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15/3-5 WELL (NORWAY)

OPTICAL AND GEOCHEMICAL STUDY

OF ORGANIC MATTER IN THE JURASSIC SECTION

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C O N T E N T S

TABLES

FIGURES (in text)

PLATES (after text)

A B S T R A C T .

The main findings from the optical and geochemical study of organic matter in the Jurassic section are :

In the Draupne formation, organic matter is abundant, mainly marine sapropelic with some terrestrial input lowerdown ; very high oil genetic potential.

In Heather formation : marine and continental organic matter ; low to very low potential.

In the Sleipner formation : kerogen of marine origin associated with land derivatives, while the underlying section includes continental organic matter : low to medium potential.

Diagenesis increases slightly more than in normal rank evolution, between 0,60 % VRo (3808,30 m) and 0,8 VRo at TD = 4130 m, and sites the Jurassic in the oil generation zone.

The migrated hydrocarbons in the 3980,75 m sandy level of the Sleipner fm. have characteristics which were previously found in syngenetical extracts from Portlandian-Kimmeridgian rocks in wells 15/3-1, 3 and 4.

POSITION MAP

BLOCK : 15 3

WELL : 15 3-5

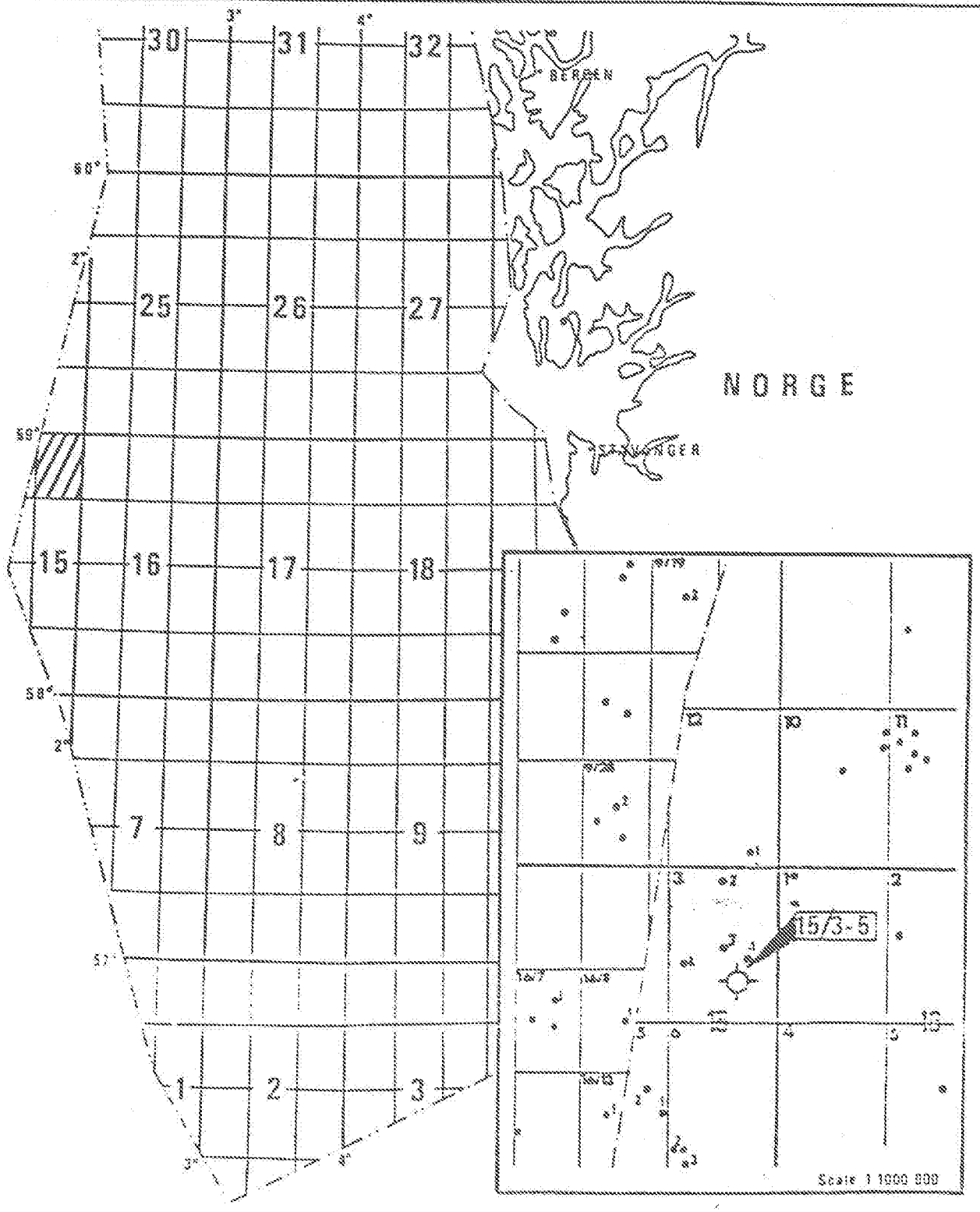
OWNER : PETRONORD GROUP

COORDINATES: X: 01° 50' 36" E
Y: 58° 47' 12,5" N

INTERSECTION OF SEISMIC LINES: 580-322 and EL 8206-413A

Scale 1 2500 000

Date



EXPLORATION DIVISION

Fig.1

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Organic matter present in the Jurassic section of 15/3-5 well (fig. 1), was studied using optical and geochemical methods.

In tranemitted light (Palynology), 33 samples (14 side wall core, 6 cores and 8 cutting samples) were analysed between 3809 m and 4124 m (T.D. 4130 m).

Reflectance and fluorescence data were obtained from 9 samples (3 SWC, 3 core and 3 cutting samples) between 3808,30 m and 4090 m.

Geochemical analysis were carried out on 42 samples (19 SWC, 6 cores and 17 cutting samples) in the same interval. In addition, total organic carbon content was measured in 10 cutting samples in the Cretaceous (3500-3800 m) ; no further data could be obtained from pyrolysis in this interval.

1 - ORGANIC CARBON CONTENT

The amount of total organic carbon (TOC) was measured in all samples (Table I) :

CRETACEOUS

(cuttings)	0.3 < T.O.C < 1 %

UPPER JURASSIC

Draupne fm. (SWC)	4 < T.O.C < 7.5 %
Heather fm. (SWC and cuttings)	2 < T.O.C < 3.5 %

MIDDLE JURASSIC

SLEIPNER (cuttings and core samples from coaly levels)	2 < T.O.C < 6 %

