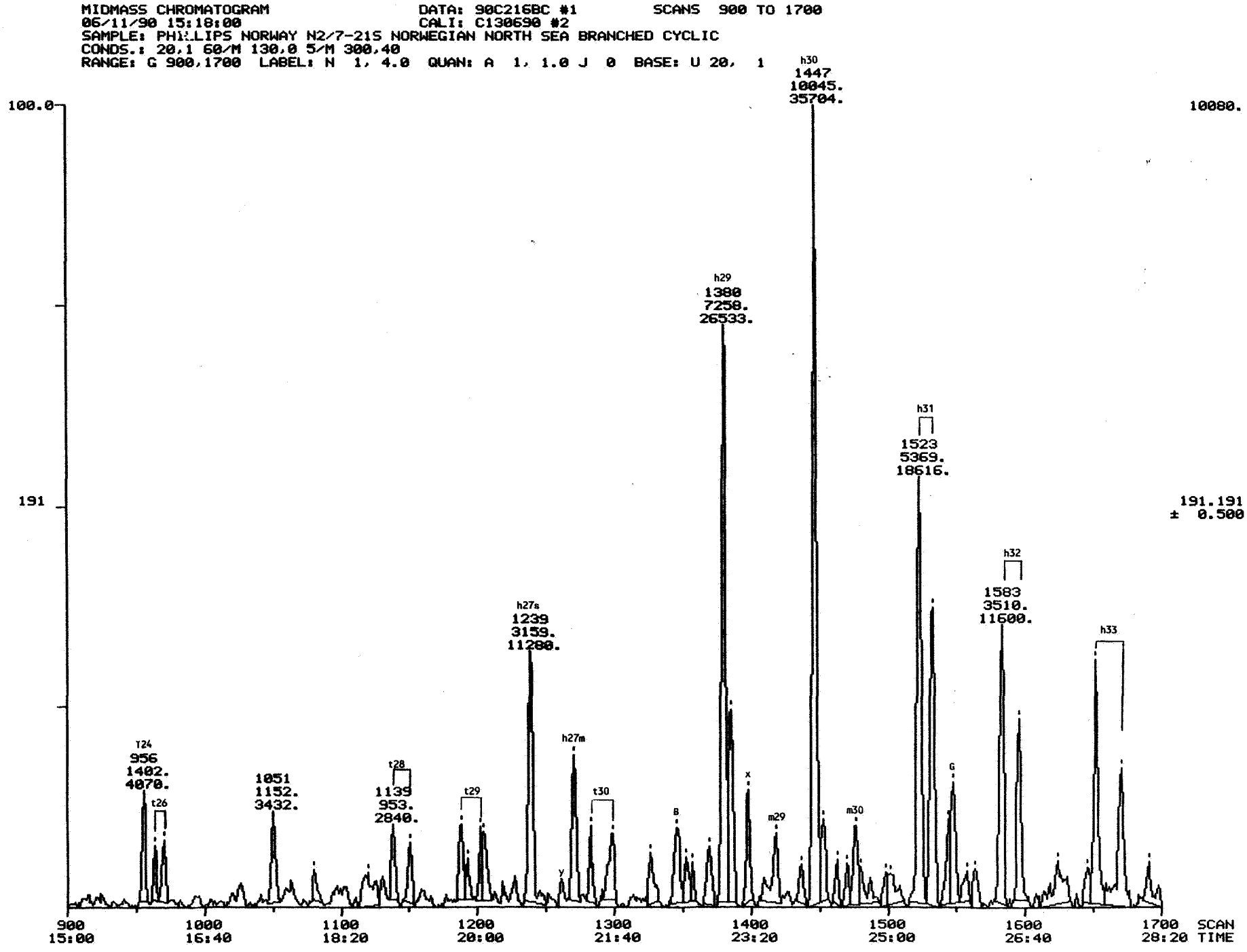


FIGURE : 10.3
WELL : N2/7-21S
DEPTH : 15281.7'

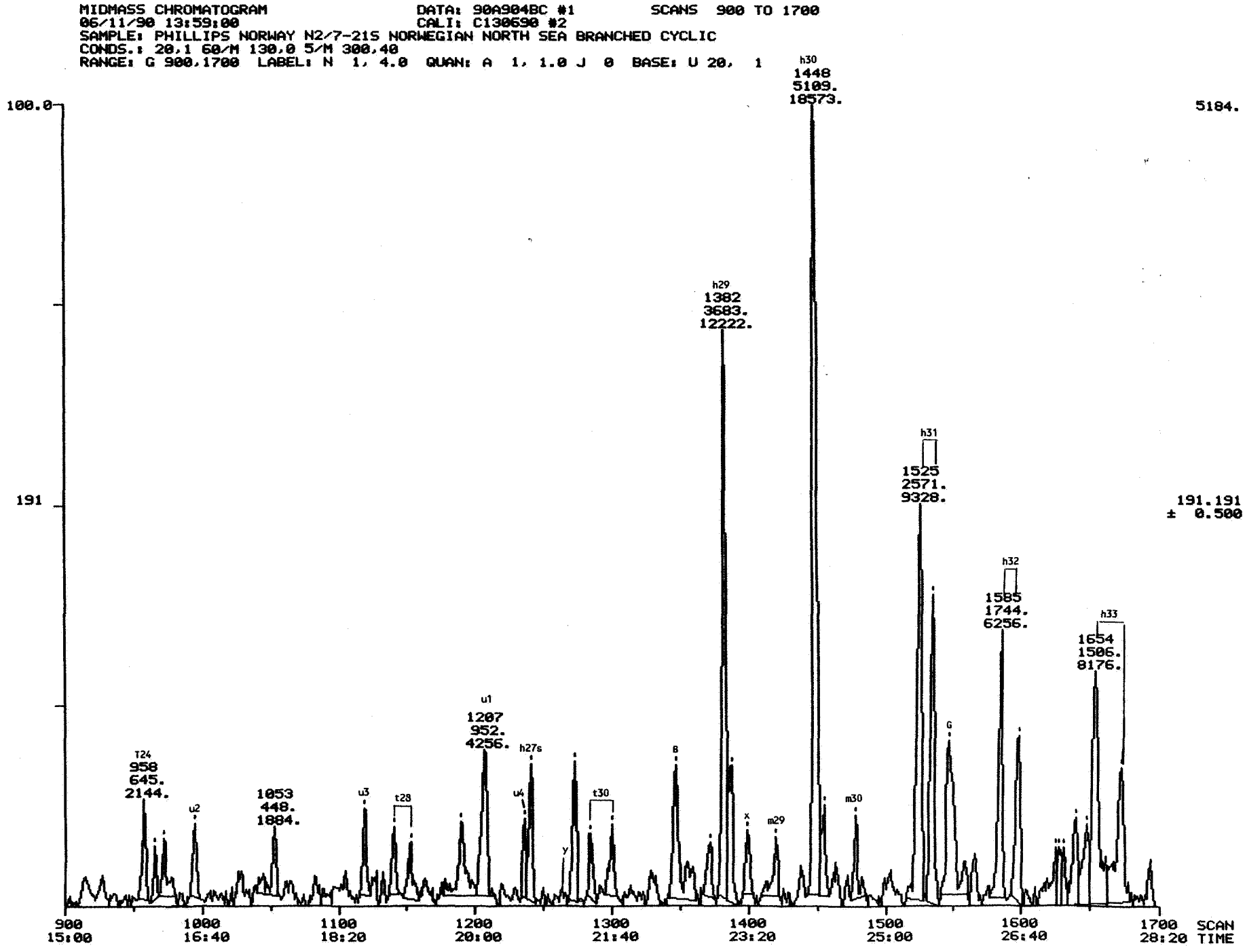


FIGURE : 10.4
WELL : N2/7-21S
DEPTH : 16521.6'

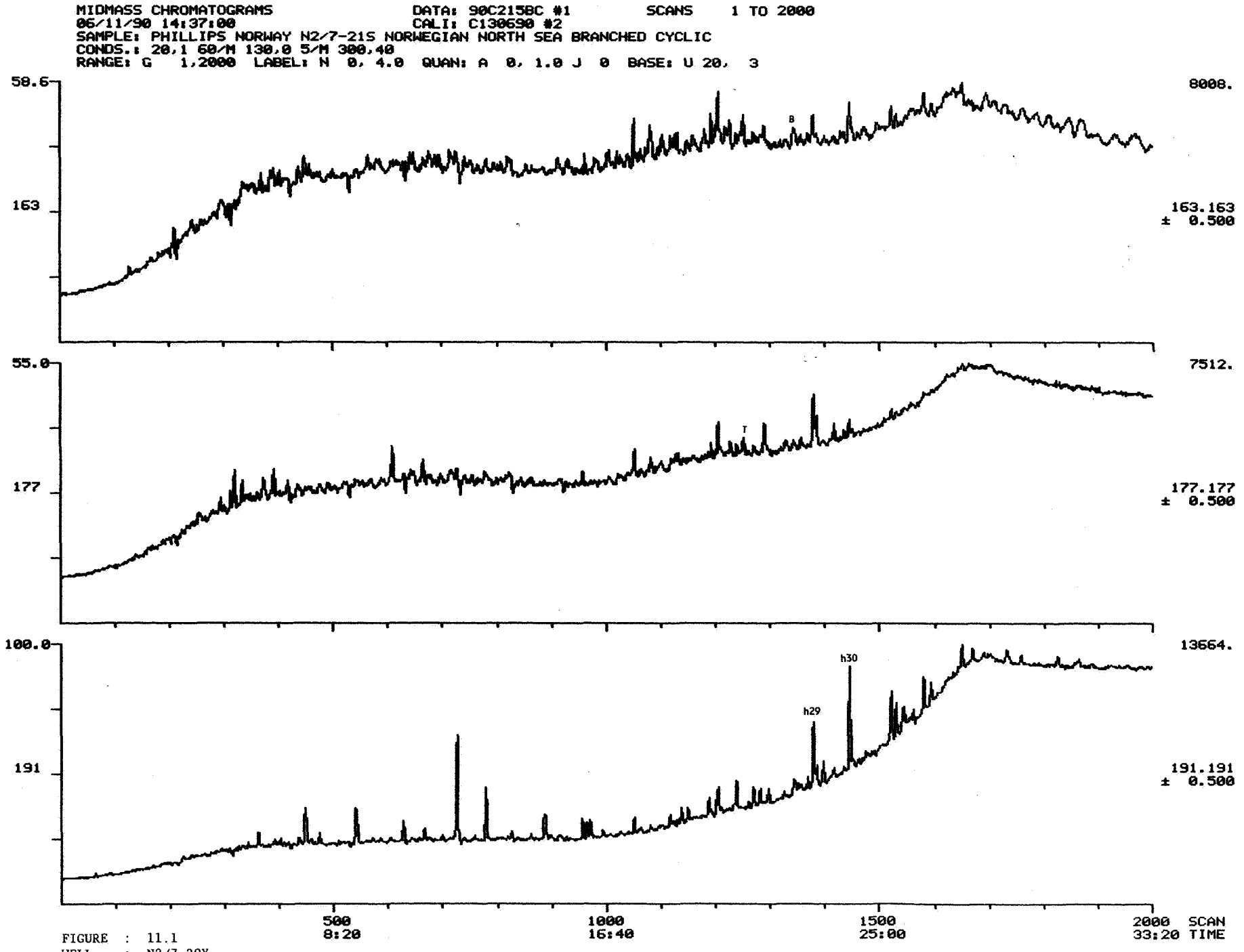


FIGURE : 11.1
WELL : N2/7-20X
DEPTH : 14753'

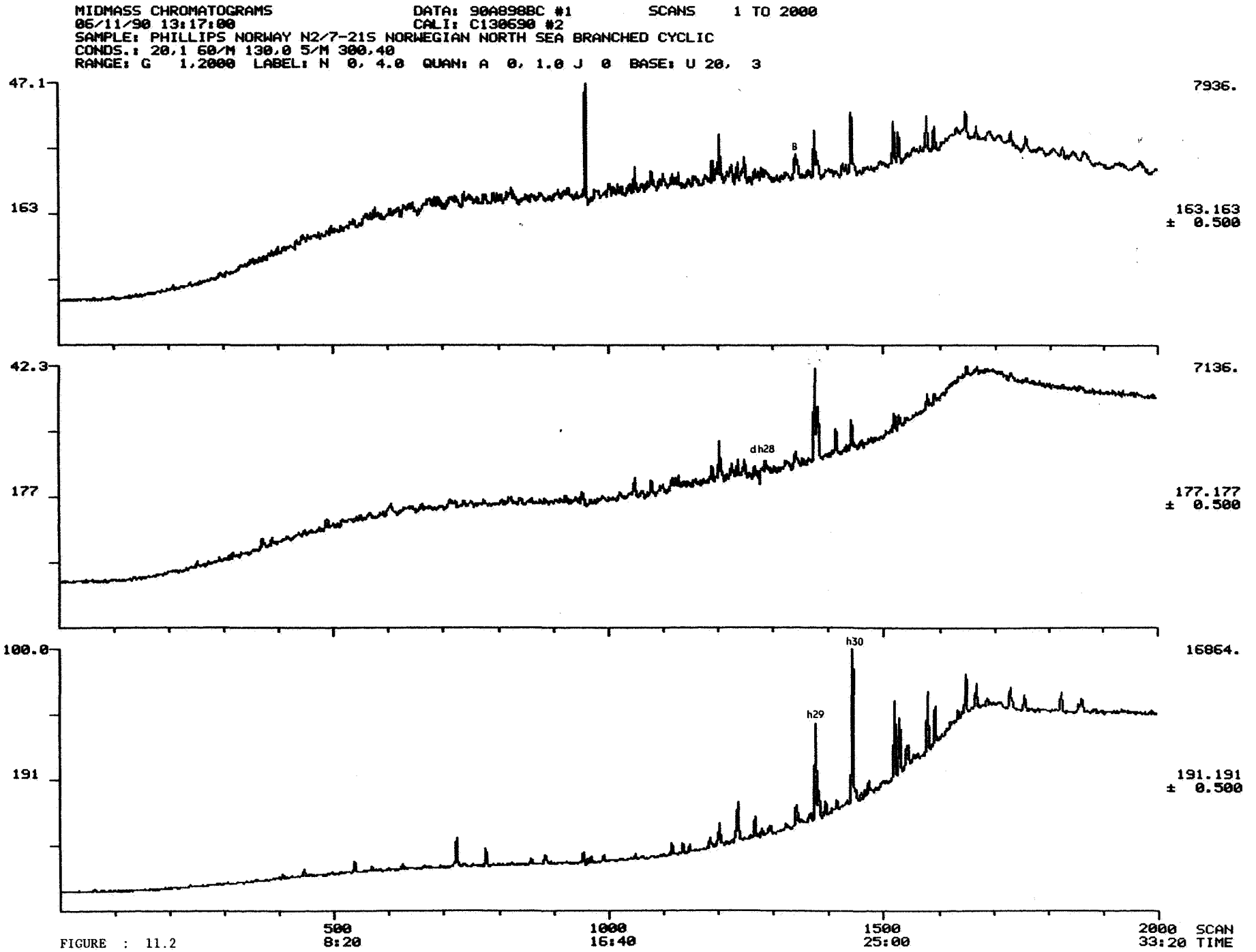


FIGURE : 11.2
WELL : N2/7-21S
DEPTH : 14267.2'

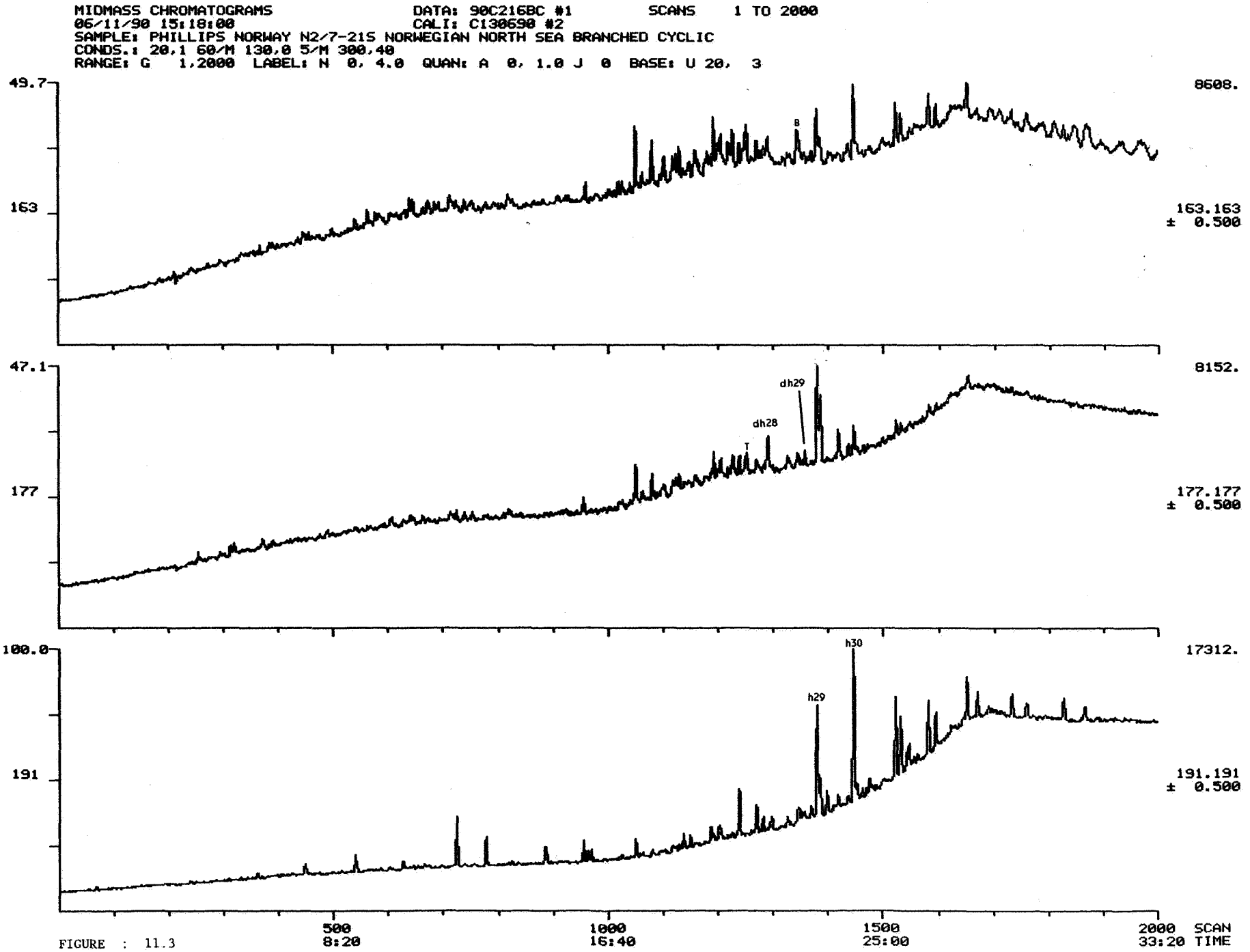


FIGURE : 11.3
WELL : N2/7-21S
DEPTH : 15281.7'

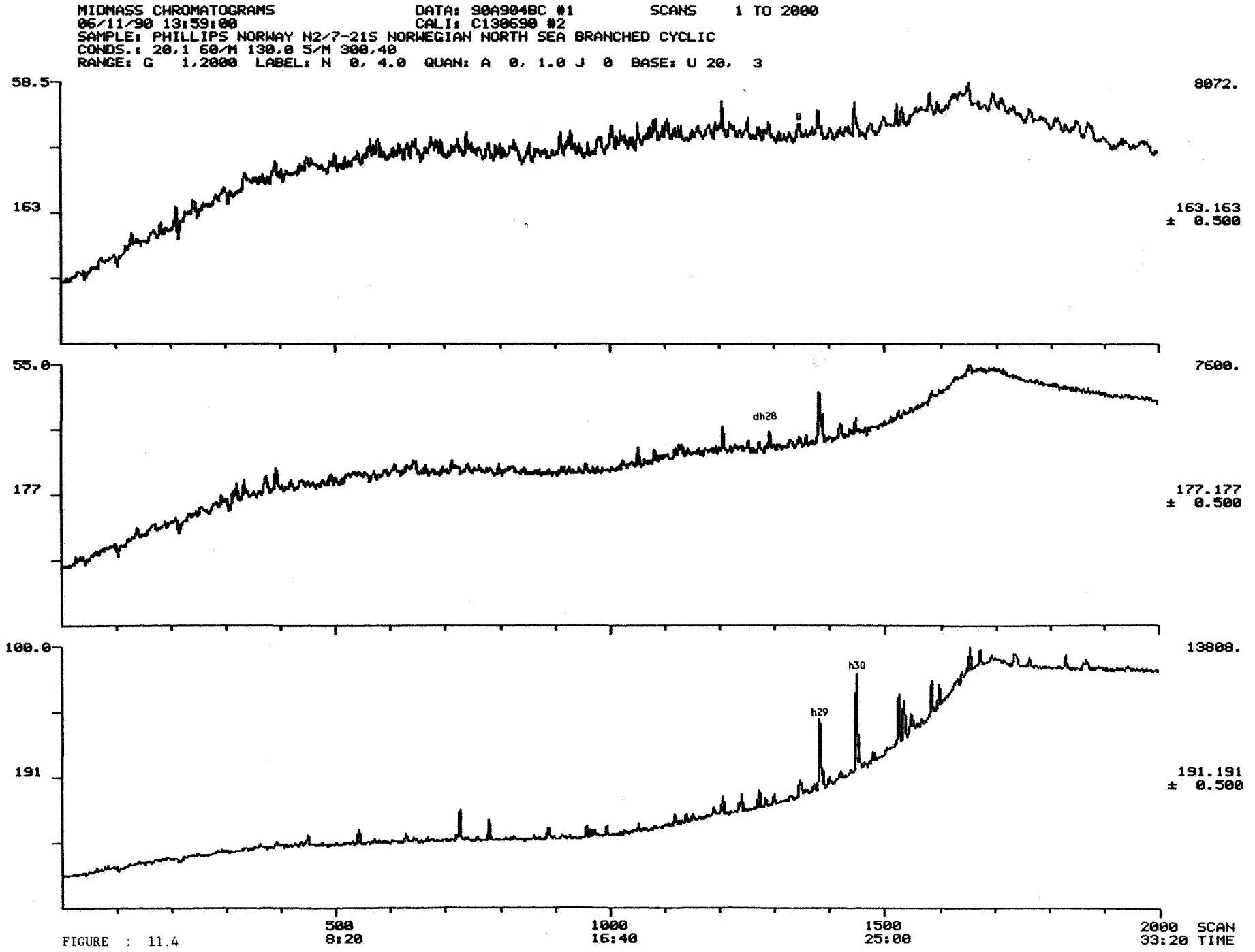


FIGURE : 11.4
WELL : N2/7-21S
DEPTH : 16521.6'

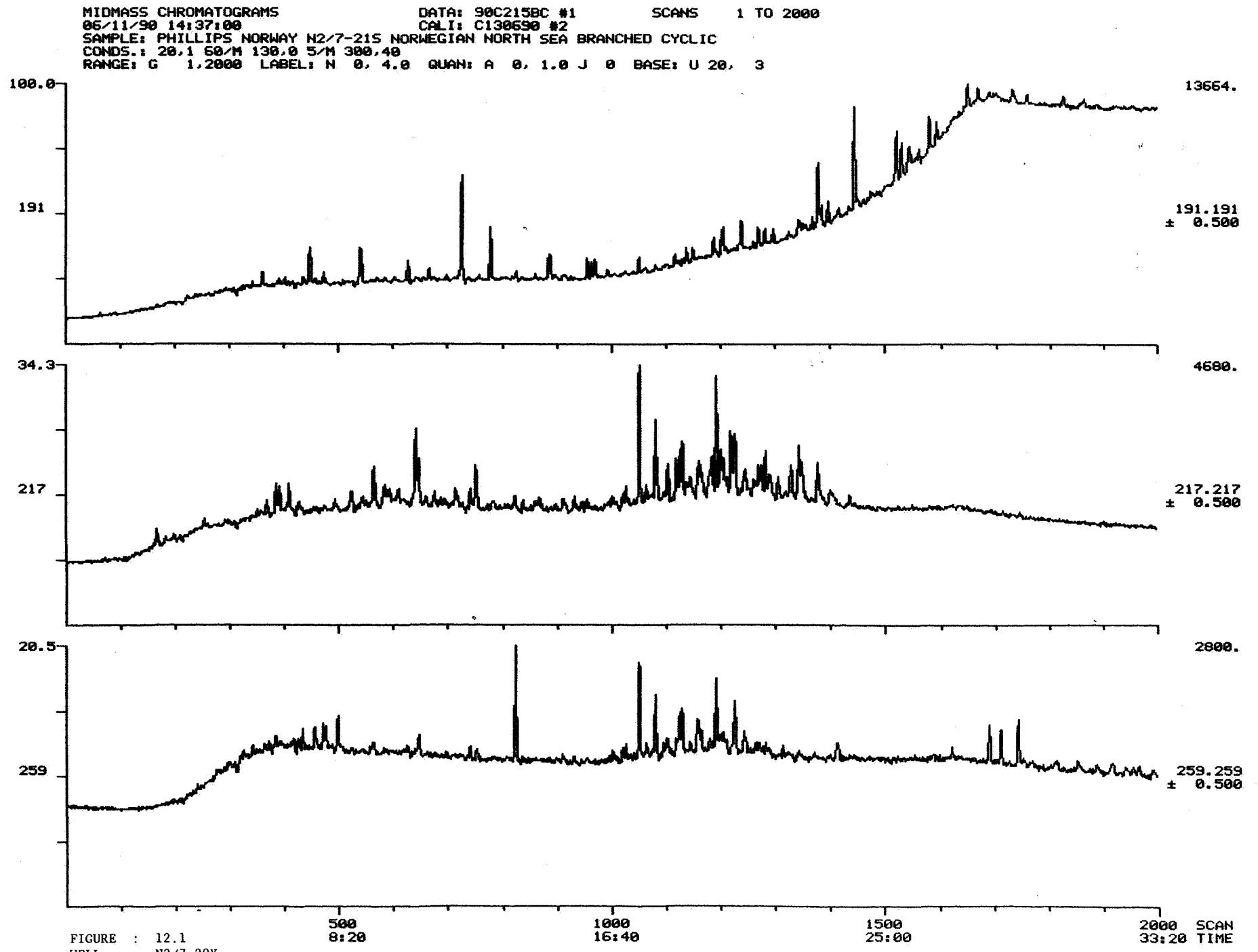


FIGURE : 12.1
WELL : N2/7-20X
DEPTH : 14753'

