



RESEARCH CENTRE

CONFIDENTIAL

SUNBURY - ON - THAMES

MIDDLESEX

EXPLORATION AND PRODUCTION DIVISION

EPR/R7068

NOVEMBER 1979

GEOCHEMICAL OPERATIONAL SERVICES GROUP

AN OIL TO SOURCE AND OIL TO OIL GEOCHEMICAL CORRELATION

STUDY OF NORTH SEA BLOCK 7/12: NORWEGIAN SECTOR

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SUMMARY

An oil to source rock correlation exercise was completed using cuttings samples from the Lias of Wells 7/12-3A and 7/12-4, in conjunction with data already available in reports (1, 2 and 3). The sediments examined from the Lias of Well 7/12-3A had little, or no, source potential for either oil or gas, in contrast to the sediment examined from the Lias of Well 7/12-4. The latter had a moderate potential to source oil, with limited quantities of gas. Stable carbon isotope $\delta^{13}\text{C}_{\text{PDB}}$ per mil ratios suggested that the sediments from the Lias of Well 7/12-3A were of marginal marine origin, with little terrestrial plant input. The sediment from the Lias of Well 7/12-4 showed evidence of a considerable terrestrial input. Stable carbon isotope ratios for two oil samples from Well 7/12-2 DST 1A and DST 3A suggested that both oils originated from a marginally marine environment with a marked terrestrial input.

Full geochemical analyses of a Jurassic oil (DST 3A) and Triassic oil (DST 1A) from Well 7/12-2 were completed to establish whether or not the two oils had a common source. Both oils were shown to be very light (Specific Gravities of 0.8274 and 0.8128 respectively), with low sulphur (0.10 and 0.05 %wts) and asphaltene contents (0.25 and 0.35 %wt). Minor differences were noted, which included a decrease in the amount of aromatic and naphthenic compounds, with a corresponding increase in the amount of normal alkanes. Sterane and pentacyclane fingerprints also showed minor differences, which may reflect differences in the thermal evolution of the oils, minor variations in the source rock, or input from minor source rocks into the main oil pool.

1. INTRODUCTION

Well 7/12-2 was the first of two exploration wells drilled by BP Petroleum Development of Norway A/S, in order to earn an interest in Licence 019 jointly held by Conoco Norway and Pelican A/S. Conoco operated the well on BP's behalf. The well was drilled to evaluate potential Upper Jurassic and Triassic reservoirs in a salt induced structure located entirely within block 7/12. T.D. was reached at 3668m BRT, within a Triassic hydrocarbon bearing sequence of poor quality sands and interbedded shales.

Wells 7/12-3 and 3A were the first appraisal wells drilled after the 7/12-2 oil find. A good "wet gas" show was encountered at 3497 - 3507m and oil stains were observed between 3603 and 3710m. Well 7/12-4 was the third appraisal well drilled in block 7/12. Significant quantities of gas were noted from 3312m downwards and the reservoir proper was encountered at 3445m in Jurassic sandstones.

2. SAMPLES AND TECHNIQUES

2 cans of wet cuttings (depth 3880 and 3910m, Lias age) from Well 7/12-3A plus 3 packets of dried cuttings bulked together (depth range 3922 - 3928m, Lias age) were examined, in addition to 7 packets of dried cuttings bulked together (depth range 3575 - 3593m, Lias age) from Well 7/12-4. Geochemical analyses were completed on two oil samples from Well 7/12-2 labelled DST 1A and DST 3A. The results obtained from the samples listed above were used in conjunction with the geochemical data from Wells 7/12-2, 3, 3A and 4. (1, 2 and 3).

The cans of wet cuttings were opened, the cuttings washed free of drilling mud and dried at 40°C in an air blown cabinet. The dried cuttings were washed to remove dust and dried in the air blown cabinet previously described. The clean, dry cuttings were hand picked to remove obvious contaminants (eg. paint, metal etc.) and cavings. This provided samples of uniform lithology, corresponding to that described on the Well Log at any one particular depth. The picked cuttings were used for pyrolysis studies, total organic carbon measurements and stable carbon isotope $\delta^{13}\text{C}$ -PDB per mil ratio determinations.

These picked cuttings were ground to rock flour, which sieved through a 180 μm sieve to remove any coarser particles. Pyrolysis studies were completed on the sieved sediment sample using a Girdel Rock Eval and a much modified Spex Chromalytics instrument. The organic richness of the sediments was determined using Total Organic Carbon (TOC) measurements. Acid soluble constituents were removed using dilute and concentrated hydrochloric acid at 60°C. The remaining material was used for TOC determinations and kerogen stable carbon isotope ($\delta^{13}\text{C}$ -PDB ‰) determinations. There was insufficient of any of the cuttings samples to complete any further geochemical studies.

Inspection Property data was obtained for both oil samples from Well 7/12-2 including specific gravities, asphaltene, wax, trace metal, nitrogen and sulphur contents. True boiling point data, n-alkane contents and distributions were also completed, in addition to Type Analysis using High Pressure Liquid Chromatography (HPLC) and stable carbon isotope ($\delta^{13}\text{C}$ -PDB per mil ratios). The n + p fractions from the HPLC separations were denormalised using molecular sieve and the denormalised samples were subsequently used for sterane and pentacyclane fingerprinting.

