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RESEARCH CENTRE

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EXPLORATION AND PRODUCTION DIVISION

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THE PETROLEUM GEOCHEMISTRY OF ROCK CUTTINGS AND SIDE-WALL CORE MATERIAL FROM THE NORTH SEA (NORWEGIAN SECTOR) WELL : NOCS 16/8-2

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SUMMARY

A geochemical survey was undertaken on 40 sediment samples over the depth interval 1690 to 2254m (Early Tertiary to Late Jurassic) for the offshore Norwegian well NOCS: 16/8-2. Poor maturity trends were encountered, but it was established that all sediments examined down to the top of the Permian salt were immature for oil generation. In general, insignificant to poor source-rock potentials were observed for all the sediments examined with the exception of those which lay within the carbonaceous mudstone beds of the Cretaceous Kimmeridge Clay Formation (2191 to 2235m). Here were encountered sediments of good to excellent source potential which were predominantly oil prone.

A total of 40 sediment samples comprising of 17 cuttings and 23 side-wall cores were examined for this geochemical study. These sediments were all within the depth interval 1690 to 2254m as requested (1), and covered ages ranging from Early Tertiary down to the Late Jurassic (just above the Jurassic mudstone/ Permian salt stratigraphic unconformity).

Although predominantly mudstones, most sediments examined contained very low amounts of autochthonous vitrinite on which to make reflectance measurements. In addition, inertinite and reworked material were common. Many of the deeper sediments contained significant amounts of bitumen as wisps, and as staining. As a result, Vitrinite Reflectance values were too widespread to give a valid linear regression correlation with depth. Autochthonous vitrinite Ro values did indicate however, that the Oil Generation Threshold (OGT) had not been reached before the Permian salt beds (Table 1). Visual Kerogen sporomorph colour estimations agreed with this conclusion, the deepest three sediments examined having kerogen spore colours rated as "3" i.e. immature (Tables 2 and 2A). Although unrealistic to quôte an OGT value at this location because of the Upper Jurassic/Permian unconformity at 2254m, if the observed degree of diagenesis continued the OGT would not have been expected before approximately 2800 - 3000m.

Visual Kerogen observations (Tables 2 and 2A) also indicated the presence of a general zero source potential for sediments of Early Tertiary down to Early Cretaceous - Valanginian (Cromer Knoll Gp.) age. Exceptions were poor oil prone kerogens at 1690 - 1720m and poor-moderate oil prone kerogens at 1990 - 2020m. In contrast, sediments examined within the carbonaceous Lower Cretaceous - Upper Berriasian (Kimmeridge Clay Fm) beds were shown to contain good oil prone kerogens.

A more detailed Pyrolysis investigation (Table 3) confirmed these suggestions with zero, or at best insignificant source potentials for sediments examined between 1690 and 2185m (Early Tertiary to the older Cromer Knoll Gp. sediments). Sediments of the Kimmeridge Clay Formation down to 2235m all had very good to excellent (MAX* 25 to 150) petroleum source potentials, while those just below from 2236 to 2254m (Late Berriasian/Oxfordian) returned to a zero/insignificant source potential once again. Kimmeridge Clay Formation sediments were investigated further by Pyrolysis-Gas Chromatography (PGC) and were all found to be oil prone, Gas-Oil Generation Indices (GOGI's) ranged between 0.2 and 0.15. Source potential for oil ranged from very good to excellent (MAX* 22 to 130) while that for gas was from moderate to very good (MAX* 3.6 to 20). Kerogen pyrolysate distributions were of the "oil" type and were low in paraffin abundance (Figures 1-5). Relatively low thermal volatilate (P1) abundances in relation to their corresponding kerogen pyrolysates (P2) (i.e. P1/(P1 + P2) ratios of the order of only 2 - 5 per cent) supports the immaturity of the sediments within the Kimmeridge Clay Formation.

Since low source potentials were indicated for the majority of sediments the Soluble Extract Study was restricted to three sediment cuttings samples selected near the top (1720 - 1750 m), middle (2020 - 2050 m), and bottom (2200 - 2230 m) of the total depth interval examined. The deepest sediment was selected from within the Kimmeridge Clay Formation. As expected, minor, almost negligible amounts of soluble organic matter were extracted from the shallower two sediments which gave rise to low Generation Indices (TSE/TOC and SAC/TOC per mil ratios) with a marked odd-over-even carbon preference in agreement with their immaturity. An intense red-coloured extract was obtained from the 2200 - 2230 m sediment which a U.V. adsorption spectrum analysis showed to be due to a very large abundance of vanadyl porphyrins. Nickel porphyrins were also detected, but in far lower abundance. In addition the SAC fraction contained major proportions of steranes and triterpanes (Figure 6), which meant that a normal-alkane Carbon Preference Index (CPI) could not be calculated with any reliability. However, the normal-alkane distribution observed, together with the predominance of steranes/triterpanes did again suggest that the oil prone kerogen from which they were derived was immature.

The organic richness of the sediments examined were evaluated in terms of Total Organic Carbon (TOC %wt) contents (Table 4). All Tertiary to Lower Cretaceous (excluding the Kimmeridge Clay Fm.) mudstone sediments had poor to moderate (0.4 - 0.7 %wt) TOC's while the Upper Cretaceous limestones contained almost negligible amounts (0.1 - 0.05 %wt) of organic carbon. The lone sediment examined within the carbonaceous Kimmeridge Clay (2200 - 2230 m) had an excellent content of organic carbon (14.5 %wt). However, the presence of significant amounts of the coal maceral inertinite (as observed by reflected light microscopy) within most kerogens would tend to lessen the source potential suggested by these TOC values.

Kerogen stable carbon isotope ratios ($\delta^{13}C_{PDB-1}$ per mil) were determined for demineralised and demineralised-after-pyrolysed (at 500°C) sediment from 2200 - 2230 m. In addition, $\delta^{13}C_{PDB-1}$ ratios were determined for the pyrolysate and Total Soluble Extract (TSE) obtained from the same depth sediment. The carbon isotope result for the kerogen (Table 7) of -26.7 per mil implies that it is of marginal marine origin and which contains a high input of land-derived material. Such a sediment would usually be expected to generate oil with $\delta^{13} C_{PDB-1}$ ratios of around -28 to -29 per mil, ie, isotopically lighter. In this instance however, pyrolysate and TSE have ratios of only -26.5 and -26.0 resepectively, that is, marginally isotopically heavier. A possible explanation for this occurrence may be the very high content (90 per cent) of isotopically heavy aromatic and residue fractions in the TSE with a low content of isotopically light SAC.

