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	REPORT TITLE AN ORGANIC GEOCHEMICAL EVALUATION OF A GAS-CONDENSATE (DST 1) IN SAGA'S 6407/2-2 WELL OFFSHORE NORWAY	DATE OF LAST REV. REV. NO.
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SUMMARY

Well 6407/2-2 encountered gas-condensate in Middle Jurassic sandstones. The fluid is very light as shown by its high API gravity, saturates content, and very low asphaltene, trace metal and sulphur contents.

Source maturity. A thermogenic origin is clearly evident. The bulk of the gasoline and heavier hydrocarbons were released at moderate maturity levels during the main phase of hydrocarbon generation, whereas the major portion of the gas comes from a more advanced maturity level around the end of the oil window.

Source origin. The major part of the gas-condensate was generated in a source rock enriched in humic organic matter. This is in favour of the Lower Jurassic Coal Unit.

DISTRIBUTION

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CONTENTS

INTRODUCTION

Well 6407/2-2 encountered gas condensate in Middle Jurassic sandstones. This report contains an organic geochemical evaluation of a test sample (DST 1, 2476-84 m) from the discovery. Included is a discussion of the source origin and maturity as well as a data base for correlation purposes.

BULK PROPERTIES

Some bulk properties of the sample are given in Table I. The liquid part of the sample is nearly clear and highly mobile. The API gravity (52.0^{o}) is very light and in good agreement with the nature of the fluid. The sulphur content is low (<0.1%), and the trace metals nickel and vanadium are present in very low quantities, <0.5 ppm and 1.1 ppm respectively.

GASEOUS HYDROCARBONS

The sample was received in a pressurised cylinder with a considerable amount of the gaseous components preserved. The molecular and carbon isotopic composition of the hydrocarbon gases are shown in Table II.

Molecular composition

The composition is dominated by methane accompanied by a significant proportion of ethane, propane, iso-butane and n-butane making up 16% of the total gas indicating a thermogen origin.

The iso-butane to n-butane ratio is 0.57, a value usually taken as indicating association with the main phase of oil generation from the source rock.

Carbon isotopes

The isotopic composition of the gaseous hydrocarbons clearly indicates a mature source origin. The narrow carbon isotopic separations between the wet gas components fit the maturity diagram of James (1983) around a LOM (level of organic metamorphism) of 13 (Figure I) indicating that the major portion of the wet gas constituents comes from a fairly high maturity. If the gas is sourced from the Coal Unit, it should be mentioned that coal-derived gases frequently indicate a source maturity 1 to 2 LOM units too high (James, 1983).

The methane value, however, falls above the calculated line. This discrepancy between measured and calculated methane separation is due to either a mixture between an immature, possibly bacterially, produced gas with a more mature gas, or a result from cracking of oil.

GASOLINE RANGE HYDROCARBONS

A preliminary chromatogram of the gasoline range hydrocarbons is shown in Figure II, and some abundances are listed in Table III. A more detailed analysis will be available in a later version of this report.

The gasoline range hydrocarbon fraction is characterised by large amounts of light aromatic hydrocarbons. The $n\text{-}C_7$ to toluene ratio is around 0.6. The abundance of iso and cycloalkanes is also noticeable suggesting a moderate thermal evolution within the oil window.

C_{15+} HYDROCARBONS

Gross composition

Prior to the chromatographic separation, GC and GC-MS analyses of the oil, the sample was evaporated under reduced pressure at 35°C. The gross composition of the stripped sample is given in Table IV. The composition is highly paraffinic, consisting of 67.3% saturates, 25.2% aromatics, 7.8% NSO-compounds and negligible amounts of asphaltenes.

Gas chromatography

Saturated hydrocarbons. A gas chromatogram of the saturated hydrocarbon fraction is shown in Figure III. The carbon preference index and isoprenoid hydrocarbon concentration ratios are included in Table IV.

The n-alkane distribution achieves a maximum below n-C_{15}, and there is a strong decrease of n-alkanes versus increasing number of carbon atoms extending out to n-C_{30}. The n-C_{17} to n-C_{27} ratio is around 17. There is neither odd nor even predominance of n-alkanes (CPI = 1.0), and the content of sterane and triterpane compounds in the C_{27+} range is very low. Based on these data the sample appears to be mature. On the other hand the pristane to n-C_{17} is somewhat high (o.6) and could indicate a lower maturity.