2 - CHARACTERISTICS OF ORGANIC MATTER

The main results of the microscopical study of organic matter are summarized on Plate 2 and Plate 3 ; geochemical data (Rock Eval pyrolysis) is shown in table I and on the IH-IO diagram (Fig. 2).

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2.1 - DRAUPNE Formation - 3808-3881 m Elogs

Early CRETACEOUS (RYAZANIAN) - Late JURASSIC (Portlandian and Kimmeridgian).

. Interval 3809-3863 m (Ryazanian, Portlandian to Middle Kimmeridgian)

A sapropelic groundmass with low fluorescence containing orange dinocysts and filamentous exinites was observed at 3808.30 m. The marin origin of the organic matter is well documented in Palynology by an influx of amorphous organic matter associated with abundant dinocysts and alga. Exinites consist mainly of land-derived Gymnosperm pollen grains.

Pyrolysis data (Table I ; Fig. 2) characterizes a Type I kerogen in SWC 8 to 13 with a noticeably high Hydrogen index of 680 at 3810,3 m ; other values vary from 225 to ca.500.

. Interval 3866-3876 m (Early Kimmeridgian)

The organic matter appears to be partly of marine origin and displays frequent dinocysts. The dominant components of the organic matter are land derived and contain abundant gymnosperm pollen grains and black woody fragments. In the SWC 3870 sample, a coaly population of inertinites (75 %) and vitrinites with a very low fluorescence (25 %) was observed, associated with a fluorescent groundmass. The fluorescence index attains a moderate value : 2.

The presence of terrestrial organic material does not affect pyrolysis data : the Hydrogen Index is still high (500) at the lower limit of this interval (3876 m). (type I and II kerogen).

2.2 - HEATHER Formation 3881-3935 m E.logs - (Early Kimmeridgian/Late Oxfordian, Middle Oxfordian and Early Oxfordian)

The marine origin of the organic matter is substantiated by abundant dinocysts. The land-derived material (Gymnosperm pollen grains and black ligneous debris) remains abundant throughout the interval. This is supported by low Hydrogen index values (< 150) and by high oxygen index values (type III kerogen).

2.3 - SLEIPNER Formation 3935-4077 m - E.logs - Middle Jurassic (BATHONIAN and BAJOCIAN)

. Interval 3940-4016.50 m - BATHONIAN

The organic matter recovered in the SWC and cores 1 and 2 samples is of marine origin and displays abundant dinocysts.

The organic matter of continental origin is composed of abundant spores and pollen grains, frequent cuticles and abundant black ligneous fragments.

