

PRODUCTION TEST

TESTING HISTORY

After abandonment of Shell Expro well 30/30-3, the rig "Borgny Dolphin" reverted to A/S Norske Shell at 2230 hrs, 07.06.81, and was towed to well 31/2-5 for re-entry and testing. (The well had been drilled with the rig "West Venture" during 1980). The first anchor was dropped 1230 hrs, 09.06.91 and after a successful re-anchoring over the location, all anchors were tension tested to 450.000 lbs. After re-establishing the guidelines the corrosion cap was pulled without incident and the BOP stack and riser were run. The cement suspension plug (1204 -1465 m) was drilled out and a temperature survey run to 1640 m (PBSD). After carrying out a velocity survey a GR-CCL log was run. The hole was circulated clean and displaced to 1.13 SG CaCl₂ brine (filtered to 2 microns).

A brine plug was set at 1593 m. After spotting a 50 bbl HEC viscosified brine pill on bottom, the oil zone test interval 1582 - 1588 m was perforated at 12 SPF with a 5" "Hyperpack" casing gun with extended port plugs in six runs.

The interval was backsurged with a 6.0 bbl chamber and subsequent losses to the formation were cured by spotting a 20 bbl HEC viscosified brine pill across the perforations.

The 5½" wire wrapped liner GP assembly was run and landed on the bridge plug at 1593 m and the SC-1 packer was set at 1557 m. In order to reduce impairment caused by completion fluids a pre-gravelpack acidization was carried out as follows:

25 bbl 15% HCL + 10% v/v U66 (mutual solvent)
and 1% v/v A-200 (inhibitor)
50 bbl 7% HCL + 1.5% v/v HF
10 bbl 3% NH₄CL
50 bbl HBF₄
10 bbl 3% NH₄CL

The gravel-pack was then carried out as follows:

- 15 bbl 'water pack' prepad (9.4 ppg)
- 18 bbl 'water pack' slurry with 7.0 ppg Baker 'Low fines', 12-20 mesh gravel (12.15 ppg)
- 5 bbl 'water pack' after pad (9.4 ppg)

Returns were lost during the gravel packing and a total of 92 bbl of waterpack was lost to the formation. The gravel-pack was squeezed to 1050 psi and ca. 5 bbl gravel-pack slurry were reversed out. A 50 bbl HEC viscosified brine pill was spotted on bottom to cure losses prior to pulling the gravel-pack wash pipe assembly.

The 5" production test string was run but a satisfactory pressure test could not be obtained. The string had to be pulled when it proved impossible to retrieve the XN plug on top of which some 2 m of pipe scale/debris were found. The string was rerun and after repairing a malfunctioning ball valve in the EZ-tree the string was landed and satisfactorily pressure tested to 5000 psi. A post gravel-pack acidization was carried out with:

- 5 bbl diesel + 10% v/v U66 (mutual solvent)
- 30 bbl 15% HCL + 10% v/v U66 and 1% v/v A-200 (inhibitor)

which were displaced with diesel. The well was opened up and cleaned up over a period of 26 hrs. At the end of the clean up phase the well was flowing 5154 bbl/day of oil. The well was closed in and a sand bailer was run to HUD of 1591 m and retrieved some gravel pack sand and pipe scale. Subsequently, 2 Sperry Sun and one Amerada pressure gauges were run. The well was opened up and beamed up in stages to a choke size of 64/64 inch for a 14-day flow period. The well was flowing some 5700 bbl/day of oil at a FTHP of 445 psig with a GOR of some 300 - 310 scf/bbl. Only traces of sand and water production were observed. The well performance data for the full duration of the test are plotted in Enclosure 6.

The well was flowed on a 64/64 inch choke for a total of 168 hours prior to being shut in for changing the pressure gauges. The average flowrate was some 5700 bbl/day of oil at a FTHP of 450 psig with a GOR of some 300 - 310 scf/bbl. After reopening the well was flowed on a 64/64 inch choke for a further 70 hours. Since the production rate GOR and watercut remained constant at the rates mentioned the well was beaned up in stages to choke size of 2 x 64/64 inch flowing through two separators.

With an average flowrate of some 7400 bbl/day of oil at a FTHP of 530 psig the GOR increased steadily to a maximum of 1366 scf/bbl after 42 hours. The well was beaned back to 64/64 inch choke and subsequently to a 56/64 inch choke prior to being shut in at 1530 hrs 12.07.81 after being flowed for a cumulative total of 338 hours. During the beaning back period the GOR reduced to 629 scf/bbl.

The pressure gauges were recovered and a sand bailer was run, with a minimal sand recovery. The well was killed with brine and all surface equipment was rigged down and tubing riser and EZ-tree pulled. To cure minor losses experienced while pulling the tubing a 50 bbl HEC viscosified brine pill was spotted on bottom. A Baker packer plug was set in the SC-1 packer and satisfactorily inflowtested with 100 psi differential. A plug of 5 m sand was spotted on top of the packer prior to setting a retrievable Baker C-1 bridge plug at 1526 m. A cement suspension plug was set from 1450 to 1261 m. The hole was circulated to 1.22 SG brine and the riser and BOP pulled. A high pressure corrosion cap was latched on to the wellhead prior to deballasting the rig. Well 31/2-5 was suspended at 1330 hrs. 19.07.81.

31/2-5 OIL TEST

<u>Date</u>	<u>Time</u>	<u>Rate</u> <u>STB/D</u>	<u>Pwf</u> <u>psig</u>	<u>PI</u> <u>B/D/psi</u>	<u>Sep. GOR</u> <u>SCF/STB</u>
26/6	0645 - 0715	1070	2211	16.5	
"	0915 - 0930	1865	2154	15.3	
"	1100 - 1230	3210	2030	13.0	
"	1800 - 2000	5520	1846	12.8	
30/6	1800 - 200	5645	1855	13.4	
01/7	1800 - 2000	5855	1861	14.1	
02/7	1800 - 2000	5840	1860	14.0	300 - 310
03/7	1800 - 2000	5935	1856	14.1	
04/7	1800 - 20000	5720	1867	14.0	
05/7	1800 - 2000	5845	1854	13.9	
06/7	1000 - 1200	5660	1866	13.8	

Reran gauges

07/7	1800 - 2000	6090	1872	15.0	
08/7	1800 - 2000	5795	1877	14.4	
09/7	1800 - 2000	5775	1851	13.5	
10/7	1800 - 2000	7235	1587	10.5	940
11/7	1300 - 1500	7305	1490	9.3	1360
11/7	1800 - 2000	6065	1731	11.1	930
12/7	1200 - 1400	5430	1802	11.4	695

Static Pressure

29/6 - 6/7 p = 2276 psig (run 1)

07/7 - 12/7 p = 2279 psig (run 2)

Table I/8.1

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GEOCHEMICAL ANALYSIS OF A CRUDE OIL SAMPLE

FROM WELL 31/2-5, NORWAY

by

J.M.A. Buiskool Toxopeus and P.J. Grantham

15 JUNI 1982

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KONINKLIJKE / SHELL EXPLORATIE EN PRODUKTIE LABORATORIUM
RIJSWIJK, THE NETHERLANDS

A/S Norske Shell

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RIJSWIJK, THE NETHERLANDS

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GEOCHEMICAL ANALYSIS OF A CRUDE OIL FROM WELL 31/2-5, NORWAY

1. INTRODUCTION

The purpose of geochemical typing of crude oils and rock extracts is to assess oil/oil- and oil/source rock correlation. In this context four objectives are of main interest:

1. to establish the type of source material from which certain crude oils or extracts originated.
2. to find in what type of environment a source rock has been deposited.
3. to estimate the maturity of the source material that has generated a certain oil or rock extract.
4. to determine whether or not a crude has been transformed (altered) after expulsion.