The pristane to phytane ratio of 2.2 is relatively high, and suggests a partially or mainly terrestrially derived nature of the source rock organic matter.

Branched and cyclic alkanes. A gas chromatogram of the branched and cyclic alkanes is shown in figure IV. Isoprenoid alkanes occur as the major compounds. This type of fingerprint is common i many crude oil samples and is indicative of a moderate maturity.

Aromatic hydrocarbons. A gas chromatogram of the total aromatic hydrobarbons is shown in Figure V. The general shape of the chromatogram is characterised by the predominance of diaromatic compounds which is typical for a condensate.

Gas chromatography mass spectrometry

Mass chromatograms of the mass numbers 191 and 217 are shown in Figure VI. Maturity sensitive features such as the ratio of the 20R and 20S isomers of the C_{29} steranes, the relative abundance of the C_{29}BB steranes, and the C_{29} and C_{30} moretane to hopane ratios suggest a low to moderate maturity level for these high carbon number biomarker compounds.

Carbon isotopic composition

Determinations of the stable carbon isotope ratios were undertaken upon the C_{15+} hydrocarbon fractions of the condensate. The values are included in Table IV. Values of -27.9 $^{o}/oo$ and - 27.2 $^{o}/oo$ were obtained for the saturate and aromatic fractions respectively. These are heavier than normally for North Sea oils.

DISCUSSION AND CONCLUSION

Maturity

The 6407/2-2 gas-condensate is of thermogenic origin.

The narrow isotopic separations between the wet gas components suggest that the bulk of the gas was released at a fairly advanced maturity level towards the end of the oil window.

The gasoline range hydrocarbon distribution, C_{15+} branched and cyclic distribution and the pristane to n-C_{17} ratio, however, point towards a more moderate maturity level.

A reasonable explanation for these features is that the bulk of the gasoline range and heavier hydrocarbons were released at moderate maturity levels during the main phase of hydrocarbon generation, whereas the major portion of the gas comes from a fairly high maturity close to the end of the oil window. The low source maturity indicated by the high carbon number biomarker compounds is probably due to overprint by trace amounts of less mature oil.

Source origin

The abundances of light aromatic hydrocarbons, pristane and phytane, and in particular the pristane to phytane ratio are consistant with a partial or main humic nature of the source rock organic matter. This is in favour of the Lower Jurassic Coal Unit as the main source for the condensate, This suggestion is further supported by the carbon isotopic composition of the saturate and aromatic fractions.

REFERENCES

JAMES, A.T.(1983): Correlation of natural gas by use of carbon isotopic distribution between hydrocarbon components. Bull. Amer. Assoc. Petrol. Geol. 67, 1176-1191.

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS USED IN THE FIGURES

Figure I : James' (1983) maturity diagram
LOM - Level of organic metamorphism

Figure II : Gas chromatogram of the gasoline range hydrocarbons

A - propane
B - iso-butane
C - n-butane
D - iso-pentane
E - n-pentane
F - 3-methylpentane
G - n-hexane
H - cyclohexane
I - n-heptane
J - benzene + 2.2-dimethylhexane + methylcyclohexane
K - toluene

Figure III : Gas chromatogram of the saturated hydrocarbons of the stripped fluid

Pr - pristane
Ph - phytane
C_{15}-C_{25} - normal alkanes

Figure IV : Gas chromatogram of the branched and cyclic alkanes of the stripped fluid

Pr - pristane
Ph - phytane
i-C_{13}-i-C_{18} - branched alkanes

Figure V : Gas chromatogram of the aromatic hydrocarbons of the stripped fluid.

N - naphtalene
A - C_1 - naphtalenes
B - C_2 - naphtalenes
C - C_3 - naphtalenes

Figure VI : Mass chromatograms of the mass number 191 and 217

m/Z 191

A - Ts, 18α (H) trisnorphopane
B - Tm, 17α (H) trisnorphopane
C - 17α (H) - norhopane
D - normoretane
E - 17α (H) - hopane
F - moretane
G - 17α (H) - homohopane (22 S)
H - 17α (H) - homohopane (22 R)
I - homomoretane
J - 17α (H) - bishomohopane (22S + 22R)
K - 17α (H) - trishomohopane (22S + 22R)
x - tricyclic terpanes

m/Z 217

q - 14α (H), 17α (H) - C_{29} sterane (20S)
r - 14β (H), 17β (H) - C_{29} sterane (20R)
s - 14β (H), 17β (H) - C_{29} sterane (20S)
t - 14α (H), 17α (H) - C_{29} sterane (20R)
x - rearranged steranes