An additional carbon isotope study was attempted on individual saturate, aromatic and residue fractions prepared by HPLC from a sample of pyrolysate. Unfortunately, there was insufficient saturate fraction material for an isotope analysis, but both the aromatic and residue fractions had isotope ratios determined at -25.4 per mil, which gives support for the kerogen being the source of the TSE. The kerogen pyrolysate distribution for this 2200 - 30 m sediment determined by PGC showed a large aromatic/naphthenic content (Figure 2). This is similar to results recently obtained for some East Midlands coal samples that are believed to have originated from a general brackish environment and it is likely that this sediment may have had a similar origin.

MAX* = Maximum theoretical hydrocarbon yield in kg/tonne

Reference

(1) Grange, A.M., BP Pet Dev Ltd, Norway, communication: AMG/lgn/665/1 651/4/80/16 12th September 1980.

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TABLE 1

VITRINITE REFLECTANCE DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH (m)	REFLECTANCE VALUES(%Ro)	COMMENTS
1690	.43(10)	L-MOD/DOM R+I/ONLY F V PAR (Y+Y/O)
1720	.41(1).6(1)	L/SML PAR I-COR+R/TWO V W PAR (Y)
1721	.41(3)	L/SML I+R PAR/V DOUBTFUL/F BW (Y/O+MID O)
1725	.45(14)	L-MOD/I+R PAR/F V PAR-TRUE?/OCC BW (LIGHT O)
1744	.4(2)	L/SML COR I SP+R PAR/TWO TRUE V SP (Y/O)
1748	.25(3).5(8)	L-MOD/R+I PAR/TR TRUE V+B (Y+Y/O)
1750	.7(2)	L/COR I+R PAR/ONLY TWO V PAR LOC/BW+BLEBS (Y/O)
1751	.53(4)	TR/F I+R PAR/F SP POSS TRUE V (Y/O)
1780	.49(1)	L/COR I SP+PAR/R/ONE V W PAR LOC (Y/O)
1840	0(0)	NDP (Y-FROM CARBONATE)
1870	0(0)	NDP (Y-FROM CARBONATE)
1950	.37(2)	TR/I+R PAR/TWO V SP LOC (LIGHT O)
1960	.56(2).76(4)	L-MOD/GN I+R PAR/TR V-TRUE? (LIGHT O)
1965	.39(2)	TR/I+R PAR/TWO V PAR LOC (NO FLUOR.)
1990	.41(5)	L-MOD/B BLEBS+W/DOM I+R/ONLY V TR (NO FLUOR.)
2007	.45(16)	MOD/I+R PAR/SUB V PAR+W (Y+Y/O)
2020	.54(15)	L-MOD/I+R PAR/F TRUE V W PAR/B BLEBS+W (Y/O)
2024	.45(5).22(1)	L-MOD/I+R PAR/V TR+ B PAR (LIGHT+MID O)
2050	.36(1).55(1)	L/I+R PAR/ONLY TWO V PAR LOC (Y)
2075	.38(12).66(1)	L-MOD/I+R PAR/SUB TRUE V (LIGHT O)
2080	.58(9).82(1)	L-MOD/DOM I+R PAR/F TRUE V PAR/BW (Y+Y/O)
2110	.62(3)	L/F I+R PAR/THREE POS TRUE V PAR LOC (Y+Y/O)
2130	.43(1).92(3)	TR-L/I+R PAR/LOWEST RO'S MEASURED-ONE TRUE? (Y/O)
2140	.5(6)	L/I+R PAR/TR TRUE V/F LGN FR-ADDITIVE? (Y/O+DP O)
2141	.58(1)	L/M I+R PAR+ONE V PAR-TRUE?? (NO FLUOR.)
2158	.64(2).37(8)	TR/SML V PAR+LGN/VAR RO-M R/NO I (NO FLUOR.)
2170	0(0)	NDP/L/I+R PAR ONLY (Y/O)
2182	.58(2)	BAR/F V+R PAR-CAVED? (Y+MID O+CARBONATE)
2185	.73(1).5(3)	TR/BW/F V PAR-VAR RO (Y/O)
2191	.43(21)	STR BS+W/L/SML V PAR-M R (Y/O)
2200	.48(15)	BS+W+BLEBS/L/I+R PAR/TR V W PAR (Y+Y/O)
2230	.62(4).33(2)	VAR BS/F PAR V+I BUT M R (Y+Y/O)
2231	.46(21)	B SATURATED/L/V+I PAR (Y/O)
2233	1.01(1).54(21)	HEAVY BS+W/L V-VAR RO/TR I (Y/O)
2235	.48(19).29(4)	OBS+W/L V+I PAR-VAR RO (Y/O+LIGHT O)
2236	.46(20)	MOD OBS/ L I+R PAR/F V+B PAR-NO W (Y/O)
2253	.44(11)	F BW/L I+V/LOW RO'S-SOME TRUE-SOME B? (Y/O+LT O)
2254	.74(8).47(1)	TR-L/V+I BUT M R (MID O)