A typical humic organic matter was observed with reflectance-fluorescence analysis, having the following characteristics :

- 3965 m : Composite coals with vitrinites (60 %), inertinites (30 %) and exinites (10 %), mainly made up of orange sporinites (Hydrogen Index : 178 ; Oxygen Index 180)

- Core 1 - 3981,50 m : Pure homogeneous or structured vitrinites and rare yellowish humic groundmass. The vitrinite grains are often surrounded by fluorescent dissolution haloes.

- Core 2 - 3990,50 - SWC 4016.50 m : A brownish groundmass of undetermined nature is predominant, with fluorescent vitrinites and bitumens. The fairly rare exinites consist of orange cutinites, sporinites and Dinocysts. This level exhibits the highest fluorescence indices (2 and 3).

  Related Hydrogen Index : 180 to 260 accords with either a mixture of kerogen types II and III (core 1) or a type II kerogen (core 2).

  An impregnation in a sandstone level in core 1 (3980,75 m) was analysed in addition by gas chromatography.

. Interval 4022.50 - 4026.70 m (core 3) - BAJOCIAN

The core 3 samples exhibit a continental organic matter with abundant Pteridophyte spores, cuticles and wood fragments.

A coal population with abundant fluorescent vitrinites, rare inertinites, and exinites (abundant sporinites and rares cutinites) was observed at 4021.55 m.

The organic material, rather rich in hydrogen (HI 200 to 450) in this interval (core 3) relates to the presence of remains of terrestrial higher plants.

. Cutting samples 4046 and 4050 - 4054 m

The organic matter recovered at 4050 - 4054 m is predominantly of continental origin, as in the above core samples. Fluorescence data obtained at 4046 m reveals predominant non-fluorescent vitrinites. Minor amounts of orange humic groundmass and one Botryococcus Alga were also observed.
The fluorescence index is 1.
The Hydrogen Index (195) and Oxygen Index (52) classify the organic matter as kerogen types II and III.

2.4 - RED SHALES (4077 - 4106 E.logs) AND LOWER SANDSTONE MEMBER (4106 - 4130 TD)

Four cutting samples between 4080 and 4124 m yielded abundant spores and pollen grains. The organic matter recovered throughout this interval is predominantly of continental origin.

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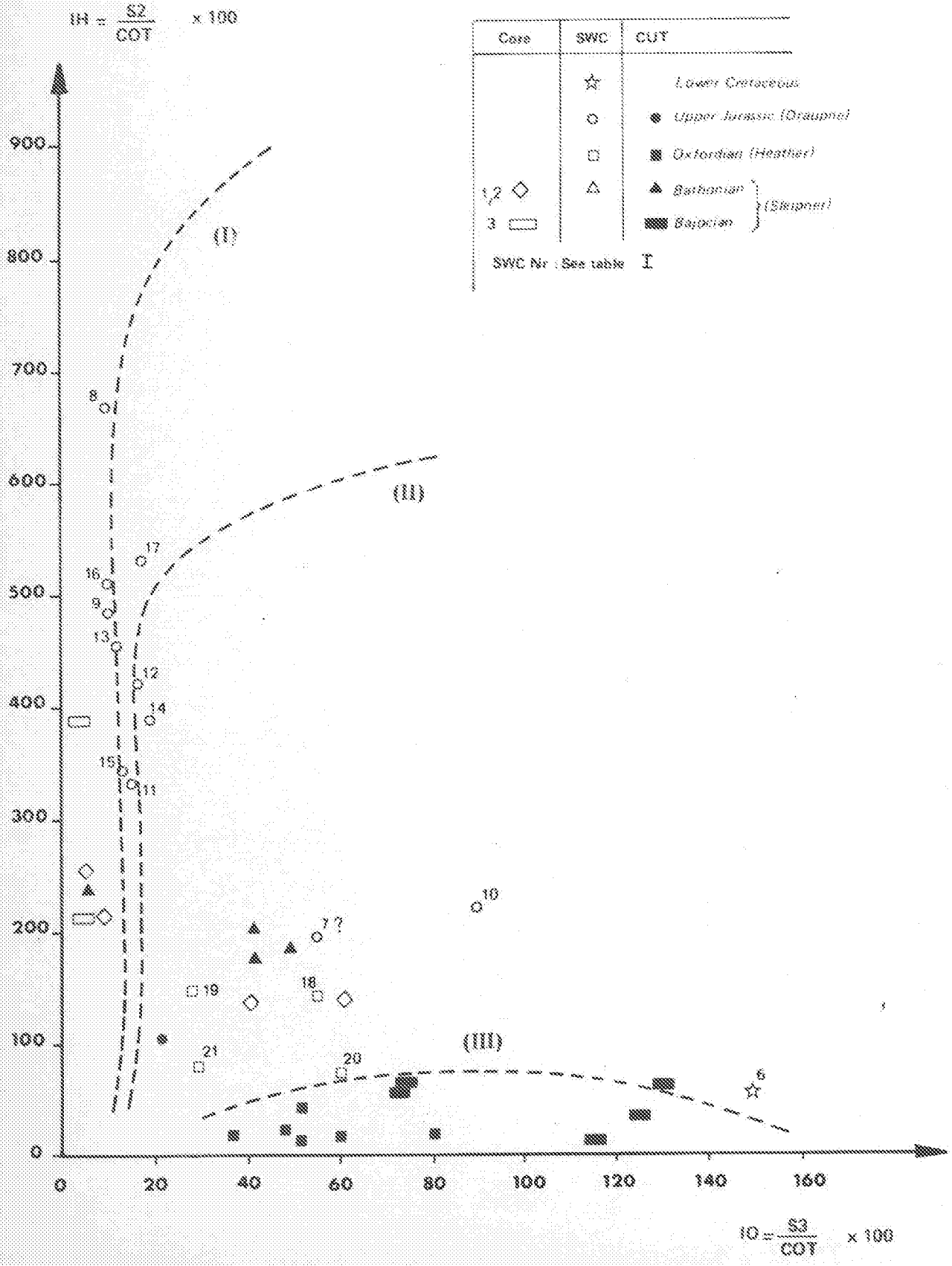