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TABLE : I

BULK PROPERTIES

API gravity	:	52.0^{o}
Sulphur	:	< 0.1 %
Nickel	:	< 0.5 ppm
Vanadium	:	1.1 ppm

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TABLE : II

GASEOUS HYDROCARBONS

Component	Molecular composition %	Carbon isotopic composition $\partial^{13}C$ (°/oo)
Methane	83.8	- 41.9
Ethane	8.9	- 25.4
Propane	4.9	- 25.2
iso-butane	0.9	- 24.3
n-butane	1.5	- 26.5

<u>Ratios</u>

Wetness (C_2-C_4/C_1-C_4) : 0.19

iso-butane/n-butane : 0.60

TABLE : III

GASOLINE RANGE HYDROCARBONS

Component	Composition %
iso-butane	0.9
n-butane	3.6
iso-pentane	4.8
n-pentane	6.1
2-methylpentane + cyclopentane	5.4
3-methylpentane	2.5
n-hexane	6.6
methylcyclopentane + 2.4-dimethylpentane	5.7
cyclohexane	9.3
2-methylhexane + 3-methylhexane	4.1
n-heptane	7.3
benzene + 2.2-dimethylhexane + methylcyclohexane	20.8
methylheptane	3.4
n-octane	6.4
toluene	12.7

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TABLE : IV

C_{15+} HYDROCARBONS

Gross composition

Saturates	: 67.3 %
Aromatics	: 25.2 %
NSO-compounds	: 7.8 %
Asphaltenes	: -

Carbon isotopic composition, $\partial^{13}C$

Saturates	: - 27.9 ‰
Aromatics	: - 27.2 ‰

GC-ratios

Carbon preference index (CPI)	: 1.0
Pristane/phytane	: 2.2
Pristane/n-C_{17}	: 0.6
n-C_{17}/n-C_{27}	: 17.1