3. RESULTS AND DISCUSSION

a) Pyrolysis Studies

The results of the pyrolysis studies are listed in Table 1. The results suggested that the sediments from both wells were contaminated by hydrocarbons, either by migration from the overlying oil-bearing sandstones, or from the drilling process. Every sample had a higher P1 figure (thermally extractable hydrocarbons) than P2 figure (kerogen pyrolysate). A P1 value of approximately 10% of the P2 value is more representative of the values normally observed in uncontaminated samples. In view of the fact that oil bearing sandstones are present above the intervals examined from both wells, it is probable that oil from these sandstones is the cause of the contamination. The distribution of the hydrocarbons from the P1 yields and P2 yields show differences (Figures 1, 2, 3 and 4) supporting the suggestion that the sediments are contaminated.

Kerogen pyrolysate yields (P2) for the sediments from Well 7/12-3A were insignificant to poor with the highest total maximum theoretical yield at 3880m of 1.2 kg/tonne. The GOGI ratio of 0.46 indicated that kerogen was both gas and oil prone. The maximum theoretical yield for oil was 0.8 kg, which is such a low yield, that it would be unlikely that any migration would occur. The kerogen pyrolysate yield (4.9 kg/tonne) for the sediment from Well 7/12-4 was of more significance. The GOGI ratio of 0.30 indicated that the kerogen was more oil than gas prone. The maximum theoretical yield for oil was 3.82 kg/tonne, and high enough for migration to become feasible.

b) Organic Richness

The results of the organic carbon determinations are included in Table 2, which also shows TOC values previously reported (1 and 2). The results demonstrate that the picked cuttings samples from the Lias of Wells 7/12-3A and 7/12-4 contained moderate to good quantities of organic carbon (TOC %wt range 1.4 - 2.1). It must be pointed out that the picking process has effectively "concentrated" the organic material available in the Lias interval. For instance, the seven packets of dried cuttings covering the interval 3575 - 3593m, Well 7/12-4 consisted

of 90% sandstone, with 5% coal (caved from higher up the well), paint and other general debris. The remaining 5% comprised shale cuttings used for TOC determinations etc. and is clearly unrepresentative of the Lias interval as a whole, but certainly representative of the interbedded shales themselves.

c) Kerogen Stable Carbon Isotope $\delta^{13}\text{C}_{\text{-PDB}}$ ‰ Ratios

The results of the kerogen carbon isotope measurements are included in Table 3, which contains isotope data previously reported (1) and isotope ratios from the geochemical analysis of the two oils from Well 7/12-2. The isotope ratios obtained from the two kerogens of Lias age, Well 7/12-3A indicate that the sediments were deposited under marine to marginal marine conditions. The kerogen at 3880m was probably closer to the palaeo shoreline than the kerogen at 3902.4m. The isotope ratio of -27.5 from the Lias of Well 7/12-4 indicated that the sediment was deposited under marginal marine conditions, with a considerable terrestrial input. Current theories relating to the relationship between kerogen carbon isotope ratios and those of crude oils suggest that crude oils should be isotopically lighter than the kerogen, if the organic material of the source rock and the crude oil are genetically related (4). In practice, the relative differences in isotope ratios is commonly of the order of -1 to -2‰. One exception to this relationship between genetically related crude oils and kerogens is the instance, where kerogens are richer in allochthonous components than autochthonous components and the allochthonous component is isotopically lighter than the autochthonous component from which the oil has sourced (5),

The stable carbon isotope ratios of the two crude oil samples from Well 7/12-2 suggest that they are of marginal marine origin, with a considerable terrestrial influence. The isotope ratio values of -28.7 and -28.8 would suggest that genetically related organic material would have isotope ratios of between -26.7 and -28.7. The kerogen isotope ratio of the sediment from the Lias of Well 7/12-4 falls within this range and cannot therefore be ruled out as a possible source of the 7/12-2 oils. However, as stressed before, the kerogen examined was only representative of a small percentage of the total Lias sequence from Well 7/12-4. The majority of the kerogen isotope ratios from the Portlandian and Kimmeridgian sediments of Wells 7/12-3 and 3A (Table 3) fall within the range -26.7 to -28.7. This fact, taken in conjunction with the high organic carbon contents of these same sediments and the thickness of the strata, clearly indicates that the Upper Jurassic must be considered as a major source for the 7/12-2 oils.

d) Crude Oil Samples DST 1A and DST 3A

Both oils were shown to be very light (Figures 5 and 6), from their distillation characteristics (TBP data) and specific gravities.

The specific gravity of DST 1A was appreciably lighter than that of DST 3A. Sulphur, nitrogen and trace metal contents of both oils were low and those from DST 1A were slightly lower than those from DST 3A. The wax contents were higher than average for North Sea Crudes ($\approx 6\%$); DST 1A had a slightly higher wax content than DST 3A, although the wax melting points were of the same order. Type analysis showed a major increase in the saturate content of DST 1A compared with that of DST 3A, with an associated decrease in the aromatic and resins content. A slight decrease in asphaltene content between DST 1A and DST 3A was also observed. Although these observed differences in Inspection Properties and Type Analysis may be due to imperfect mixing resulting from permeability "barriers" within the reservoir system, or differences in source input, they could also be due to differences in thermal evolution of oils within a single oil column. The general trend of evolution with increase in depth and hence temperature, is a decrease in specific gravity, sulphur and nitrogen contents associated with an increase in the amount of saturated molecules, consistent with theoretical considerations (6).