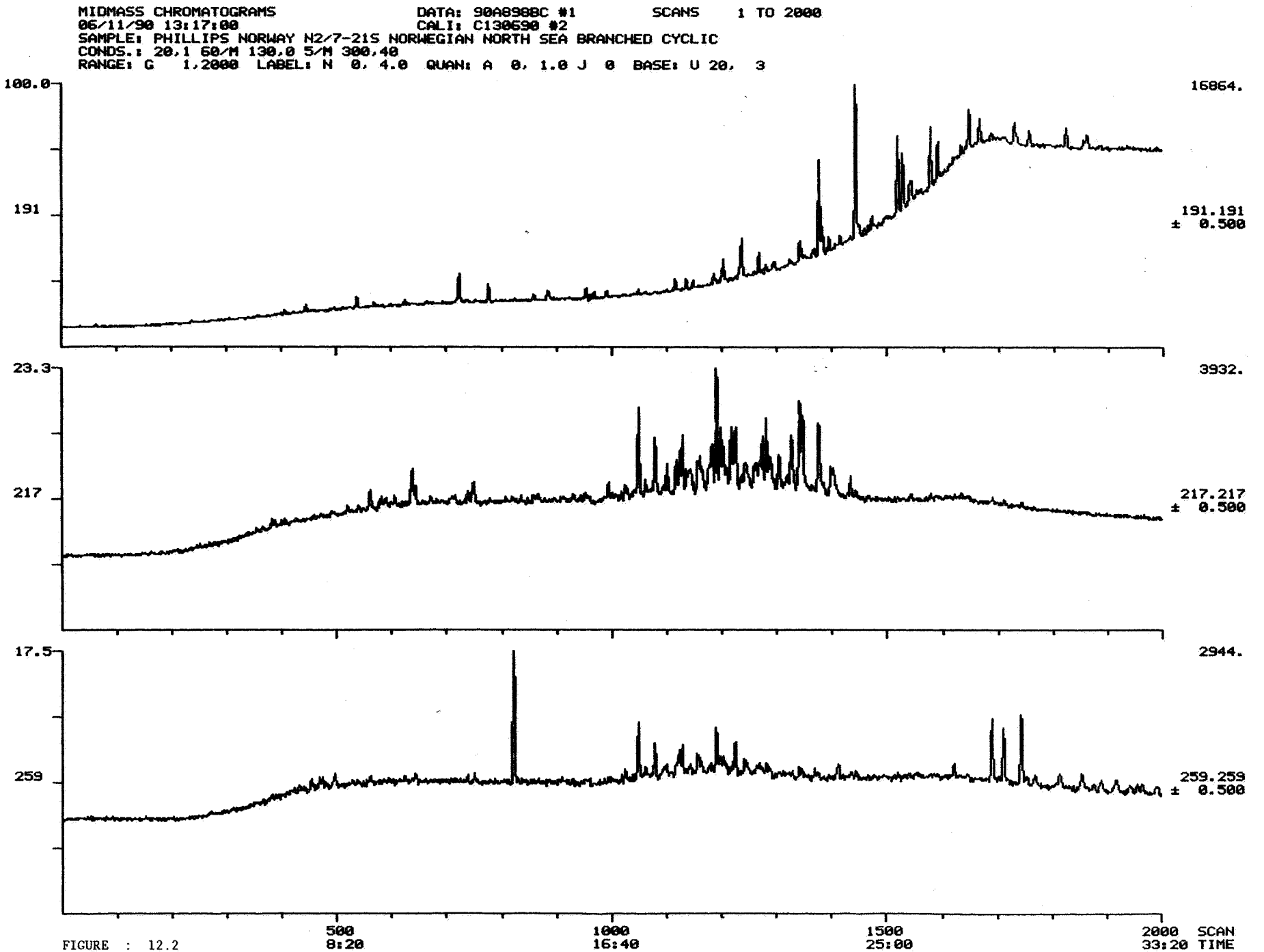


FIGURE : 12.2
WELL : N2/7-21S
DEPTH : 14267.2'

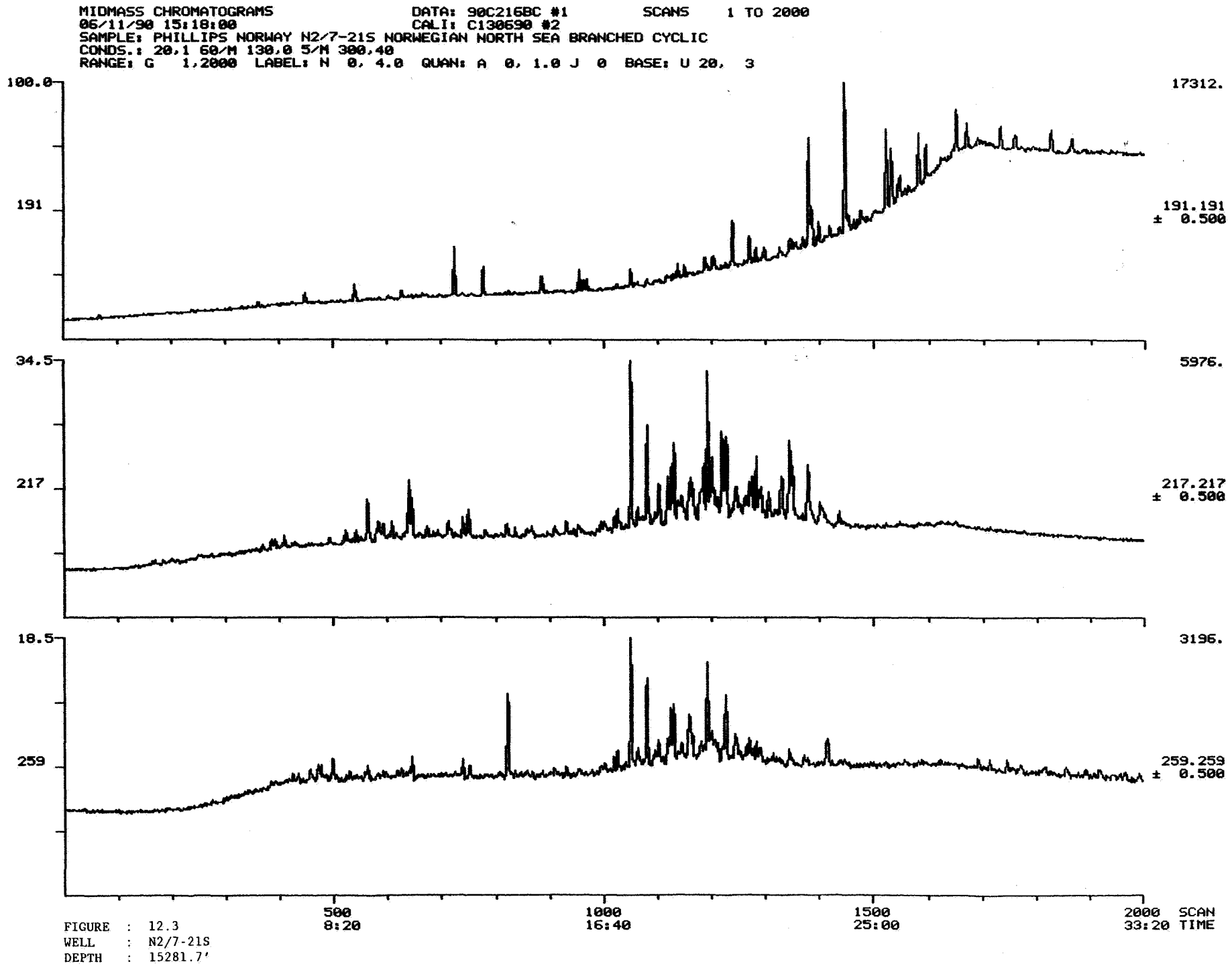


FIGURE : 12.3
WELL : N2/7-21S
DEPTH : 15281.7'

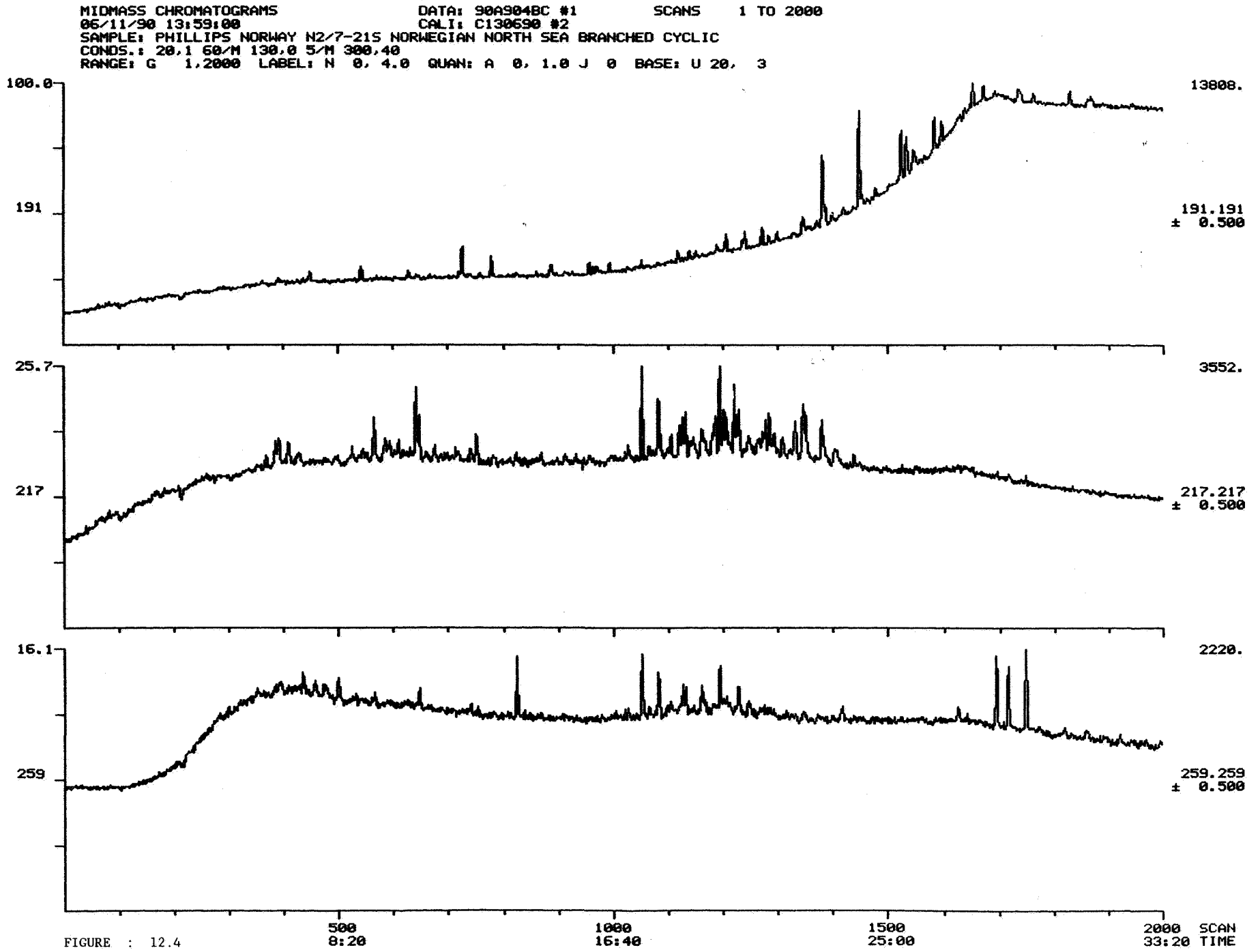


FIGURE : 12.4
WELL : N2/7-21S
DEPTH : 16521.6'

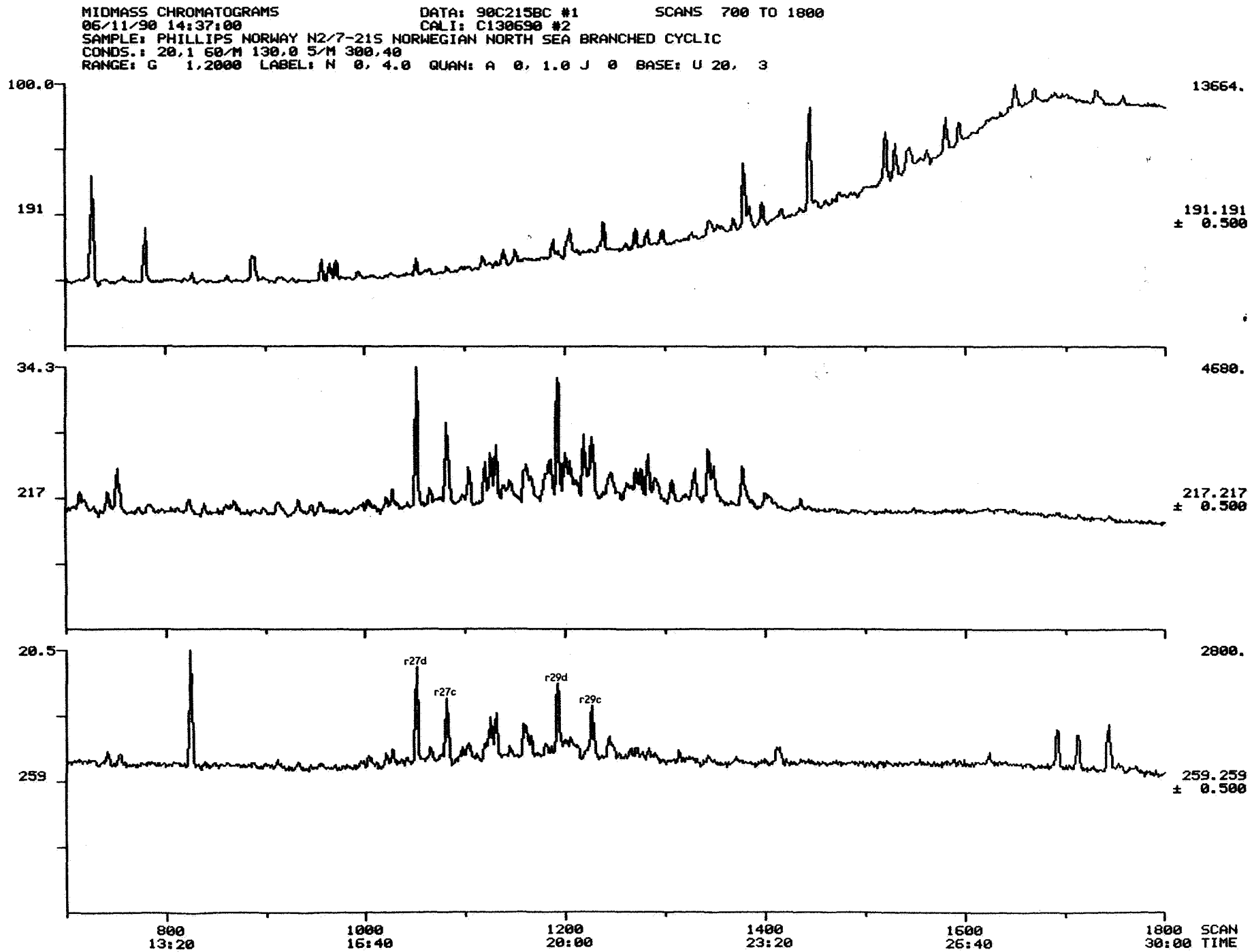


FIGURE : 13.1
WELL : N2/7-20X
DEPTH : 14753'

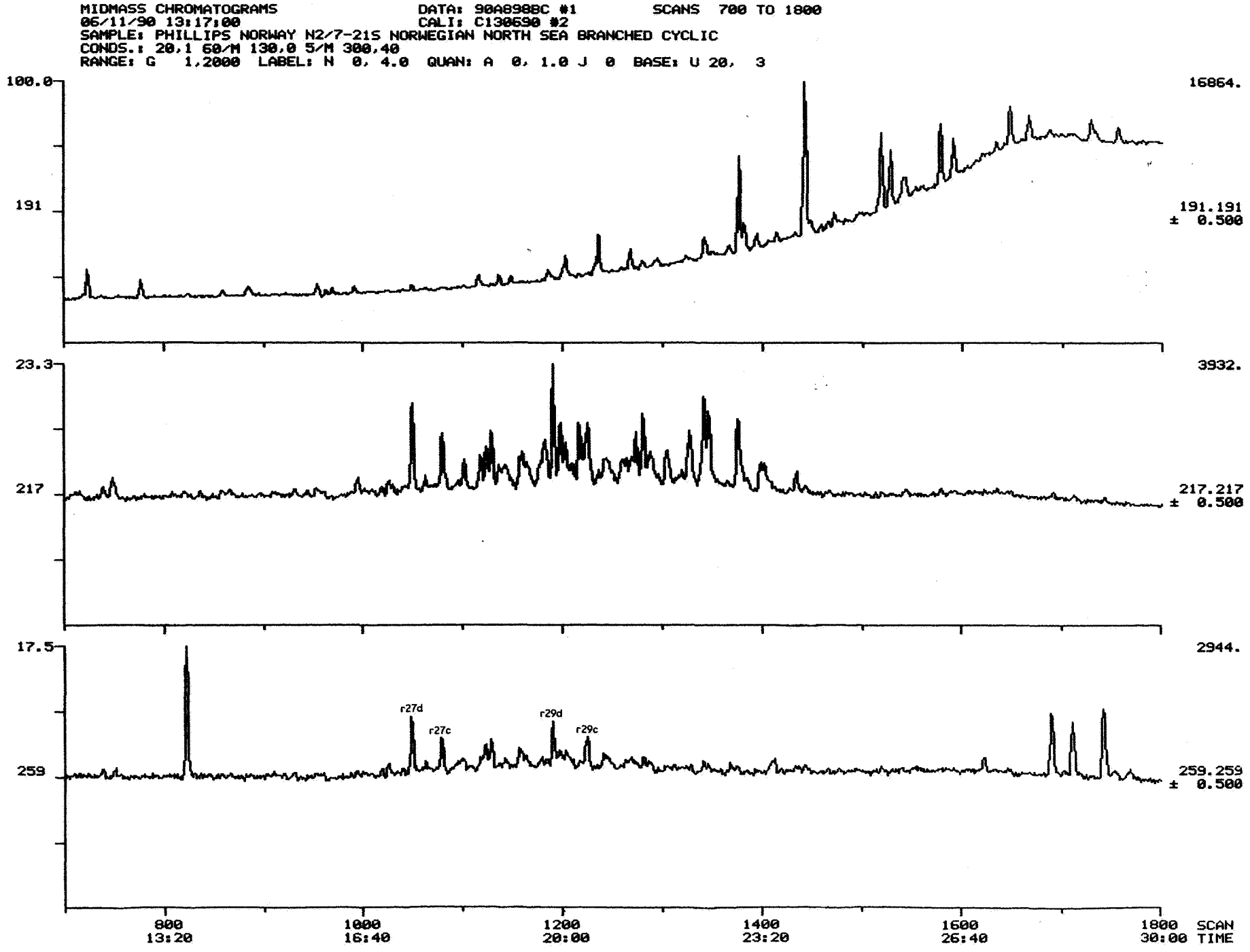


FIGURE : 13.2
WELL : N2/7-21S
DEPTH : 14267.2'

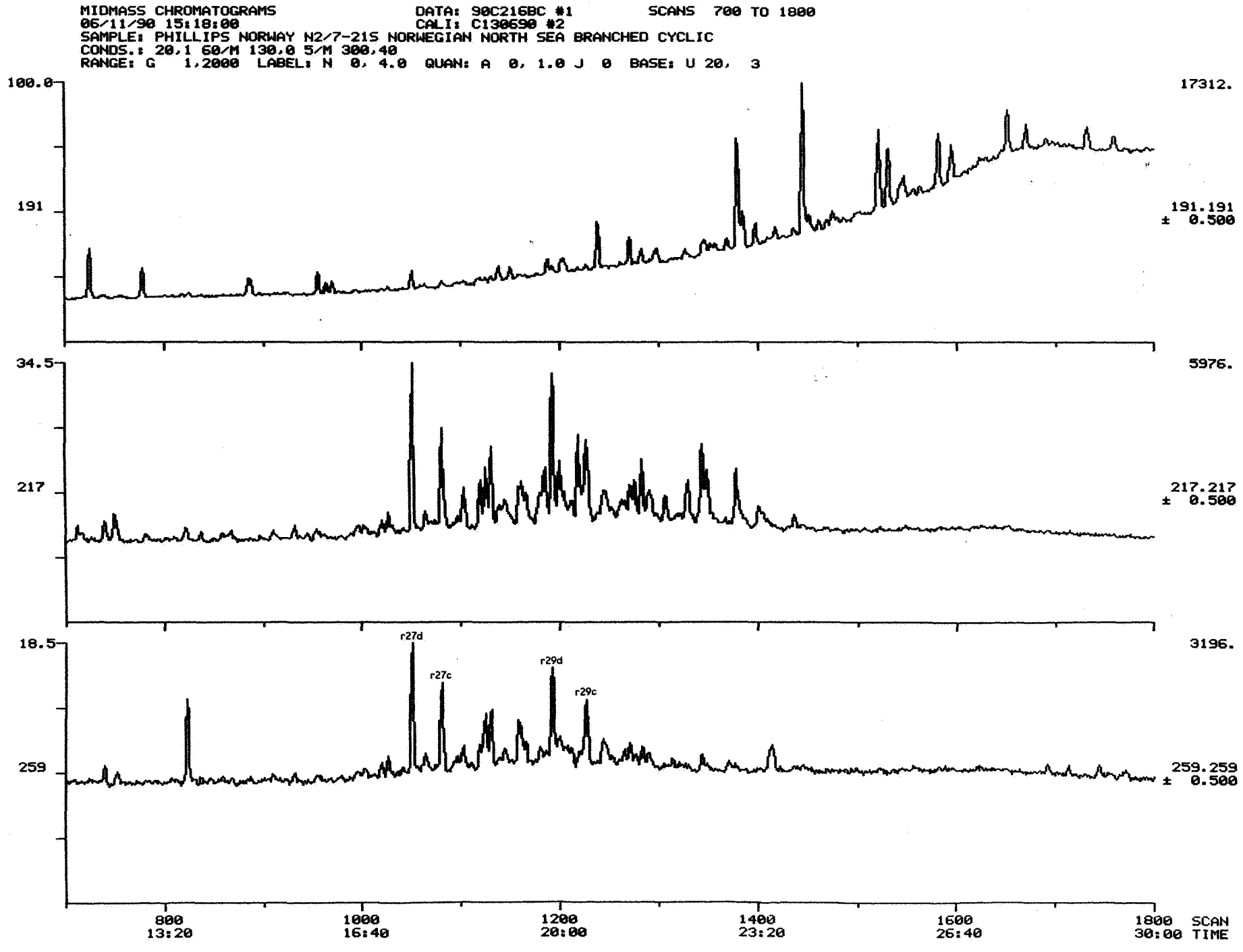


FIGURE : 13.3
WELL : N2/7-21S
DEPTH : 15281.7'

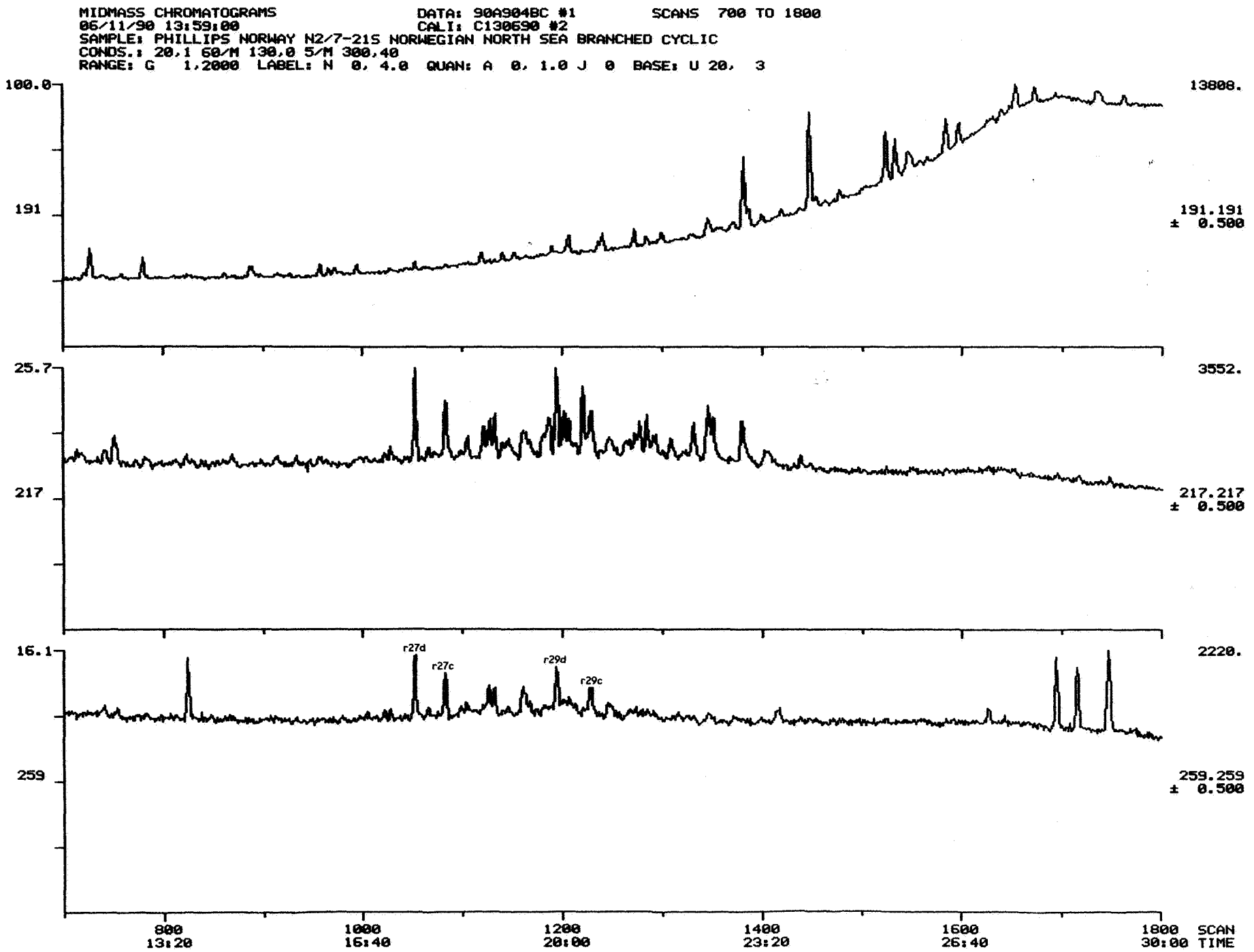


FIGURE : 13.4
WELL : N2/7-21S
DEPTH : 16521.6'

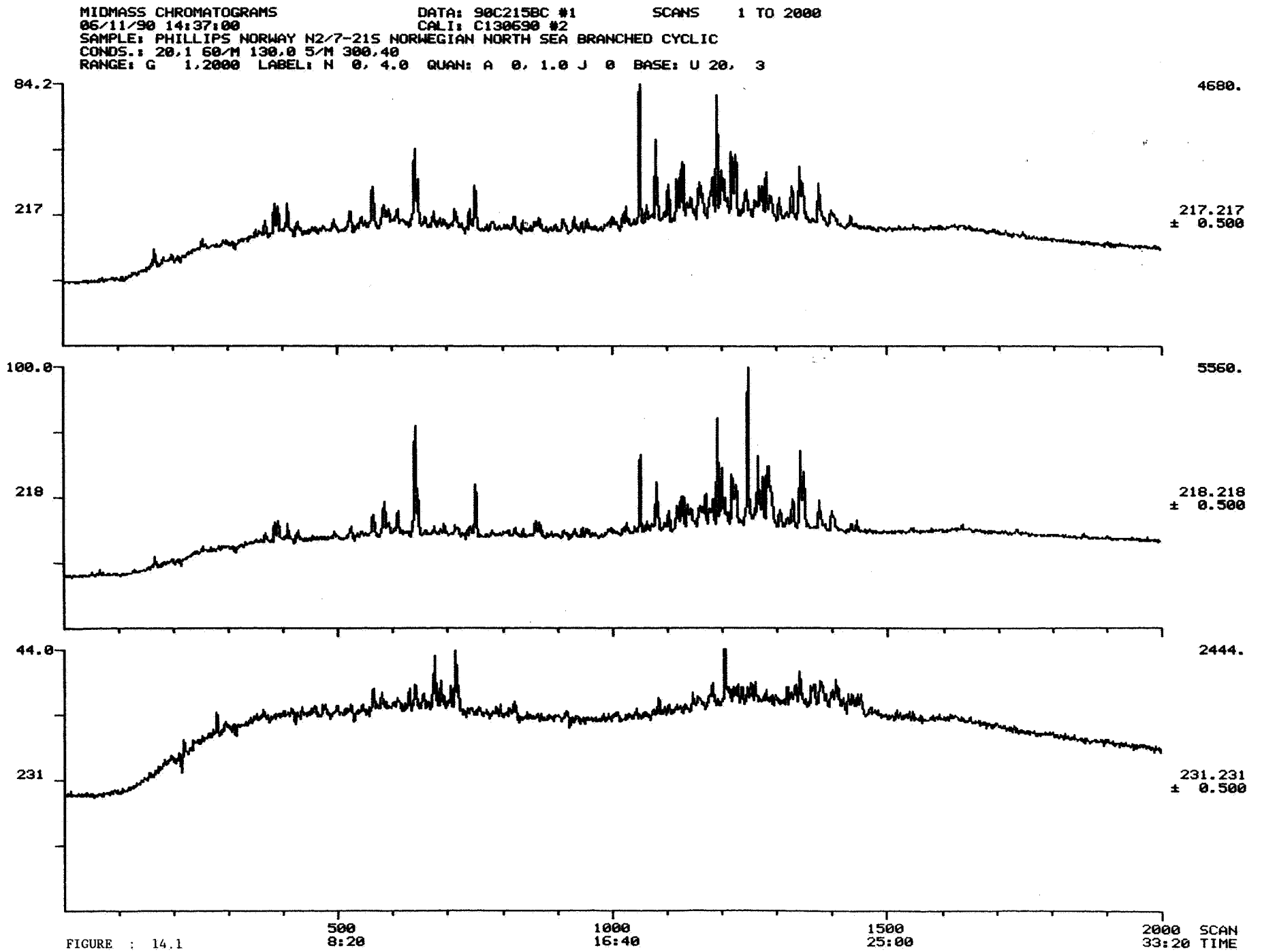


FIGURE : 14.1
WELL : N2/7-20X
DEPTH : 14753'