Fig. 2 - 15/3-5 - HYDROGEN INDEX - OXYGEN INDEX DIAGRAM

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Marine dinocysts which are sporadically observed relate to cavings from overlying late Jurassic marine series.

Fluorescence data obtained at 4090 m revealed a dark brownish groundmass (index 0.25), rare Exinites and one Tasmanacean Alga. Two populations of vitrinites, one of mud additives and one of granulous vitrinites, are present.

3 - THERMAL EVOLUTION

The thermal evlution with depth may be summarized as follows.

LITHOSTRATIGR.	Depth (m)	VRo %	VRo % equiv. Fluores.	TAI	Pyrolysis Tmax (°C)	Conclusions
	3808.30		0.60		434	0.60
DRAUPNE	SWC 3809					
	to			2.5	433-437	≠ 0.60
	SWC 3876					
	SWC 3882					
HEATHER	to			2.5	438-441	≠ 0.60
	SWC 3897					
	Cut.3910					
	to			2.5	438-442	≠ 0.60
	Cut. 3945					
	SWC 3965	0.70		3		0.70
	Core 3981.50	0.70		3	442	0.70
	Core 3985.50			3		0.70
	Core 4000.25			3	to	0.70
SLEIPNER	SWC 4016.50			3		0.70
	Core 4022.50			3	447	0.70
	Core 4026.70			3		0.70
	Cut. 4046	0.80			436 (?)	0.80