The stable carbon isotope ratios of the two oils, $\delta^{13}\text{C}_{\text{-PDB}}$ ‰ of -28.7 and -28.8 for DST 1A and DST 3A respectively, are in very close agreement and must suggest an origin from similar types of source rock.

Sterane distributions of oil samples DST 1A and DST 3A showed similarities to one another and also to sterane distributions from sediment extracts from Well 7/12-3 and 3A (1). The major differences observed were the distributions of the regular steranes (numbers > 10), which show a decrease in the relative amounts of a 20R epimer compared with their respective 20S epimer. This has been associated with increases in the thermal evolution of sediment extracts (7). Differences were also observed in the pentacyclane distributions, which again have been associated with increases in the thermal evolution of oils (8). For instance, the ratio of pentacyclanes D to G increases with increase in thermal evolution, as do the ratio of pentacyclanes 1 and 2. A further indication of an increase in the thermal evolution of the oils was a decrease in the concentrations of the steranes and pentacyclanes relative to their respective saturate fractions. The concentration of steranes and pentacyclanes in DST 1A was significantly less than the concentration in DST 3A. This is consistent with an increase in thermal maturity. However, the differences could also be attributed to variations in the source kerogen, or input from a minor source into a main oil pool. In this instance, the oils are separated by permeability "barriers" of mature shale, which would contribute only very small amounts of steranes and pentacyclanes to the oil. More contribution would be provided if the reservoired crude had a long migration pathway.

When undertaking genetic comparisons between oil samples it is important that a wide range of geochemical parameters are used. This approach minimises the possibility of incorrect conclusions being drawn from a bias in one single parameter, arising from outside influences.

4. CONCLUSIONS

- (i) Kerogens from the Lias of Well 7/12-3A have insignificant potential to source liquid hydrocarbons. The kerogen examined from the Lias of Well 7/12-4 has a moderate potential to source liquid hydrocarbons.
- (ii) The organic richness of sediments from the Lias of Well 7/12-3A and Well 7/12-4 was moderate to good (TOC %wts. 1.4 - 2.1). The sediment examined from Well 7/12-4 had the highest organic carbon content. However, this value is only applicable to the shale hand picked from the cuttings samples, the majority of which was sandstone.
- (iii) Kerogen stable carbon isotope ratios $\delta^{13}\text{C}_{\text{-PDB}}$ ‰ suggested that the kerogen examined from Well 7/12-3A was unlikely to have contributed to the 7/12-2 oil. This is in contrast to the kerogen examined from Well 7/12-4, which is likely to source oil with isotope ratios similar to those of the oil from 7/12-2.
- (iv) Consideration of the organic richness, thickness of the sedimentary sequence and kerogen isotope ratios, would lead to the suggestion that the Upper Jurassic, is more likely to be the major source of the 7/12-2 oils than the Lias.
- (v) The two oils DST 1A and DST 3A are similar to one another. The observed differences may be attributed to differences in thermal evolution of oil in a single oil column, though the possibility of minor source differences between the two oils cannot be ruled out.

REFERENCES

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- 6) Tissot, B.P. and Welte, D.H. 1978 Petroleum Formation and Occurrence. Part IV, Chapter 5. Springer-Verlag.
- 7) Mackenzie, A.S., Patience, R.L. and Maxwell, J.R. In Press (Subject of Personal Communication with Dr. J. Maxwell, University of Bristol).
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TABLE 1

PYROLYSIS DATA NOCS BLOCK 7/12

WELLS: 7/12-3A AND 7/12-4 (LIAS)

SAMPLE DEPTH (m)	P1 kg/tonne	P2 kg/tonne	GOGI RATIO	GAS YIELD kg/tonne	OIL YIELD kg/tonne
Well 7/12-3A					
3880	4.3	1.2	0.46	0.38	0.82
3910	2.7	0.2			
3922 - 3928	0.7	0			
Well 7/12-4					
3575 - 3593	6.6	4.97	0.30	1.14	3.82

TABLE 2

TOTAL ORGANIC CARBON CONTENTS

NOCS BLOCK 7/12

WELL	DEPTH	AGE	TOTAL ORGANIC CARBON %WT
7/12-3	3310	Hauterivian	0.63
	3474.8	Valanginian	0.69
	3495	Barremian	0.82
	3498	"	3.1
	3500	Portlandian	8.0
	3525	"	2.1
	3555	"	0.63
7/12-3A	3638.4	Kimmeridgian	1.4
	3696.9	"	0.18
	3746.9	"	0.33
	3794.4	"	0.54
	3845.9	"	0.36
	c3880	Lias	1.7
	3902.4	"	0.7
	c3910	"	1.5
	c3922 - 3928	"	1.4
	3949.1	Trias	0.25
	3992.7	"	0.02
4047.4	"	0.75	
7/12-4	2580	Eocene	0.1
	2610	"	2.1
	2640	"	1.9
	2675	Palaeocene	1.1
	2680	"	0.84
	2685	"	0.69
	2690	"	0.64
	2710	Danian	0.71
	2785	"	0.01
	2845	"	<0.01
	3192	Valanginian	0.26
	3197	"	0.26
	3210	"	0.18
	3215	"	0.22
	3220	"	0.25
	3225	"	0.16
	3245	"	0.31