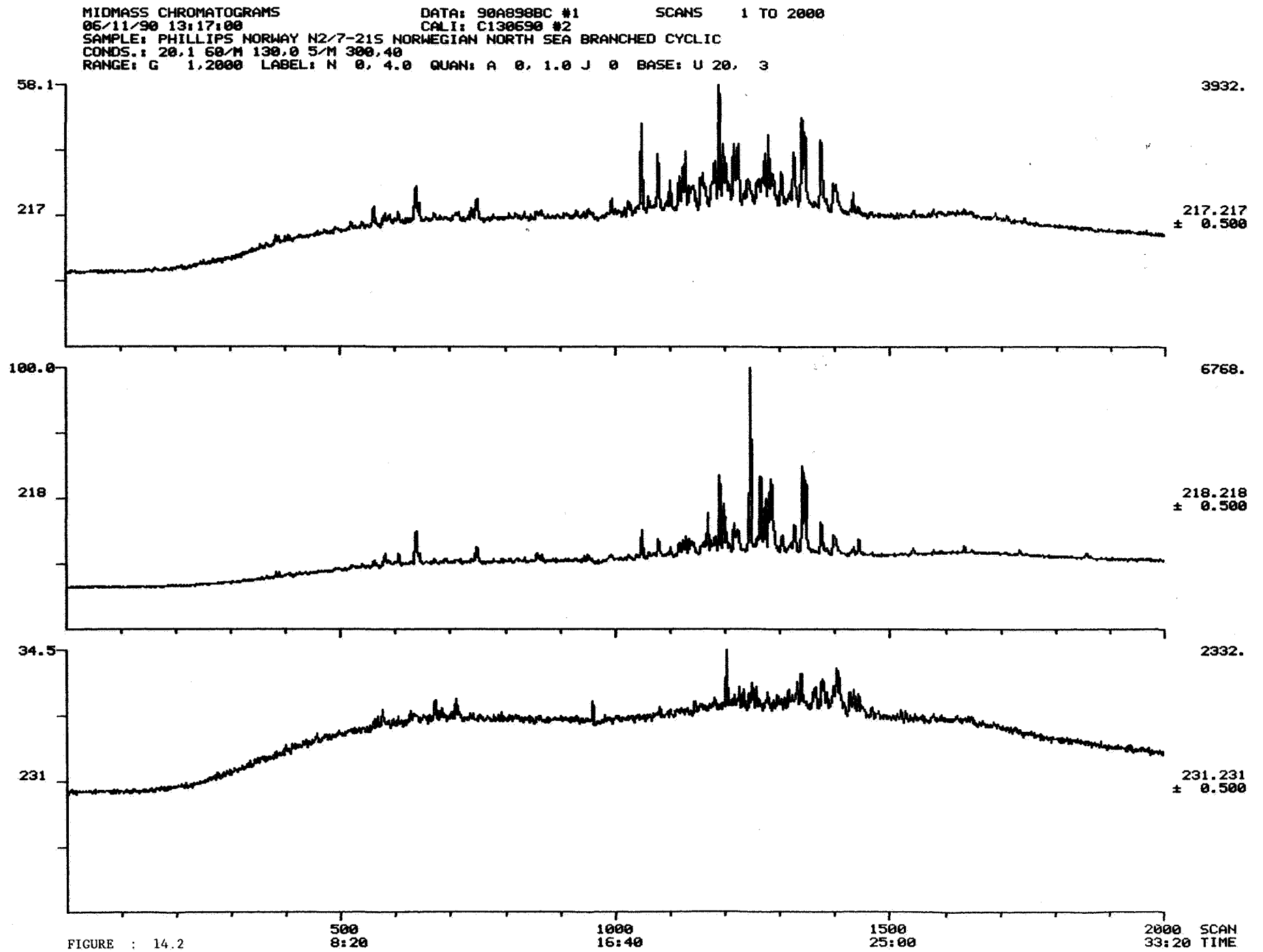


FIGURE : 14.2
WELL : N2/7-21S
DEPTH : 14267.2'

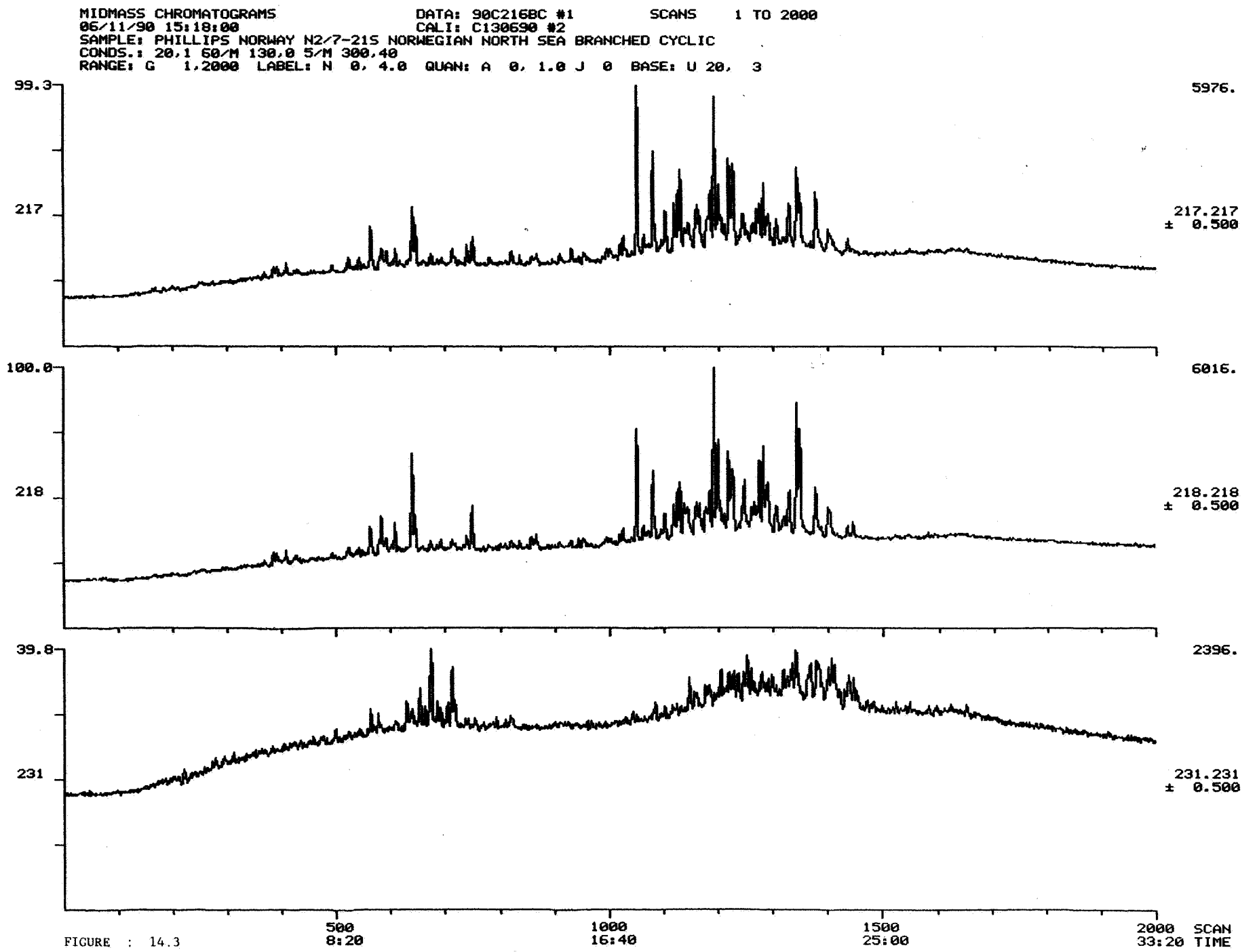


FIGURE : 14.3
WELL : N2/7-21S
DEPTH : 15281.7'

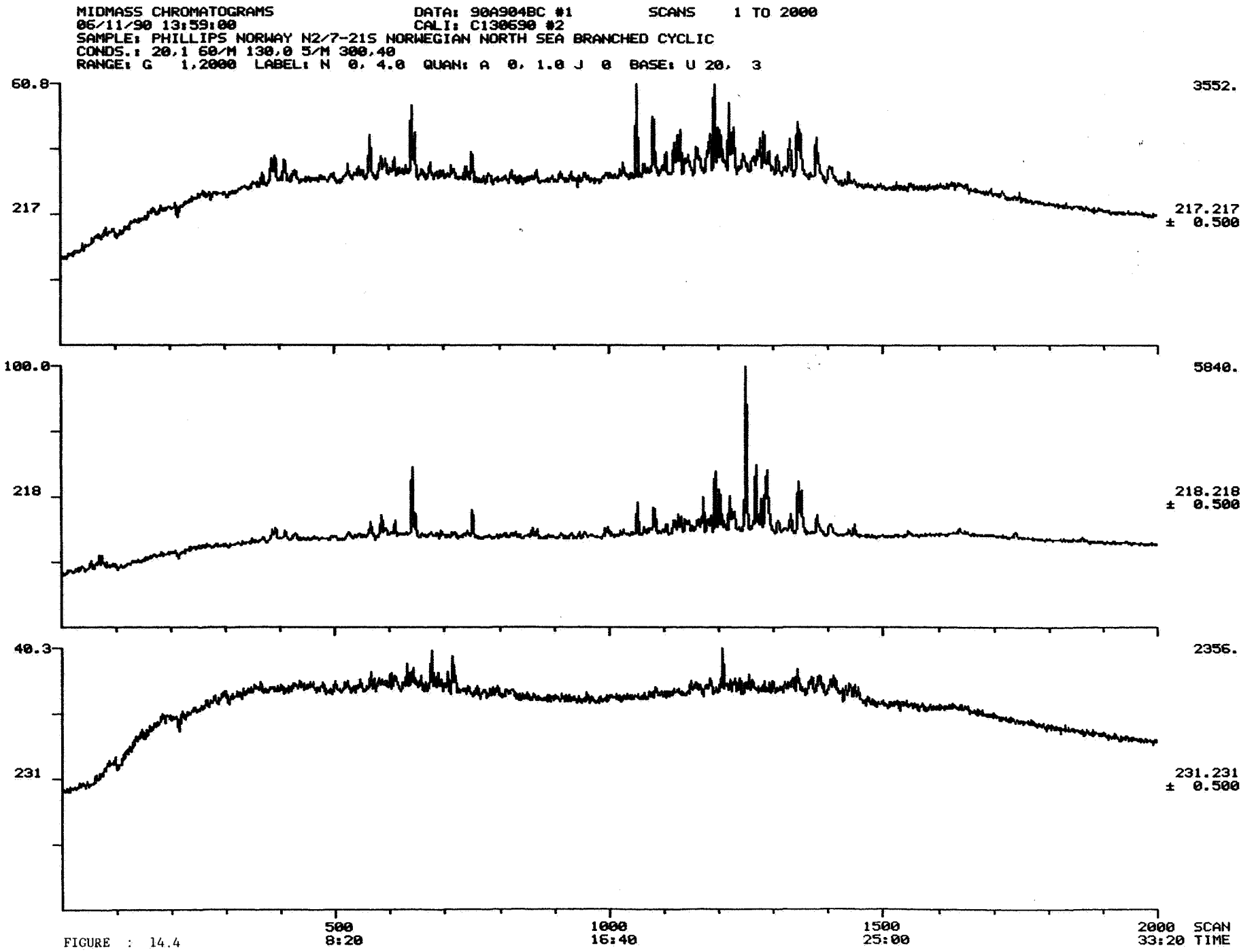


FIGURE : 14.4
WELL : N2/7-21S
DEPTH : 16521.6'

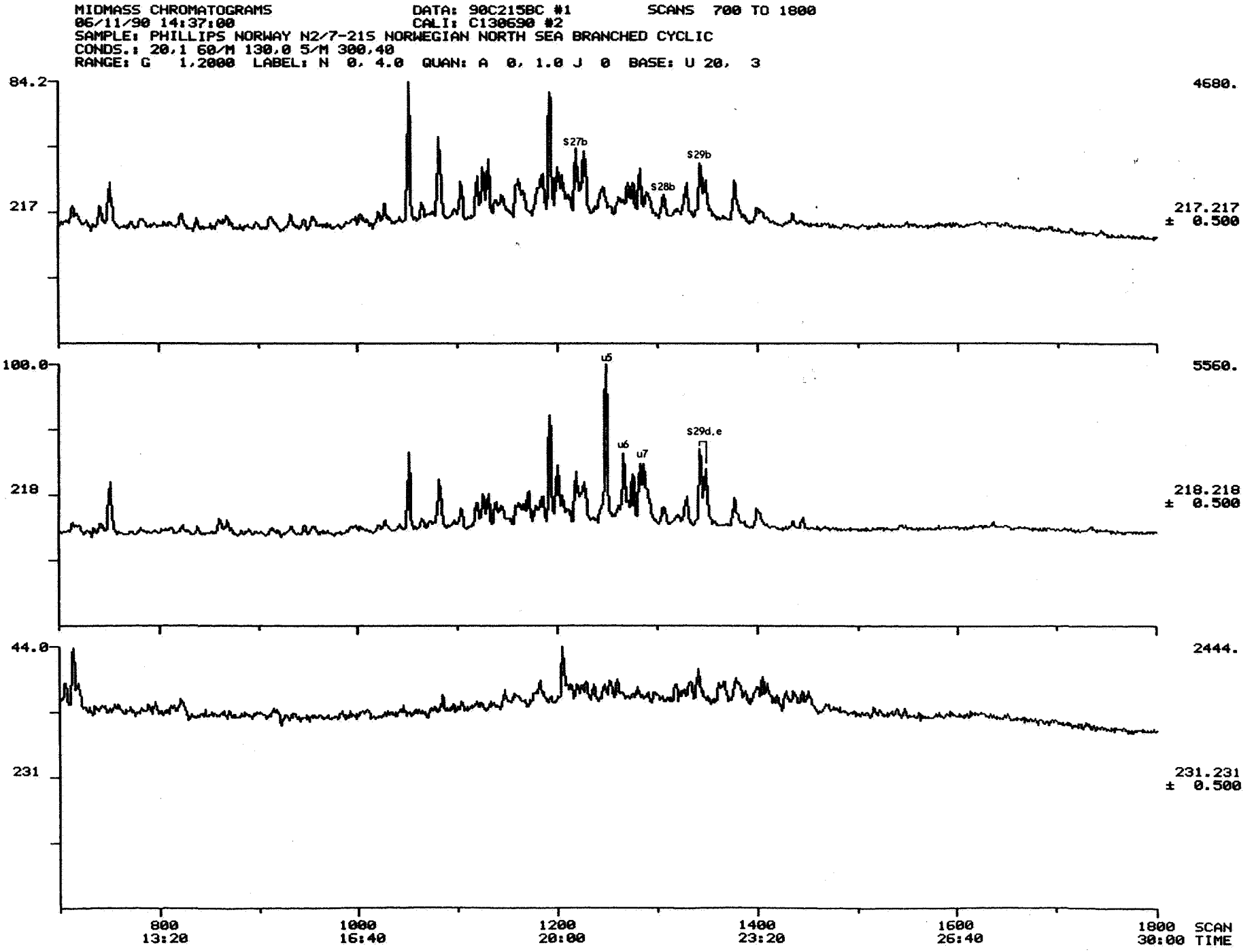


FIGURE : 15.1
WELL : N2/7-20X
DEPTH : 14753'

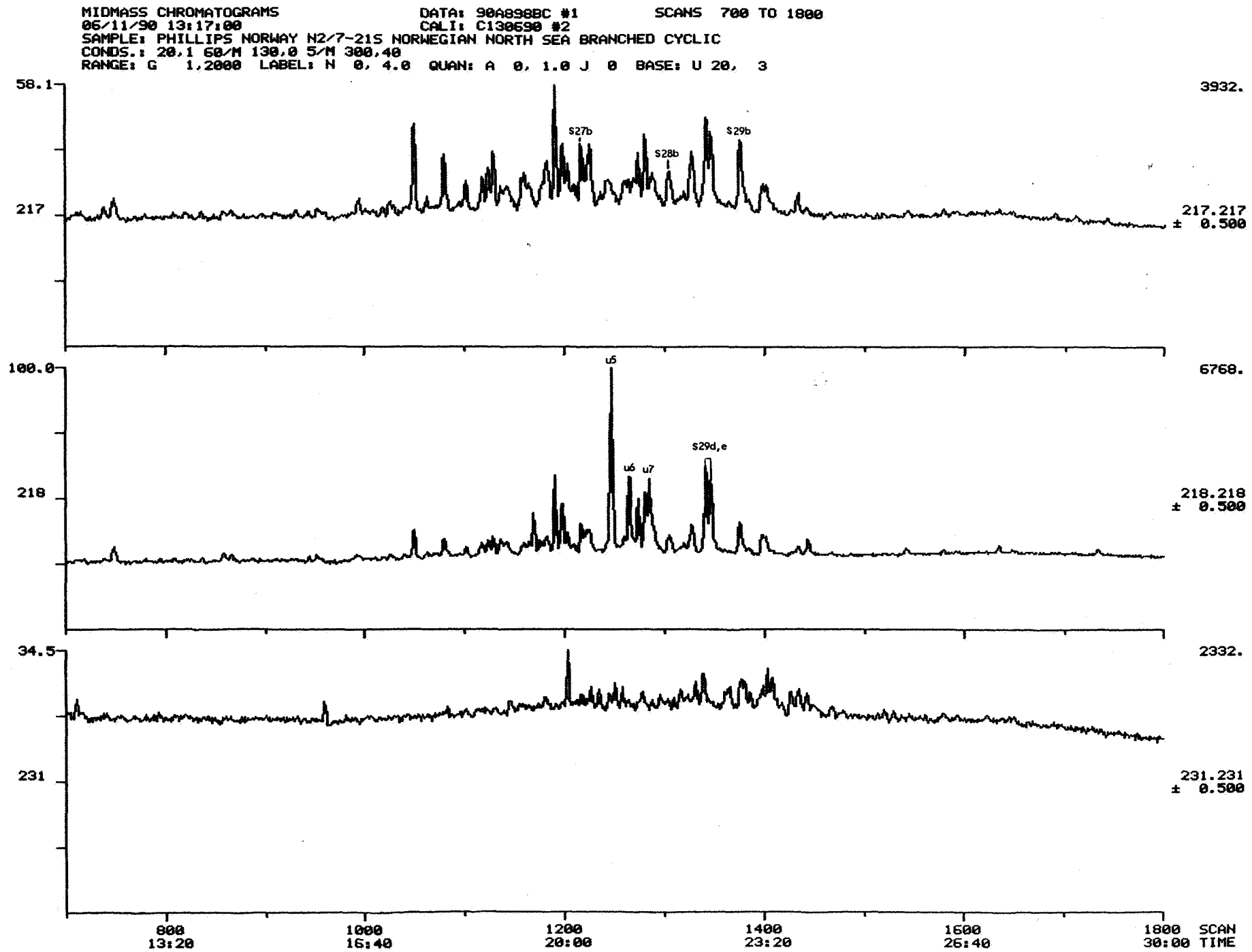


FIGURE : 15.2
WELL : N2/7-21S
DEPTH : 14267.2'

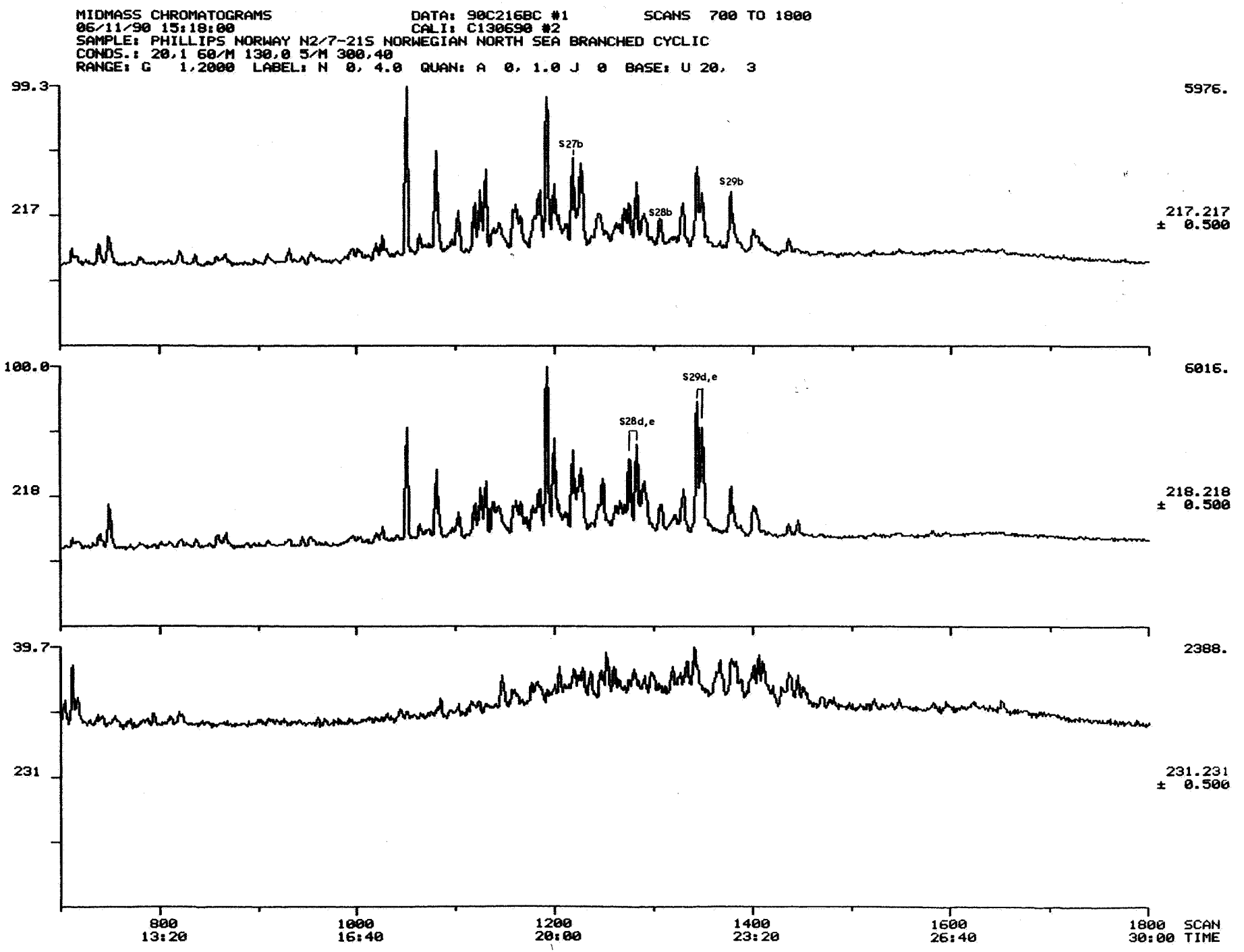


FIGURE : 15.3
WELL : N2/7-21S
DEPTH : 15281.7'

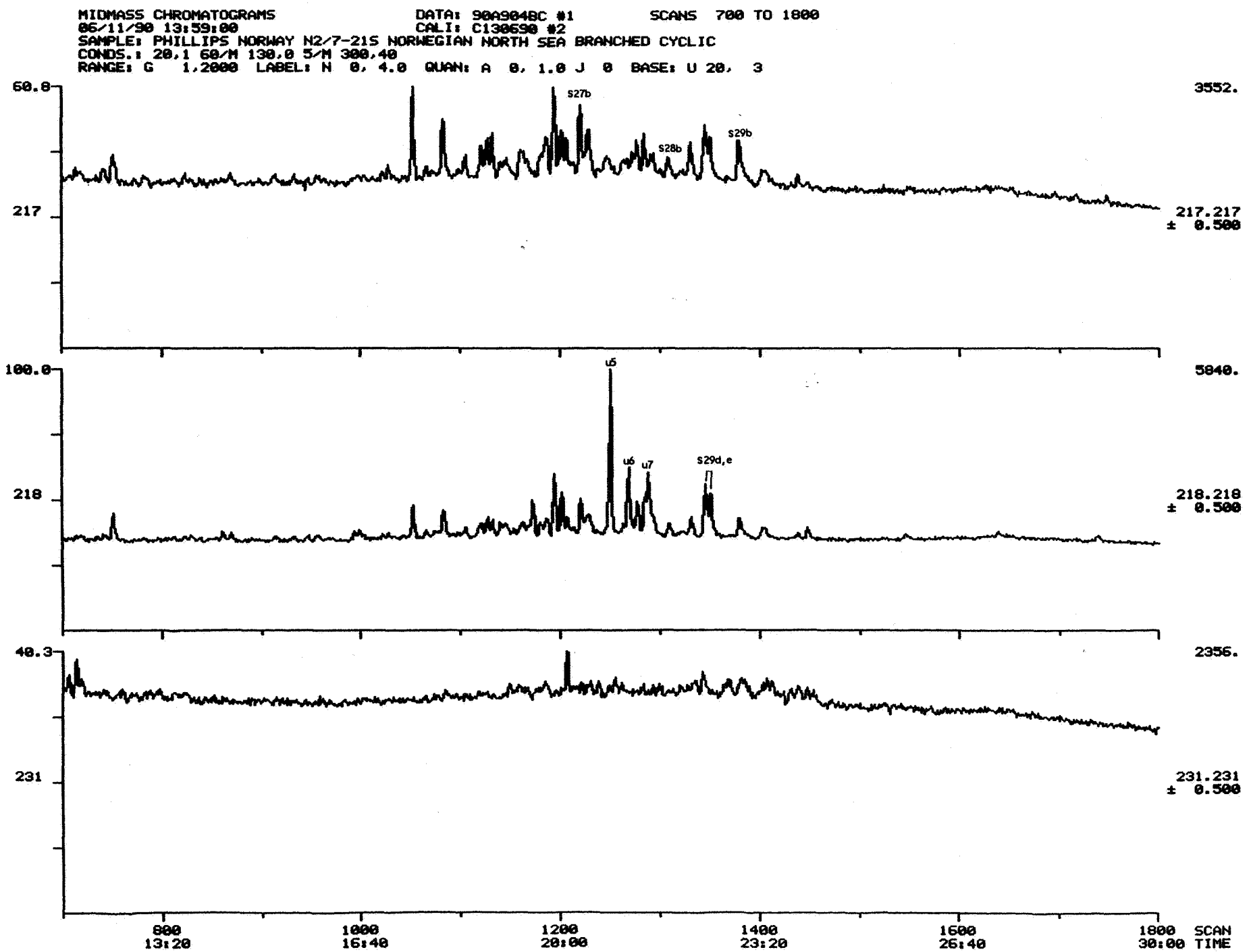


FIGURE : 15.4
WELL : N2/7-21S

FIGURE : 16.1 WELL : N2/7-20X
DEPTH : 14753'