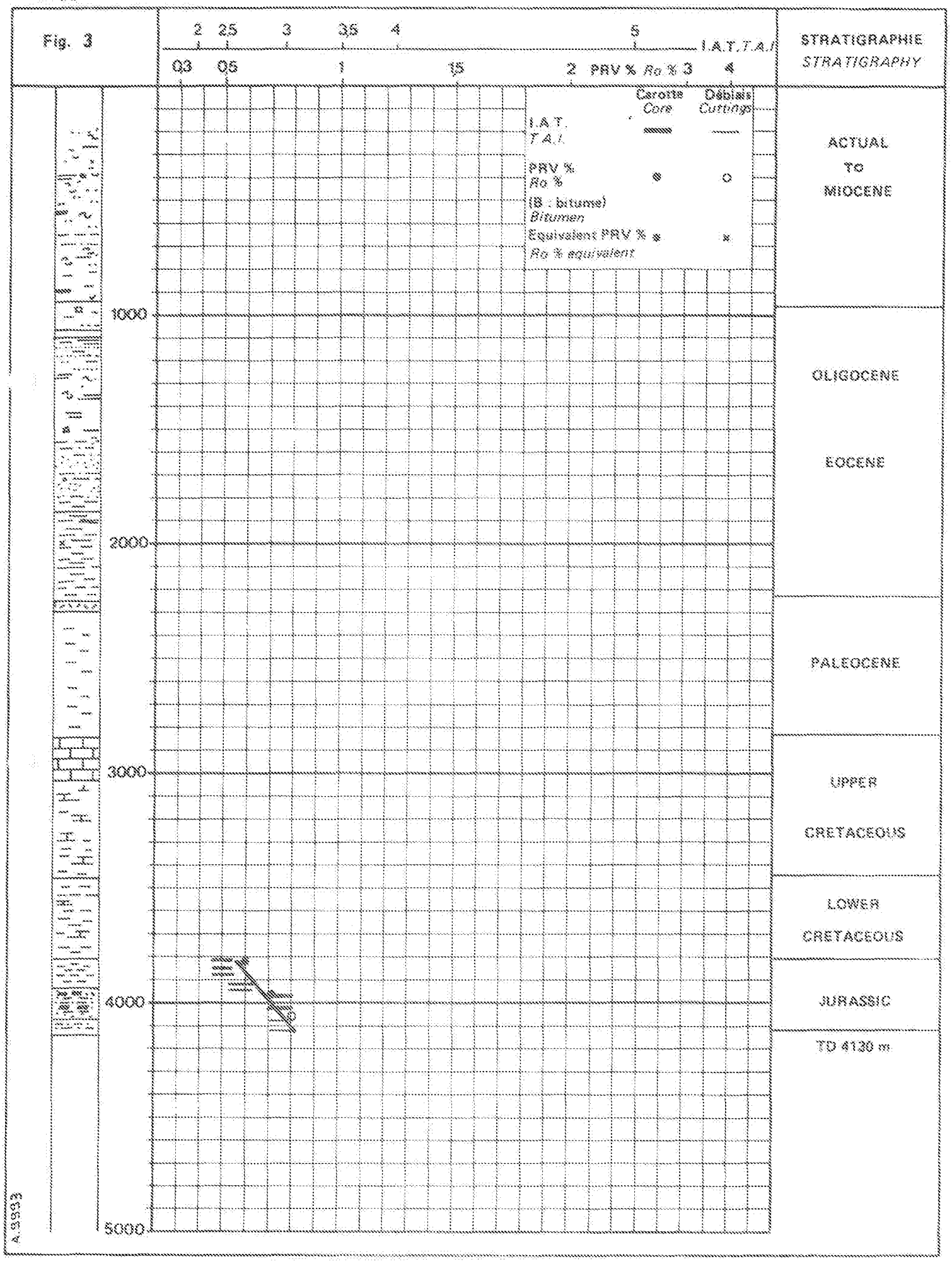
TABLE II - THERMAL EVOLUTION

PAYS NORWAY
COUNTRY

SONDAGE 15 / 3 - 5
WELL

PROFIL de MATURATION
MATURATION PROFILE

Fig. 3



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The thermal evolution based on the non-fluorescent vitrinite (see fig. 3) gives a reflectance of 0.70 to 0.80 % VRo in the Sleipner formation.

The fluorescence of some of the vitrinites prevents a more accurate rank being given . In the Draupne Formation the orange coloration of the Dinocysts orange coloration in fluorescence points to a rank of at least 0.60 % VRo equivalent.

Temperatures of the maximum yield of pyrolysis products increase from 432°C in the Draupne fm. to 447°C in the Sleipner, corresponding to a large range of the oil formation zone : except for the cutting sample at 4046 m, these temperatures agree fairly well with optical data.

This rank increase in about 280 m is slightly higher than the normal rank evolution.

4 - GENETIC POTENTIAL

The main findings result from thermal analysis (Rock-Eval pyrolysis) are : free hydrocarbons, as peak S1 and amount of hydrocarbons produced during pyrolysis.

All results are reported in table I, and Plate 1 bis.

Genetic potential may be summarized as follow :

- CRETACEOUS (3500 - 3800 m),
  no potential : < 0,1 kg of hydrocarbons per tonne of rock.

- U. JURASSIC

  DRAUPNE Fm :

  Very high potential related to the very good quality of the organic material. In these low - mature levels, potentials are in their initial state ; free hydrocarbons account for 10 to 20 % (see production Index PI) of total potential in the range 15 to 50 kg/tonne.

  HEATHER Fm :

  The predominance of ligneous material (HI < 50) results in a low potential < 2 kg/tonne.

Higher values are in the top of this formation (early Kimmeridgian - Late Oxfordian) : in two cored (SWC) levels at 3882 and 3886 m, the genetic potential is nearly 5 kg/tonnes. Formation of gaseous hydrocarbons is probable, from this organic material.

It should be noticed that high Production Index values (S1)/(S1 + S2) on plate 1 bis are not significant, due to low values of potentials S1 + S2.

- MIDDLE JURASSIC

The most representative samples of the Bathonian series are SWC and core (1,2) samples. Potentials between ca. 3 and 7 kg/tonne are considered medium. Liquid hydrocarbons already formed account for about 15 - 30 % of the total potential.