FIGURES IN PARENTHESES INDICATE NUMBER OF READINGS
SEE LIST OF ABBREVIATIONS OVERLEAF

TABLE 1A

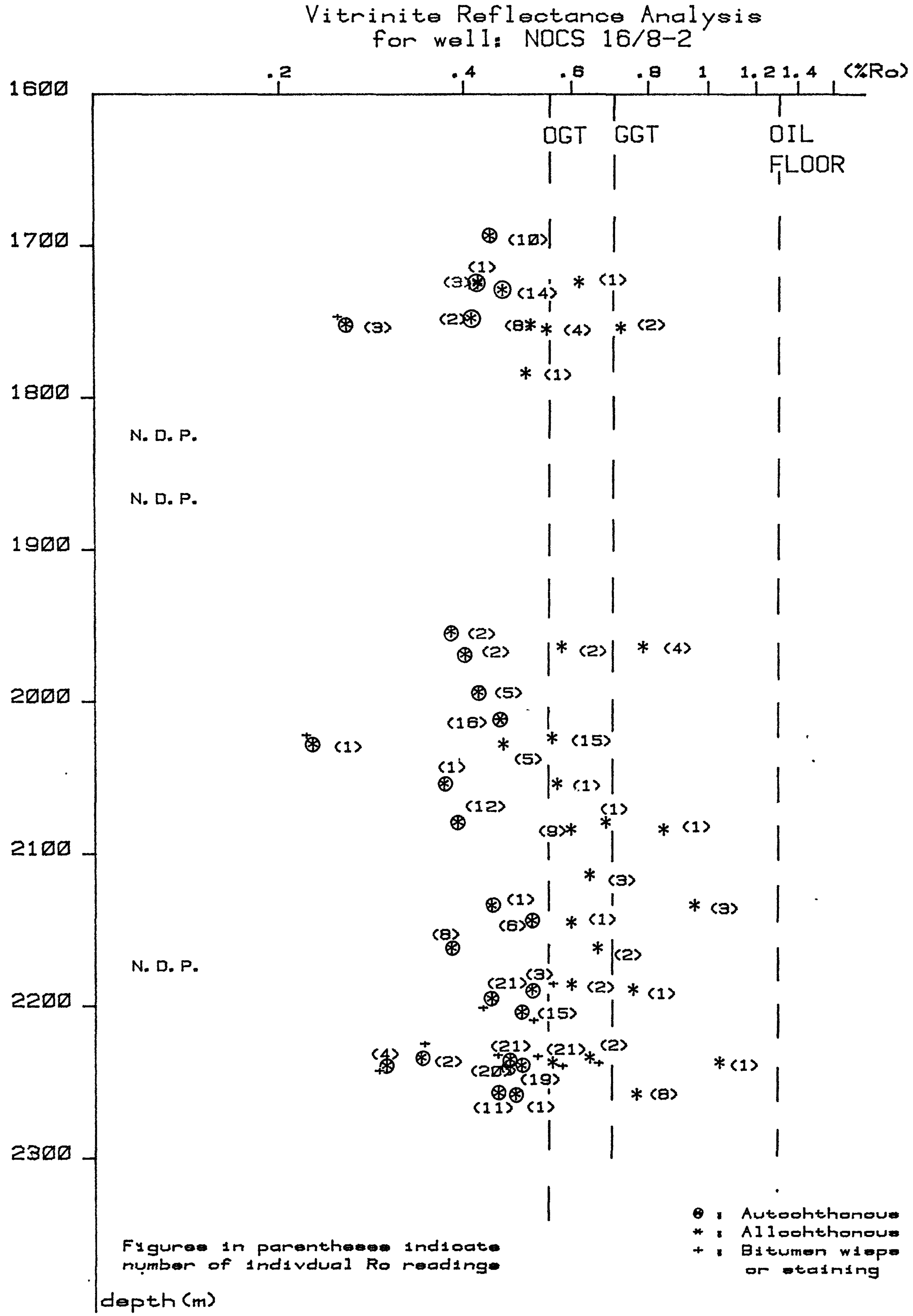
VITRINITE TABLE ABBREVIATIONS

ANS	ANISOTROPIC	B	BITUMEN
BS	BITUMEN STAINING	BW	BITUMEN WISPS
BAR	VIRTUALLY BARREN	CAV	CAVED
CARB	CARBARGILITE	COR	CORRODED
CTGS	CUTTINGS	DD	DIFFERENTIATION DIFFICULT
DMA	DRILLING MUD ADDITIVE	DOM	DOMINANT
F	FEW	FL	FLUORESCENCE
FR	FRAGMENTS	G	GOOD
GN	GNARLED	GRAN	GRANULARITY
I	INERTINITE	INST	INTERSTITIAL
L	LOW ORGANIC CONTENT	LGN	LIGNITE
LOW	LOWEST REFLECTANCES MEASURED	M	MOSTLY
MOD	MODERATE ORGANIC CONTENT	NDP	NO DETERMINATION POSSIBLE
NTV	NO TRUE VITRINITE	OBS	OVERALL BITUMEN STAINING
OCC	OCCASIONAL	OX	INDICATIONS OF OXIDATION
P	POOR	PAR	PARTICLES
PL	PLENTIFUL-PLENTY	POS	POSSIBLY
R	REWORKED	RM	REWORKED MATERIAL
RO	REFLECTANCE MEASUREMENT	RES	RESIN
RICH	RICH-HIGH ORGANIC CONTENT	S	SOME
SC	SCRUFFY	SH	SHALE
SLT	SILTSTONE	SML	SMALL
SP	SPECKS	SUB	SUBORDINATE
STC	STRUCTURE	STR	STRONGLY
TB	TURBO-DRILLED	TR	TRACE
TEL	TELINITIC	V	VITRINITE
VL	V.LOW ORGANIC CONTENT	VW	VITRINITE WISPS
VAR	VARIABLE (HIGH) RO	VST	VITRINITE STRINGERS
W	WISPS-WISPY	WH	WHOLLY
*	ALLOCTHONOUS	=	EQUAL PROPORTIONS

SPORE FLUORESCENCE COLOURS UNDER U.V. LIGHT

G	GREEN	Y	YELLOW
O	ORANGE	R	RED
LT	LIGHT	M	MID
D	DEEP	P	PALE

TABLE 1B



Vitrinite Reflectance Analysis
for well: NOCS 16/8-2
.2 .4 .6 .8 1 1.2 1.4 (%Ro)
1600
1700
1800
1900
2000
2100
2200
2300
OGT
GGT
OIL FLOOR
N.D.P.
N.D.P.
N.D.P.
⊛ : Autochthonous
* : Allochthonous
+ : Bitumen wieps or staining
Figures in parentheses indicate number of indivdual Ro readings
depth (m)

TABLE 2

VISUAL KEROGEN DESCRIPTIONS

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH(m)	SPORE COLOUR	SOURCE POTENTIAL
1690	2/3	POOR OIL
1744	2/3-3	NONE
1750	2/3-3	NONE
1870	3	NONE-LEAN
1950	3-4	NONE
1990	3-3/4	POOR-MODERATE OIL
2050	3-4	NONE
2110	3-4	NONE
2158	3-4	NONE
2170	3-4	NONE
2200	3	GOOD OIL
2230	3	GOOD OIL
2231	3	GOOD OIL