The following notes are intended as a guide to the interpretation of geochemical parameters. They are keyed to the tabulated results of the current study.

2. SYNOPSIS OF INTERPRETATION OF GEOCHEMICAL PARAMETERS

API Gravity

The API gravity scale for oils is related to its specific gravity by the following formula:

$$\text{degrees API} = \frac{141.5}{\text{S.G. at } 60^{\circ} \text{ F}} - 131.5$$

Crude oils commonly range from 10-60° API. The specific gravity is mainly determined by the maturity of the source material at the time of oil expulsion and by the extent of alteration the oil has undergone (e.g. bacterial degradation, physical or thermal transformation).

Extract (Ethyl Acetate)

Rock samples are crushed and powdered and subsequently extracted in a soxhlet apparatus using ethylacetate as a solvent. The extract, freed from solvent by evaporation, is used in further analyses.

Organic Carbon after Extraction

In the extracted rock sample the organic carbon content is determined using a LECO instrument. It is generally accepted that an organic carbon content of at least 0.5% defines the lower limit for a source rock. However, this is somewhat arbitrary, dependent on the convertibility of the organic matter type into hydrocarbons and on the expulsion capability of the source beds. In this respect only the percentage of pyrolysable organic matter is of interest.

Sulphur content

The sulphur content of a crude oil depends on:

1. the kerogen type (high or low sulphur) of the source rock, which is in turn related to its environment of deposition.
2. the level of organic metamorphism of the source rock at the time of expulsion.
3. the degree of transformation (bacterial or physical) of the crude.

The major part of the sulphur in crude oils is present in the heavy ends (higher boiling-point fraction). As bacterial degradation of a crude oil preferentially removes the light ends, the sulphur content of a crude is increased by mere concentration though usually to a not too significant extent. High-sulphur crudes are associated with sulphur-rich source material, deposited in strongly reducing environments (often rich in carbonates or cherts). Sulphur-rich crudes are often heavy, being expelled at a low maturity level. Low sulphur crudes are related to low sulphur source material, deposited either in non-marine environments or in marine siliciclastic sequences. Furthermore oils expelled at a high level of organic metamorphism of the source rock are always low in sulphur, regardless of their original source material.

Porphyryns

Porphyryns are nitrogen-containing ring components often found in petroleum as nickel or vanadyl complexes. It is generally accepted that the porphyryns are derived from chlorophyll during early diagenesis. A predominance of vanadyl over nickel porphyryns is associated with a deep marine environment of deposition of the source matter, whilst nickel porphyryn predominance is linked with coastal or lagoonal waters with terrestrial influx.

Normal-Alkane Distribution

The saturated hydrocarbons of an oil (or rock extract) are separated by elution chromatography and then analysed by temperature-programmed gas chromatography. The n-alkane distribution of an oil displayed in the chromatogram provides information on its origin, maturity and possible transformation.

The shape of the n-alkane distribution reflects the original source material. The envelope of the n-alkane distributions of marine crude oils and source rock extracts are, for instance, concave, whereas landplant-related crudes and extracts usually show a convex or even bimodal n-alkane distribution.

Sometimes there is a marked predominance of odd-numbered n-alkanes over the even ones. This odd/even predominance (expressed as a 'carbon preference index') is often used as an index of maturity. However, this can be done in only a few specific cases. Indeed a distinct odd/even predominance in the C₂₅₊ region is indicative of a landplant wax contribution in the source material while oils and extracts of marine origin do not exhibit such odd/even predominance. Biodegraded oils are characteristically deficient in n-alkanes. Severe bacterial degradation will result in a complete removal of n-alkanes and finally even of the isoprenoids (see Fig. A).

Isoprenoid isoalkanes

Many crude oils and source-rock extracts contain a series of isoalkanes with structures based on the isoprene unit. They are believed to be derived from phytol, a hydrolysis product of chlorophyll. The most common isoprenoids in crude oil are pristane and phytane. The relative abundances of these two compounds, expressed as pristane/phytane ratio, pristane/n-C₁₇, or phytane/n-C₁₈ is mainly an indication of the depositional environment of the source rock. High pristane/phytane and pristane/n-C₁₇ ratios are related to a swampy environment of deposition with low bacterial activity. Low ratios are expected in open aquatic conditions (marine or fresh water), where there is abundant bacterial activity.

C₇ Distribution

Crude oil samples are distilled to obtain the volatile fraction boiling below 120°C. This fraction is subsequently analysed by gas chromatography to obtain a detailed distribution of all C₇ hydrocarbon isomers. A triangular plot of straight-chain (normal), monobranched, and polybranched C₇ alkanes is used to distinguish slightly bacterially degraded or transformed crudes from their unaltered counterpart (Fig. B). In a plot of n-C₇ alkanes - branched alkanes - naphthenes oils of similar origin form clusters, while also some information is obtained from this triangular plot about the environment of deposition of the related source rocks (see Fig. B). Note that this latter plot cannot be used for (even slightly) bacterially degraded crude oils. The relative abundances of C₇ alkanes, naphthenes and aromatics may be used to determine whether waterwashing in the reservoir has occurred.

Mass spectrometric analysis

Parameters M1 and M2

From the mass spectra of crude oils and extracts two parameters M1 and M2 can be derived, which are very useful for oil and source rock characterisation. The positions in these triangular diagrams give information about the original source material as is indicated in Fig. C. Note that parameter M1 cannot be used for bacterially degraded crude oils.

DOM of oils

The maturity of the oil and/or extract can be calculated from mass spectrometric data. The calculated maturity is expressed in DOM (degree of organic metamorphism) units, which cover the following ranges:

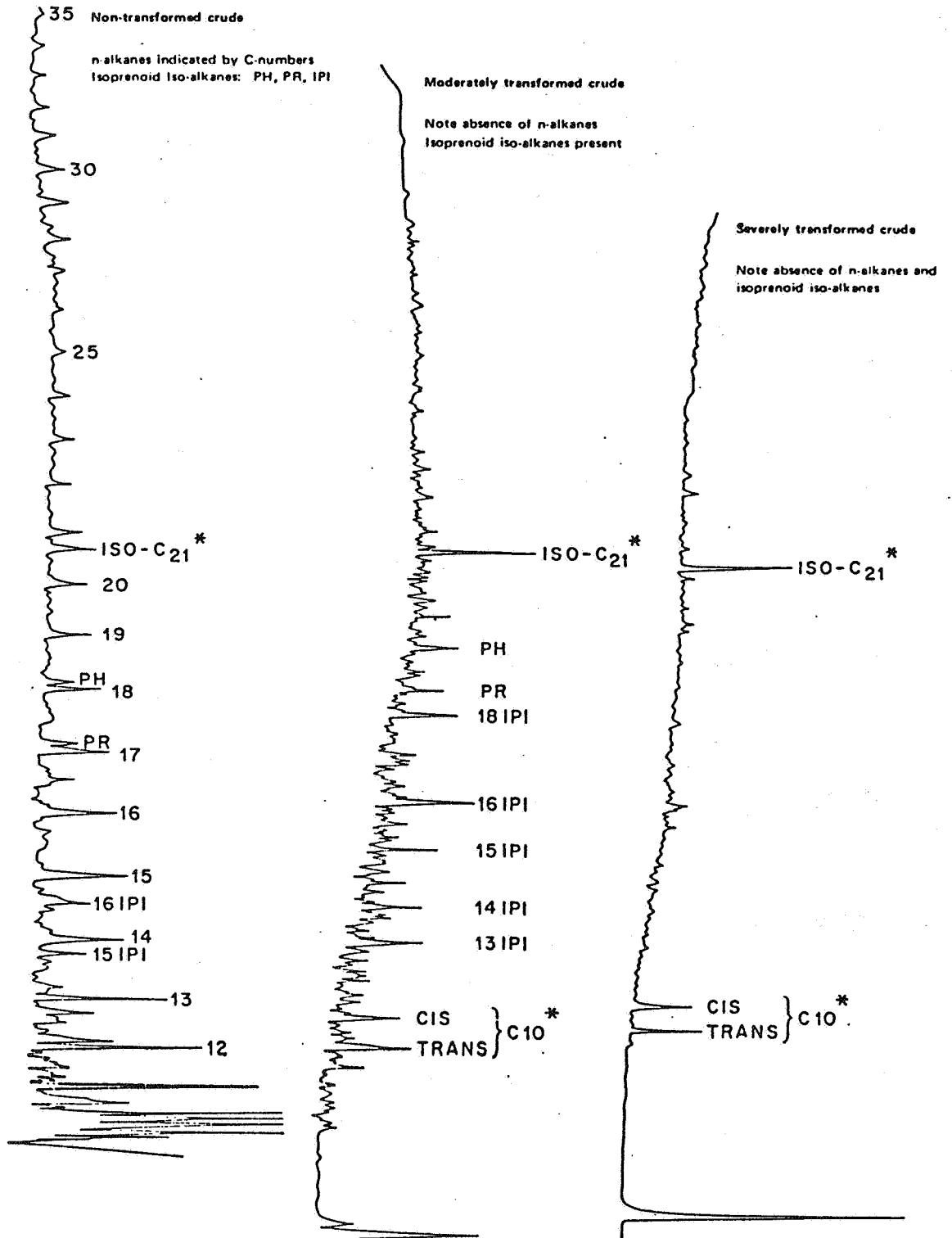
<u>DOM</u>	<u>MATURITY ZONES</u>
<60	Immature
60-75	Mature for oil generation
75-92	Mature for gas generation Post mature for oil generation
>92	Post mature for both oil and gas.

Sterane and triterpane parameters

Steranes and triterpanes are chemical fossils which can be used in geochemical typing. Combined gas chromatographic-mass spectrometric (GC-MS) analysis gives sterane and triterpane fragmentograms. These are gas chromatograms in which all the peaks are those of either steranes or triterpanes. Examples of the triterpane fragmentograms of a land-plant and a marine crude can be seen in Fig. D. Further differentiation between marine crudes can be obtained from sterane fragmentograms (see Fig. E).

From this analysis the organic matter can be classified into material derived from:

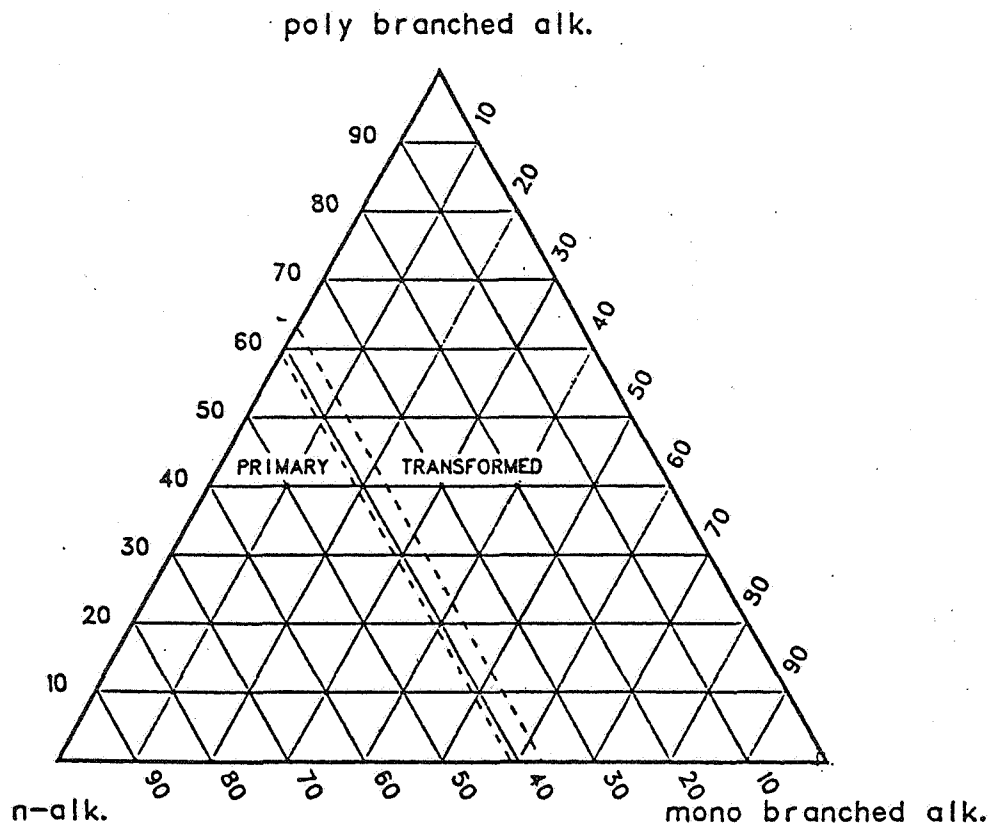
- I. resinous land-plant material
- II. mixed land-plant/S.O.M. material or algae
- IIIA reworked marine phytoplankton plus bacteria
- IIIB reworked algae plus bacteria.