TABLE 2 - CONTINUED

TOTAL ORGANIC CARBON CONTENTS

NOCS BLOCK 7/12

WELL	DEPTH	AGE	TOTAL ORGANIC CARBON %WT
7/12-4	3355	Valanginian	0.29
	3275	"	0.40
	3288	"	0.28
	3312	"	0.21
	3327	"	0.35
	3335	"	0.55
	3339	Portlandian	0.89
	3345	"	3.5
	3347	"	0.71
	3349	"	2.5
	3351	"	9.5
	3357	"	4.6
		"	2.1
	3595	Trias ?	0.05
	3610	"	2.5
	3615	"	0.15
	3620	"	0.08

Key: c = cuttings samples

TABLE 3

STABLE CARBON ISOTOPE $\delta^{13}\text{C-PDB}$ ‰ DATA

NOCS BLOCK 7/12

WELL	DEPTH (m)	SAMPLE TYPE	$\delta^{13}\text{C-PDB}$ ‰
7/12-2	3640.5 - 3665.5	Oil DST 1A	-28.7
	3426.5 - 3638.7	Oil DST 3A	-28.8
7/12-3	3310	Kerogen	-25.9
	3495	Kerogen	-26.4
	3498	Kerogen	-27.3
	3500	Kerogen	-28.6
	3525	Kerogen	-28.1
	3555	Kerogen	-25.9
7/12-3A	3683.4	Kerogen	-28.1
	3696.9	Kerogen	-28.1
	3746.9	Kerogen	-26.0
	3794.4	Kerogen	-26.7
	3845.9	Kerogen	-25.2
	c3880	Kerogen	-26.3
	3902.4	Kerogen	-25.0
	3941.1	Kerogen	-24.6
	3992.7	Kerogen	-24.8
	4047.4	Kerogen	-24.0
7/12-4	c3575 - 3593	Kerogen	-27.5

KEY: c = Cuttings

TITLE: CRUDE OIL ANALYSIS

WELL/LOCATION: 7/12-2: NORWAY

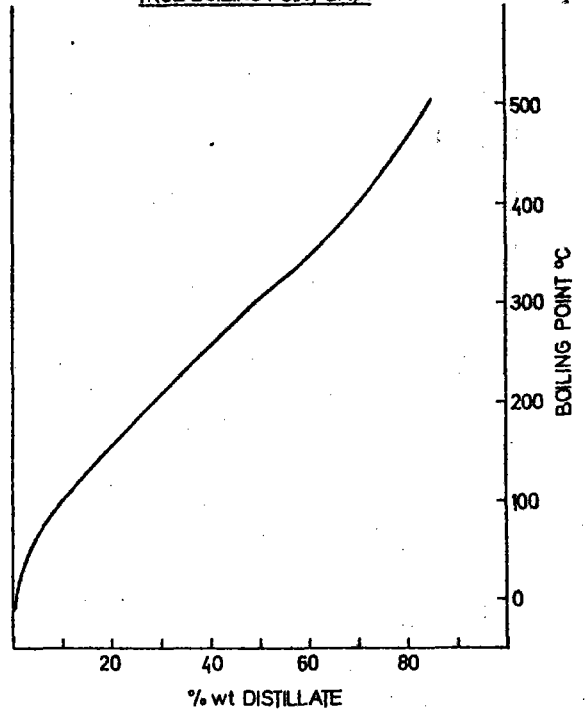
DST/1A

DEPTH: 3640.5-3665.5 m

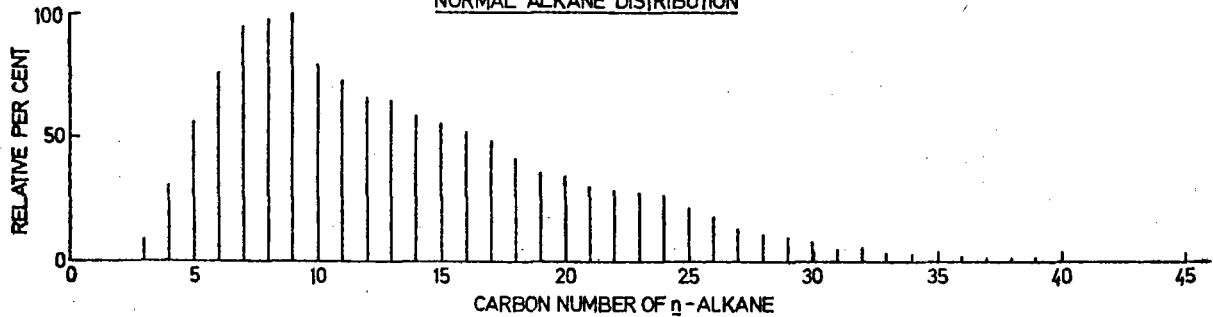
GEOCHEMICAL DATA:

API GRAVITY	60°F		
SPECIFIC GRAVITY	60/60°F		0.8128
SULPHUR		%wt	0.051
WAX		%wt	9.3
WAX m pt		°C	52.0
POUR POINT		°C	
ASPHALTENES		%wt	0.35
NICKEL		ppm	<1
VANADIUM		ppm	<1
NICKEL/VANADIUM RATIO			
NITROGEN		ppm	140
TOTAL ACIDITY		mg KOH/g	
KINEMATIC VISCOSITY	(cSt AT 20°C) (cSt AT 100°F)		8.24
TYPE ANALYSIS (from HPLC)			
N+P		%wt	78.5
(A+H) ₁		%wt	16.6
(A+H) ₂		%wt	
RESINS		%wt	4.9
CARBON ISOTOPE RATIO	δc ¹³ ‰		28.7
n-ALKANE CPI			1.0
PRISTANE/PHYTANE RATIO			1.4

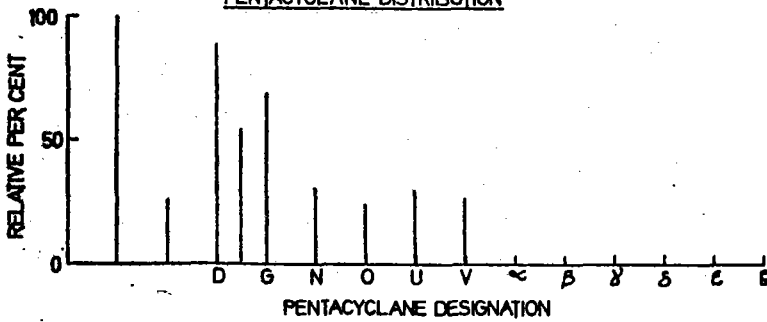
TRUE BOILING POINT DATA



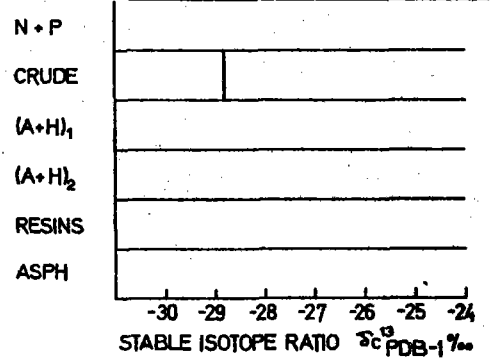
NORMAL ALKANE DISTRIBUTION



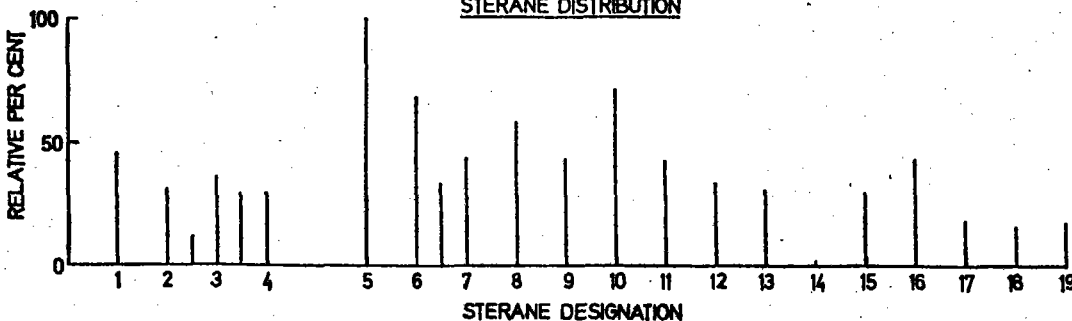
PENTACYCLANE DISTRIBUTION



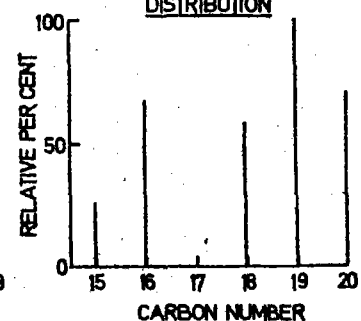