TABLE 2A - VISUAL KEROGEN OBSERVATIONS SUMMARY

SAMPLES Docs 16/8-2

	DB 1242	DB 1241	DB 1240	DB 1239	DB 1238	DB 1237	DB 1236	DB 1235	DB 1234	DB 1233
Depth in metres	2170-2200	2158	2110-2140	2050-2080	1990-2020	1950	1870-1900	1750-1780	1744	1690-1720
Type	clay	Swc	clay	clay	clay	Swc	clay	clay	Swc	clay
Amount of Organic Matter	Small	V. Small	Small	Small	Mod.	V. Small	V. Small	Small	Small	Small
MIOSPORES (1-2 Trace/Rare, 3 Common, 4 Frequent, 5 Abundant)	3	1-2	1-2	3	1-2	1-2	1-2	4	4	4
PHYTOPLANKTON EXCLUDING TASMANITIDS (1-2, 3, 4, 5)	4	1-2	4	4	3	3	1-2	4	4	4
TASMANITIDS (1, 2, 3)					1				1	1
FORAM LININGS (1, 2, 3)	1									
MEGASPORES (1, 2, 3)										
OTHER MICROFOSSILS (1, 2, 3)				1						1
CUTICLES (1-2, 3, 4-5)			1-2							1-2
OTHER TISSUES (1-2, 3, 4-5)	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
BROWN 'WOOD': LIGNITE (1-2, 3, 4-5)					1-2				1-2	1-2
BLACK 'WOOD': VITRINITE + INERTINITE (1-2, 3, 4-5)	4-5	1-2	4-5	4-5	1-2	4-5	3	4-5	4-5	3
BLACK 'WOOD': INERTINITE ONLY (1-2, 3, 4-5)										
FINELY DISSEMINATED PARTICLES (1-2, 3, 4-5)	1-2, 3	1-2	1-2, 3	3, 4-5	3	1-2, 3	3	1-2, 4-5	3, 4-5	3, 4-5
AMORPHOUS VASCULAR PLANT MATERIAL (1-2, 3, 4-5)										
AMORPHOUS MATTER OF ALGAL ORIGIN, MARINE (M) /NON MARINE (N) (1-2, 3, 4, 5)	1-2	1-2	1-2	1-2	4	1-2		1-2	1-2	3, 4
PRESERVATION STATE (good, fair, poor)	fair	fair	fair	fair	fair	good, fair	fair	fair	fair, poor	good, fair
Reworking							✓			
ENVIRONMENT OF DEPOSITION (undiff. mar., open mar., restricted mar., nr. shore mar./strong terrig.infl., some mar. influence/brackish, non-mar./freshwater)	open mar.	undiff. mar.	open mar.	open mar.	restricted mar.	open mar.	undiff. mar.	open mar. → nr. shore mar./strong terrig.infl.	undiff. mar.	undiff. mar. → restricted mar.
COLOUR/MATURATION (1, 2, 3, 4, 5, 6, 7)	3, ○4 ↓	3, ○4 ↓	3, ○4 ↓	3, ○4 ↓	3 ↓	3, ○4 ↓	3	2-3 ↓	2-3 ↓	3
SOURCE POTENTIAL	None	None	None	None	Poor-Mod. Oil	None	None-Lean	None	None	Poor Oil

TABLE 2A - VISUAL KEROGEN OBSERVATIONS SUMMARY

SAMPLES NOCS 16/8-2.

Number	Depth in metres	Type	Amount of Organic Matter	Miospores (1-2 Trace/Rare, 3 Common, 4 Frequent, 5 Abundant)	Phytoplankton excluding Tasmanitids (1-2, 3, 4, 5)	Tasmanitids (1, 2, 3)	Other Tissues (1-2, 3, 4-5)	Black 'Wood': Vitrinite + Inertinite (1-2, 3, 4-5)	Finely Disseminated Particles (1-2, 3, 4-5)	Amorphous Matter of Algal Origin, Marine (M)/Non Marine (N) (1-2, 3, 4, 5)	Preservation State (good, fair, poor)	Environment of Deposition	Colour/Maturation (1–7)	Source Potential
DB 1243	2200-2230	ctgs	V. large	4	3	3 [10]		1-2	4-5	5	poor	restricted mar.	3	Good Oil.
DB 1244	2231	*swc	V. large	1-2 [6]	1-2 [6]			1-2	1-2	5	poor	restricted mar.	3	Good Oil.
DB 1245	2230-2260	ctgs	large	1-2	3	3 [10]	1-2	1-2	4-5	5	poor	restricted mar.	3	Good Oil.

Other columns on the form (no entries): Foram Linings (1, 2, 3); Megaspores (1, 2, 3); Other Microfossils (1, 2, 3); Cuticles (1-2, 3, 4-5); Brown 'Wood': Lignite (1-2, 3, 4-5); Black 'Wood': Inertinite Only (1-2, 3, 4-5); Amorphous Vascular Plant Material (1-2, 3, 4-5); Reworking. Environment of Deposition classes: undiff. mar., open mar., restricted mar., nr. shore mar./strong terrig.infl., some mar. influence/brackish, non-mar./freshwater.

KEY:-
6: FIRST SLIDE ONLY
7: FUNGAL REMAINS
8: RESIN DROPLETS
9: MICROTHYRIATES
10: MOSTLY PTERIDOSPERMOPSIS.

TABLE 3

ROCK-EVAL AND PYROLYSIS DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH (M)	P1 KG/TONNE	P2 KG/TONNE	GOGI	OIL YIELD KG/TONNE	GAS YIELD KG/TONNE
1690	0	.1			
1720	0	0			
1721	.1	.1			
1725	0	0			
1744	0	.1			
1748	0	.2			
1750	0	0			
1751	0	.1			
1780	0	0			
1810	0	0			
1840	0	0			
1870	0	0			
1950	0	0			
1960	0	.1			
1965	0	0			
2007	.1	.2			
2020	0	0			
2024	0	.1			
2050	0	0			
2075	0	.1			
2080	0	0			
2110	0	0			
2130	0	.2			
2140	0	0			
2140	0	0			
2158	0	0			
2170	0	0			
2182	.1	0			
2185	.1	.3			
2191	1	46.7	.2	38.9	7.8
2200	5.2	119	.15	103.5	15.5
2231	6.7	148.6	.15	129.2	19.4
2233	1.5	26	.16	22.4	3.6
2235	1.9	46	.15	40	6
2236	0	0			
2253	.1	.2			
2254	0	0			