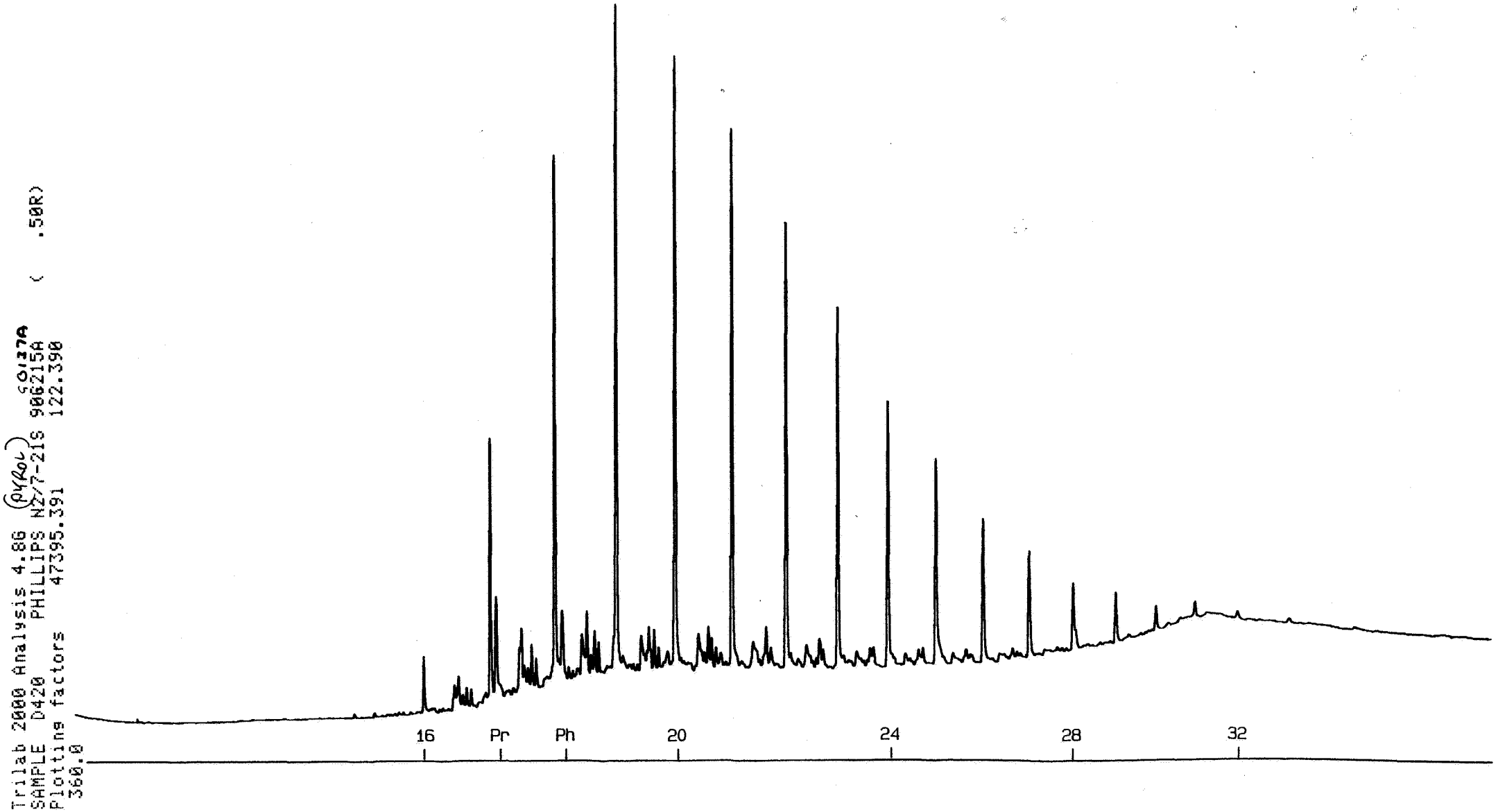
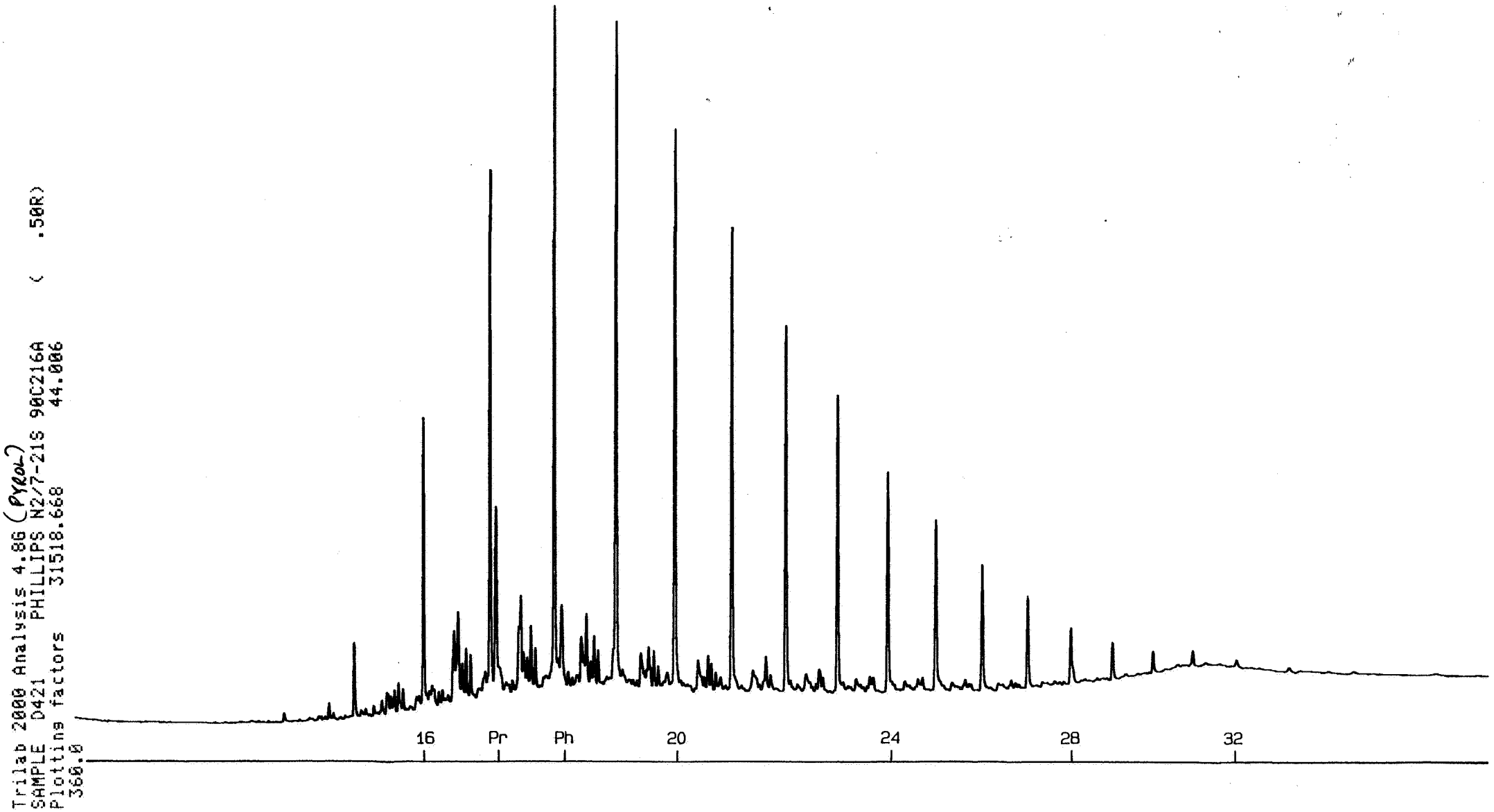


FIGURE : 16.2 WELL : N2/7-21S
DEPTH : 14267.2'

FIGURE : 16.3 WELL : N2/7-21S
DEPTH : 15281.7'



Trilab 2000 Analysis 4.8G (Pyrol)
SAMPLE D432 PHILLIPS N2/7-21S 90A904A (.50R)
Plotting factors 208957.031 1011.048
360.0

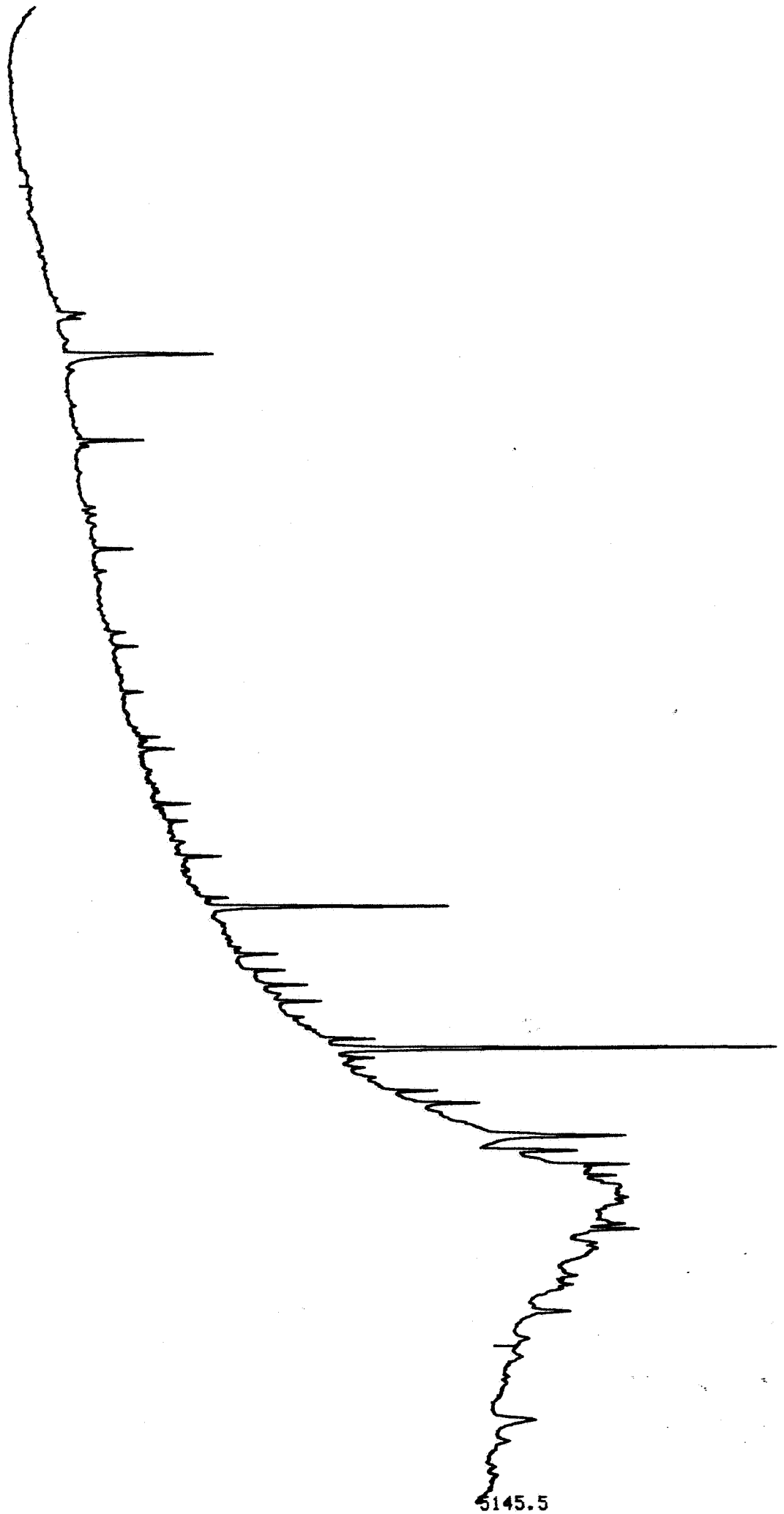


FIGURE : 16.4 WELL : N2/7-21S
DEPTH : 16521.6'

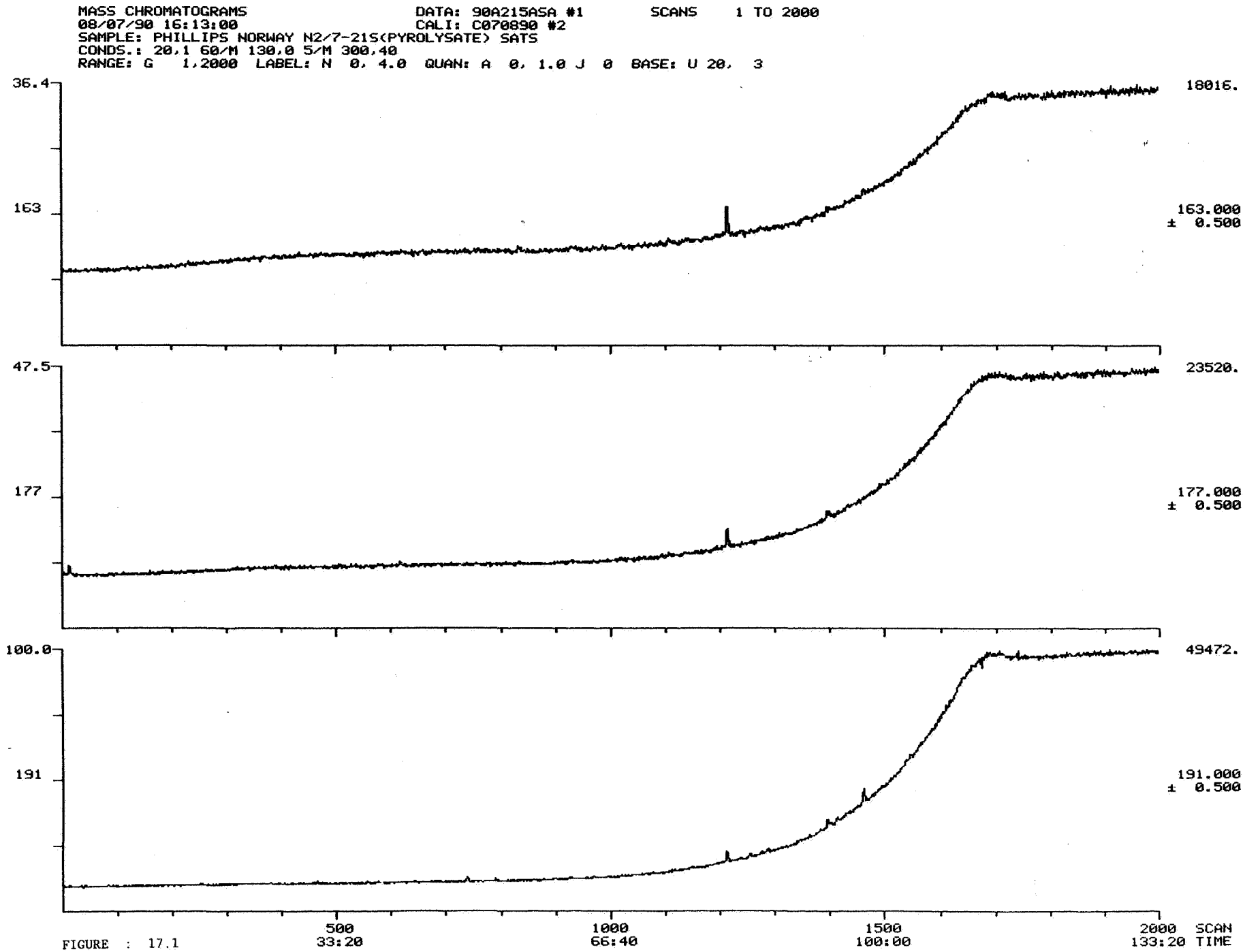


FIGURE : 17.1
WELL : N2/7-20X
DEPTH : 14753'

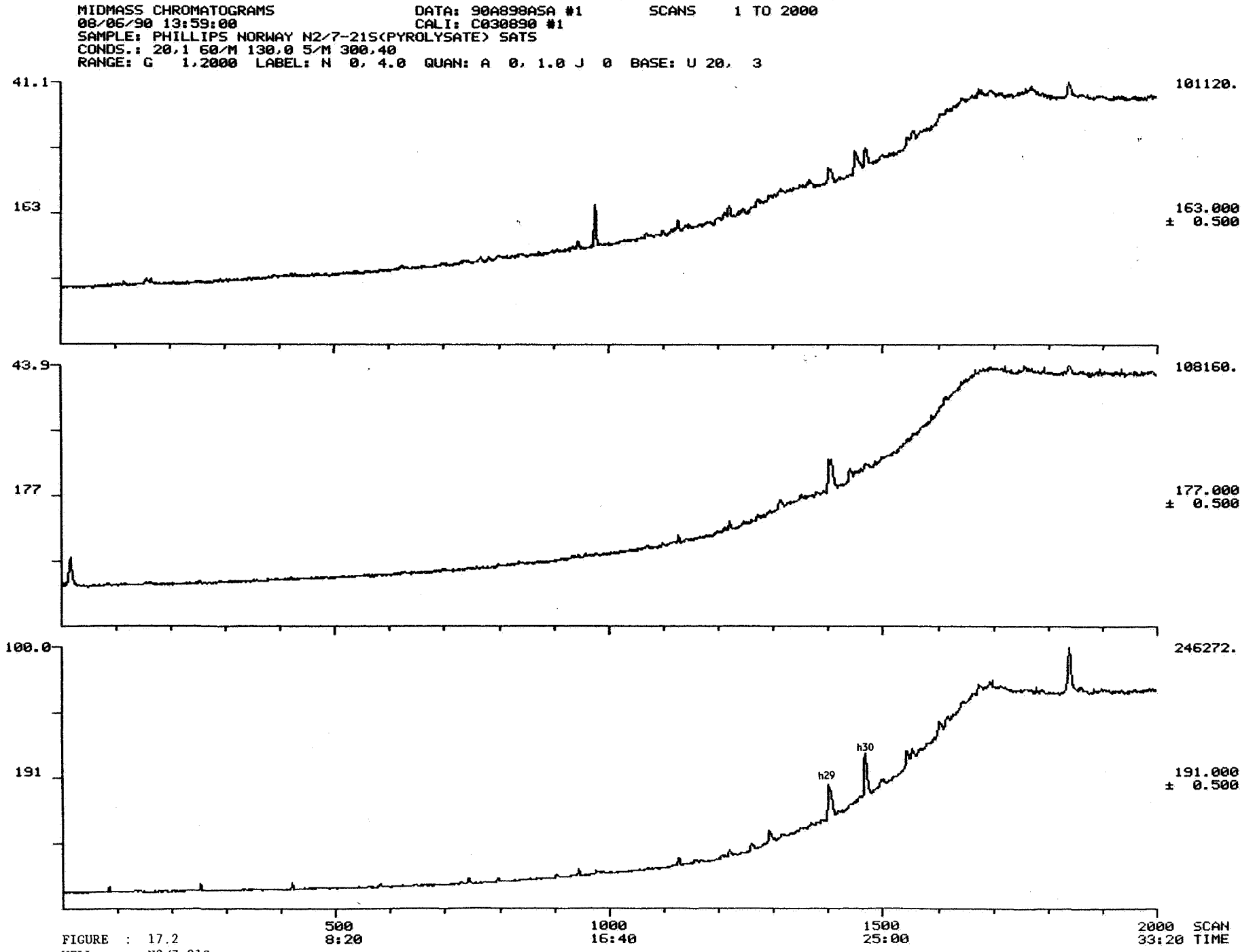


FIGURE : 17.2
WELL : N2/7-21S
DEPTH : 14267.2'

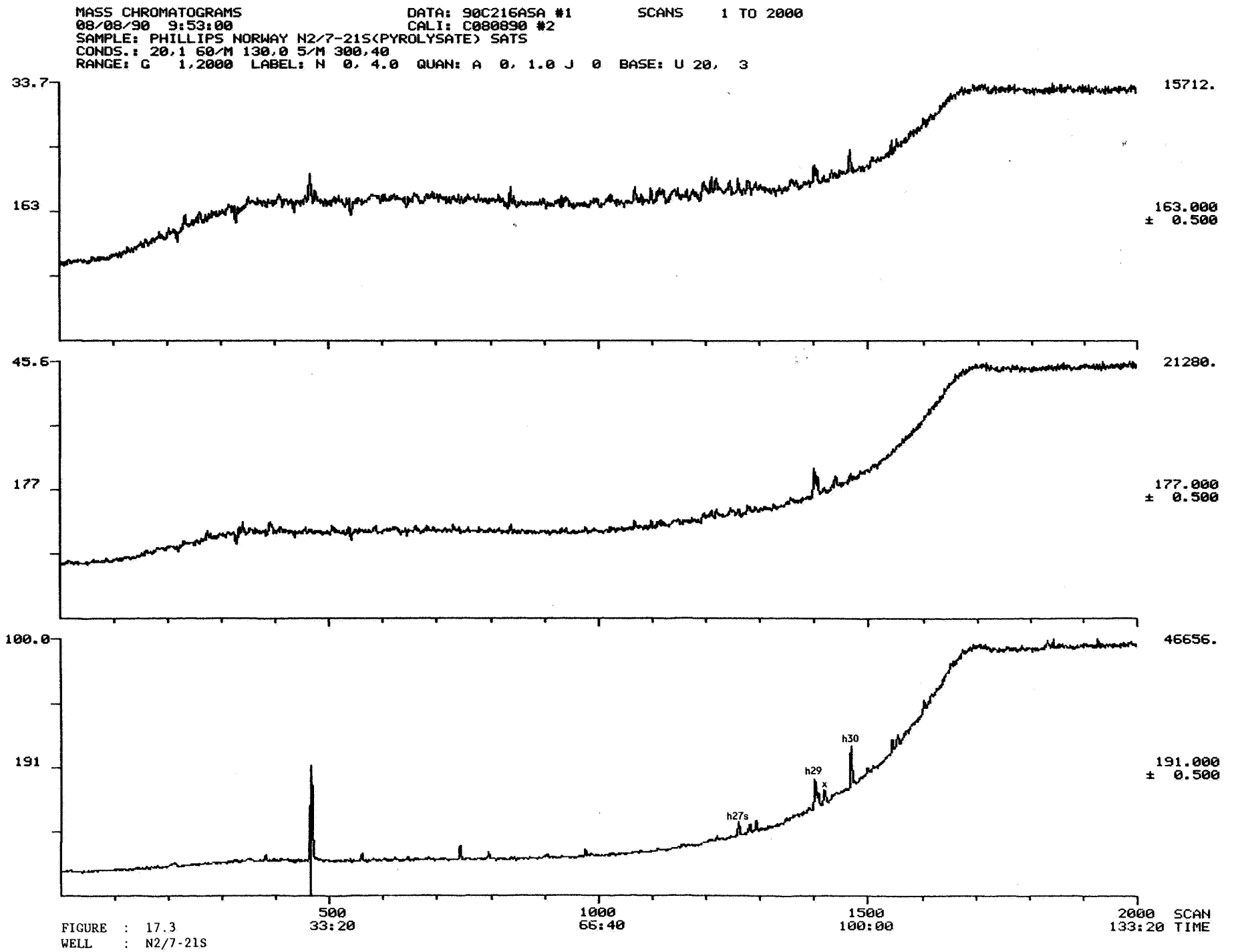


FIGURE : 17.3
WELL : N2/7-21S
DEPTH : 15281.7'

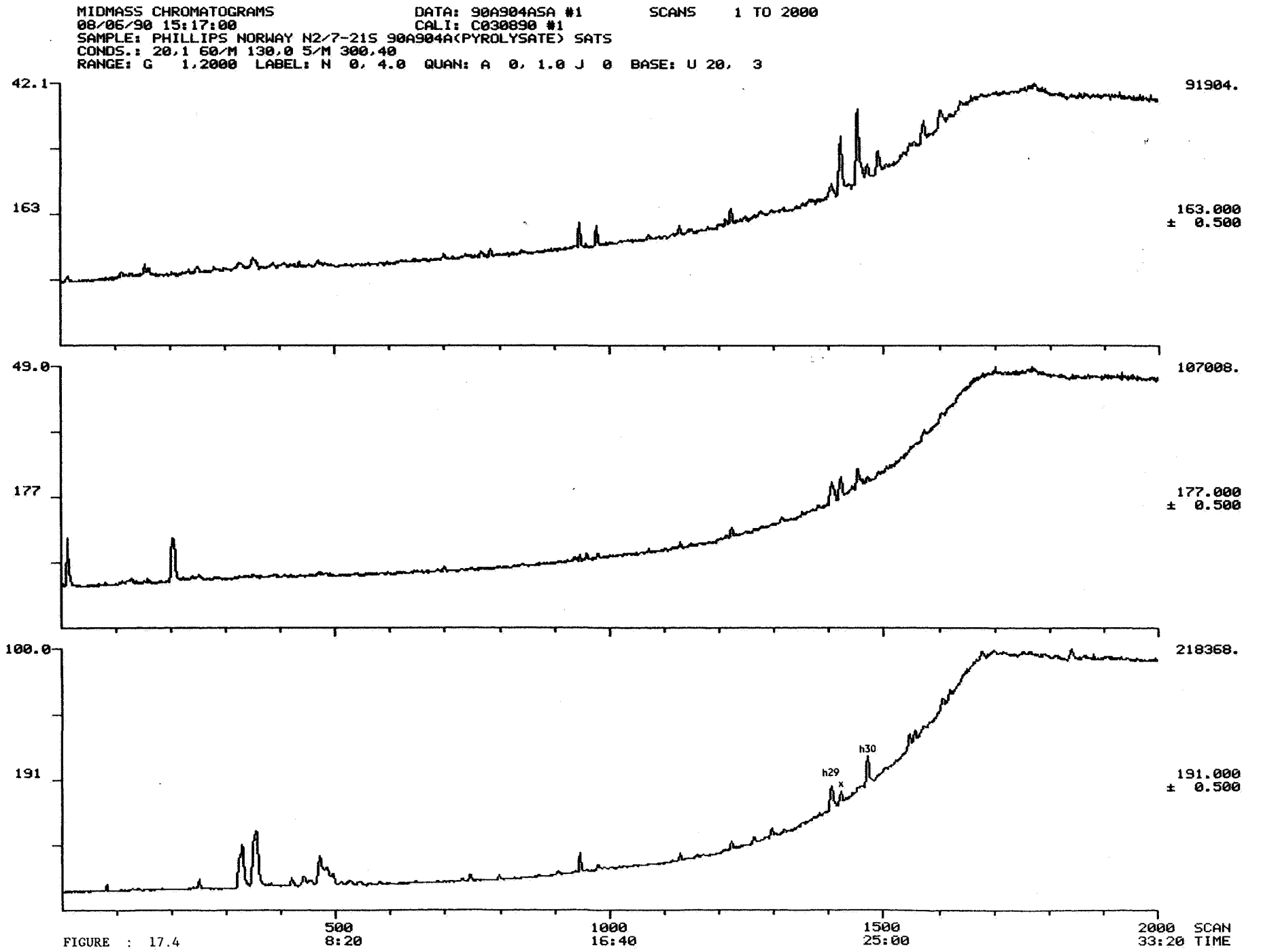


FIGURE : 17.4
WELL : N2/7-21S
DEPTH : 16521.6'