At the top of the Bajocian series, potential (which depends on TOC content) is very high, up to 90 kg/tonne in coaly levels (core 3) where organic material is hydrogen rich. Below 4050 m, genetic potential is very low, less than 1 kg/tonne of rock.

5 - ANALYSIS OF EXTRACTS

Soluble organic matter was extracted (chloroform as solvent) from 5 samples taken from Draupne and Sleipner formations. In the latter a core samples in a sandy level (3980,75 m) is slightly impegnated (1 % w/w) with hydrocarbons (see core description).

The main results related to extractable organic matter content as well as data from liquid and gas chromatography are given in the table III and fig. 4 (for composition) whereas gas chromatograms are provided on plates 4 to 7.

The indigeneous character of extracts at 3870, 3935 and 4019 m is shown by EOM/TOC ratio values (table III) and by the abundance of polar compounds and aromatics (fig. 4). In contrast, the migrated product at 3280,75 m is mainly compose of hydrocarbons : S + A = 80 % of the extract.

Detailed characteristics are as follows (table III and fig. 5) :

3870 m : sapropelic source (Pr/n-C17) / (Ph/n-C18) = 1,6 in a low state of maturation (S/A, X1 and X2 values, Carbon Preference index, Pr/n-C17 and Ph/n-C18).

.../...

TABLE III

15/3 - 5 - MAIN GEOCHEMICAL DATA FROM ANALYSIS OF EXTRACTS

	SAMPLE DEPTH, m.	Cut. 3870	Cut. 3935	Core = 1 3980.75	Cut. 4019
	FORMATION	DRAUPNE	SLEIPNER (top)	SLEIPNER	SLEIPNER
	TOC, w/w %	4.6	16.1	1	6.3
	EOM, w/w %	0.38	2.05	1	0.40
	100 EOM/TOC	8.2	12	100	6
COMPOSITION OF EXTRACTS (%)	ASPHALTENES	22.2	56.3	3.5	43.2
	RESINS	28.4	18.2	15.9	22.6
	SATURATES (S)	17.0	4.9	48.9	12.2
	AROMATICS (A)	32.2	20.4	31.5	21.9
	S + A	49.2	25.3	80.4	34.1
	S / A	0.53	0.24	1.55	0.56
C5 - C15	n-alkanes % TV:	20	19	51	26
	X1 = n-C6/MCP	1.37	1.13		1.43
	X2 = n-C7/DMCP:	2.38	2.47		3.19
	Z1 = n-C10/DMN:	1.42	0.99		2.52
$C15^+$ (saturates)	n-alkanes %Sat:	18	31	21	28
	Pr/n-C17 (A)	1.07	0.95	0.51	0.51
	Ph/n-C18 (B)	0.67	0.25	0.57	0.22
	Pr / Ph	1.67	3.35	0.82	2.34
	A / B	1.60	3.84	0.89	2.31
	CPI (n-C20 - n-C30):	1.05	1.16	0.95	1.23

S / A — Saturated HC/aromatic HC
MCP,DMCP — Methylcyclopentane, dimethylcyclopentane
Pr, Ph — Pristane, Phytane