TABLE 4

LITHOLOGY AND TOC DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH(m)	AGE	PICKED LITHOLOGY	%TOC	%CARBONATE
1690	PALAEOCENE	C-MUDSTONE	0.4	15.7
1750	PALAEOCENE	C-MUDSTONE	0.6	16.5
1780	PALAEO./L-CRET.	C-MUDSTONE	0.5	19.2
1810	L-CRETACEOUS	C-LIMESTONE	0.01	68.3
1870	L-CRETACEOUS	C-LIMESTONE	0.05	70.1
1960	E-CRETACEOUS	C-MUDSTONE	0.7	20.1
2020	E-CRETACEOUS	C-MUDSTONE	0.5	29.7
2050	E-CRETACEOUS	C-MUDSTONE	0.5	24.9
2080	E-CRETACEOUS	C-MUDSTONE	0.5	21.4
2170	E-CRETACEOUS	C-MUDSTONE	0.4	22.8
2200	E-CRETACEOUS	C-MUDSTONE	14.5	14.5

SAMPLE TYPES :-
N-CORE SAMPLE — O-OUTCROP
S-SIDEWALL CORE — C-CUTTINGS

TABLE 5

SEDIMENTS SOLUBLE EXTRACT DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH (m)	TOC %wt	TSE/TOC o/oo	SAC/TOC o/oo	CPI	ASPHALTENES %wt
1720	NO TOC DETERMINATION			n.d.	n.d.
2020	.5	4	<1	n.d.	n.d.
2200	14.5	63	6	n.d.	n.d.

TABLE 6

SEDIMENTS SOLUBLE EXTRACT DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH(m)	%SAC	%TSE	PRIST/PHYT	PRIST/C-17	PHYT/C-18
1720	VERY LOW AMOUNT OF EXTRACT OBTAINED				
2020	VERY LOW AMOUNT OF EXTRACT OBTAINED				
2200	9.9	.915	n.d.	n.d.	n.d.

TABLE 7

CARBON ISOTOPES DATA

WELL: NOCS 16/8-2
LOCATION: NORTH SEA (NORWEGIAN SECTOR).

DEPTH (m)	ISOTOPE RATIO PERMIL	SAMPLE TYPE
2200	-26.7	KEROGEN
2200	-26.8	PYROLYSED (@ 500°C) KEROGEN
2200	-26.5	PYROLYSATE (TOTAL)
2200	-25.4	PYROLYSATE (AROMATIC FRACTION)
2200	-25.4	PYROLYSATE (RESIDUE FRACTION)
2200	-26	T.S.E.