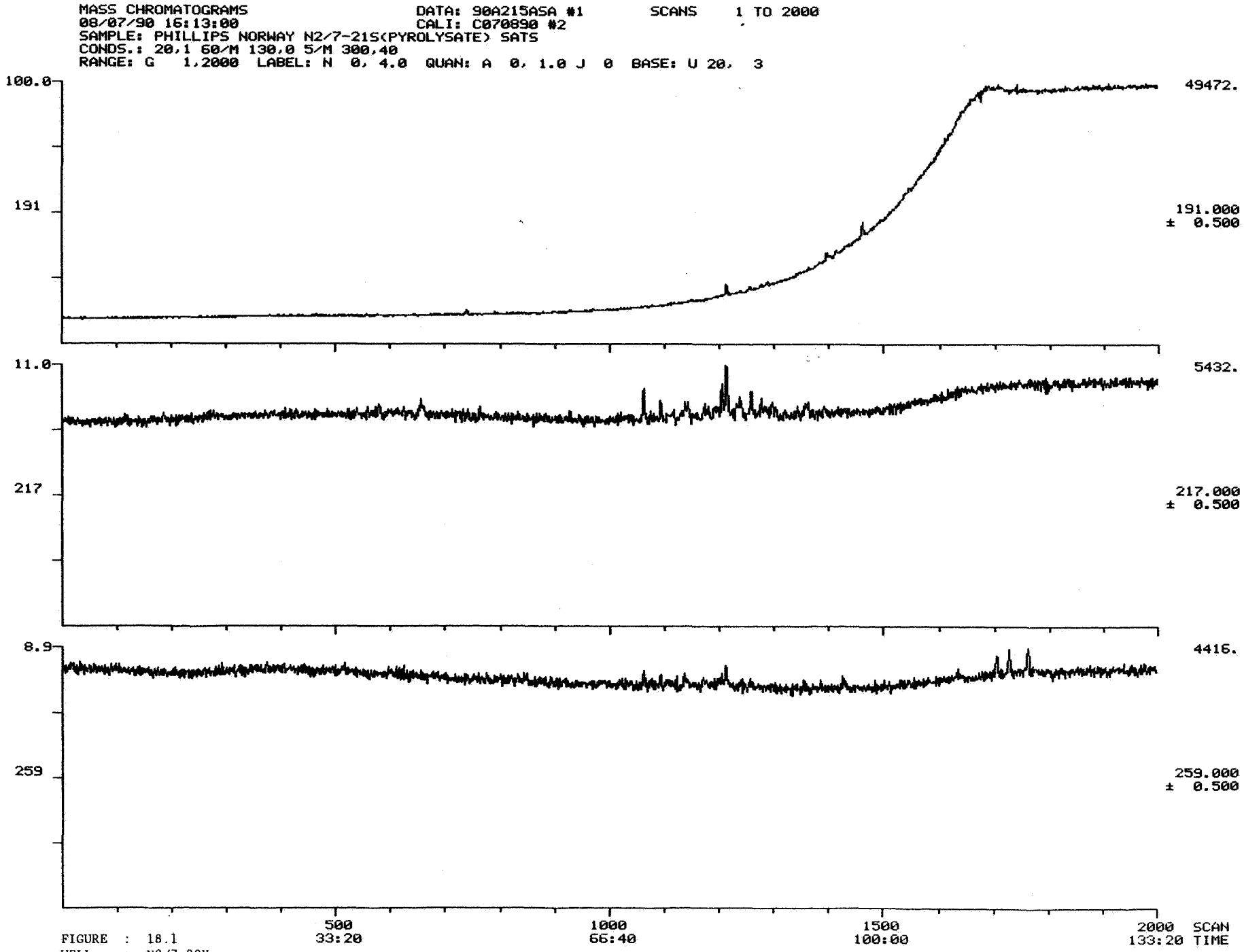


FIGURE : 18.1
WELL : N2/7-20X
DEPTH : 14753'

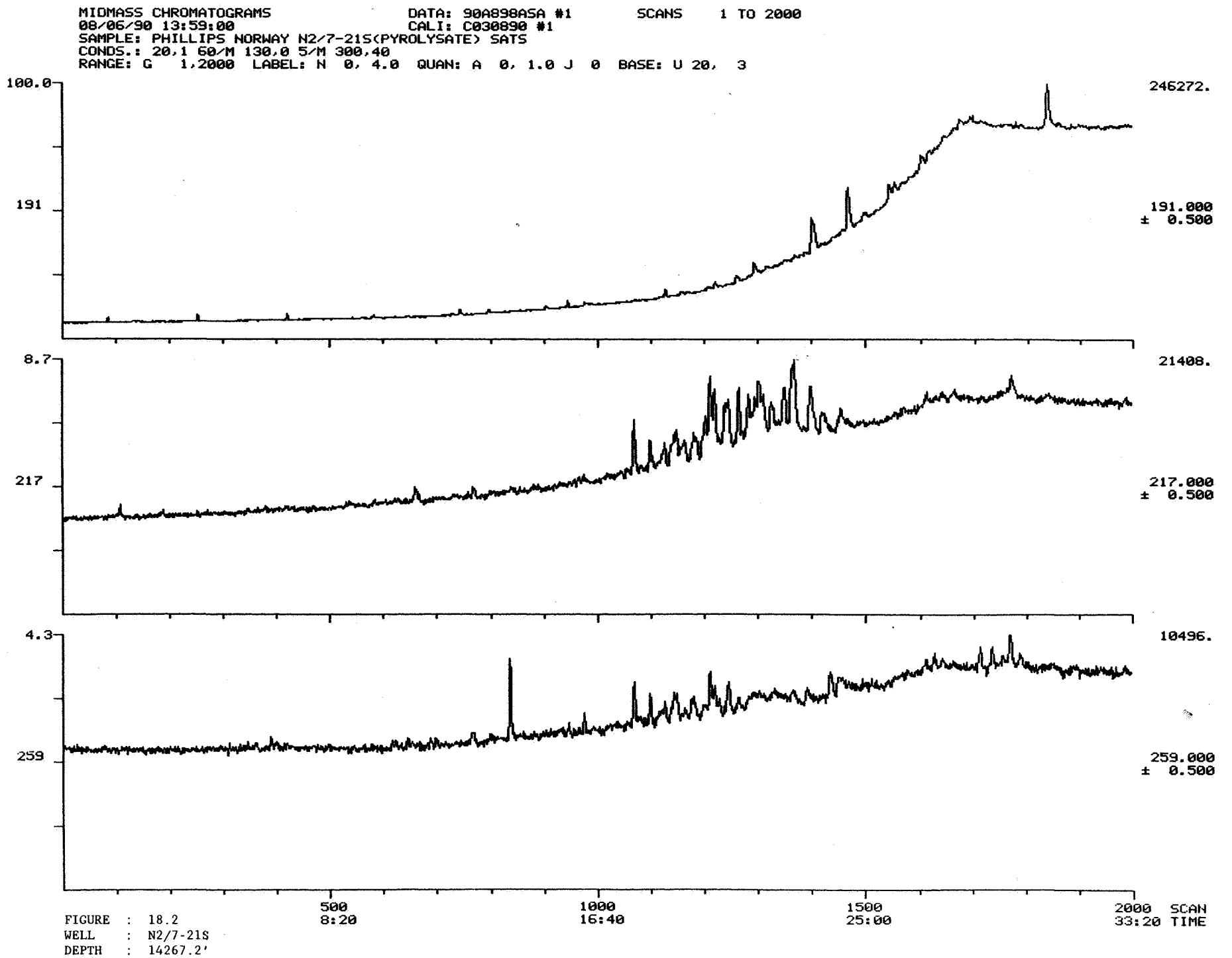


FIGURE : 18.2
WELL : N2/7-21S
DEPTH : 14267.2'

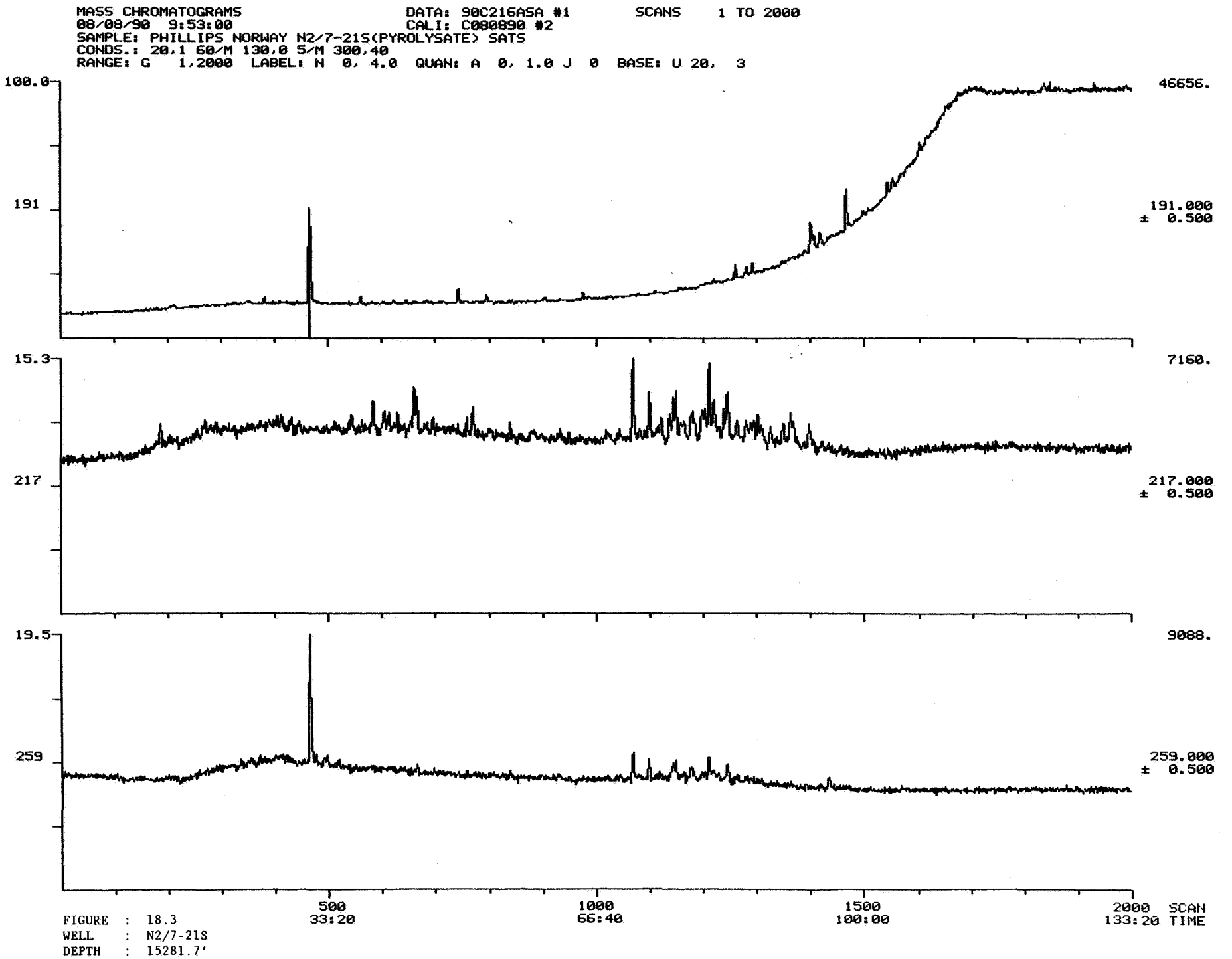


FIGURE : 18.3
WELL : N2/7-21S
DEPTH : 15281.7'

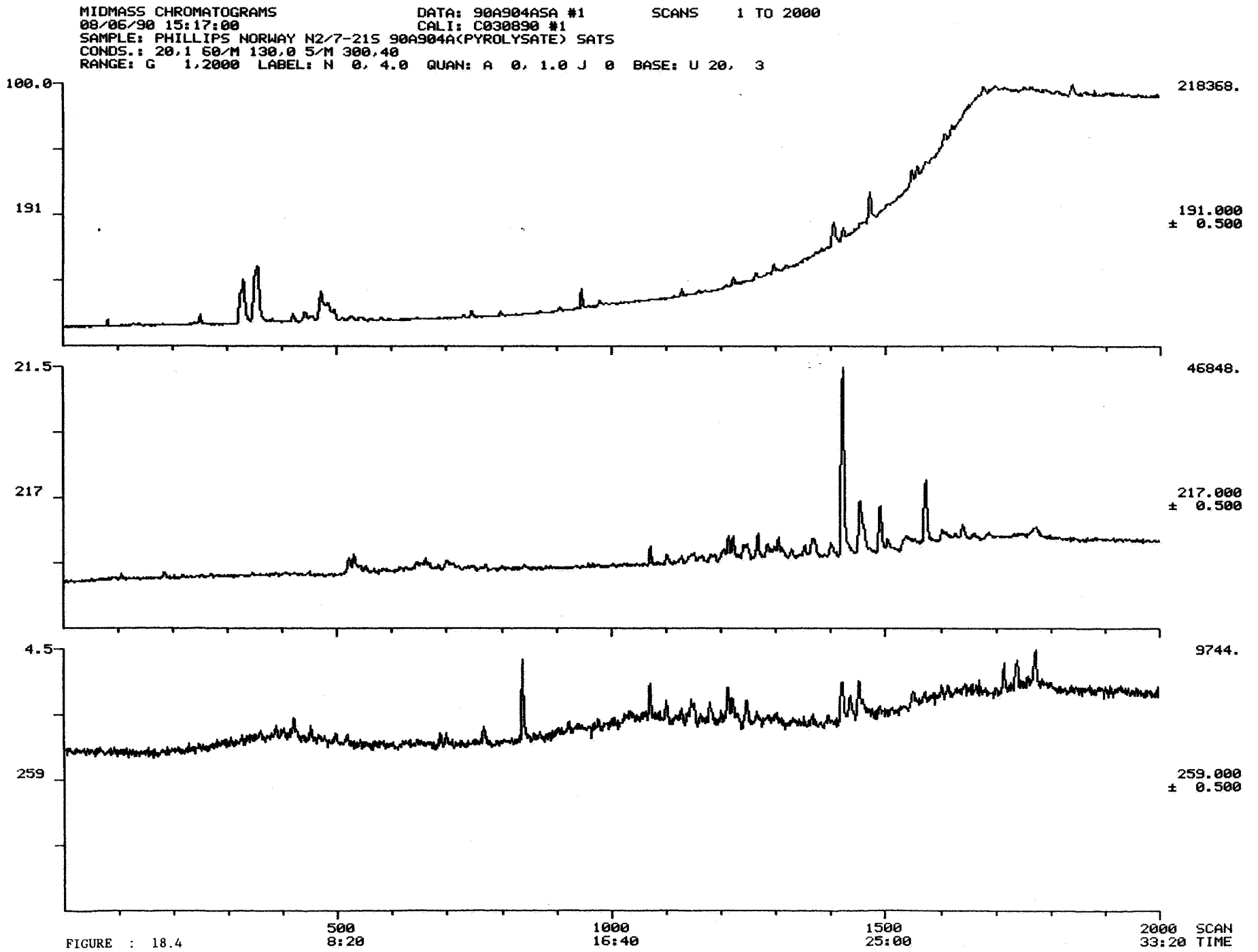


FIGURE : 18.4
WELL : N2/7-21S
DEPTH : 16521.6'

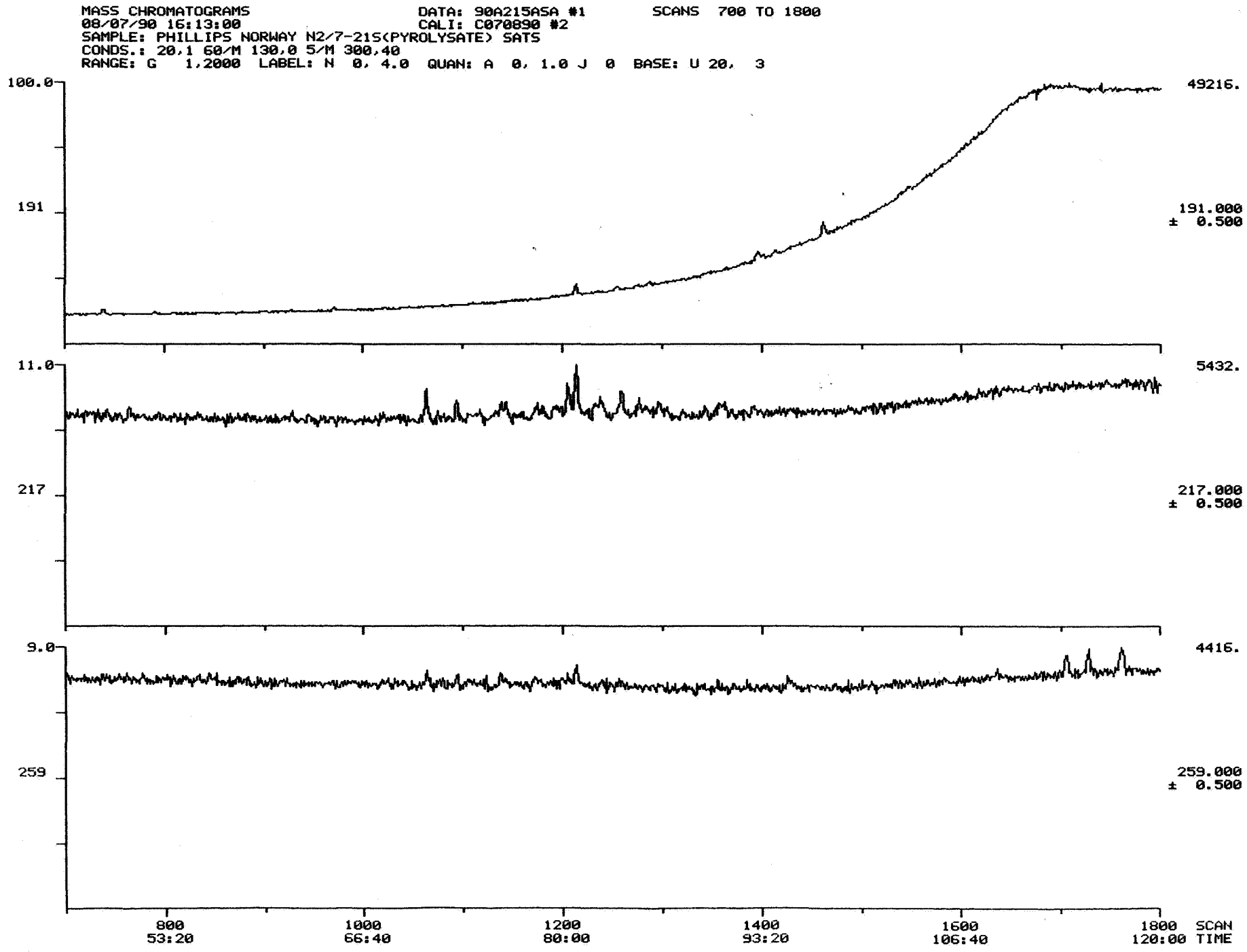


FIGURE : 19.1
WELL : N2/7-20X
DEPTH : 14753'

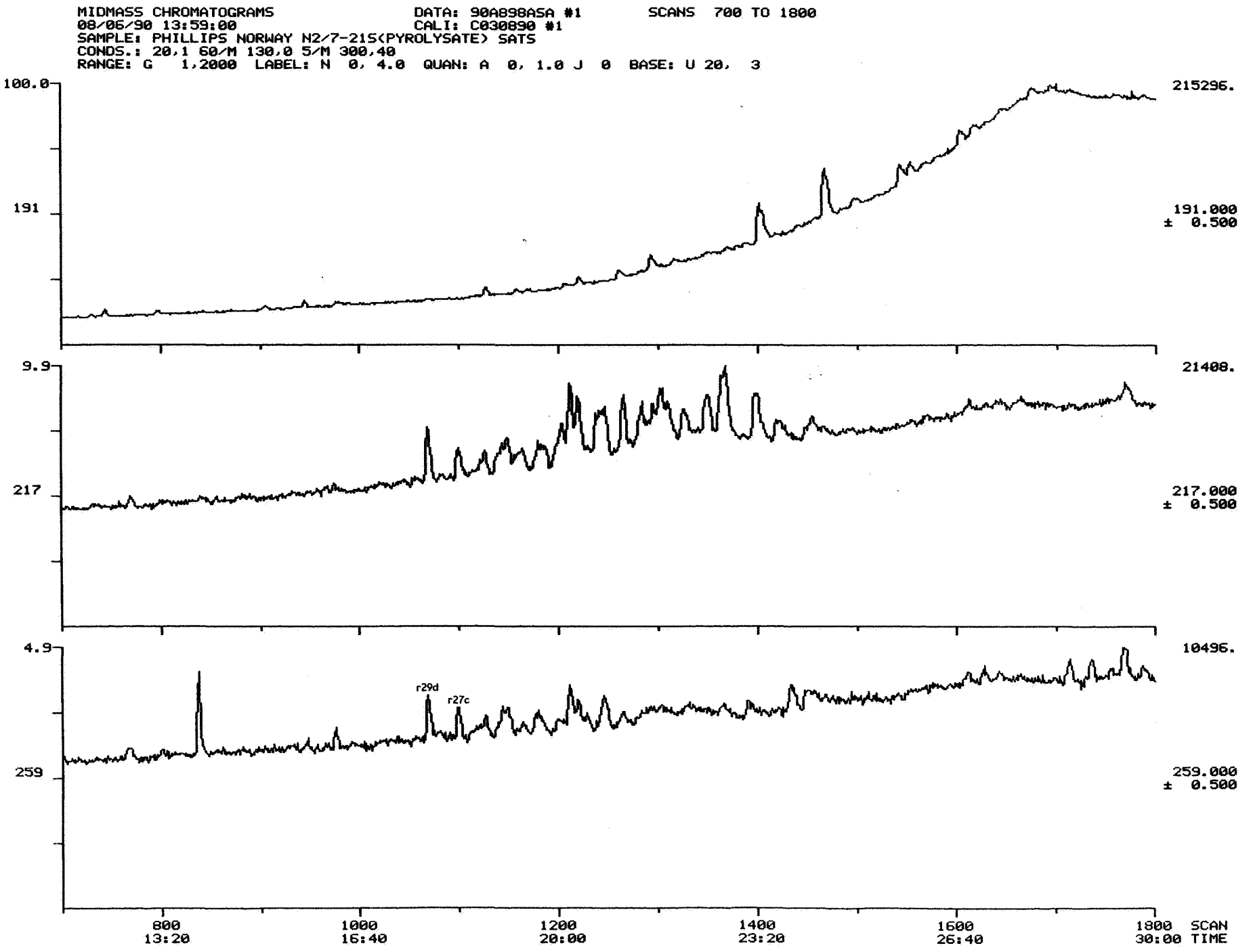


FIGURE : 19.2
WELL : N2/7-21S
DEPTH : 14267.2'

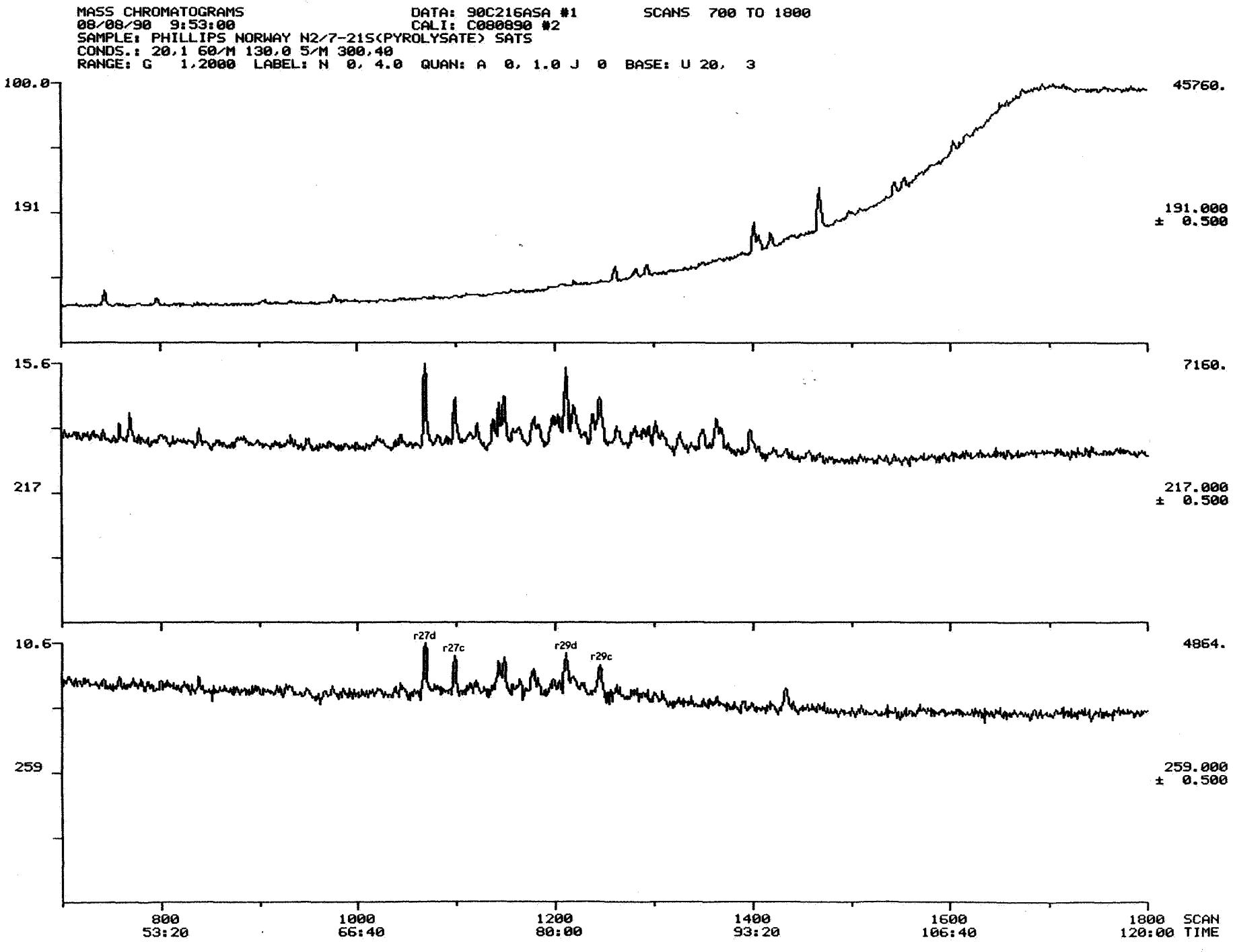


FIGURE : 19.3
WELL : N2/7-21S
DEPTH : 15281.7'

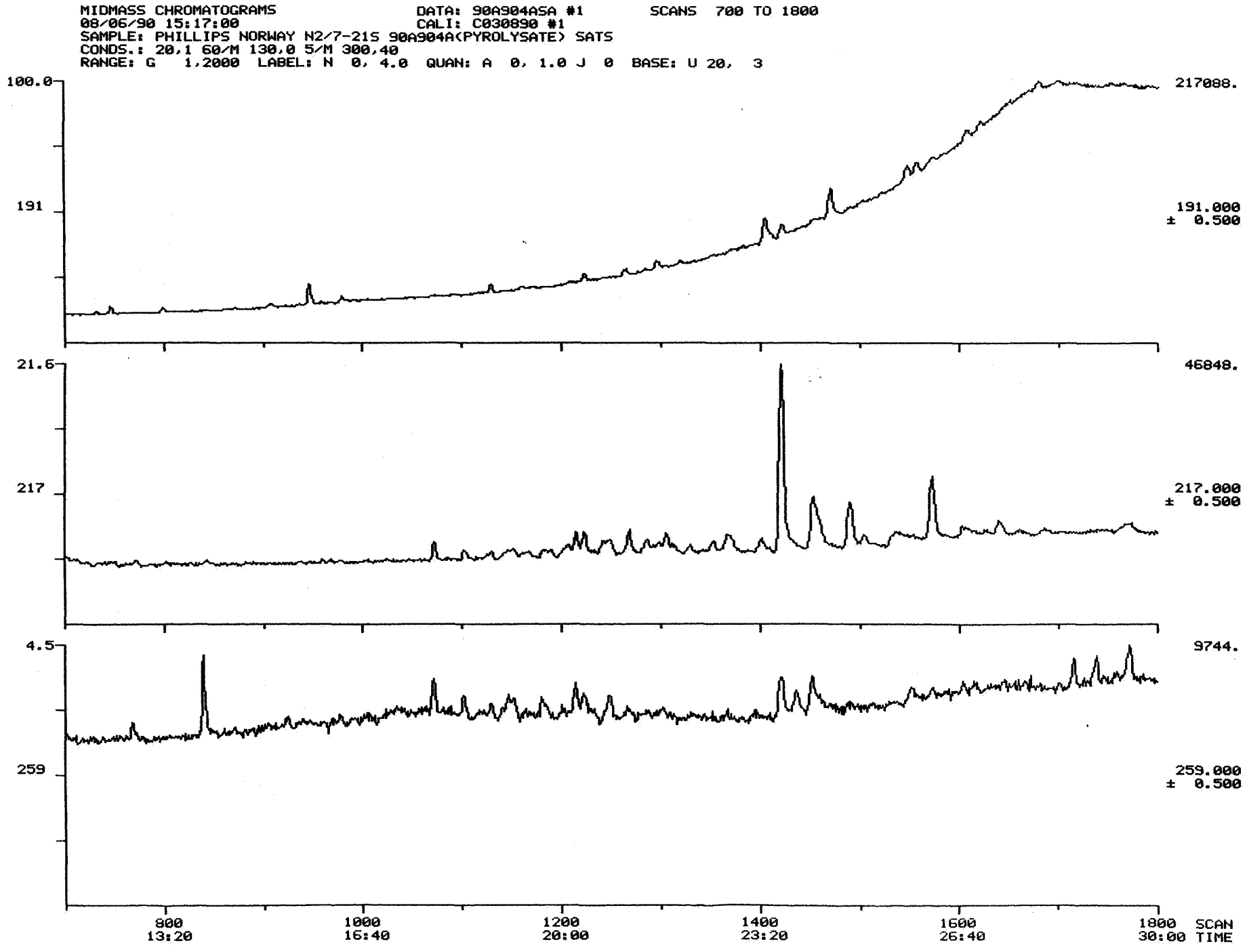


FIGURE : 19.4
WELL : N2/7-21S
DEPTH : 16521.6'