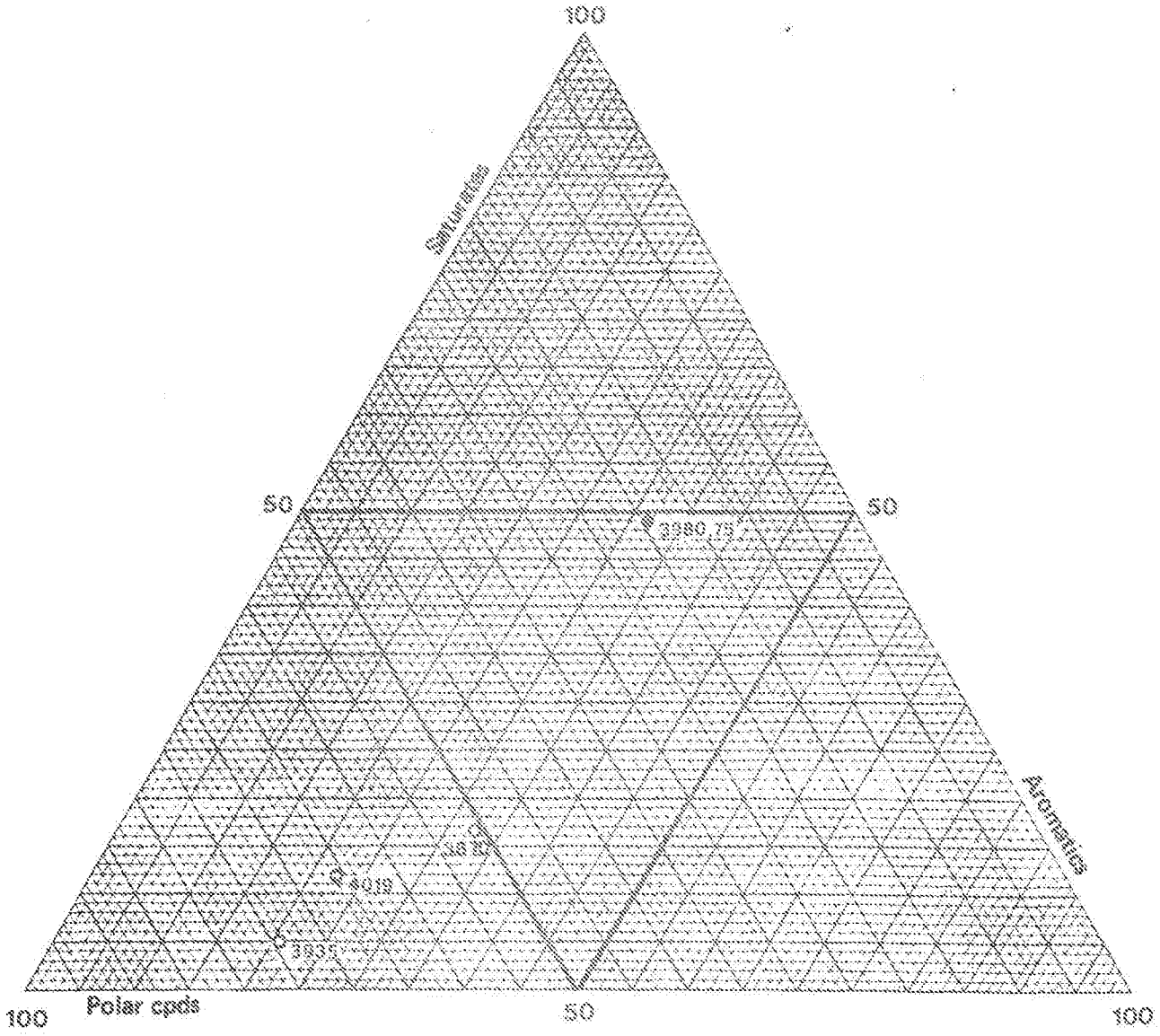

Fig. 4 - COMPOSITION OF EXTRACTS

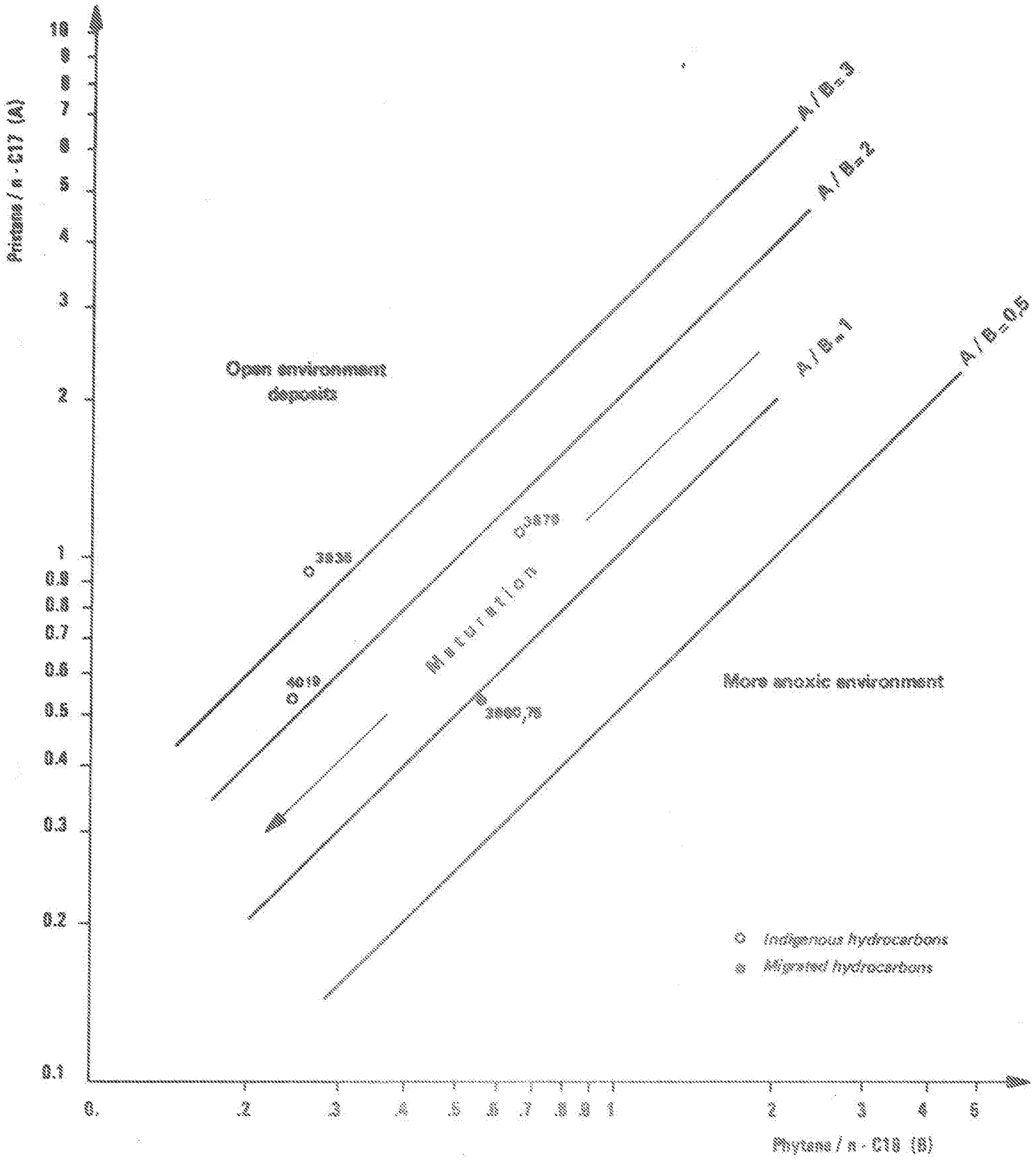

Fig. 8 - (PRISTANE / n - C17) / (PHYTANE / n - C18) DIAGRAM

3935 and 4019 m : characteristics are generally similar in spite of slight differences which are linked to the composition of kerogens (more coaly in 3955 m sample) in ligneous facies. A medium maturation state is given (X1, X2 index and C.P.I values) according with fluorescence and TAI, 0,7 ~ 0,8 % VRo equivalent and 3 respectively.

3980.75 m (shown in core 1) : these migrated hydrocarbons are quite different from the syngenetical ones studied here. The chromatography patterns suggest an origin other than Bathonian. From saturates analysis, the main characteristics are :

. (Pristane / n-C17) / (Phytane / n-C18) ≠ 0,9

. Predominance of even numbered carbon n-alkanes over odd n-alkanes between n-C20 and n-C30 : C.P.I. = 0,95.

These characteristics are usually associated and they are often attributed to carbonate or highly reducing environmental conditions.

It is worthy of note that both characteristics were found in syngenetical extracts from Portlandian ~ Kimmeridgian levels, in the previous geochemical studies (1), (2), (3) of 15/3 wells :

15/3 - 1	4075 m
15/3 - 3	4150 m
15/3 - 4	3696 m

6 ~ CONCLUSION