C-13/C-12 ISOTOPE RATIOS RELATIVE TO PDB STANDARD

FIGURE 1

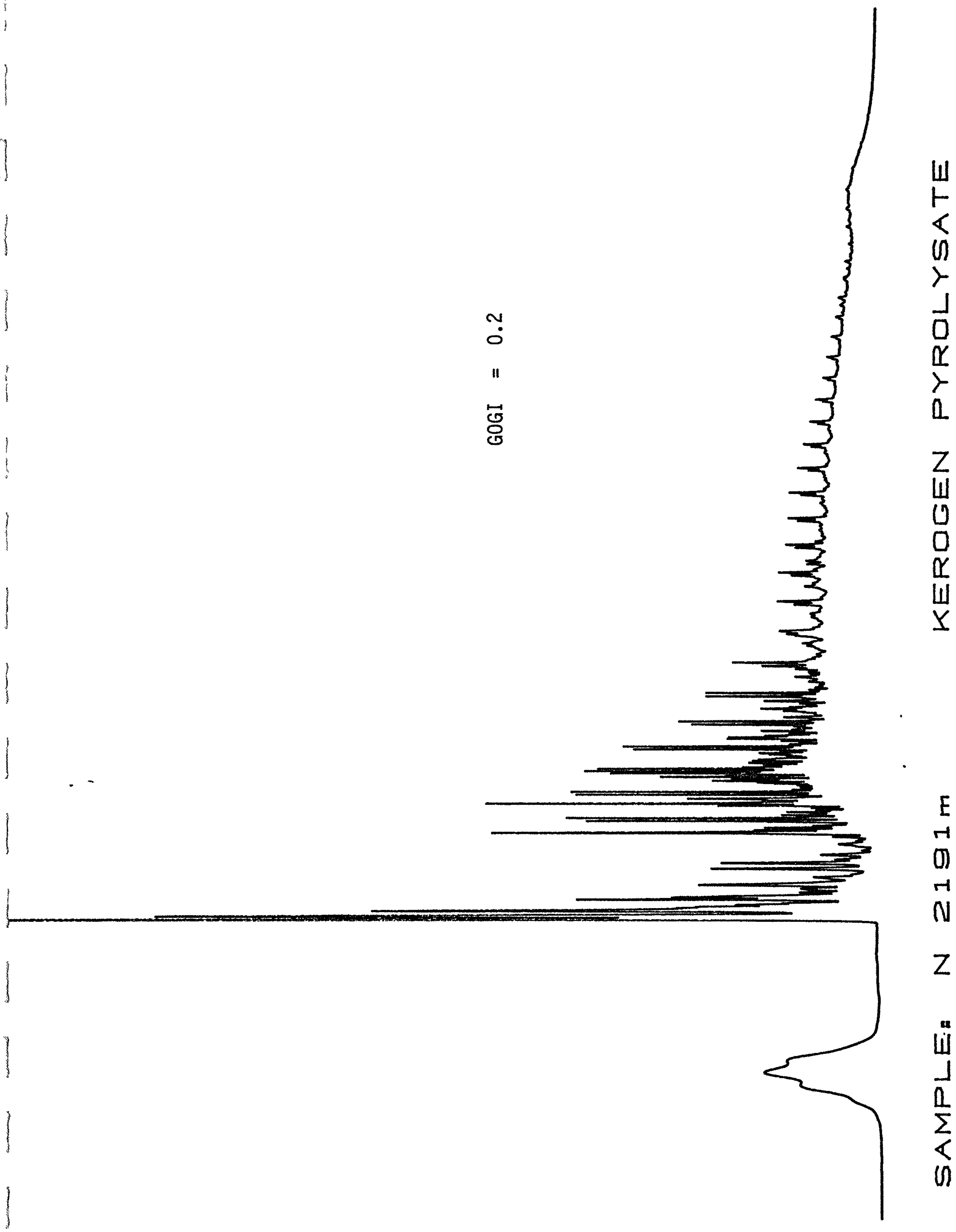


FIGURE 2

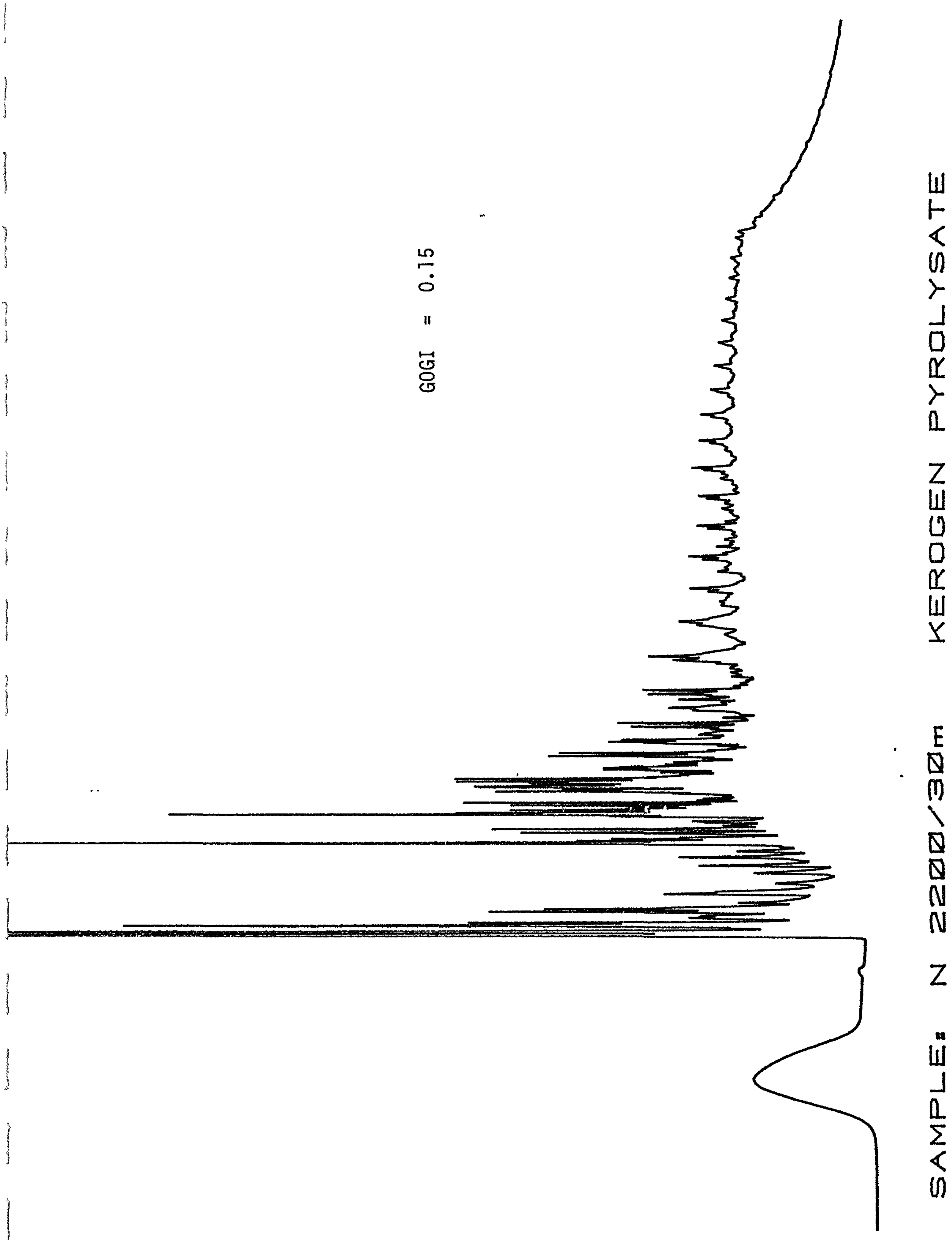