STABLE CARBON ISOTOPE DISTRIBUTION



STERANE DISTRIBUTION



ACYCLIC ISOPRENOID DISTRIBUTION



TITLE: CRUDE OIL ANALYSIS

WELL/LOCATION: 7/12-2 NORWAY

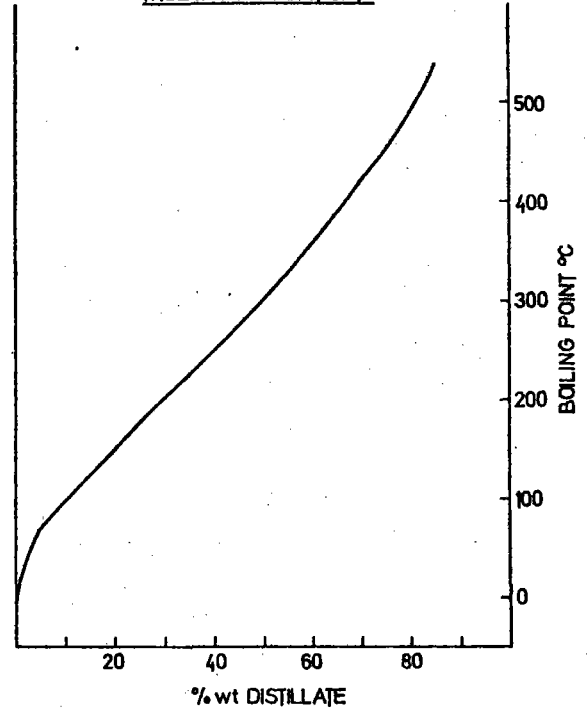
DST/3A

DEPTH: 3426.5 - 3638.7m

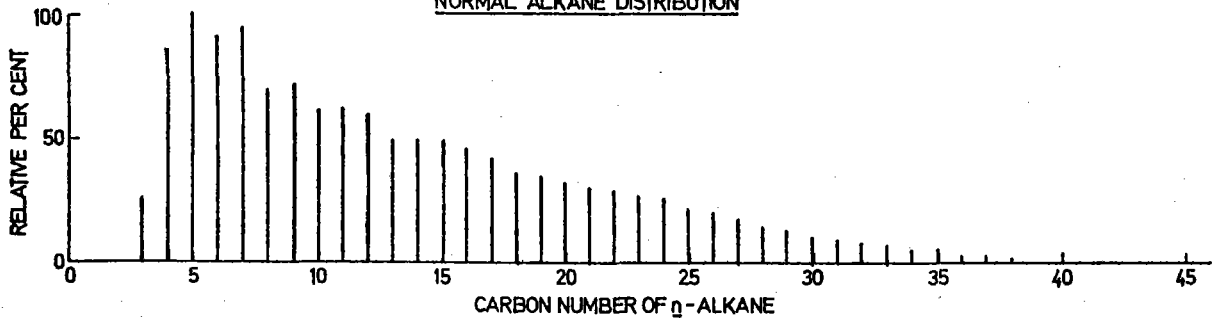
GEOCHEMICAL DATA:

API GRAVITY	60°F		39.5
SPECIFIC GRAVITY	60/60°F		0.8274
SULPHUR		%wt	0.10
WAX		%wt	7.0
WAX m pt		°C	58.0
FOUR POINT		°C	3
ASPHALTENES		%wt	0.25
NICKEL		ppm	1
VANADIUM		ppm	<1
NICKEL/VANADIUM RATIO			
NITROGEN		ppm	510
TOTAL ACIDITY		mg KOH/g	10.1
KINEMATIC VISCOSITY	(cSt AT 70°F)		10.1
TYPE ANALYSIS (from HPLC)			
N+P		%wt	66.2
(A+H) ₁		%wt	22.4
(A+H) ₂		%wt	11.3
RESINS		%wt	
CARBON ISOTOPE RATIO	δC ¹³ ‰		-28.8
n-ALKANE CPI			0.997
PRISTANE/PHYTANE RATIO			1.4