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FIGURE : I

JAMES' (1983) MATURITY DIAGRAM

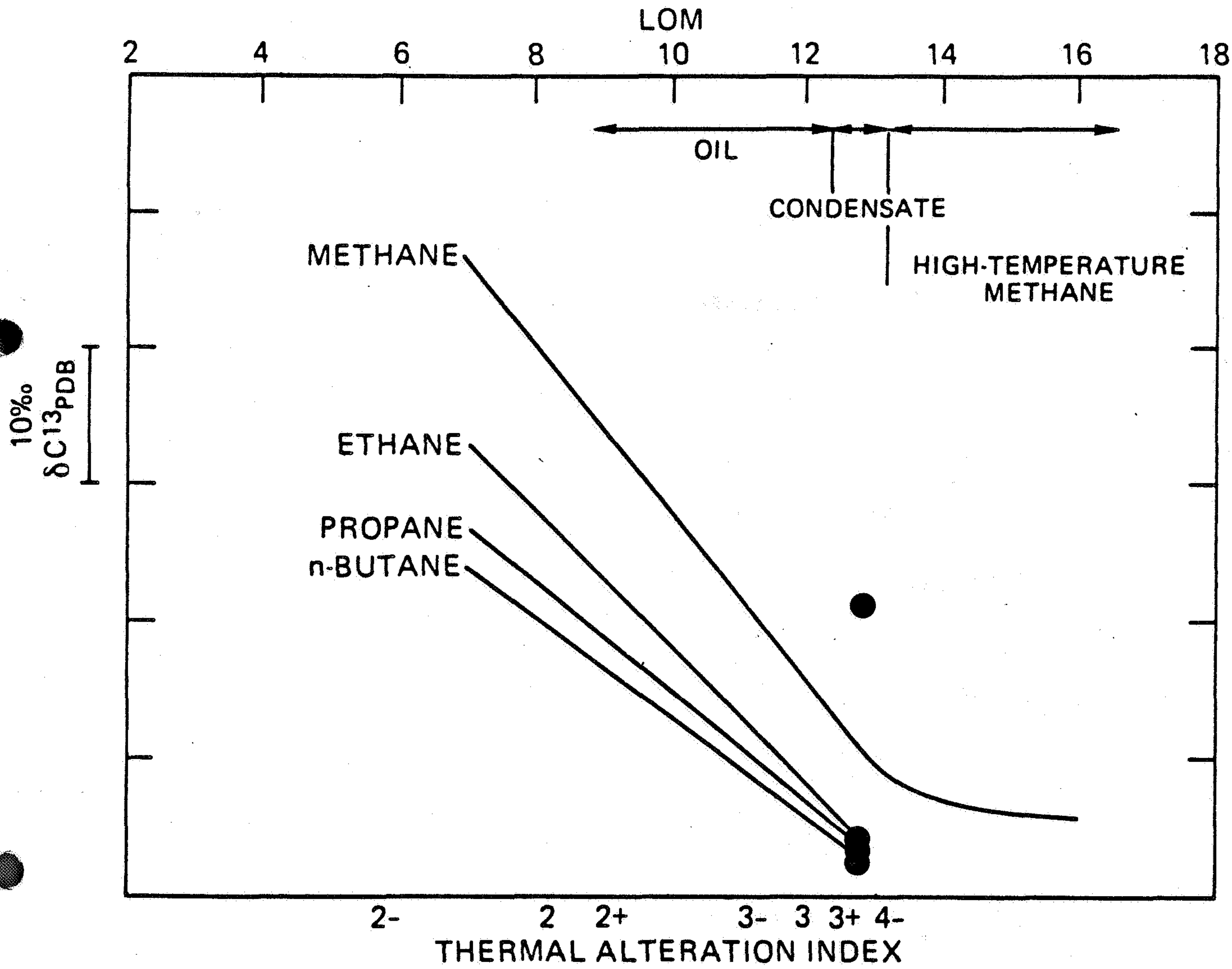