FIGURE 3

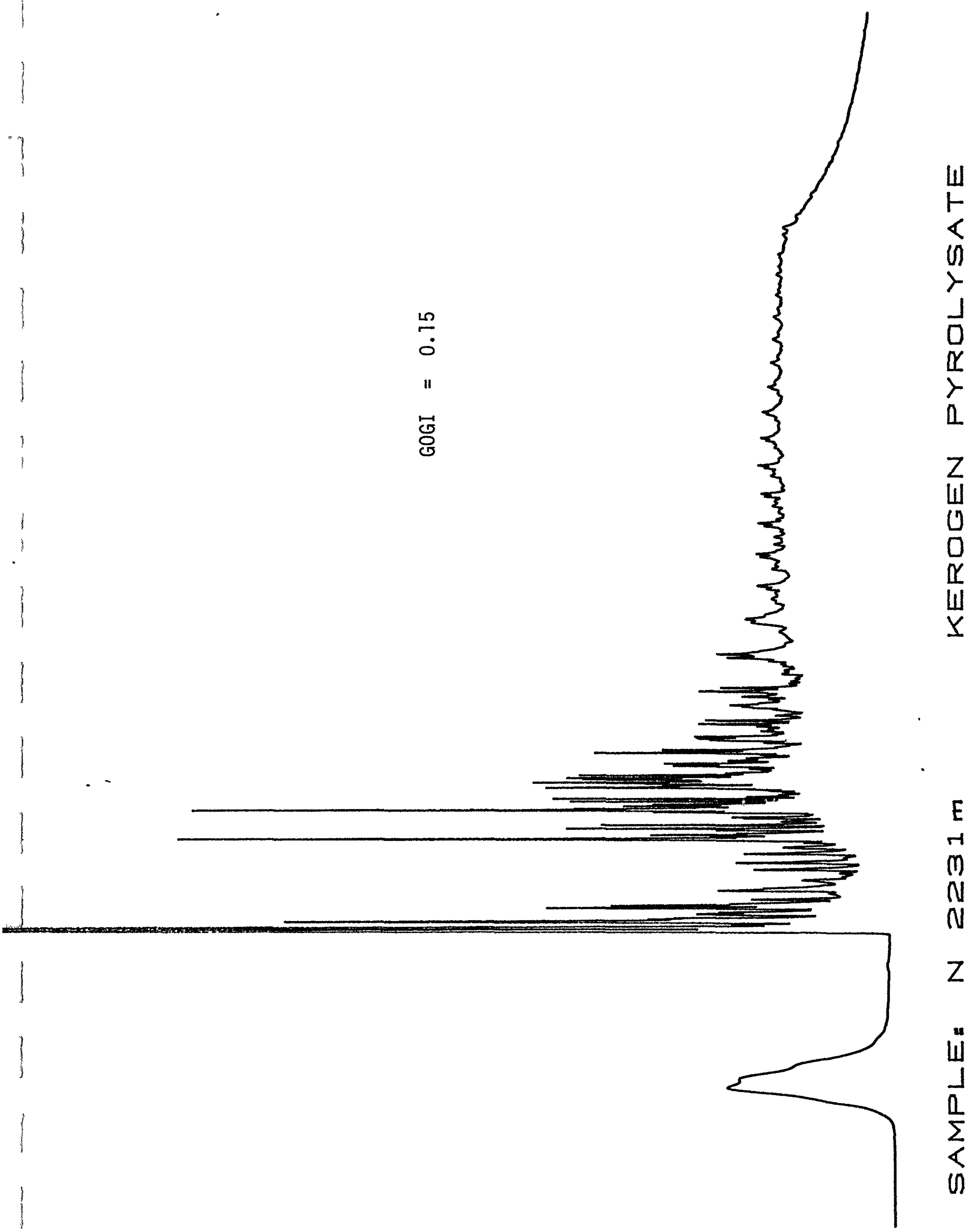


FIGURE 4

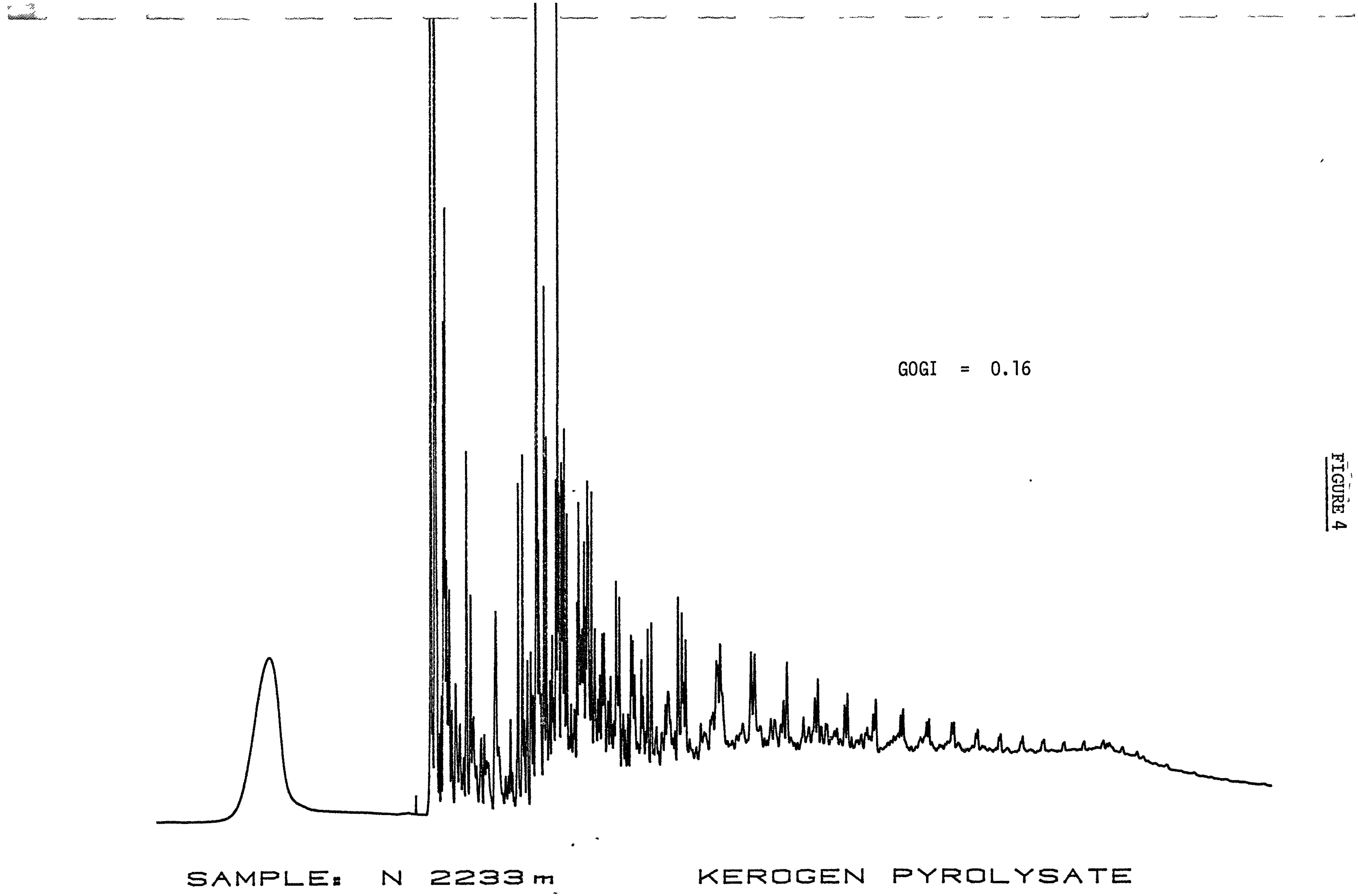


FIGURE 5