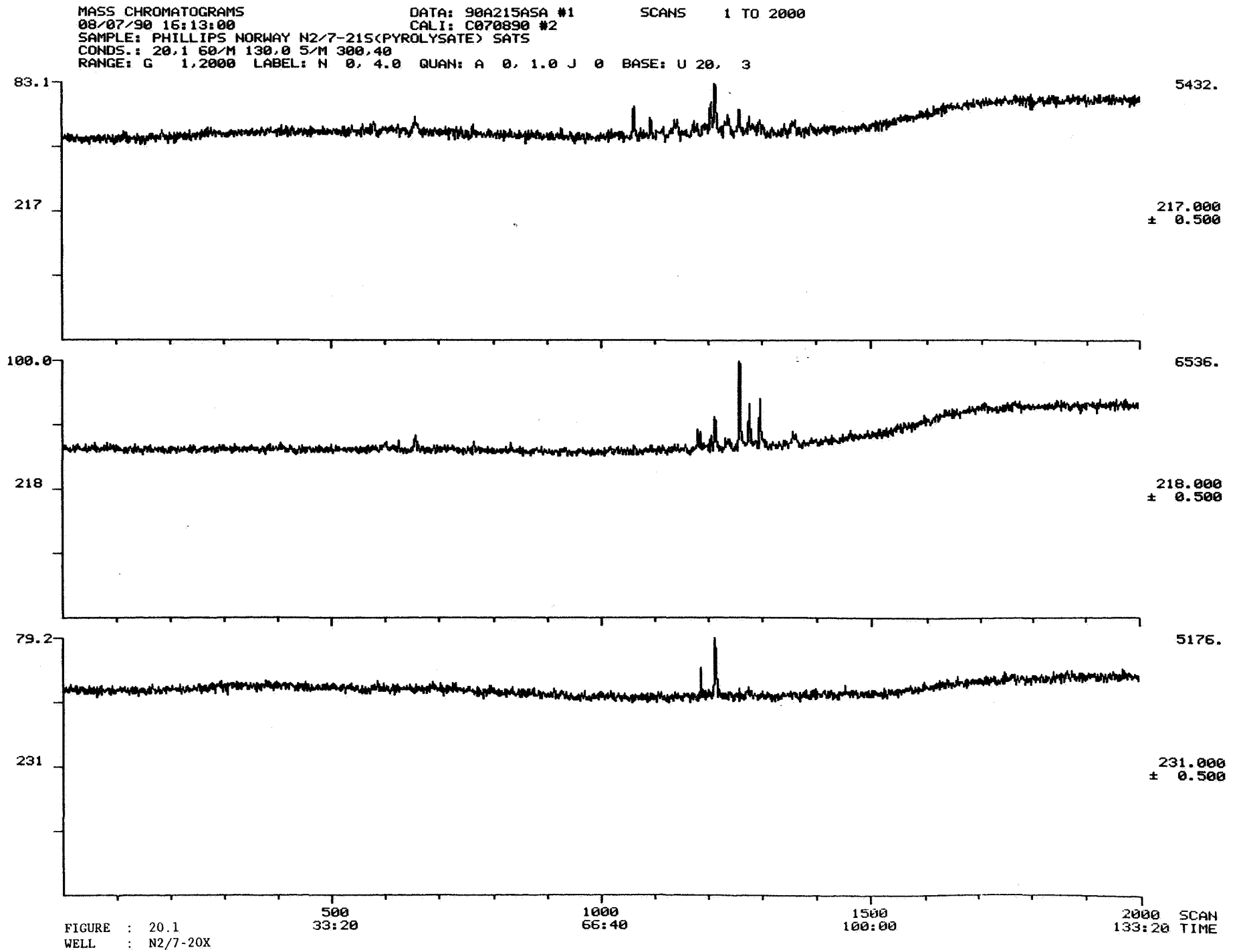


FIGURE : 20.1
WELL : N2/7-20X
DEPTH : 14753'

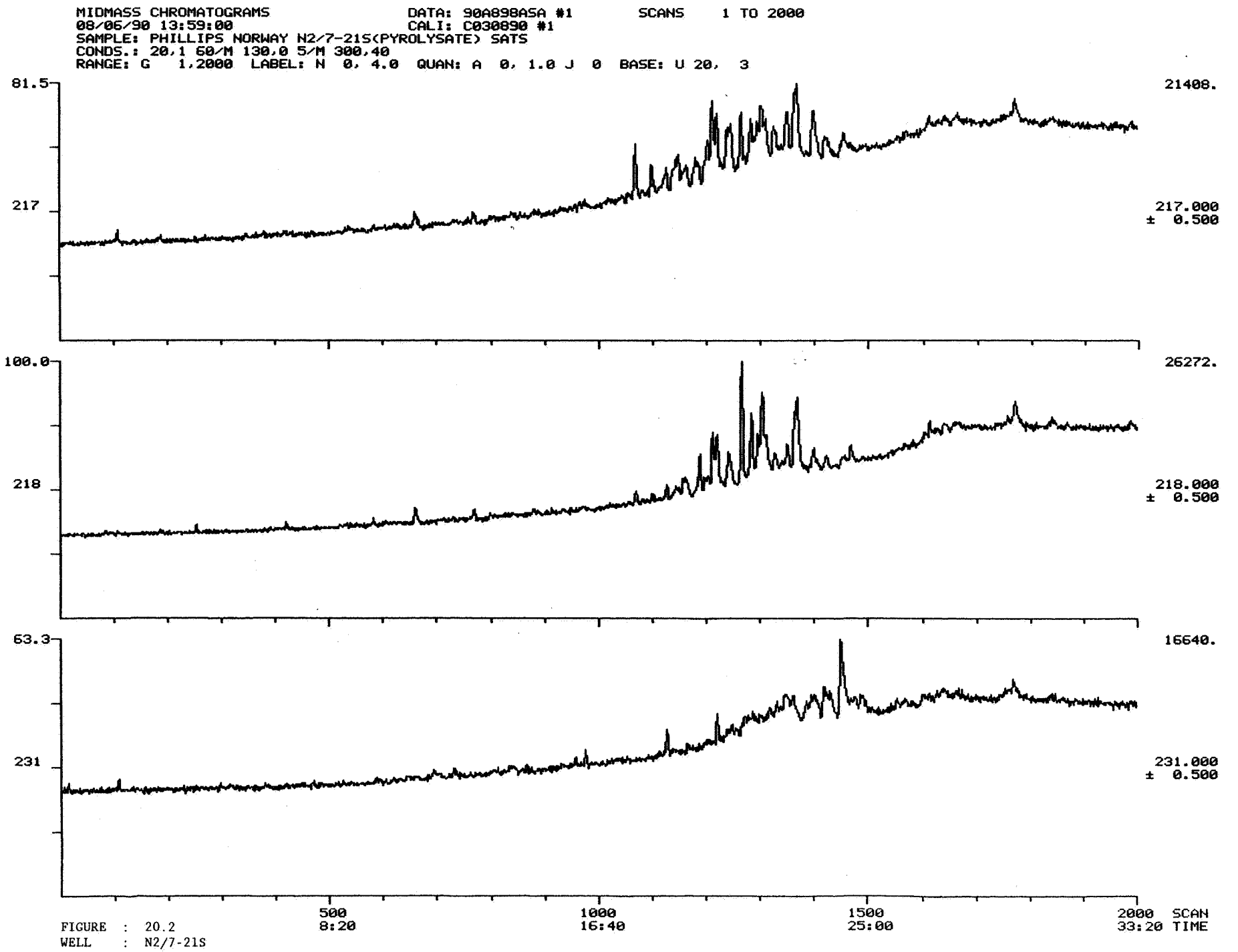


FIGURE : 20.2
WELL : N2/7-21S
DEPTH : 14267.2'

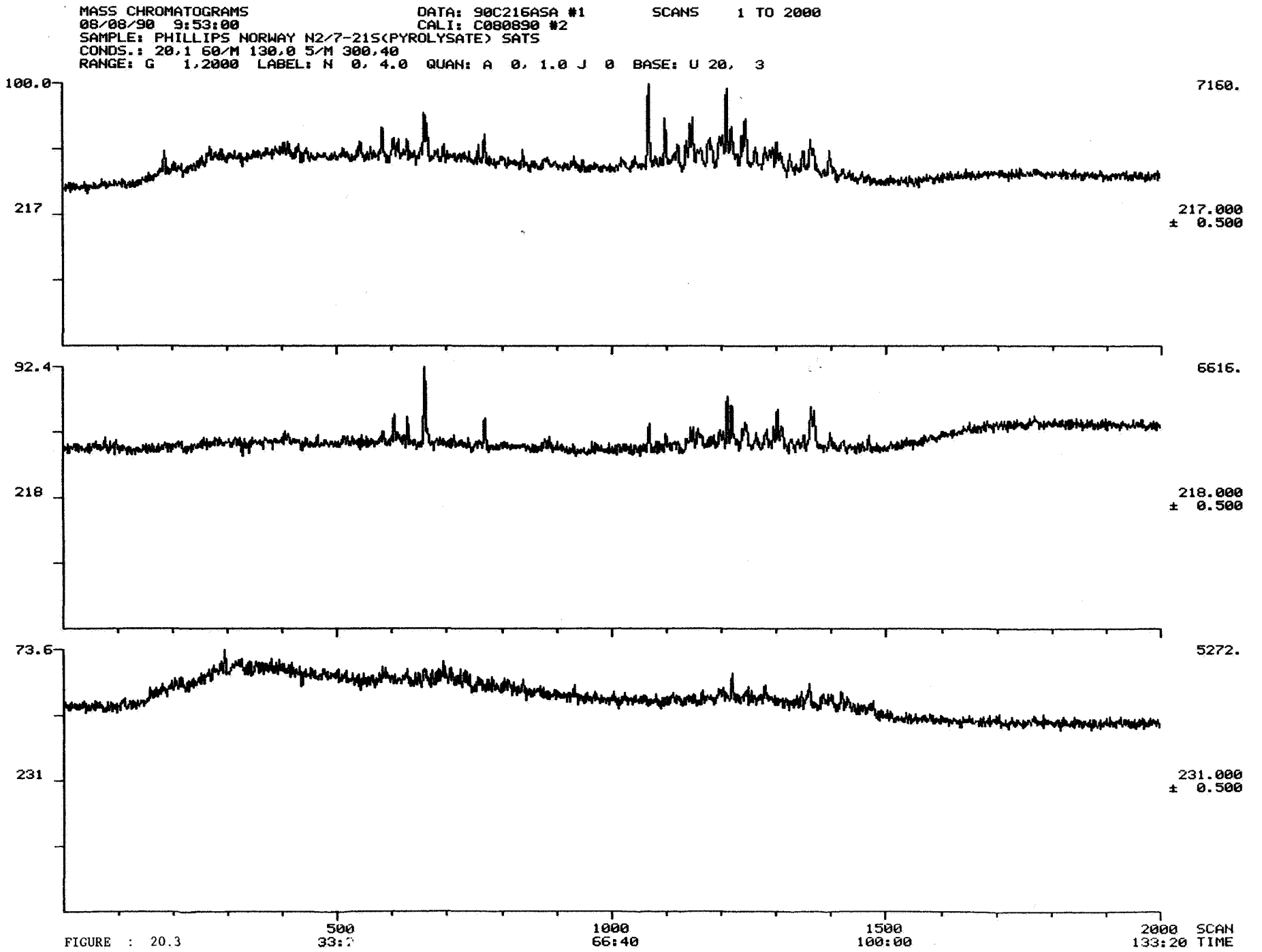


FIGURE : 20.3
WELL : N2/7-21S
DEPTH : 15281.7'

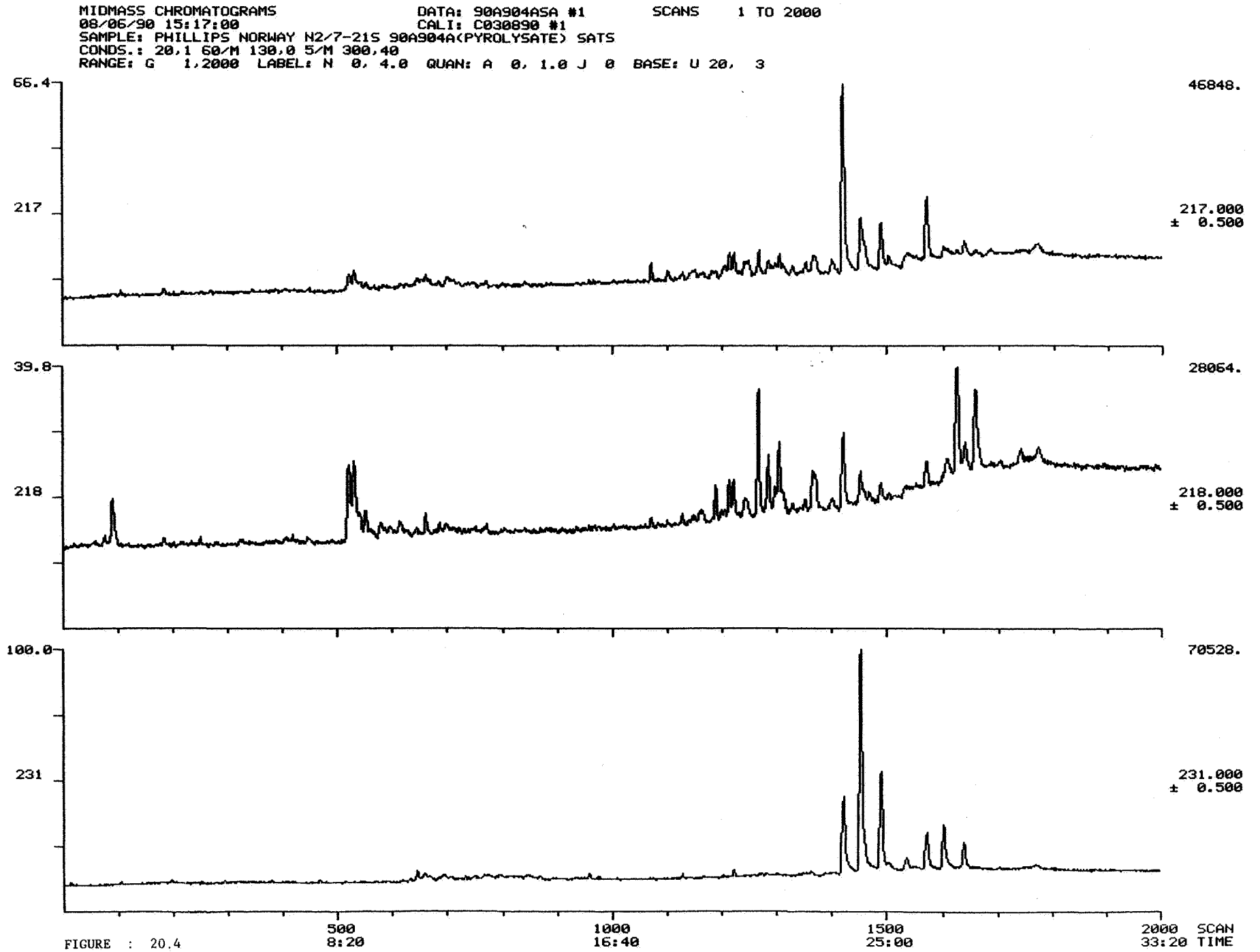


FIGURE : 20.4
WELL : N2/7-21S
DEPTH : 16521.6'

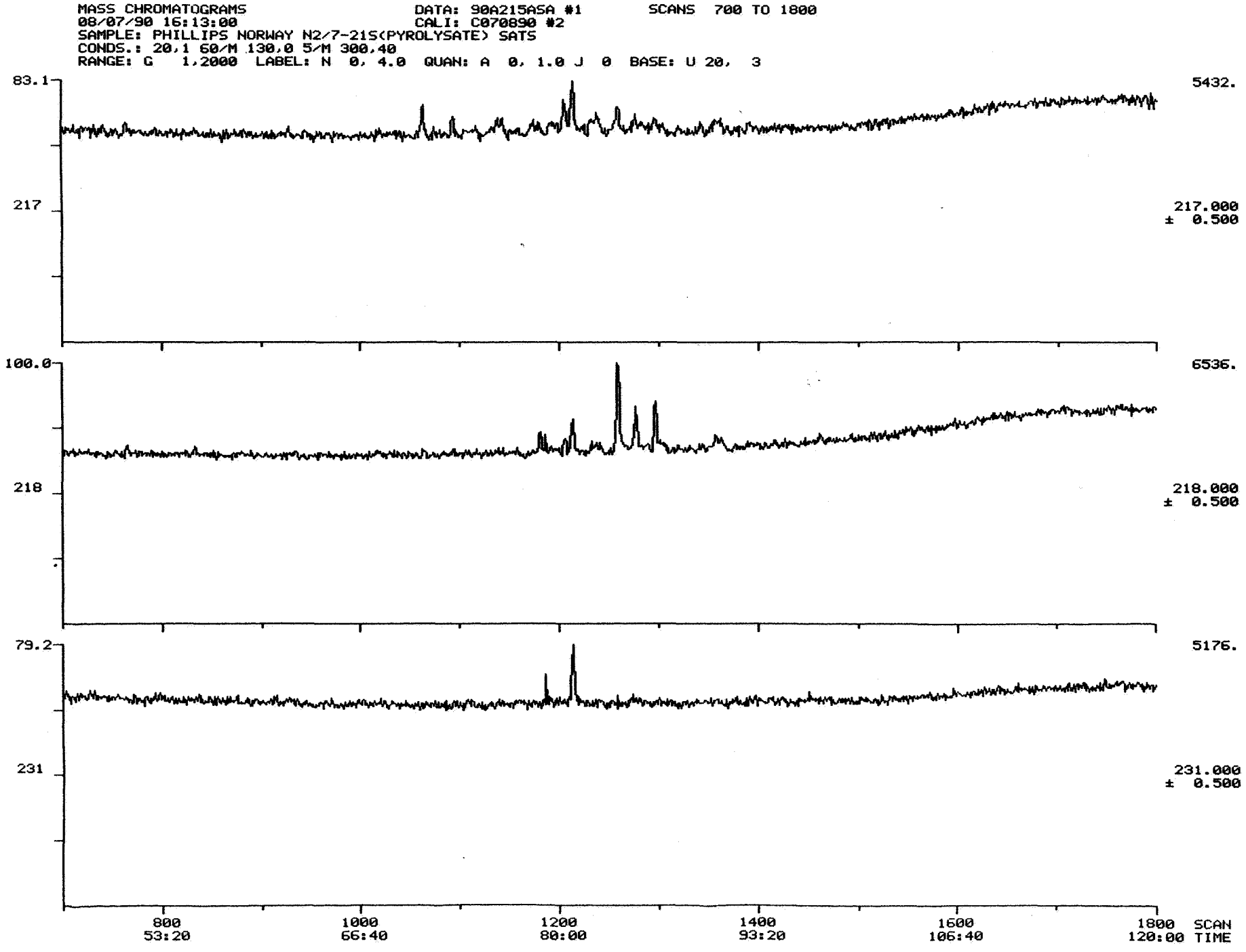


FIGURE : 21.1
WELL : N2/7-20X
DEPTH : 14753'

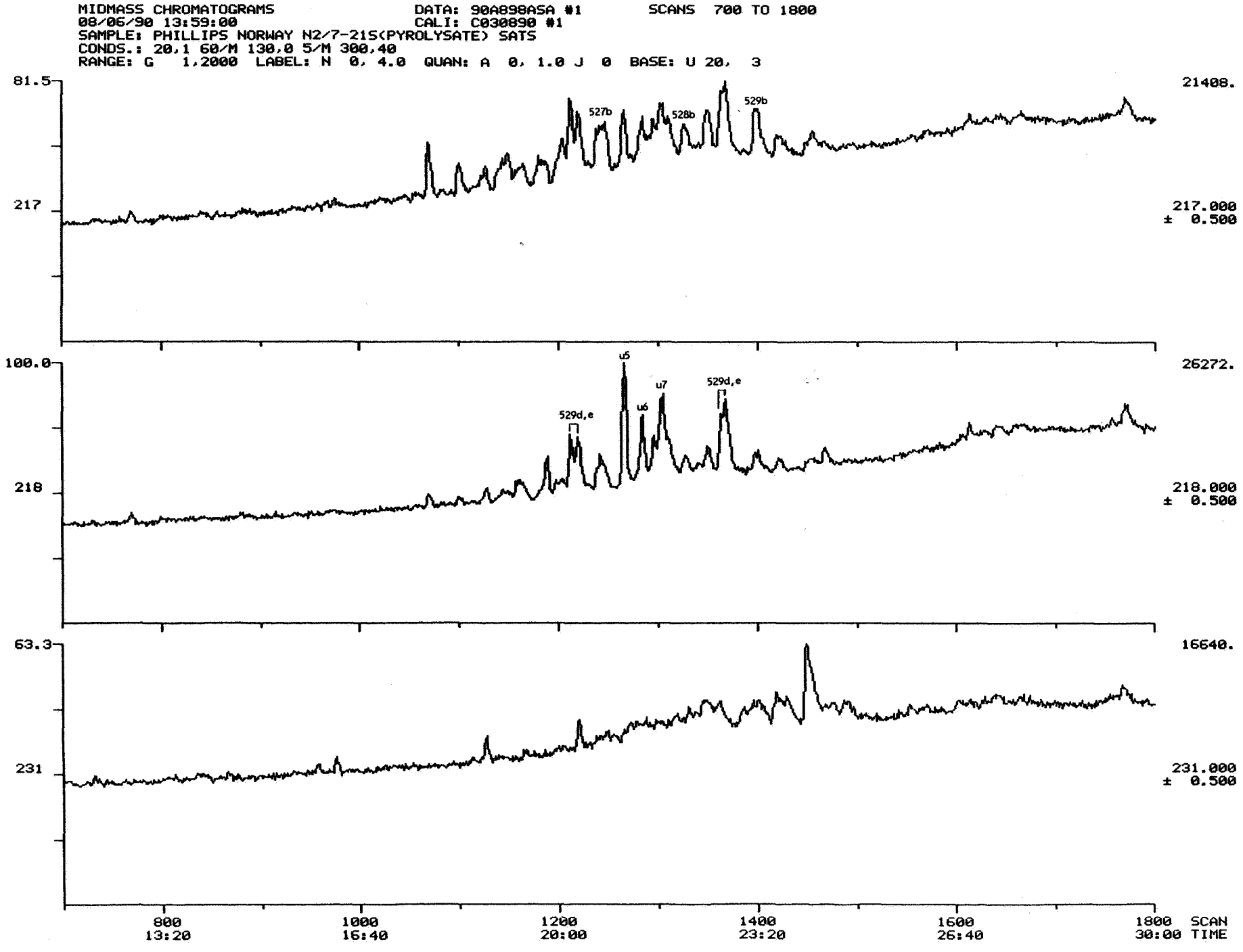


FIGURE : 21.2
WELL : N2/7-21S
DEPTH : 14267.2'

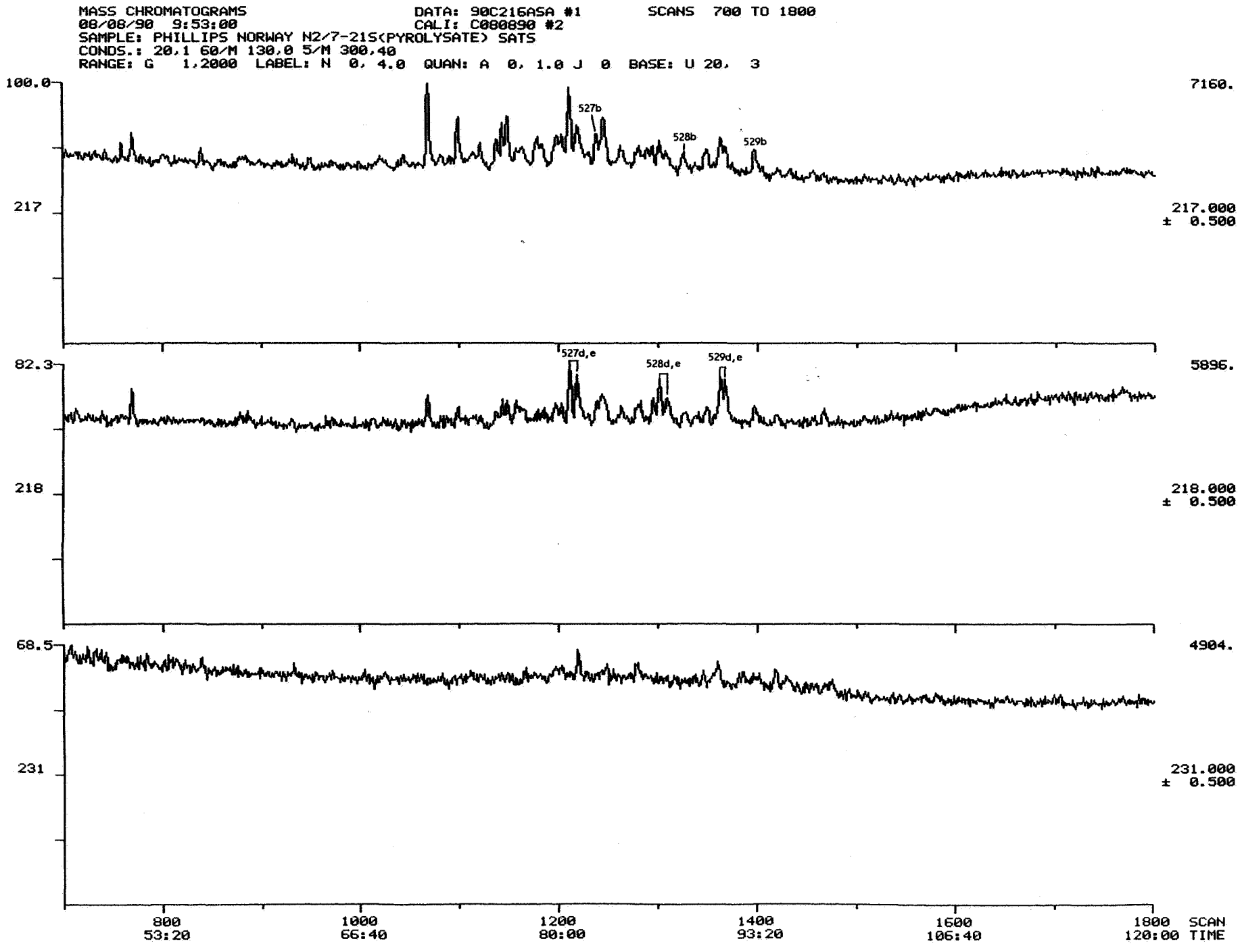


FIGURE : 21.3
WELL : N2/7-21S
DEPTH : 15281.7'