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FIGURE : II

GASOLINE RANGE HYDROCARBONS

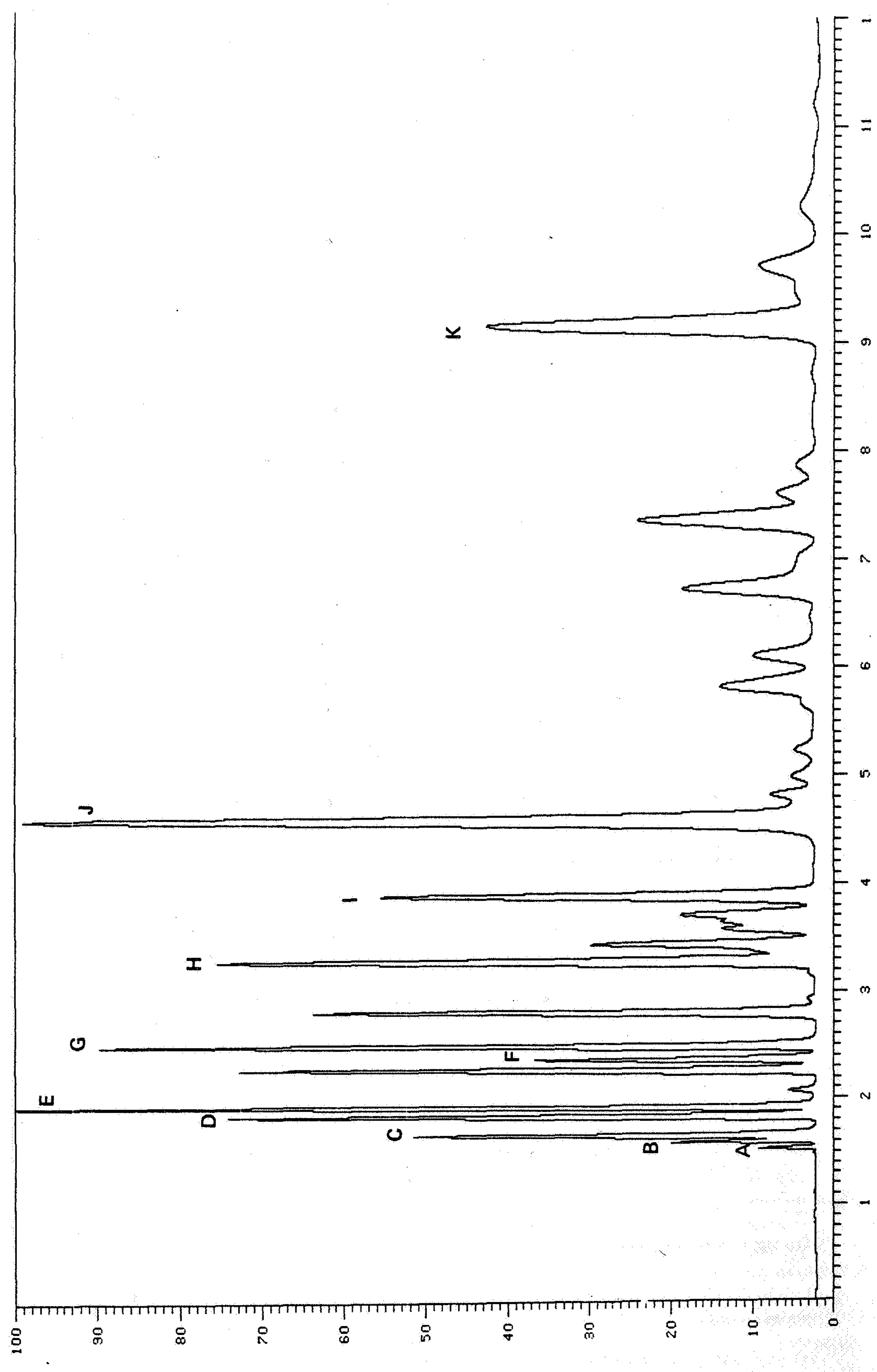

FIGURE : III

SATURATED HYDROCARBONS