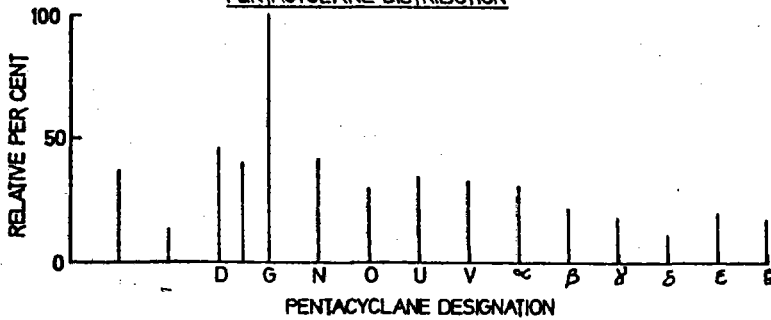
TRUE BOILING POINT DATA



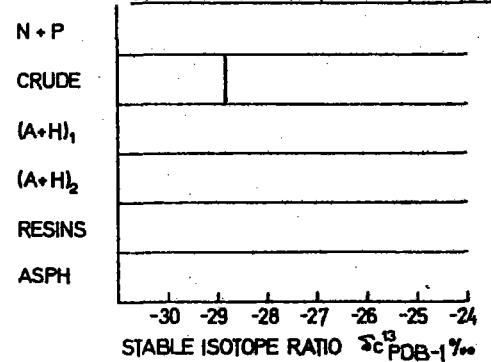
NORMAL ALKANE DISTRIBUTION



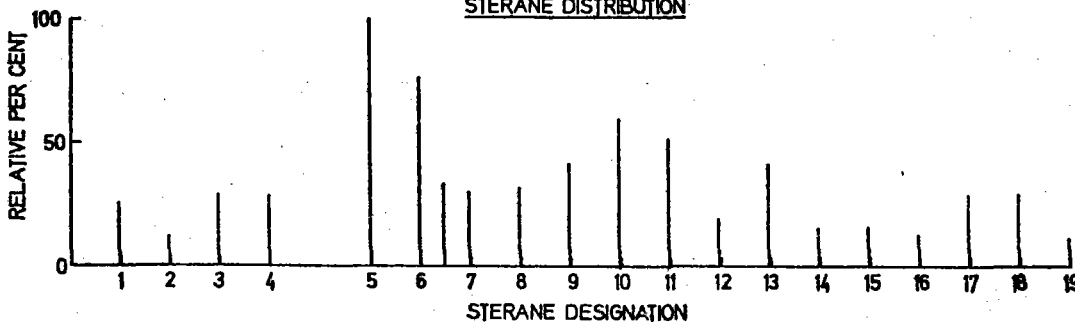
PENTACYCLANE DISTRIBUTION



STABLE CARBON ISOTOPE DISTRIBUTION



STERANE DISTRIBUTION



ACYCLIC ISOPRENOID DISTRIBUTION

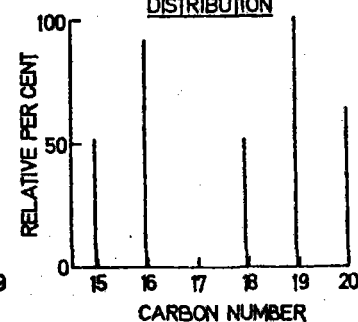


FIGURE 3

P1 DISTRIBUTION