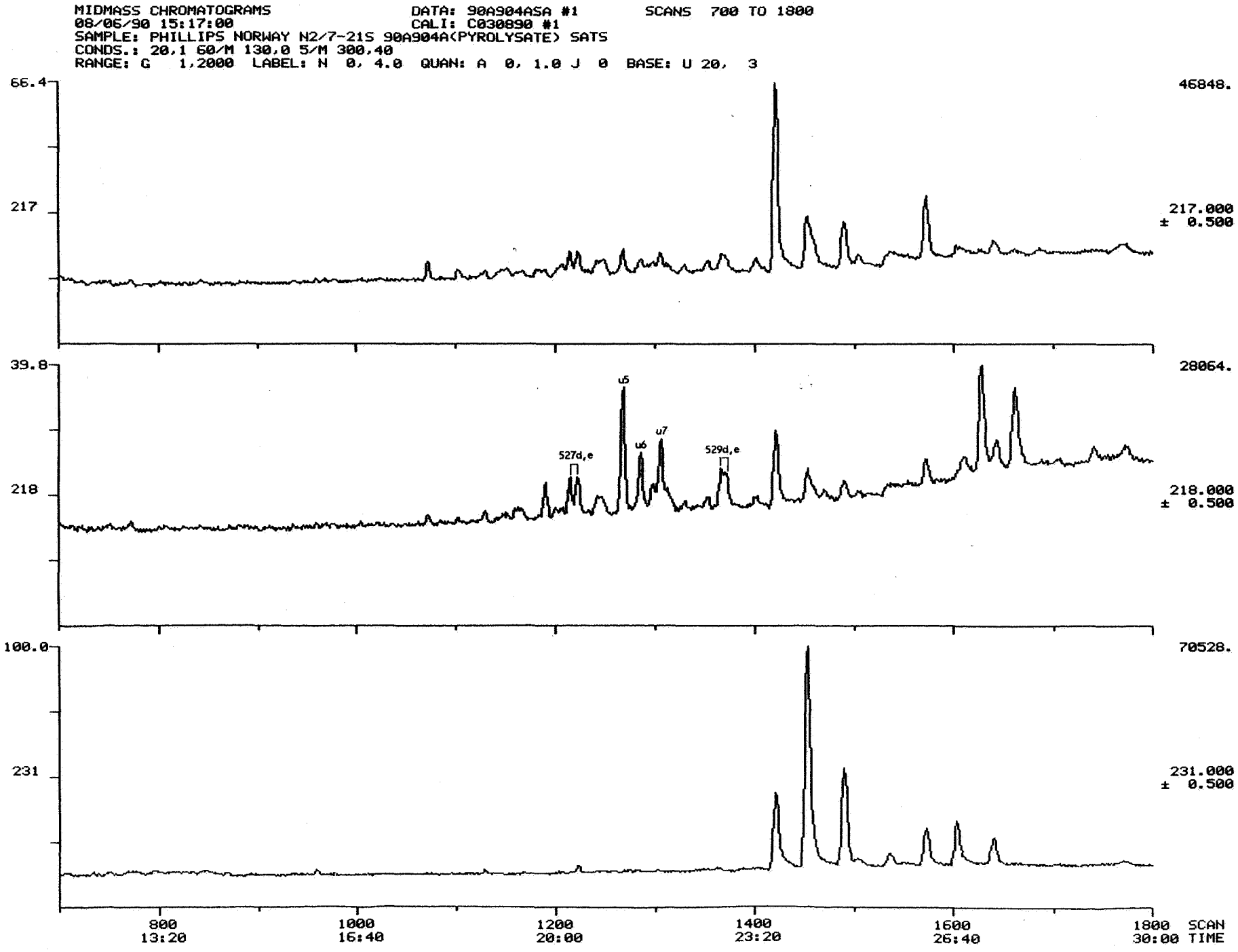


FIGURE : 21.4
WELL : N2/7-21S
DEPTH : 16521.6'

PLATE 1(A-D)

PLATE 1A

N2/7-20X well
14767' (drillers depth, RKB)

Large mass of solid bitumen of relatively high reflectance (mean 1.05%).

PLATE 1B

N2/7-20X well
14767.2' (drillers depth, RKB)

As Plate 1A. Lower reflectivity, translucent dolomite rhomb in lower left margin.

PLATE 1C

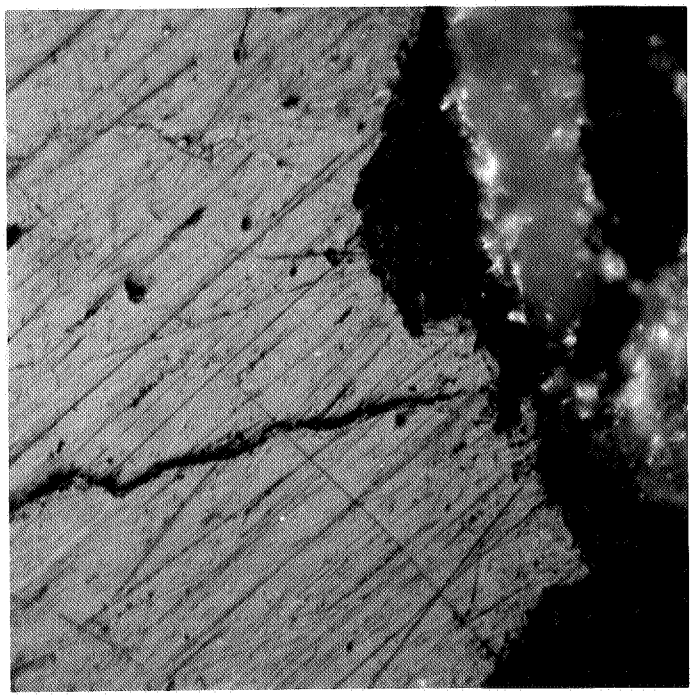
N2/7-21S well
16493.1' (drillers depth, RKB)

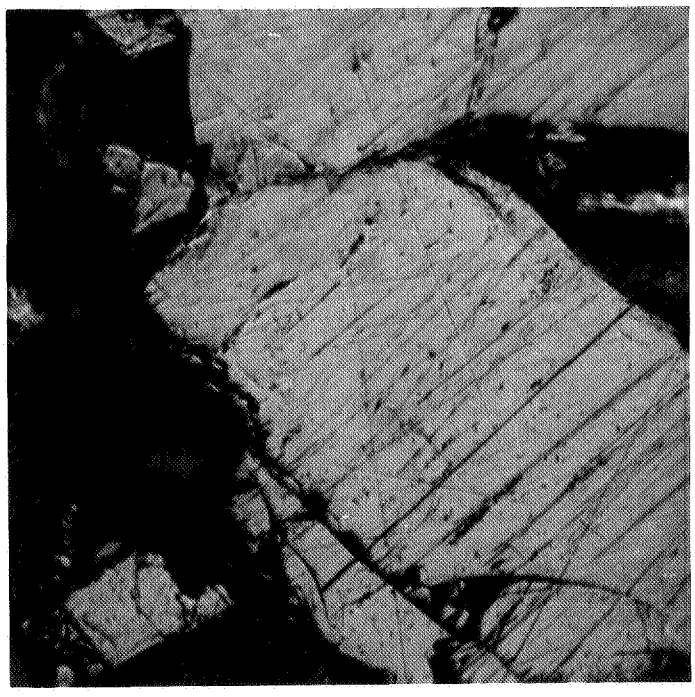
Solid bitumen associated with vermicular kaolinite. Bitumen of relatively high reflectivity (mean 1.38%). Solid bitumen completely infills spaces between kaolinite layers. Bitumen precursor must have been a mobile fluid and emplaced subsequent to kaolinite formation.

PLATE 1D

N2/7-21S well
16493.1' (drillers depth, RKB)

As Plate 1C.





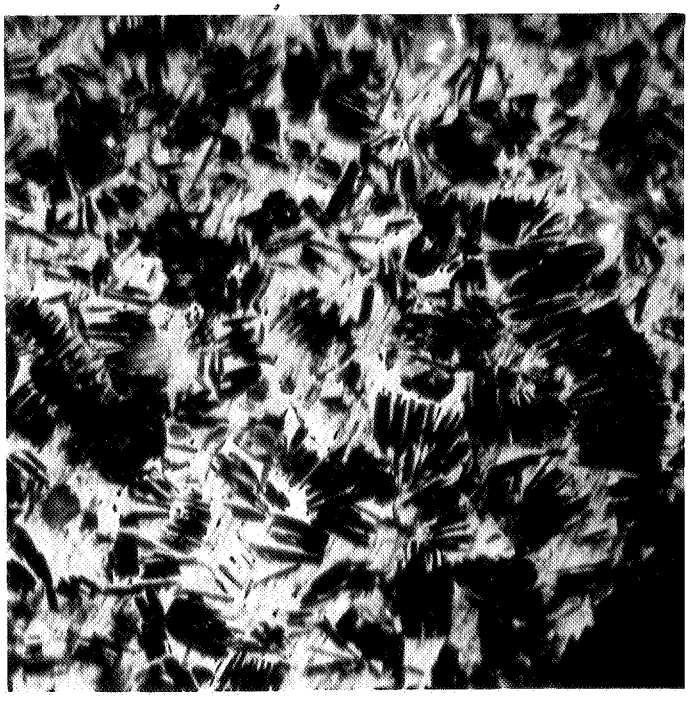


PLATE 2(A-D)

PLATE 2A

N2/7-21S well
14267.2' (drillers depth, RKB)

Finely disseminated bitumen associated with carbonate fracture fill.

PLATE 2B

N2/7-21S well
16215.7' (drillers depth, RKB)

Solid bitumen with carbonate cement.

PLATE 2C

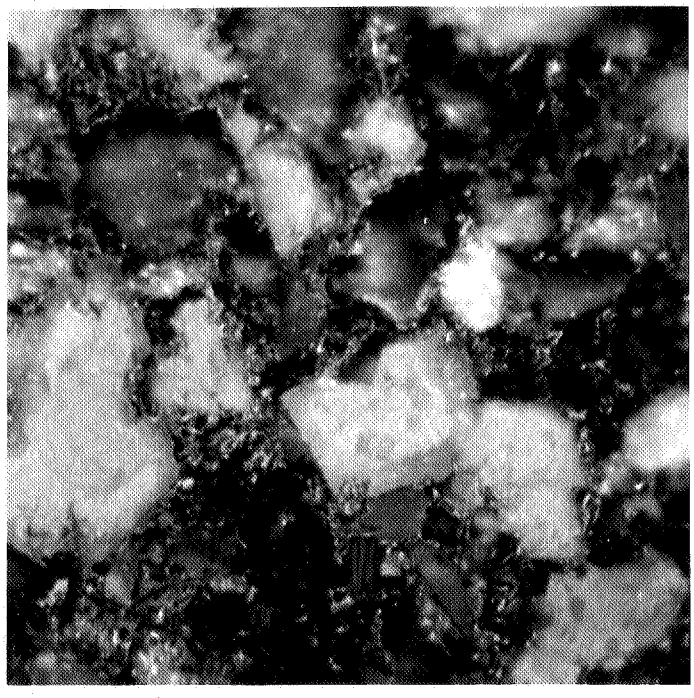
N2/7-21S well
16215.1' (drillers depth, RKB)

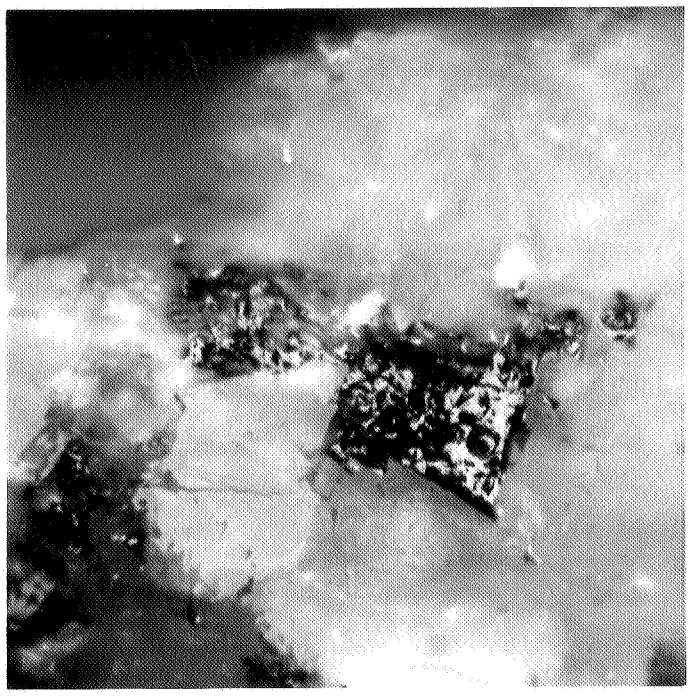
Solid bitumen associated with carbonate cement material. Solid bitumen has assumed geometry of pore space, and therefore must have been a fluid, possibly a tarry, degraded, but mobile oil at the time of carbonate cement formation.

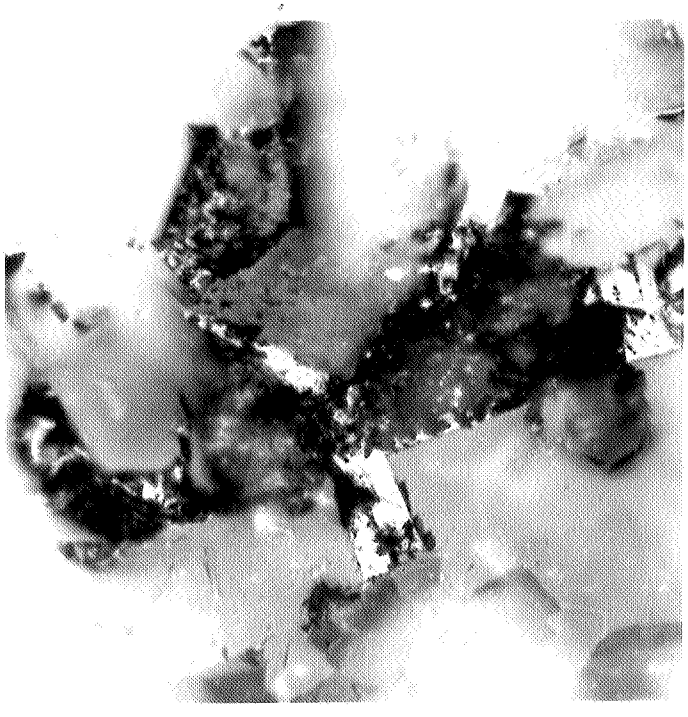
PLATE 2D

N2/7-21S well
16215.7' (drillers depth, RKB)

As Plate 1C.







APPENDIX 1

Abbreviations used in Analytical Data Sheets

APPENDIX 1
ABBREVIATIONS USED IN ANALYTICAL DATA SHEETS

a/a	-	as above
Ac	-	acritarchs
ADD	-	mud additive
Al	-	algae
Am	-	amorphous
ang	-	angular
ANH	-	anhydrite
aren	-	arenaceous
arg	-	argillaceous
BAS	-	basalt
bd	-	bedded/bedding
B(IT)	-	bitumen/bituminous
bl	-	blue
bld	-	bleached
blk	-	black
bri	-	brilliant
brn	-	brown
calc	-	calcareous
CALT	-	calcite
carb	-	carbonaceous
CGL	-	conglomerate
CHK	-	chalk
CHT	-	chert
CLYST	-	claystone
CMT	-	cement
Comp	-	composite
crs	-	coarse
CSG	-	casing point/shoe
Ctgs	-	ditch cuttings
Cu	-	cuticle
C(vd)	-	caved
decarb	-	decarbonated
Di	-	dinocysts
dk	-	dark
DLT	-	dolerite
DOL/dol	-	dolomite/dolomitic
dsk	-	dusky
Ex	-	exinite
Exs	-	exsudatinite
extr	-	extracted
f	-	fine
fel	-	feldspathic
fer	-	ferruginous
flu	-	fluorescence
fm	-	formation
foss	-	fossils/fossiliferous
fr	-	friable
frac	-	fracture
frags	-	fragments
Fu	-	fusinite
GLC/glc	-	glauconite/glauconitic
gn	-	green
grd	-	graded/grading to
grns	-	grains
gy	-	grey
GYP	-	gypsum
HAL	-	halite
hd	-	hard
hor	-	horizontal
H(RV)	-	high reflecting vitrinite
i-	-	iso-
i/b	-	inter-bedded
IGN	-	igneous rocks
inc	-	including
Inert	-	inertinite
lam	-	laminae/laminated
LCM	-	lost circulation material
LIG/Lig	-	lignite/lignitic
lns	-	lens(es)
L(RV)	-	low reflecting vitrinite
LST	-	limestone
lt	-	light
mass	-	massive
MDST	-	mudstone
med	-	medium
MET	-	metamorphic rocks
mic	-	mica/micaceous
micr	-	micritic
min	-	mineral
mnr	-	minor
mod	-	moderate
mtl	-	mottled
n-	-	normal
NA	-	not available
nod	-	nodule/nodular
NS	-	no sample
occ	-	occasional
ol	-	olive
ool	-	oolitic
orng	-	orange
OS	-	oil stain
P	-	picked lithology
pal	-	pale
Ph	-	phytane
pnk	-	pink
por	-	porous/porosity
pp	-	purple
Pr	-	pristane
pred	-	predominantly
Prt	-	present
PYR/pyr	-	pyrite/pyritic
QTZ(T)	-	quartz(ite)
Re	-	resin
R(ew)	-	reworked
rnd	-	round(ed)
Sap	-	sapropel
sbng	-	subangular
sbrd	-	subrounded
SCI	-	spore colour index
Sf	-	semifusinite
sft	-	soft
SH	-	shale
shly	-	shaly
sil	-	siliceous
sks	-	slickenside surface
SLA	-	slate
SLT(ST)	-	silt(stone)
slty	-	silty
SND	-	sand
sndy	-	sandy
Sp	-	spores
SST	-	sandstone
st	-	stained
stks	-	streaks
suc	-	sucrosic
surf	-	surface
SWC	-	side wall core
TD	-	total depth
TOC	-	total organic carbon
tr	-	trace(s)
trns	-	transparent
v	-	very
vgt	-	variegated
Vit	-	vitrinite
vn	-	vein
VOLC	-	volcanic rocks
VR	-	vitrinite reflectivity
wht	-	white
xln	-	crystalline
yel	-	yellow
-	-	no analysis carried out
*	-	analysed but no data obtained
gy-gn	-	greyish green
gy/gn	-	grey-green (gradation)
gn-gy	-	greenish grey

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

APPENDIX 2

Analytical Procedures and Techniques

APPENDIX 2

ANALYTICAL PROCEDURES AND TECHNIQUES

This appendix summarises the main steps in the analyses carried out in the Robertson Research International Ltd. petroleum geochemistry laboratories. Analytical pathways are shown on the flow chart (Appendix Figure 1) and details of laboratory procedures and techniques are given in the text. These may in certain circumstances be adapted to suit particular samples or conditions. Interpretation guidelines are also defined.

1. Sample Preparation

General

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

Kerogen Preparation

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

2. Maturity Evaluation

The techniques employed for interpreting maturity and thermal history in these laboratories are based mainly on spore colouration and vitrinite reflectivity measurement, supplemented by data obtained from airspace gas and gasoline analysis, pyrolysis Tmax, and hydrocarbon analysis including gas chromatography and gas chromatography-mass spectrometry.

Spore Colouration

Sporomorph colour is assessed using a >20μ sieved kerogen fraction viewed in transmitted light on a standard palynological microscope. Unusual hues are checked using incident blue/UV light fluorescence. Measurement is made by eye against reference sets of single grain spore mounts and trained operators achieve a high degree of accuracy and reproducibility. The 1 to 10 Spore Colour Index (SCI) scale was designed for linearity with increasing depth and temperature and correlates approximately with the following zones of oil generation: 1.0 to 3.5, immature; 3.5 to 5.0, early mature, generation of low gravity oils (28 to 35 °API); 5.0 to 7.0, middle mature, generation of medium gravity oils (35 to 42°API); 7.0 to 8.5, late mature, generation of light oils (>42°API) and condensates; 8.5 to 10, post mature, generation of condensate, wet gas and, ultimately, dry gas. Linearity of scale is of great value in prediction, by extrapolation, of the depth to any part of the oil generation sequence. The value of SCI measurement lies in the objective selection of measured grains, so minimising problems of caving and reworking, and in its more direct correlation against oil generation than vitrinite reflectivity measurement. Limitations in its use concern the difficulty of correlation against other colour scales and the insensitivity of the scale in the late to post mature region. Anomalous colours may result from bleaching or staining during deposition and diagenesis. The correlation of SCI against Thermal Alteration Index (TAI) given on the SCI versus depth plot in the reports was made by direct comparison of Staplin's standard slides with SCI standard slides.

Vitrinite Reflectivity

The majority of preparations examined under reflected light in these laboratories are made using >20μ sieved kerogen, mounted in resin blocks and polished with carborundum and alumina although total kerogen may be used when sample size is

limited. Picked coals, organic-rich shales or limestones containing solid bitumen are mounted directly in resin blocks and polished in the usual way. Measurement is made on a Leitz Orthoplan microscope fitted with an MPV Compact photometer which feeds values direct to a desk top computer for data processing from each sample. The system is calibrated against glass standards and reflectance values are expressed as arithmetic means of measurements taken in oil immersion (R_o or $R_{m\ oil}$). R_{max} and R_{min} may be measured and quoted in certain circumstances but the difference is insignificant below about R_o 1.0%. Some operator selection of particles during measurement is essential and obvious contaminants or non-vitrinitic material are noted but not necessarily quoted. The value quoted on data tables is that which is interpreted as most appropriate, but other possibilities may also be given. Plotted figures assume a logarithmic increase of reflectance with depth. R_o 0.5% is a widely accepted threshold value for the onset of oil generation, although as the kinetics of oil generation may not be identical to those of vitrinite reflectivity development this must be seen only as a general guide. The floor for oil generation is characterised by a reflectance value of about 1.3%. Wet gas generation peaks at a value of about 1% and ceases at the 2% level. Dry gas generation peaks at a reflectance of about 1.5% and ceases at the 3% to 4% level. Correlation of reflectance values with other maturity parameters may not be universal because of time-temperature factors and is best made on a local basis.

Reflectivity measurement is a widely used and versatile tool which may be readily calibrated against easily obtained standards. It is applicable over a wide range of maturity stages from immature to post mature (0.2% to 5% R_o). High surface intercepts on plotted figures and discordances at faults and unconformities can give realistic estimates of the amount of section missing. It is of limited value in Early Palaeozoic sections where land plant material is absent, although a general guide to maturity may be obtained from chitinous organic matter. Even a skilled operator may have difficulty in distinguishing indigenous vitrinite from some forms of inertinite, anomalously reflecting "pseudovitrinite", cavings and reworked fragments.

Airspace Gas Analysis

Wet cuttings are collected at the well site and sealed in partly full cans containing bactericide. In the laboratory, the airspace (headspace) gas is extracted using a can piercer fitted with a septum and analysed by gas chromatography. The proportions of methane, ethane, propane, iso- and n-butane are calculated from integrated peak areas by comparison with a standard mixture of these gases. Methane is the dominant gas in immature and post mature sediments, comprising 90-100% of total gas, falling to 30-70% in mature sediments. The onset of maturity for oil generation (SCI 3.5) is characteristically marked by an increase in wet gas (C_2-C_4) to between 10 and 20% with further increases in maturity indicated by a decrease in the ratio of iso- to n-butane. Ratios of >1.0 are typical for immature sediments and <0.5 are usual in mature sediments. Departures from composition versus depth trends may be useful in indicating migrant gas at faults, unconformities or reservoir rocks but limit the method as a reliable maturity indicator. Airspace gas analysis is an inexpensive and rapidly executed method of screening samples for further maturity and hydrocarbon content determinations.

Gasoline Analysis and Cuttings Gas Analysis

Cuttings samples received wet, preferably in sealed containers, are suitable for gasoline and cuttings gas analysis. A portion of the washed cuttings sample is retained wet, pulverised in a sealed shaker and warmed to expel the C_1 to C_7 hydrocarbon components into the shaker airspace. A sample of this airspace gas is then removed and analysed by gas chromatography either for cuttings gas (C_1 to C_4) or gasolines (C_4 to C_7). Up to 28 hydrocarbon components are identified in the C_4 to C_7 range and their relative proportions calculated from integrated peak areas with reference to standard mixtures. Immature source rocks yield low total abundances and limited numbers of components whereas mature source rocks usually contain a full complement of identified hydrocarbons with the onset of maturity indicated by a rapid rise in total gasoline abundances with depth. Anomalous amounts of gasolines may mark the presence of oil stain. Gasolines may be used in oil to oil or oil to source rock correlations but the concentration of some of the measured components is not only a function of source but also depends on maturity, migration and alteration in the reservoir. Using the most stable compounds, pairs with similar chemical structure and boiling points are reduced to pair ratios and compared with the same pair ratios in other oils or possible source rocks. Gasoline analysis is a valuable tool in that it measures directly the hydrocarbons being generated from a sediment but its sensitivity in detecting traces of oil places constraints on its use as a maturity indicator.

Rock-Eval Pyrolysis, Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) in Maturity Analysis

These three analytical processes measure parameters which are functions of both maturity and kerogen type. Data from them may give a general guide to maturity but if the kerogen types are known, more specific conclusions may be drawn. From Rock-Eval data, the temperature of maximum rate of pyrolysis, Tmax, is the most useful datum; gas chromatograms of alkanes, separated from source rock extracts or oils, yield carbon preference indices (CPI) and isoprenoid ratios; GC-MS quantitative fragmentograms provide abundance ratios for specific compounds which are particularly useful in assessing the level of maturity at which source rock hydrocarbons or oils have been generated. All these supplementary data may be used to confirm results from visual analysis or supplant them if poor or unavailable.

3. Source Rock Evaluation

Total Organic Carbon Content (TOC)

Organic carbon values are obtained by treating 0.1g of crushed rock sample with hot, concentrated HCl to remove carbonates. The washed residue is filtered on to a glass fibre pad and ignited in a Leco carbon analyser. For screening purposes, samples are analysed singly but where further analyses, such as pyrolysis or solvent extraction are anticipated, a duplicate sample is run. Blanks and standards are run as routine and where values from duplicated samples do not concur within strict accuracy limits, they are rerun. Where samples are heavily stained with oil, either from natural deposits or drilling mud, TOC is repeated on the dried, solvent extracted sample.

TOC measurement is fundamental in assessing source rock quality since when combined with kerogen type and maturity, a full description of the potential to generate oil may be given. It is found in practice that sediments containing less than 0.3% TOC are unlikely to have any source potential, those containing between 0.3% and 1% may be marginal sources but the better quality sources contain in excess of 1% TOC. Screening by TOC is therefore an inexpensive and rapid method of selection of samples for further analysis in source potential evaluation.

Rock-Eval Pyrolysis

Pyrolysis data are obtained using the IFP-Fina Rock-Eval apparatus. 100 mg of crushed, whole rock either from bulk sample or picked lithology is weighed accurately into a crucible and introduced into a furnace at 250°C. Free hydrocarbons (roughly equivalent to solvent extractable hydrocarbons) are volatilised and quantified by flame ionisation detector (FID) to give Peak 1 (S_1, ppm). The furnace temperature is increased to 550°C at 25°C/minute and within this range, kerogens crack to give hydrocarbons, measured by FID to give Peak 2 (S_2, ppm) and carbon dioxide, measured by thermal conductivity detector (TCD) to give Peak 3 (S_3, ppm). The temperature at the maximum rate of evolution of cracked volatiles (Tmax) is measured automatically but can also be monitored visually. The instrument is calibrated daily using standards both at the beginning of the work period and at regular intervals thereafter and crucible blanks are run as routine. The tabulated data in reports comprise the following parameters:

Tmax °C - temperature of maximum rate of Peak 2 hydrocarbon evolution.