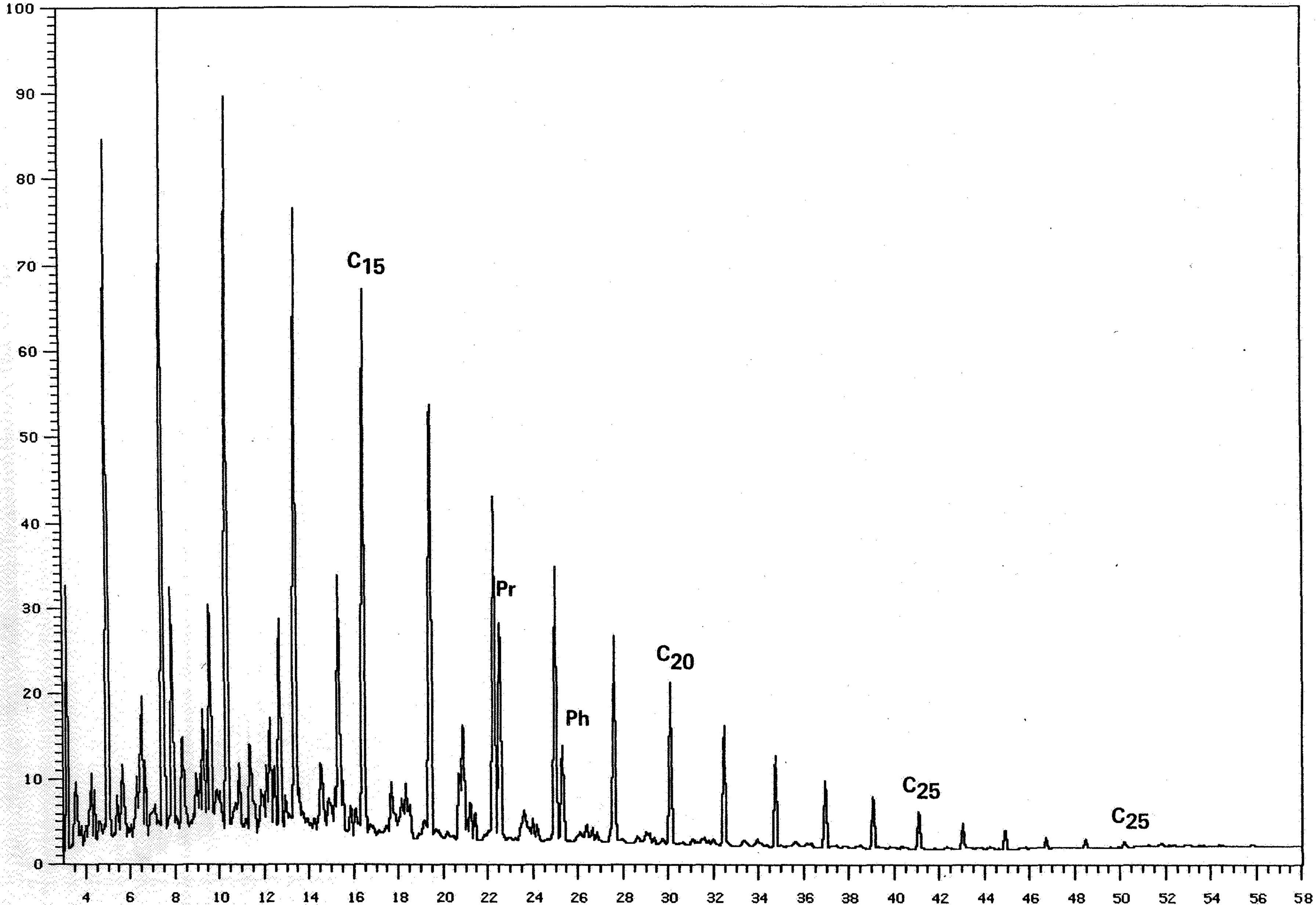

FIGURE : IV

BRANCHED AND CYCLIC ALKANES

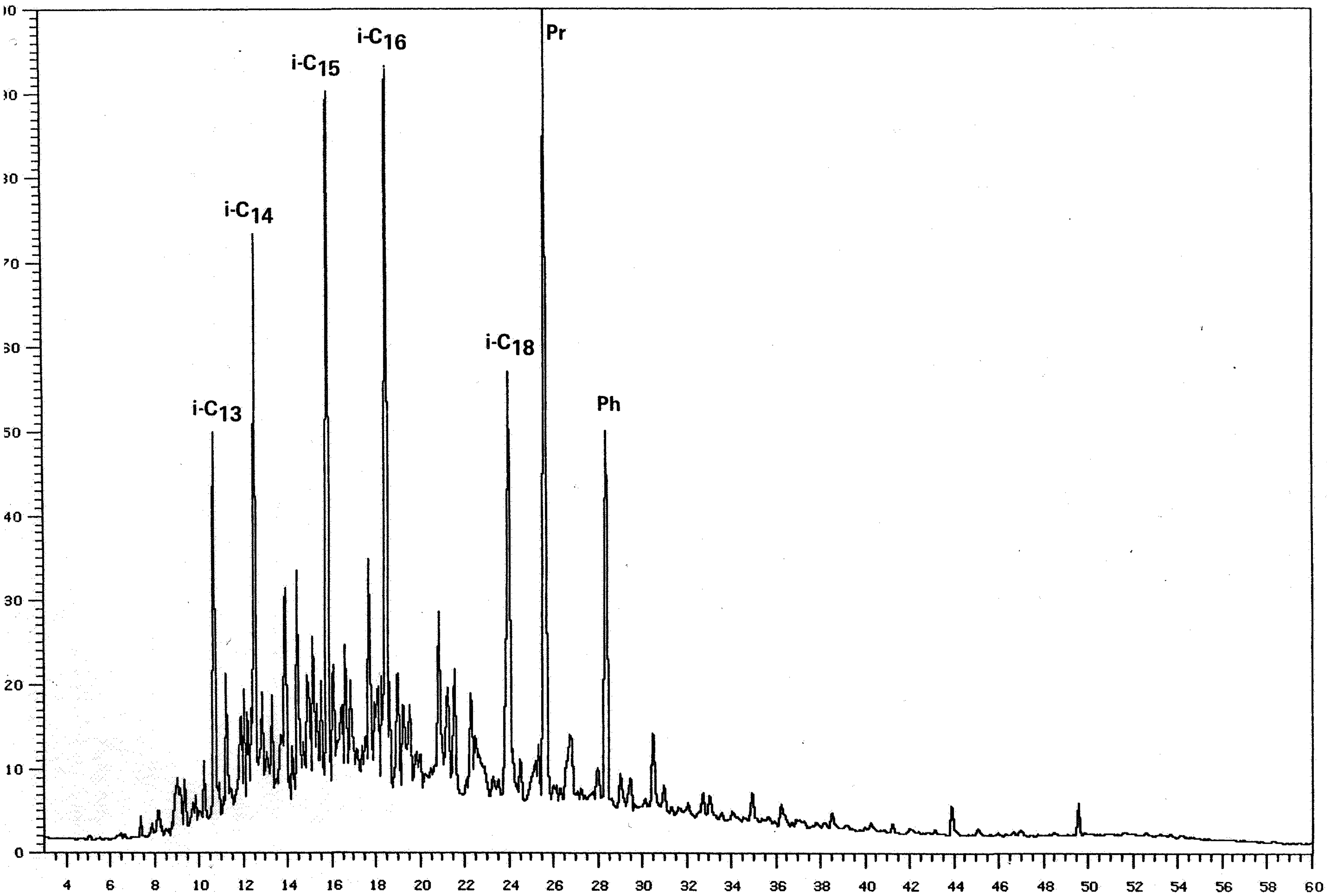

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FIGURE : V