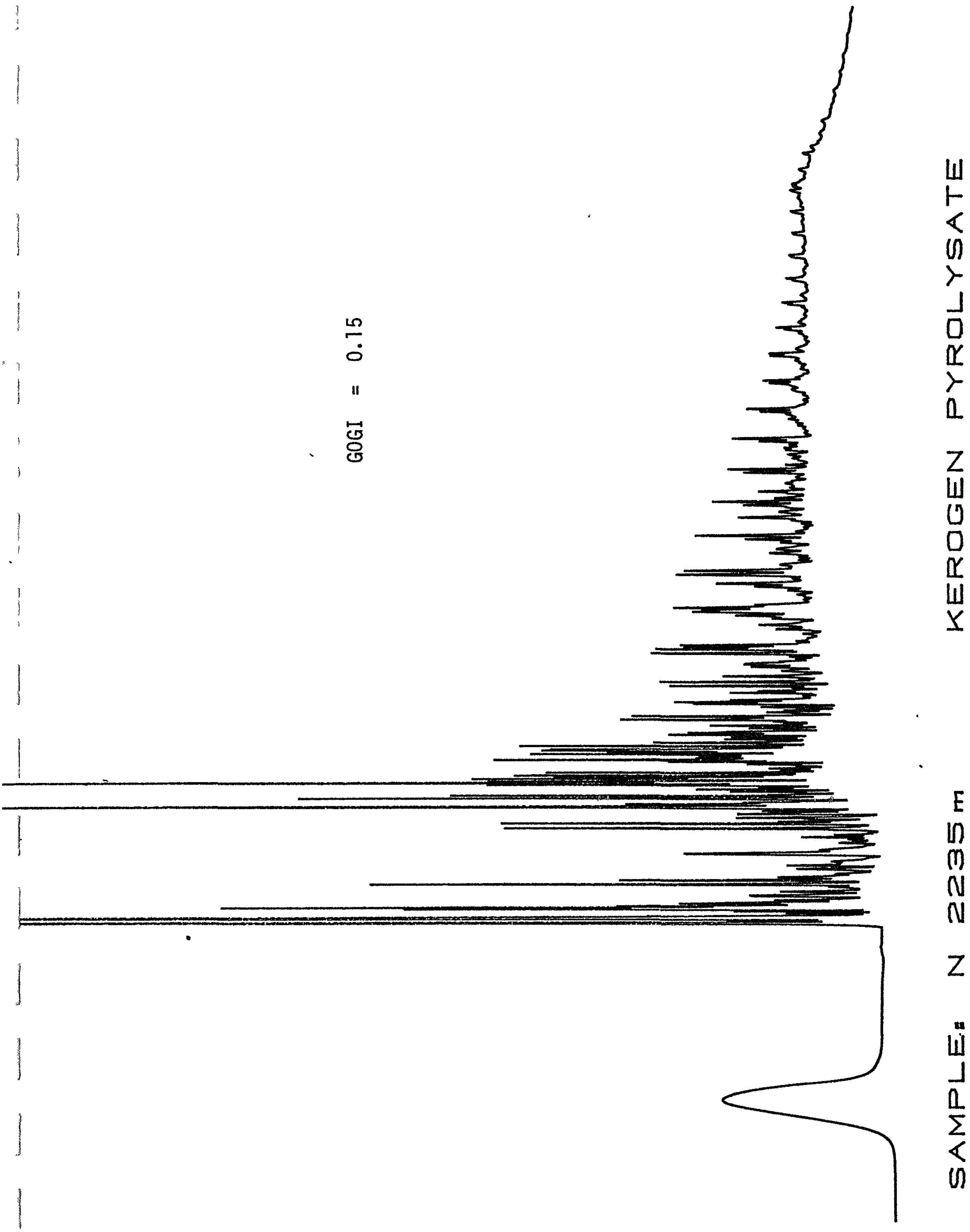
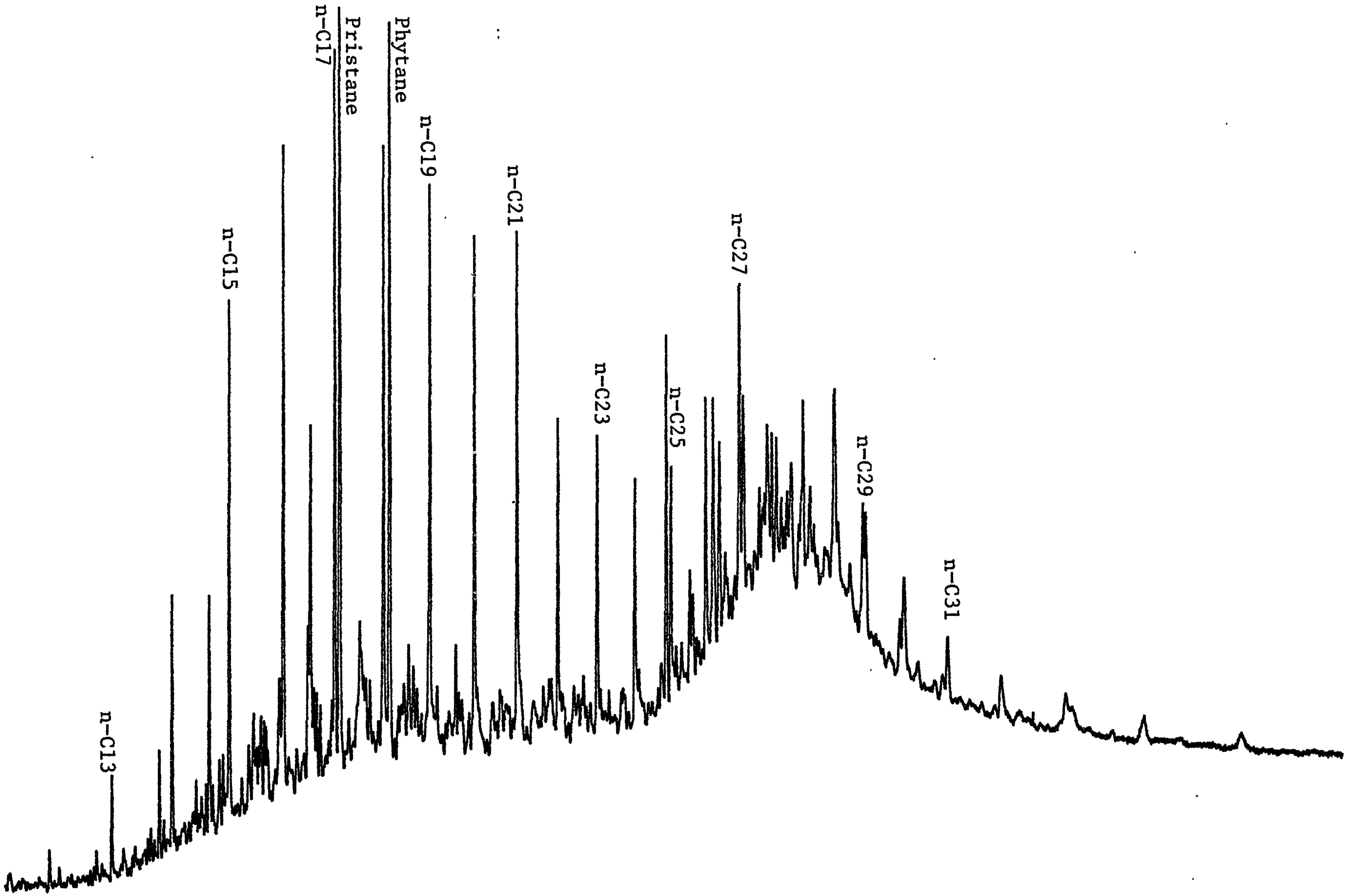


FIGURE 6



SAMPLE: N 2200/30m SATURATES FRACTION