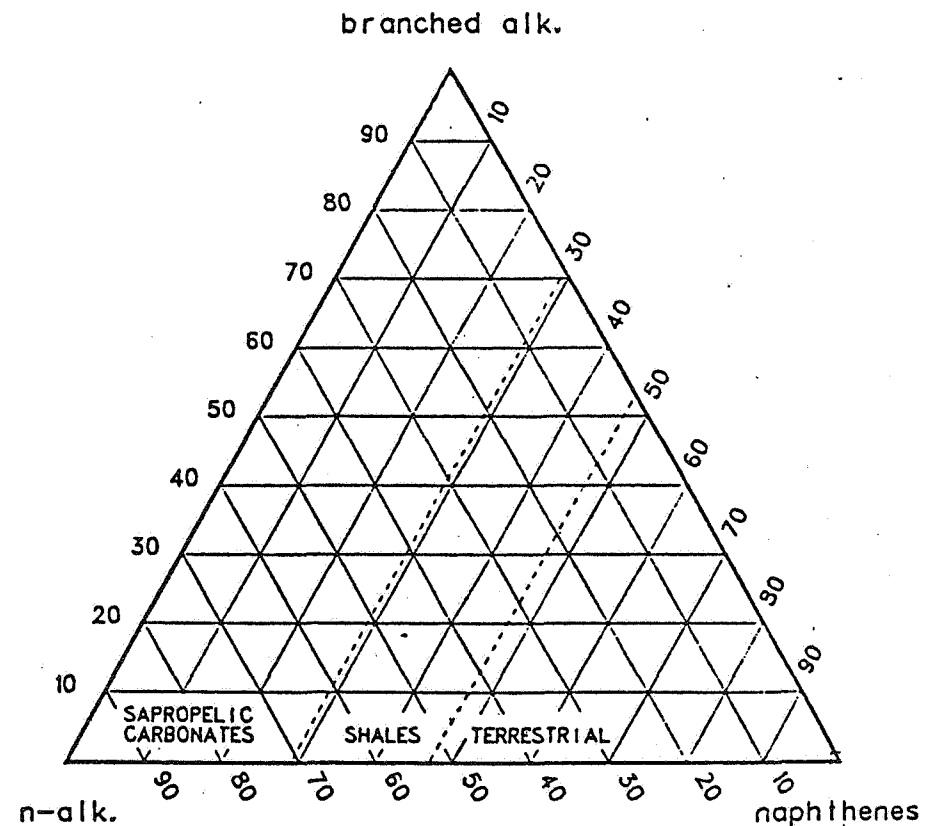
*STANDARD COMPOUNDS ADDED FOR IDENTIFICATION

BACTERIAL DEGRADATION DISPLAYED IN GAS CHROMATOGRAMS OF SATURATED HYDROCARBONS.

C₇-ALKANE DISTRIBUTION

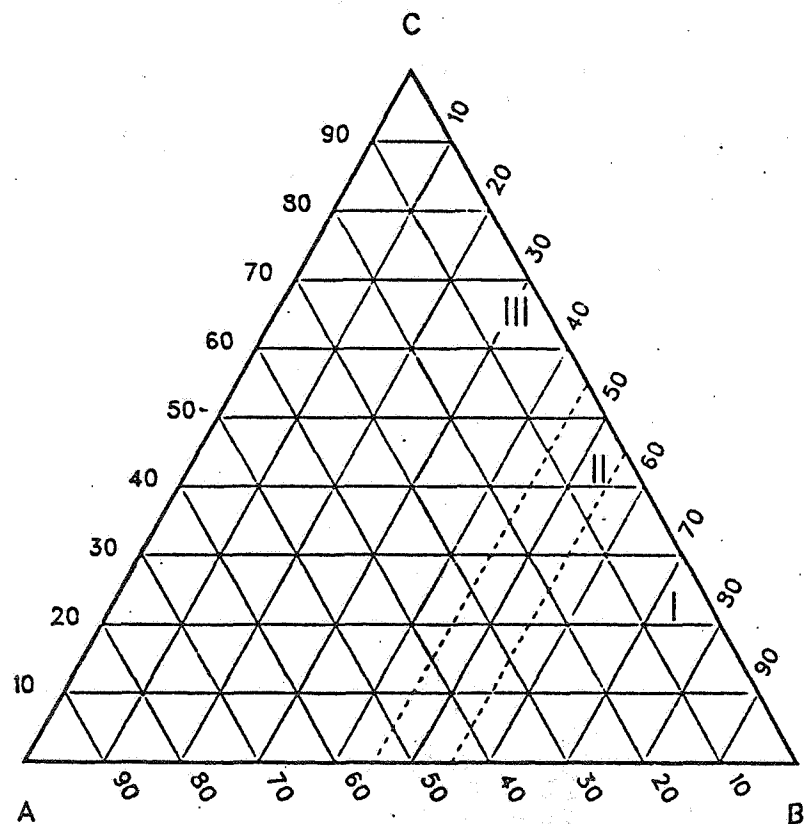


C₇-ALKANE/NAPHTHENE DISTRIBUTION

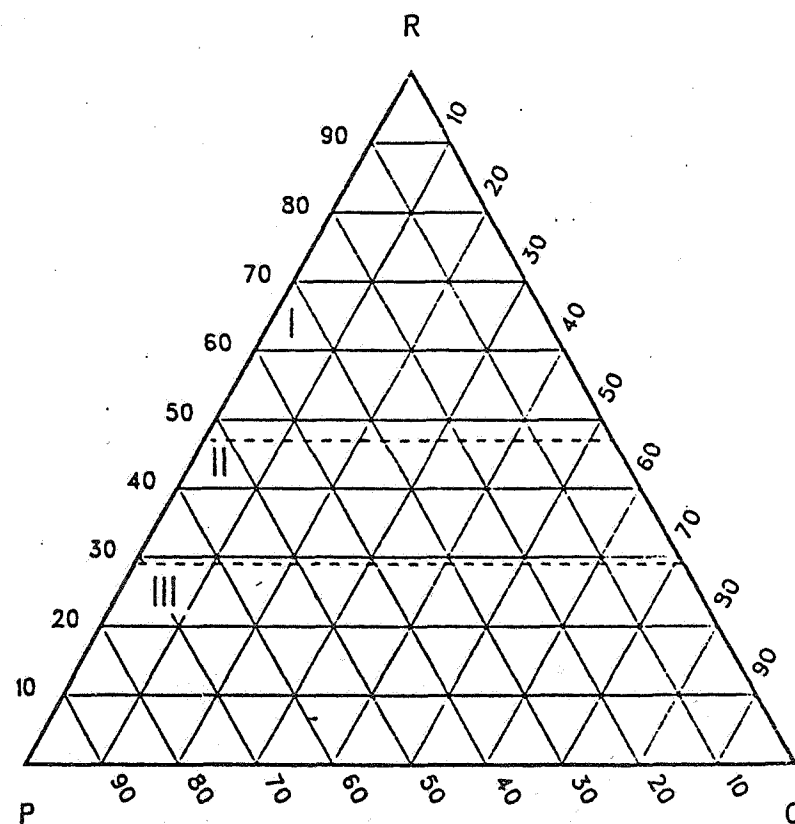


C₇ DISTRIBUTION FOR CHARACTERISATION OF RELATED SOURCE MATERIAL.