AROMATIC HYDROCARBONS

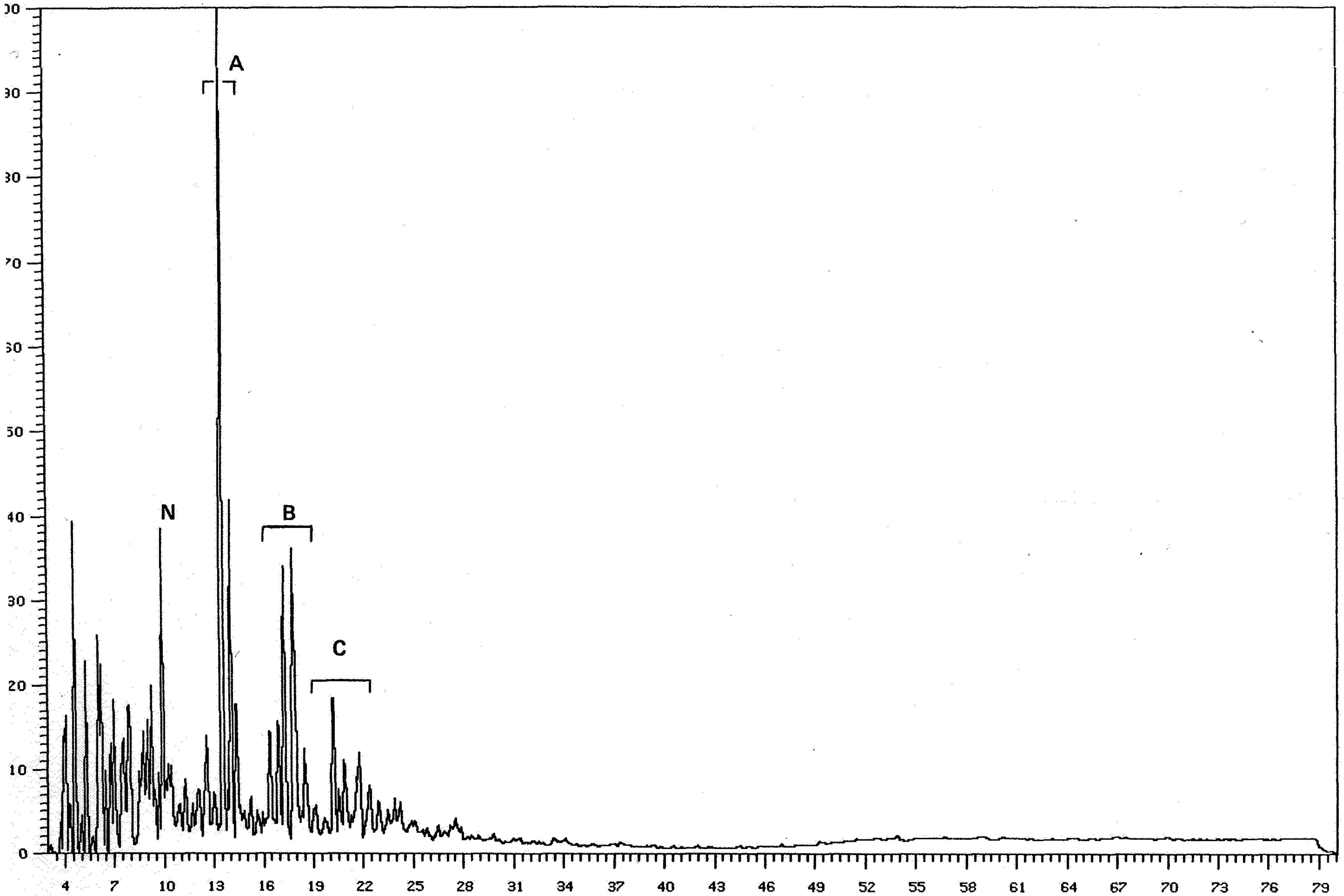

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FIGURE : VI

MASS CHROMATOGRAMS