Hydrogen Index (HI) - S_2/TOC (mg/g) or ratio of released hydrocarbon to organic carbon content. This is a measure of the hydrocarbon generating potential remaining in the kerogen as opposed to that of the whole rock.

Oxygen Index (OI) - S_3/TOC (mg/g) or ratio of released carbon dioxide to organic carbon content.

Production Index (PI)- S_1/S_1+S_2, or ratio of the amount of hydrocarbons released in the first stage of heating to the total amount of hydrocarbons released and cracked during pyrolysis.

Potential Yield (PY) - S_2 (ppm) or total of hydrocarbons released during cracking of kerogen compared to original weight of rock.

Tmax, hydrogen index and oxygen index are each functions of both maturity and kerogen type. Using published and empirical data, it has been possible to assemble a model to show the relationships of these factors to maturity as measured by spore colouration and vitrinite reflectivity for a selection of pure kerogen types. The kerogen types used are algal sapropel (type I), waxy sapropel (type II), vitrinite (type IIIA) and inertinite (type IIIB) and a computer program has been devised by which the amounts of these components may be calculated from the HI, OI, Tmax and maturity

data for any sample. These are the values expressed in the "kerogen composition by calculation" columns tabulated in the reports.

The hydrogen index is a measure of the hydrocarbon generating potential of the kerogen and is analogous to the atomic H/C ratio. Immature, organically rich source rocks and oil shales give values above 500, mature oil source rocks give values between 200 and 550. For a given kerogen type, these values progressively diminish with increasing maturity.

The temperature of maximum rate of pyrolysis depends partly on the kerogen type but the transition from immature to mature organic matter is marked by temperatures between 415° and 435°C. The maturity transition from oil and wet gas generation to dry gas generation is marked by temperatures between 455° and 460°C. In practice, greater variation than these ideal temperature ranges may be seen, but they are nevertheless useful as general guides to the level of maturity attained by the sediment.

The production index increases with maturity from values near zero for immature organic matter to maximum values of 0.15 during the late stages of oil generation. Anomalously high values indicate the presence of oil or contaminants. The potential yield is an indication of the predicted yield of hydrocarbons from the source rock at optimum maturity and is a measure of the quality of the source rock. For immature sediments, values of 0 to 2000 ppm of hydrocarbon characterise a poor source rock, 2000 to 6000 ppm fair, 6000 to 20 000 ppm good and above 20 000 ppm very good.

Pyrolysis techniques have in recent years provided a major advance in the assessment of source rock quality and generating potential. Hydrocarbon yields from immature source beds examined on-structure may be translated into actual oil productivity from the same beds in mature basinal, off-structure situations. Models relating maturity and kerogen type may be used to define original source rock quality grades which are of great value in mapping organic facies. Amorphous kerogen types, indistinguishable in microscopic preparations over a wide range of chemical properties, may be readily differentiated by pyrolysis. The problem of analysing bulk samples containing mixed kerogens has been largely overcome by the kerogen type/maturity model and anomalous results arising from the presence of caving contamination and drilling mud additives can usually be explained by inspection. High oxygen indices sometimes occur as a result of the presence of metastable carbonates and in such cases the sample is acid decarbonated and re-run.

Visual Examination of Kerogen Concentrates

All palynological preparations on which SCI determinations are made are also examined for kerogen type. Visual estimations of the relative abundance of the broad groups vitrinite, inertinite and sapropel are made on the total kerogen slide mount but reference is also made to the >20μ sieved fraction to assist in identification. The scheme of identification is shown in Appendix Table 1. Full use is made of incident blue or UV light in distinguishing immature or early mature oil-prone kerogen from gas-prone kerogen.

Extract Analysis

The soluble organic materials present in rocks can be extracted with organic solvents, fractionated and analysed. The type and amount of material extracted depends largely upon the nature of the contained kerogen and its maturity, although the presence of migrant oil or drilling contamination may be the determining factors.

A maximum of 40g of crushed sample is extracted for a minimum of 12 hours in a Soxhlet apparatus using laboratory redistilled DCM. The solvent and the more volatile components (approximately up to $\underline{n}$-C_{15}) are lost by evaporation in an air flow and the resulting total extract is weighed, dissolved in hexane and separated into alkane (saturate) hydrocarbon, aromatic hydrocarbon, resene and asphaltene (polar) fractions by silica adsorption chromatography in the Iatroscan process.

Larger fractions, suitable for further analysis, are obtained by column chromatography. The extract is run through a short glass column packed with silica and alumina and eluted with hexane (to give the saturate fraction), (3:1 hexane: toluene mixture (to give the aromatic fraction) and methanol (to give the polar, or resene and asphaltene, fraction). A small proportion of non-eluted polar compounds usually remains on the column.

The data tabulated in reports comprise the following parameters:

Total extract - soluble organic matter, heavier than about $\underline{n}$-C_{15+}, expressed as ppm of weight of rock.

Hydrocarbons - sum of alkane and aromatic hydrocarbons, expressed as ppm of weight of rock.

Extract % of organic carbon (EPOC) - $\frac{\text{total extract ppm}}{\text{TOC x 100}}$; the extractability.

Hydrocarbons mg/g of organic carbon - total hydrocarbons normalised to 1g of organic carbon.

Hydrocarbons % extract - total hydrocarbons as a proportion of total extract.

Alkanes % hydrocarbons - the proportion of alkanes (saturates) in the total hydrocarbons. The proportion of aromatics is (100 minus this value) expressed as a percentage.

The extractability of oil-prone sapropelic organic matter increases rapidly in the oil generation zone and diminishes to very low values in post mature sediments. Overall the extractability of sapropelic organic matter is greater than that of gas-prone humic organic matter for similar levels of maturity. Samples with extractabilities of greater than 20% generally contain migrant oil or are contaminated with mud additives.

As maturation proceeds in the oil generation zone the proportion of hydrocarbons in the total extract increases from less than 20% to a maximum in the most productive horizons of around 60%. This trend is reversed as the oil-condensate zone is entered. The relative proportions of alkanes to aromatics can be used as a check for low levels of contamination. Fractions of the extract, separated by column chromatography are retained for further analysis by gas chromatography or for stable carbon isotope determination.

Capillary Gas Chromatography of C_{15+} Alkanes

A portion of the Soxhlet extract is eluted with hexane through a short silica column to yield the saturate hydrocarbon fraction. This fraction is evaporated in a stream of dry nitrogen at room temperature. A small portion of the fraction is then taken up in hexane and introduced into a 25 metre, wall-coated, open tubular glass capillary column coated with OV-1, or equivalent, mounted in a Carlo Erba gas chromatograph which is temperature programmed from 70°C to 270°C at 3°C/minute.

C_{15+} chromatograms are inspected for the distributions of $\underline{n}$-alkanes, and the presence and abundance of isoprenoids (particularly pristane and phytane), steranes and triterpanes and unresolved envelopes of naphthenic compounds. The ratios pristane:phytane and pristane:$\underline{n}$-C_{17} are calculated. Carbon Preference Index (CPI) values quoted are those as defined by Philippi as the ratio $2C_{29}$ to $(C_{28}+C_{30})$ unless otherwise stated. Chromatography may reveal information about the kerogen type of the source rock, its maturity and condition of deposition and, if migrant oil is present, whether this has been water-flushed or biodegraded. Contaminant drilling mud additives may be identified.

Capillary Gas Chromatography of Aromatic and Branched/Cyclic Alkanes

The aromatic portion of the Soxhlet extract is eluted from a short silica/alumina column by a hexane/toluene mixture. The dried fraction is taken up in DCM and introduced into a 25 metre, wall-coated, open tubular glass capillary column coated with OV-1, or equivalent, mounted in a Carlo Erba gas chromatograph which is temperature programmed from 70°C to 270°C at 3°C/ minute.

Branched chain alkanes are separated from normal alkanes by urea adduction and treated as for total alkanes.

Gas Chromatography-Mass Spectrometry

Mass spectrometry is a technique in which molecules are bombarded with high energy electrons causing ionisation and fragmentation of the molecules into ions of varying mass(m) and charge(z). The way in which a molecule fragments into ions of various m/z value is known as its fragmentation pattern, or mass spectrum and is unique. When linked to a gas chromatograph the mass spectrometer can be used in two different modes:

1. Full Scan Mode: A mass spectrum is obtained of each peak eluting from the gas chromatograph and a structural identification of the compound producing that peak can be made.

2. Multiple or Single Ion Monitoring Mode: The mass spectrometer is tuned to certain m/z values to detect whether a compound, eluting from the gas chromatograph, fragments to give an ion at that value. Certain fragmentations are indicative of specific compound types and the most commonly monitored fragment ions used in petroleum geochemistry are those with m/z values of 191, 217 and 259 which are the principal fragment ions obtained from groups of alkanes known as triterpanes, regular steranes and rearranged steranes respectively. These are compounds containing 27 to 35 carbon atoms arranged in a polycyclic, normally 4 or 5 ring, structure, occurring in the $\underline{n}$-C_{26} to $\underline{n}$-C_{35} region of a gas chromatogram. The basic molecular skeletons of these compounds are very similar to those of the original organic matter deposited in the sediment and so these 191, 217 and 259 distribution plots, known as mass fragmentograms or mass chromatograms, form a pattern characteristic of the source material. This technique of "fingerprinting" is also one of the more exact methods of correlating an oil to its source, or to another oil.

Carbon Isotope ($^{13}C/^{12}C$) Ratio Analysis

Carbon has two stable isotopes, the more abundant ^{12}C isotope and the heavier ^{13}C isotope, which in nature forms about 1% of carbon. Deviations from the $^{13}C/^{12}C$ ratio are extremely small and carbon isotope ratios, as measured by mass spectrometry, are expressed as deviations from a standard, the Pee Dee Belemnite carbonate (PDB standard) in parts per thousand (parts per mil; $^{o}/oo$). Positive deviations indicate ^{13}C enrichment and conversely, negative deviations indicate ^{13}C impoverishment.

While the carbon isotope ratios of oils and rock extracts can range from -20 to -32 $^{o}/oo$ depending on the source organic matter type, the difference between a specific oil and its source is small. Measurements are usually made on the C_{15+} alkane and aromatic hydrocarbon fractions separately and there should be no more than 1 $^{o}/oo$ difference between the oil and its source for either fraction. If there is any doubt that the source rock extracts are not indigenous to the source rock kerogen, the carbon isotope ratio of the extracted source rock kerogen can be measured.

Pyrolysis-Gas Chromatography

The hydrocarbon pyrolysate derived from thermal, anhydrous cracking of kerogen is analysed by capillary gas chromatography. A few mg of rock, kerogen or asphaltene is heated to 600°C for 20 seconds in the injector of a gas chromatograph. The chromatograph oven is kept at -30°C during pyrolysis and then raised to 300°C at a programmed rate of 7.5°C/minute. Chromatograms produced this way are often very different from those of source rock extracts or oils in that branched and cyclic isomers are generated freely giving numerous, closely spaced peaks, along with unsaturated, alkene (olefin) hydrocarbons. The "doublet" peaks often observed in these chromatograms comprise alkene-alkane pairs, the first eluting, and usually smaller peak, being the alkene. The chromatograms range from C_1 to C_{30} or above and although variable, are broadly characteristic of source rock type. Gas-prone kerogen cracks to give a more limited molecular weight range of products, concentrated towards the light ends, whereas oil-prone kerogen gives more prominent alkene-alkane doublets in the C_{12} to C_{30} region. The largest peak from both types is usually methane.

Elemental Analysis

Total (unsieved) kerogen is prepared as described in Section 1. The dried material is combusted in oxygen in an elemental analyser and the oxides of carbon, hydrogen, nitrogen and sulphur are measured. The unburnt residue is the ash content. Oxygen is usually calculated by difference but can be determined separately if required. Results are quoted as percentage weights of C, H, O, N, S and Ash with the atomic ratio H/C and O/C calculated and plotted on the standard van Krevelen diagram. The relative amounts of C, H and O present in organic matter are dependent on both source and maturity. At known maturity levels, some measure of source quality may be determined. Limitations of the method in source rock assessment involve the difficulty of obtaining pure kerogen (in particular, free from pyrite) and the lack of a simple, direct determination of oxygen content.

4. Oil Analysis

RRI laboratories offer a wide range of oil analyses both for geochemical purposes and industrial use. Physical property determinations are based mainly on IP methods and are available for lubricating oils, fuels and greases as well as crudes. Frequently measured properties of crude oils presented in geochemistry reports include: API gravity, pour point, viscosity and contents of water, sulphur, wax, asphaltene, nickel, vanadium and other metals. Chemical analysis of oils involves the following:

Whole oil gas chromatography - using split syringe injection and a temperature programme from -20°C or -30°C up to 270°C at 4°C/minute.

Associated gas - if oil has high gas/oil ratio.

Gasoline analysis - as for gasolines in rock samples but a weighed quantity of oil is used.

Topping of the oil - this is equivalent to the removal of the fraction boiling below about 210°C and gives a more standardised product for comparison of gas chromatograms of the C_{15+} fraction.

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

5. Gas Analysis

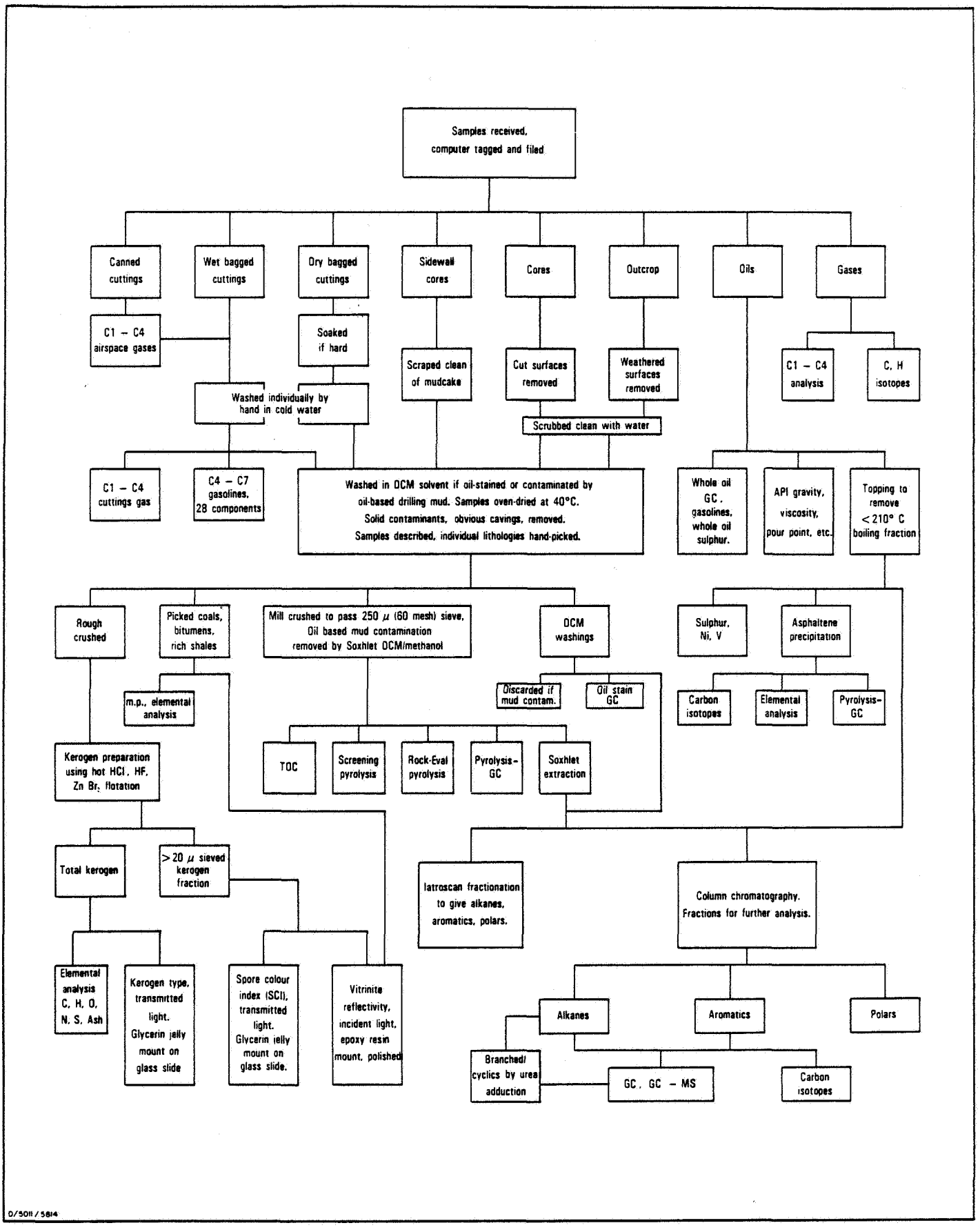
The hydrocarbon gases, C_1 to C_4, may be collected from the airspace of sealed canned samples or may be received from well-site tests in a special sealed gas cylinder (gas mouse). Chromatographic separation of the C_1 to C_4 gases is effected as described under airspace gas analysis. In addition, the separated gas components may be analysed for stable carbon and hydrogen isotope composition which may provide valuable clues to the origin of the gas.

6. Solid Bitumen Analysis

In some oil fields, problems are encountered where bitumen developments form continuous or patchy layers within reservoirs, dividing the pay zones and acting as barriers to natural fluid movement or inhibiting enhanced oil recovery techniques. Integrated geochemical and sedimentological studies aim to produce geological models capable of predicting the occurrence of bitumen layers and their likely thickness and ability to act as permeability barriers. Of further concern are the past or present relationships between the bitumen and reservoired oil, their source rocks and the timing of bitumen formation.

Analysis schemes involve screening of samples by assessing the amount of bitumen in polished core pieces using reflected light microscopy, followed by solvent extraction of control samples to estimate the proportion of solvent soluble bitumen. Different phases of bitumen formation are differentiated by reflectance measurement as described for vitrinite reflectance measurement. Soluble extracts are fractionated to give alkane, aromatics, asphaltene and resene components. Separated bitumens may be subjected to elemental analysis.

FLOW CHART FOR GEOCHEMICAL ANALYSIS



APPENDIX FIGURE 1

APPENDIX 3

Index of Alkane Molecular Biomarker GC-MS Peak Assignments

STERANES

5β(H)14α(H)17α(H) and 5α(H)14α(H)17α(H) C_{27}, C_{28} and C_{29} regular steranes and 5α(H)14β(H)17β(H) C_{27}, C_{28} and C_{29} isosteranes

Peak	Assignment
S27a	C_{27} 5β(H)14α(H)17α(H) 20R cholestane
S27c	C_{27} 5α(H)14α(H)17α(H) 20S cholestane
S27d	C_{27} 5α(H)14β(H)17β(H) 20R isocholestane
S27e	C_{27} 5α(H)14β(H)17β(H) 20S isocholestane
S27b	C_{27} 5α(H)14α(H)17α(H) 20R cholestane
S28a	C_{28} 24-methyl-5β(H)14α(H)17α(H) 20R cholestane
S28c	C_{28} 24-methyl-5α(H)14α(H)17α(H) 20S cholestane
S28d	C_{28} 24-methyl-5α(H)14β(H)17β(H) 20R isocholestane
S28e	C_{28} 24-methyl-5α(H)14β(H)17β(H) 20S isocholestane
S28b	C_{28} 24-methyl-5α(H)14α(H)17α(H) 20R cholestane
S29a	C_{29} 24-ethyl-5β(H)14α(H)17α(H) 20R cholestane
S29c	C_{29} 24-ethyl-5α(H)14α(H)17α(H) 20S cholestane
S29d	C_{29} 24-ethyl-5α(H)14β(H)17β(H) 20R isocholestane
S29e	C_{29} 24-ethyl-5α(H)14β(H)17β(H) 20S isocholestane
S29b	C_{29} 24-ethyl-5α(H)14α(H)17α(H) 20R cholestane

Configurations:

a 5β(H)14α(H)17α(H) 20R (immature or biological configuration)
b 5α(H)14α(H)17α(H) 20R (regular or normal sterane)
c 5α(H)14α(H)17α(H) 20S (regular or normal sterane)
d 5α(H)14β(H)17β(H) 20R (isosterane)
e 5α(H)14β(H)17β(H) 20S (isosterane)

Notes:

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

C_{30} 4-desmethylsteranes have been indentified and are considered to be biological markers for marine organic material; however, these compounds cannot be differentiated from C_{30} 4-methylsteranes without metastable ion monitoring (GC-MS-MS). C_{30} 4-desmethylsteranes occur with 5α(H)14α(H)17α(H) 20R and 20S and 5α(H)14β(H)17β(H) 20R and 20S (isosterane) configurations.

REARRANGED STERANES (DIASTERANES)

13β(H)17α(H) and 13α(H)17β(H) C_{27}, C_{28} and C_{29} rearranged steranes

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

Configurations:

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

Notes:

All rearranged steranes listed are likely to be 24R and 24S epimers which, with the exception of C_{28} 24-methyl-13β(H)17α(H) diacholestanes, cannot normally be separated with the chromatography conditions used.

The C_{29} 24-ethyl-13β(H)17α(H) 20S diacholestane co-elutes with the C_{27} 5α(H)14β(H)17β(H) 20R isocholestane and the C_{29} 24-ethyl-13α(H)17β(H) 20R diacholestane co-elutes with the C_{28} 24-methyl-5α(H)14β(H)17β(H) 20R isocholestane under normal chromatography conditions.

C_{30} rearranged steranes also occur, with 13β(H)17α(H) 20R and 20S and 13α(H)17β(H) 20R and 20S configurations.

METHYLSTERANES

4α(H) and 4β(H) C_{28}, C_{29} and C_{30} methylsteranes

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

Configurations:

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

TRIC ent

Peak ricyclic terpane
tricyclic terpane
t_{19} tricyclic terpane
t_{20} / $_{22}$ tricyclic terpane
t_{21} / $_{23}$ tricyclic terpane
t_{2} / C_{24} tricyclic terpane
t_2 C_{25} tricyclic terpane
t_2 C_{26} tricyclic terpanes
t C_{27} tricyclic terpanes
t C_{28} tricyclic terpanes
C_{29} tricyclic terpanes
C_{30} tricyclic terpanes

C_{28}, C_{29} and C_{30} tricyclic terpanes occur as isomeric (at C-22) C_{22} and tricyclic terpanes are generally less abundant, suggesting branching at ese positions. Tricyclic terpanes of higher molecular weight, up to C_{40} and igher, have been identified, but are unusual.

TETRACYCLIC TERPANES

Seco-17,21-hopanes

Peak	Assignment
T24	C_{24} tetracyclic terpane
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} 17α(H)21β(H) and 17β(H)21β(H) hopane and 17β(H)21α(H) moretane series

C_{27} and C_{29} to C_{35} 17α(H)21β(H) hopane series

Peak	Assignment
h27s	C_{27} 18α(H)-22,29,30-trisnorneohopane (Ts)
h27m	C_{27} 17α(H)-trisnorhopane (Tm)
h29	C_{29} 17α(H)21β(H)-30-norhopane
h30	C_{30} 17α(H)21β(H)-30-hopane
h31S	C_{31} 17α(H)21β(H)-30,31-homohopane 22S
h31R	C_{31} 17α(H)21β(H)-30,31-homohopane 22R
h32S	C_{32} 17α(H)21β(H)-30,31-bishomohopane 22S
h32R	C_{32} 17α(H)21β(H)-30,31-bishomohopane 22R
h33S	C_{33} 17α(H)21β(H)-30,31-trishomohopane 22S
h33R	C_{33} 17α(H)21β(H)-30,31-trishomohopane 22R
h34S	C_{34} 17α(H)21β(H)-30,31-tetrakishomohopane 22S
h34R	C_{34} 17α(H)21β(H)-30,31-tetrakishomohopane 22R
h35S	C_{35} 17α(H)21β(H)-30,31-pentakishomohopane 22S
h35R	C_{35} 17α(H)21β(H)-30,31-pentakishomohopane 22R

C_{27} and C_{29} to C_{35} 17β(H)21α(H) moretane series

Peak	Assignment
m29	C_{29} 17β(H)21α(H)-30-normoretane
m30	C_{30} 17β(H)21α(H)-30-moretane
m31	C_{31} 17β(H)21α(H)-homomoretane
m32	C_{32} 17β(H)21α(H)-bishomomoretane

C_{27} 17β(H) and C_{29} to C_{35} 17β(H)21β(H) hopane series

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

Notes:

C_{29} to C_{35} pentacyclic triterpane (hopane) series of compounds have been identified with 17α(H)21β(H) (hopane), 17β(H)21α(H) (moretane) and 17β(H)21β(H) (hopane) configurations.

C_{27} trisnorhopanes have no side-chain at C-21 and have either the 17α(H) or the 17β(H) configuration, the former being the more thermally stable and the latter form generally present in immature samples only. The the C_{27} 18α(H)-trisnorneohopane (T_s) is more thermally stable than C_{27} 17α(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).

OTHER PENTACYCLIC TRITERPENOIDS

Peak	Assignment
T	C_{27} 17α(H)18α(H)21β(H)-25,28,30-trisnorhopane
Tm	C_{27} 17β(H)18α(H)21α(H)-25,28,30-trisnormoretane
B	C_{28} 17α(H)18α(H)21β(H)-28,30-bisnorhopane
Bm	C_{28} 17β(H)18α(H)21α(H)-28,30-bisnormoretane
G	C_{30} gammacerane
O	C_{30} 18α(H) oleanane
J	C_{30} 18β(H) oleanane ("compound J")
L	C_{30} lupane
Y	C_{27} triterpane (structurally unelucidated)
X	C_{30} triterpane (structurally unelucidated)

Notes:

The C_{30} 18α(H) oleanane and 18β(H) oleanane (formerly "compound J" of Grantham) coelute on standard GC columns.

The structurally unidentified C_{27} and C_{30} pentacyclic terpanes are peaks Y and X, respectively, of Philp and Gilbert (1986).

NUCLEAR DEMETHYLATED HOPANES and NUCLEAR DEMETHYLATED MORETANES

C_{26} and C_{28} to C_{34} 17α(H)21β(H)-25-norhopanes and 17β(H)21α(H)-25-normoretanes

Peak	Assignment
dh26s	C_{26} 18α(H)-22,25,29,30-tetrakisnorneohopane
dh26m	C_{26} 17α(H)-22,25,28,30-tetrakisnorhopane
dh28	C_{28} 17α(H)21β(H)-25,30-bisnorhopane
dm28	C_{28} 17β(H)21α(H)-25,30-bisnormoretane
dh29	C_{29} 17α(H)21β(H)-25-norhopane
dm29	C_{29} 17β(H)21α(H)-25-normoretane
dh30R	C_{30} 17α(H)21β(H)-25-norhomohopane 22S
dh30S	C_{30} 17α(H)21β(H)-25-norhomohopane 22R
dh31R	C_{31} 17α(H)21β(H)-25-norbishomohopane 22S
dh31S	C_{31} 17α(H)21β(H)-25-norbishomohopane 22R
dh32R	C_{32} 17α(H)21β(H)-25-nortrishomohopane 22S
dh32S	C_{32} 17α(H)21β(H)-25-nortrishomohopane 22R
dh33R	C_{33} 17α(H)21β(H)-25-nortetrakishomohopane 22S
dh33S	C_{33} 17α(H)21β(H)-25-nortetrakishomohopane 22R
dh34R	C_{34} 17α(H)21β(H)-25-norpentakishomohopane 22S
dh34S	C_{34} 17α(H)21β(H)-25-norpentakishomohopane 22R

Notes:

Nuclear demethylated hopanes are biological markers for severe bacterial degradation. 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 unusual and are indicative of the severest levels of biodegradation. C_{25}, C_{27}, C_{28} and C_{29} demethylated tricyclic terpanes occur as isomeric (at C-22) pairs.