Parameter M1



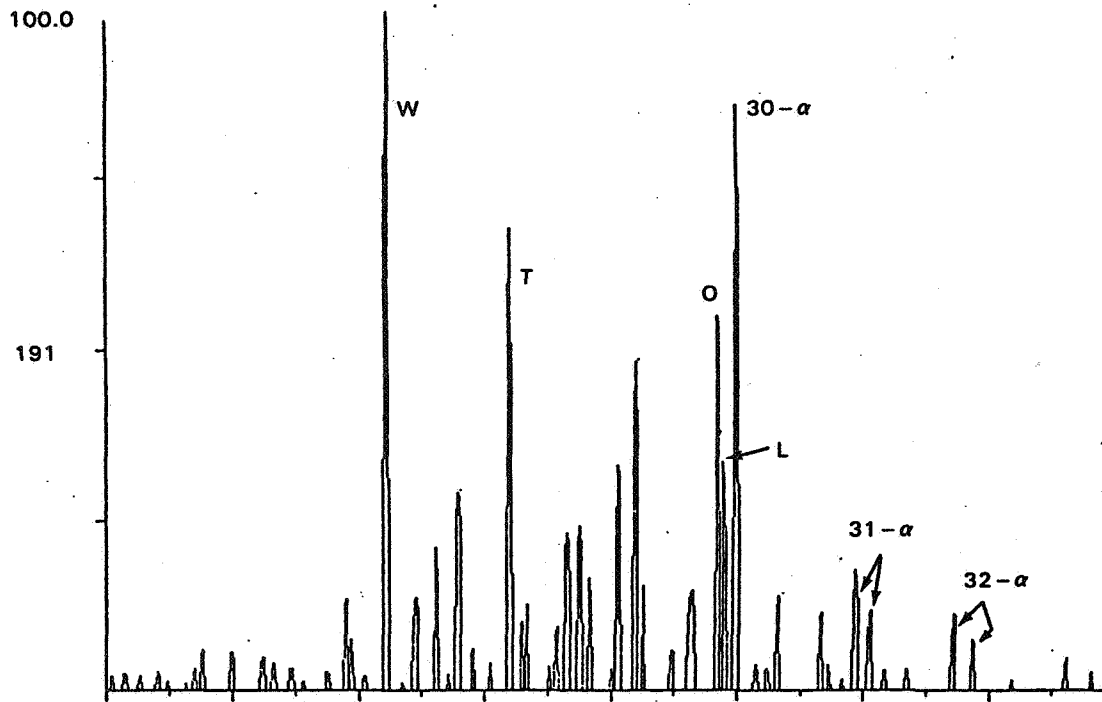
Parameter M2



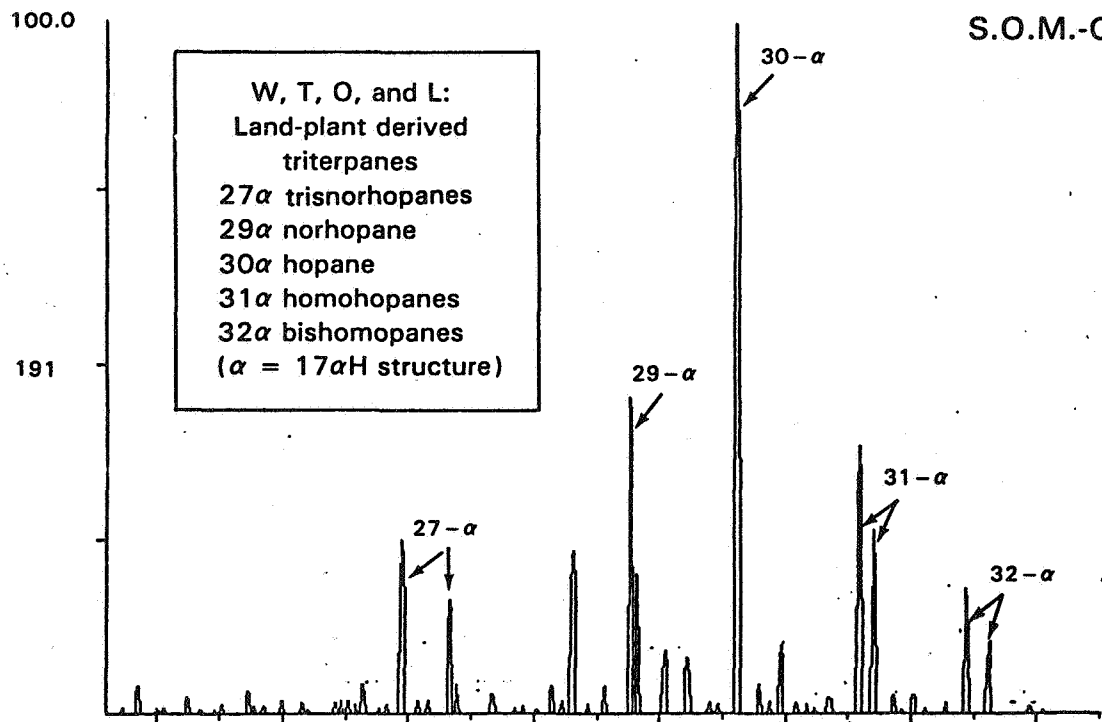
- I LANDPLANT-DERIVED CRUDES WITH SUBSTANTIAL RESIN CONTRIBUTION TO SOURCE MATTER
- II CRUDES OF MIXED ORIGIN
- III CRUDES DERIVED FROM SOM AND/OR ALGAL MATTER

PARAMETERS M1 AND M2 TO TYPE RELATED SOURCE MATERIAL.

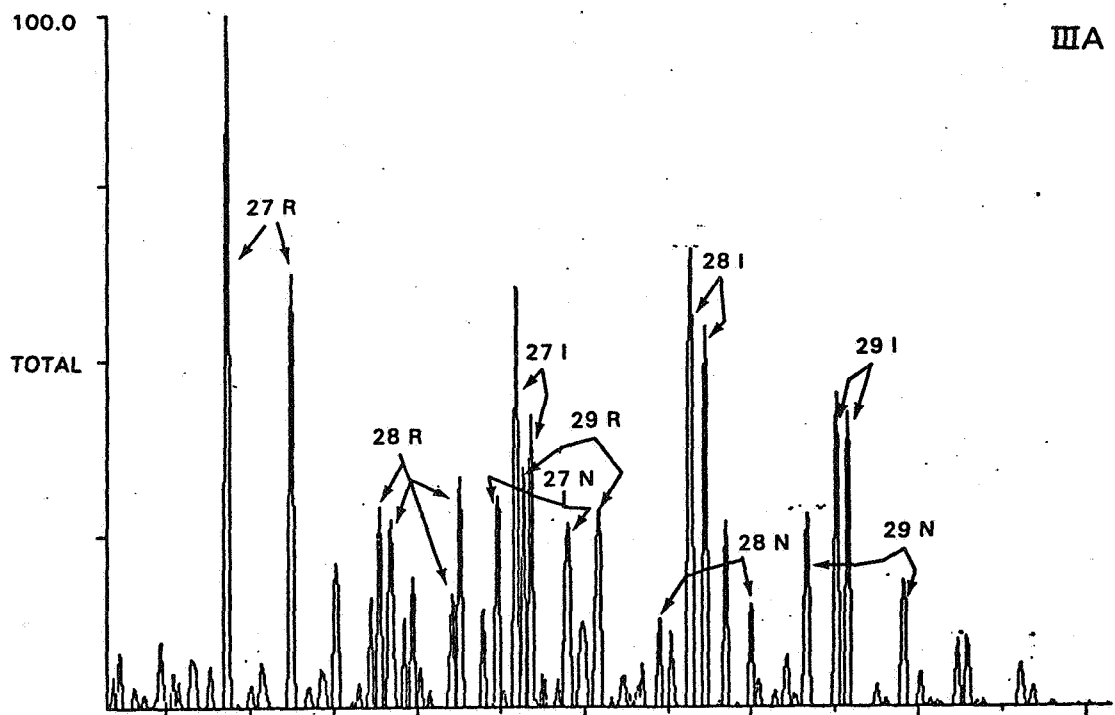
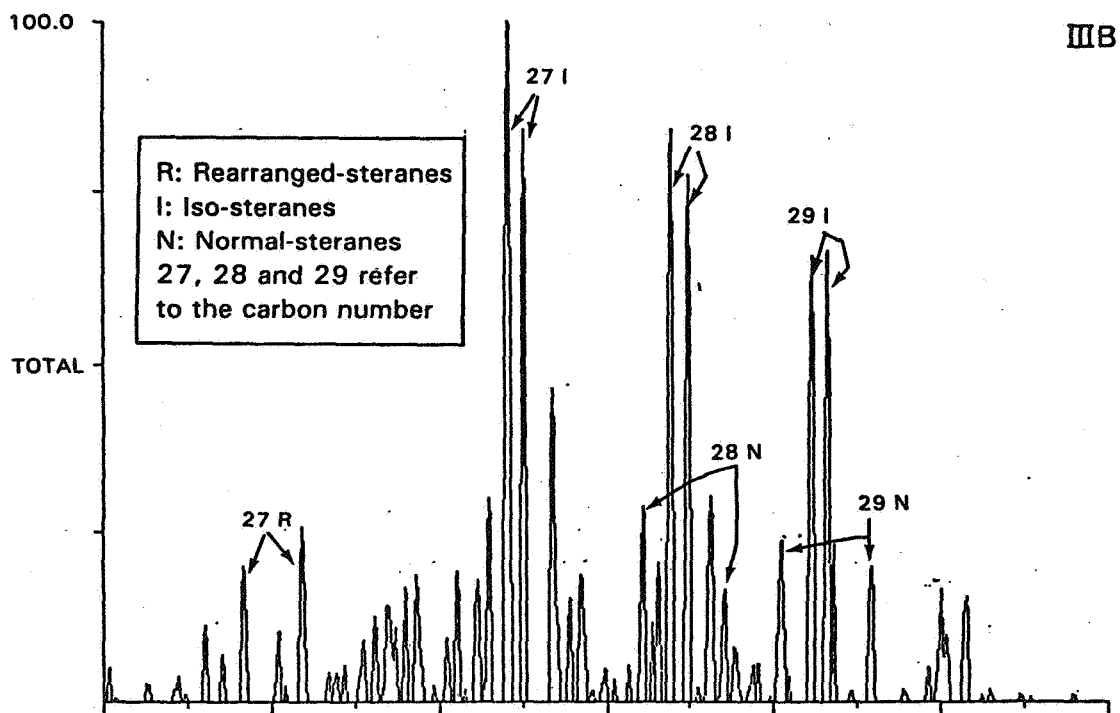
LAND-PLANT CRUDE