WELL: 7/12-3A, DEPTH: 3880m, ATTEN: 8 x 10

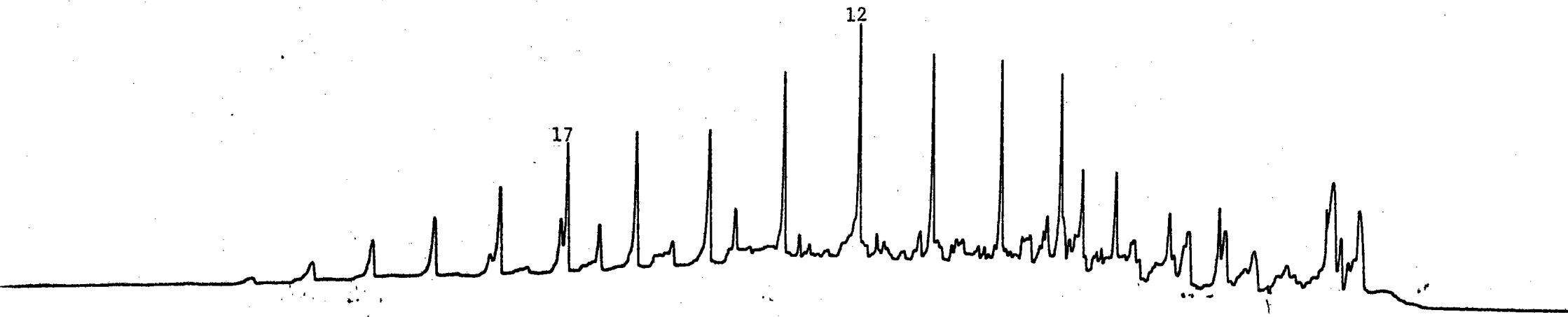


FIGURE 4

P2 DISTRIBUTION

WELL: 7/12-3A, DEPTH: 3880m, ATTEN: 8 x 10

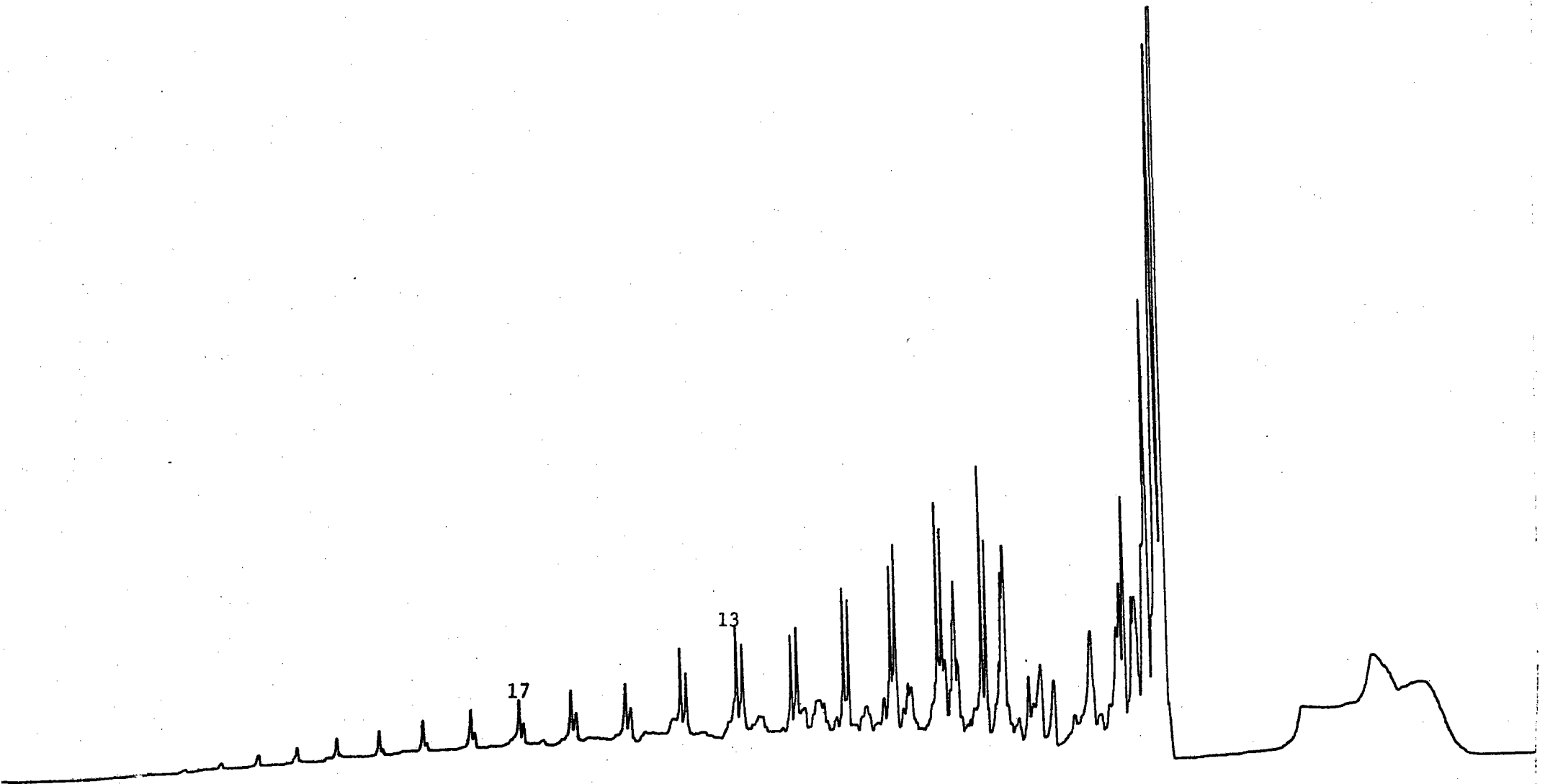


FIGURE 5

P1 DISTRIBUTION

WELL: 7/12-4, DEPTH: 3573 - 3593m, ATTEN: 8 x 10

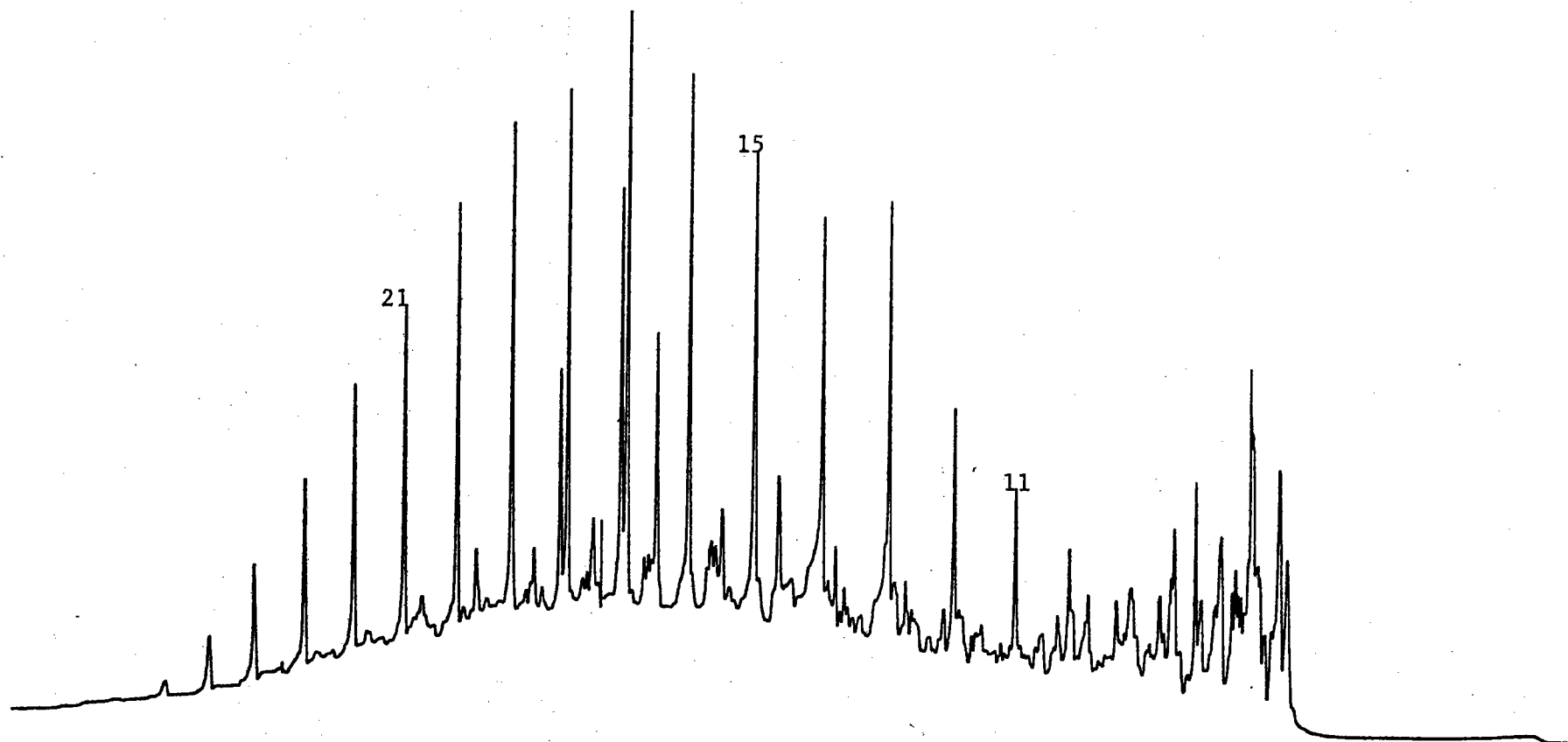


FIGURE 6

P2 DISTRIBUTION

WELL: 7/12-4, DEPTH: 3573 - 3593m, ATTEN: 8 x 10