S.O.M.-CRUDE



TRITERPANE FRAGMENTOGRAMS OF CRUDES DERIVED FROM LAND-PLANT AND STRUCTURELESS ORGANIC MATERIAL RESPECTIVELY



STERANE FRAGMENTOGRAMS OF TYPE III A AND III B CRUDE OILS

3. RESULTS AND DISCUSSION

A geochemical analysis has been carried out on a crude oil sample from well 31/2-5. The results are shown in Table 1 and in Figures 1-4. The results indicate the following:

- 3.1 The gas chromatogram of the saturated hydrocarbons (Fig. 1) and the C₇-alkane distribution (Fig. 2) indicate that the crude is heavily bacterially degraded.
- 3.2 The DOM of oil is susceptible to bacterial degradation which lowers the figure. Hence, the DOM of oil of 63 and also the sterane/triterpane fragmentograms (Fig. 4) indicate that the crude was generated from a mature source rock.
- 3.3 As the crude oil is bacterially degraded, no definite conclusions can be drawn from the parameter M₁ and the C₇-alkane/naphthene distribution. However, the parameter M₂ (Fig. 3) and the sterane/triterpane fragmentograms (Fig. 4) indicate that the source rock contained structureless organic matter of bacterially-reworked-phytoplanktonic origin.
- 3.4 Most geochemical parameters are influenced by the bacterial degradation. However, the carbon isotope value, the parameter M₂ and the sterane/triterpane fragmentograms are similar to an average North Sea crude oil.

4. CONCLUSIONS

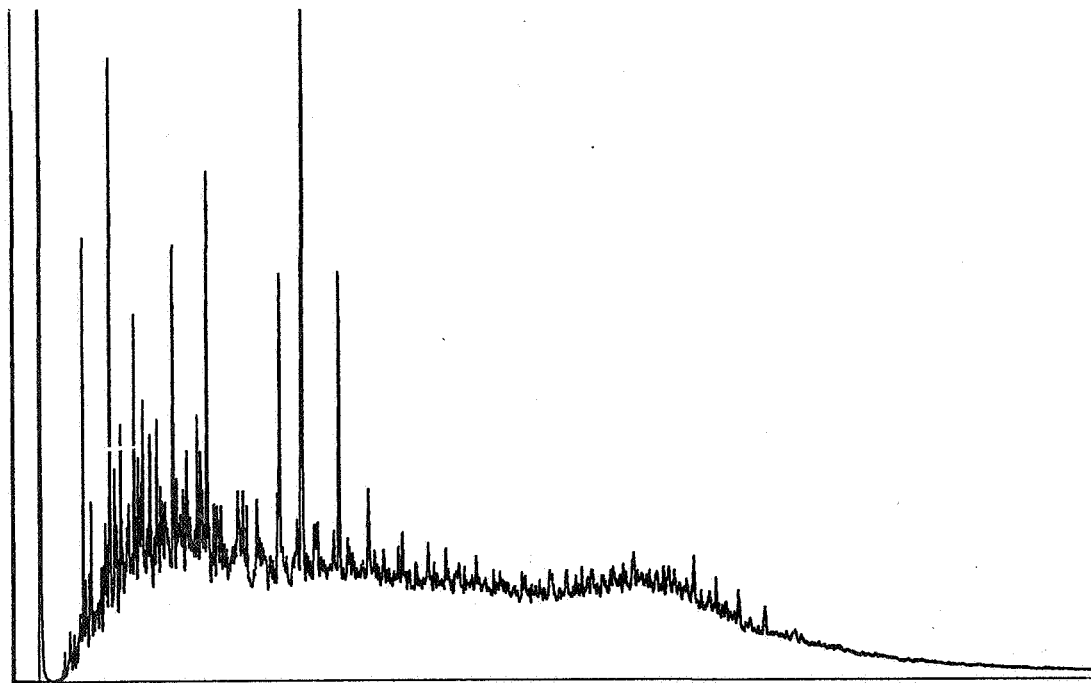
The crude oil from well 31/2-5, Norway, is heavily bacterially degraded. The crude was generated from a mature source rock which contained structureless organic matter of bacterially-reworked-phytoplanktonic origin. The carbon isotope value, the parameter M₂ and the sterane/triterpane fragmentograms show similarities with an average North Sea crude oil.

TABLE 1 - GEOCHEMICAL DATA OF OILS

Sample	31/2-5*
API	28.7
specific gravity	0.8832
%w. boil. <120°C	9.0
% sulphur	0.30
ppm V as metals	1
ppm Ni as metals	2
pristane/phytane	
pristane/nC17	N.D.
phytane/nC18	
C ₇ -distribution	
C ₇ -alkane	
nC7	1
monobranched	49
polybranched	50
C ₇ -alk/naphthene	
nC7	0
naphthenes	83
branched alkanes	17
C ₇ -alk/naphth/arom	
nC7	15
naphthenes	75
aromatics	10
Parameter M ₁	
A	15
B	17
C	68
Parameter M ₂	
P	22
Q	51
R	27
DOM of oil	63
% asphaltenes	0.3
% saturates**	48
% aromatics	16
% heterocompounds	8
% rest	28
$\delta^{13}\text{C}/\text{oo}$	-28.1

** Determined by column chromatography

N.D. = not detectable

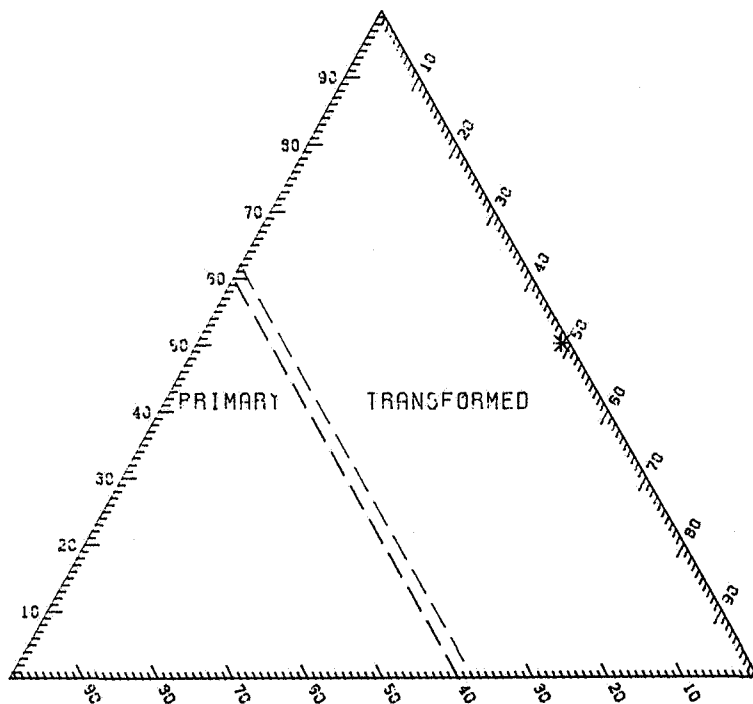


GAS CHROMATOGRAM OF SATURATED HYDROCARBONS

FIG. 1, NORWAY 31/2-5

C7-ALKANE DISTRIBUTION

POLY BR-ALK.

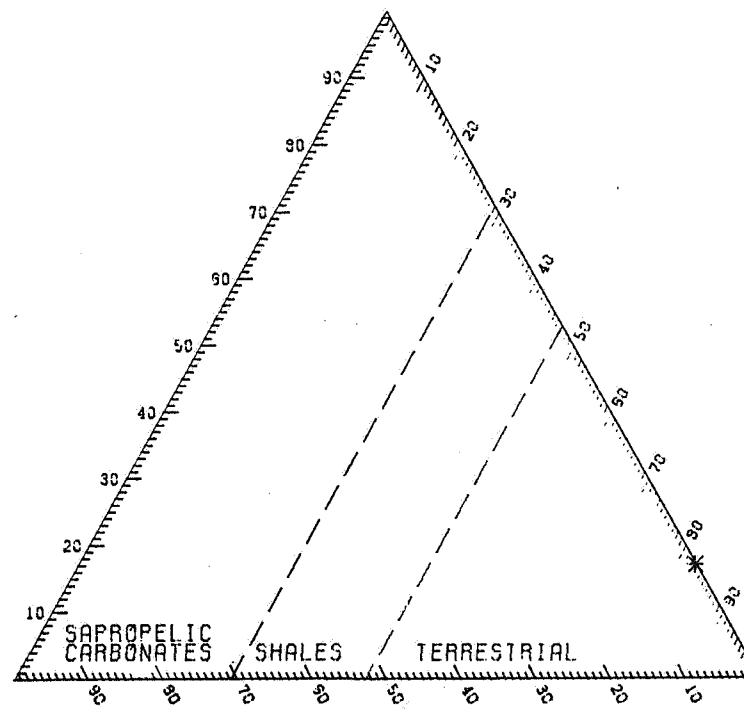


N-ALK.

MONO BR-ALK.

C7-ALKANE/NAPHTHENE DISTRIBUTION

BR-ALK.

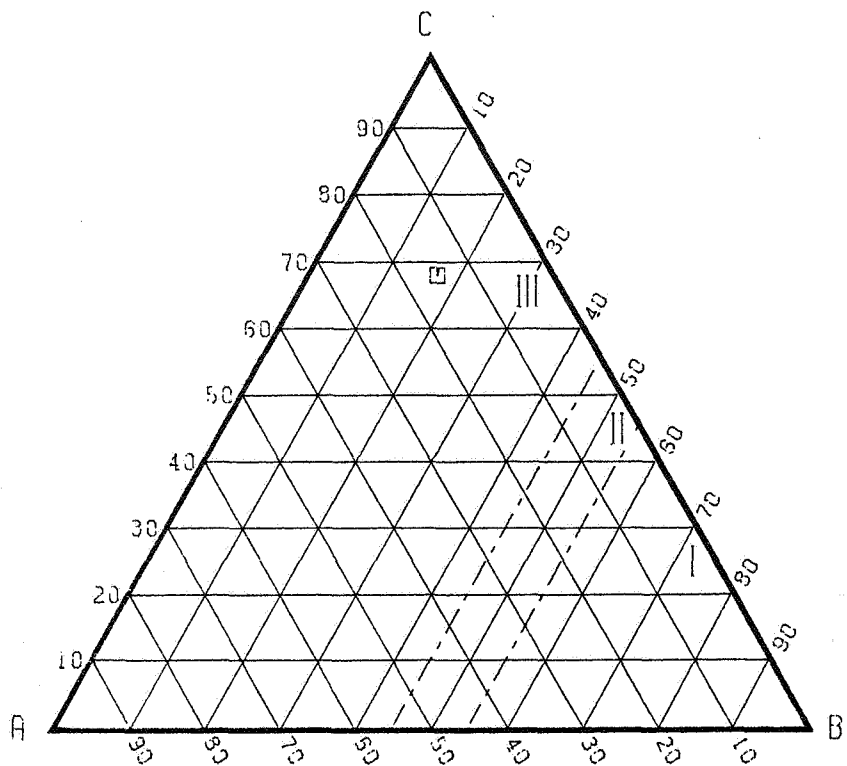


N-ALK.

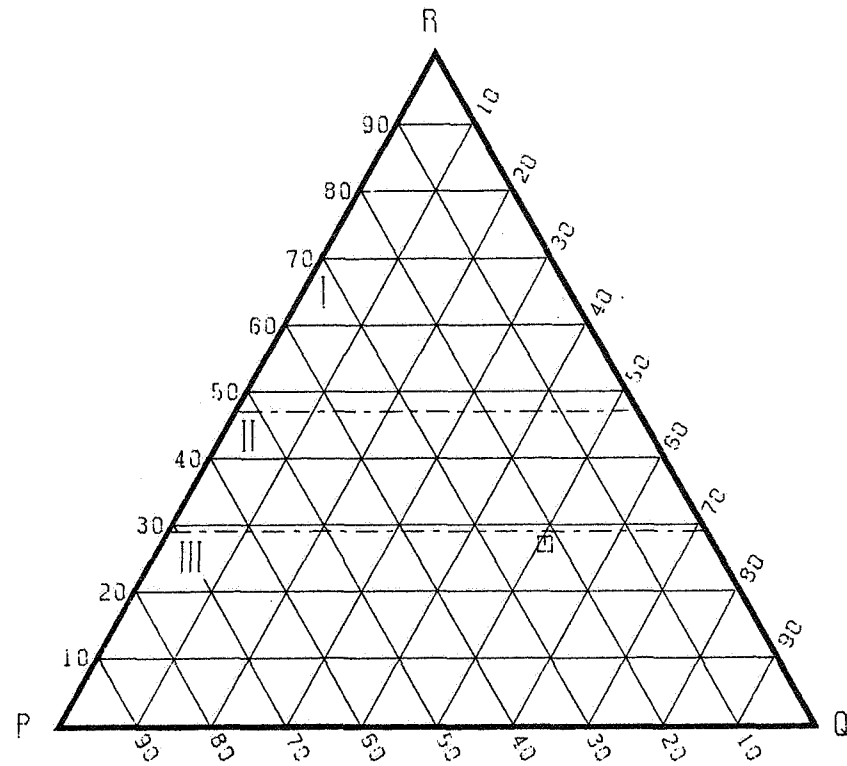
NAPHTHENES

COUNTRY	WELL/OUTCROP	DEPTH/ SAMPLE NR.
* NORWAY	31/2-5	UNKNOWN

PARAMETER M1



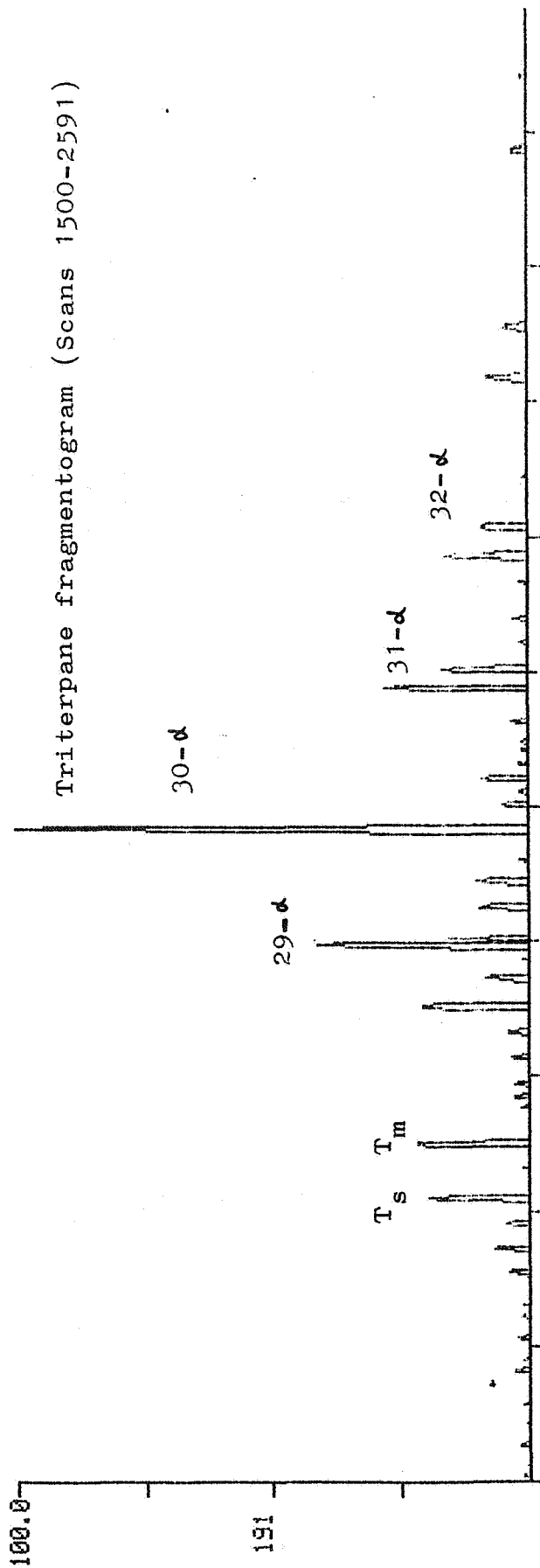
PARAMETER M2



- I LANDPLANT-DERIVED CRUDES WITH SUBSTANTIAL RESIN CONTRIBUTION TO SOURCE MATTER
- II CRUDES OF MIXED ORIGIN
- III CRUDES DERIVED FROM SOM AND/OR ALGAL MATTER

LEGEND
□ - 31/2-5

Triterpane fragmentogram (Scans 1500-2591)



Sterane fragmentogram (Scans 1400-1950)

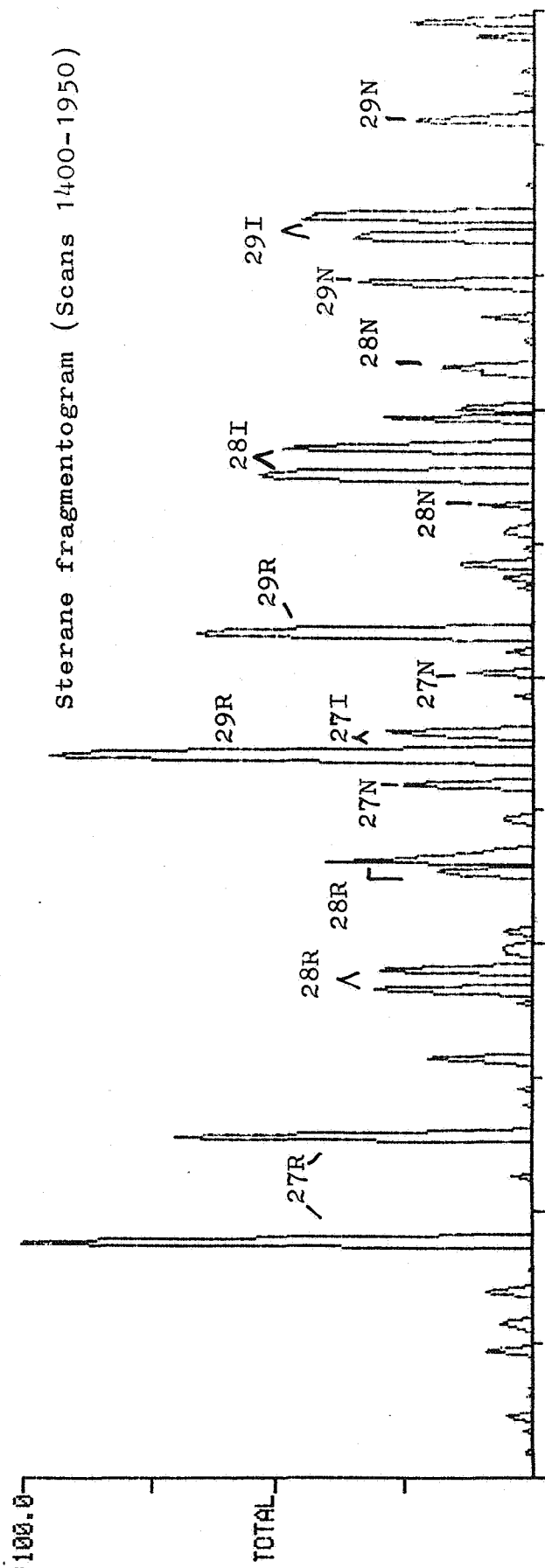


FIG. 4. GC-MS analysis 31/2-5

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