- The upper part of the DRAUPNE Formation (Portlandian/Kimmeridgian and Middle Kimmeridgian) contains dominantly marine, amorphous kerogen. A significant terrestrial organic matter input is observed in the lower part (Early Kimmeridgian). Inertinites are the dominant components of the terrigeneous material at 3870 m. Exinites mainly include Gymnosperm pollen grains. This organic stock in a low state of maturation gives DRAUPNE Fm a very high oil potential.

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(1) 15/3 - 1 well - Geochemical study of the Jurassic - B. PHILIPPE 2035 n° 6/1324 R - Bss April 1976

(2) 15/3 - 3 well - Organic matter from Jurassic series - Geochemical and optical studies - P. CAILLEAUX - P. ROBERT - GEO/LAB Bss n° 0/1857 RP - JANUARY 1980.

(3) 15/3 - 4 well - Optical and geochemical study (Jurassic section) - P. CAILLEAUX - P. ROBERT - GEO/LAB Bss n° 2/2339 RP October 1982.

- Both algal marine and continental originating kerogen is recovered in the HEATHER Formation (Late, Middle and Early Oxfordian).
  Resulting oil genetic potential is low. Kerogen is rather gas-oil.

- Marine-originating organic matter is identified in the Bathonian series (SLEIPNER Formation). This result is consistent with the kerogen distribution pattern for this area during Bathonian times. The associated land-derived material includes vitrinites, inertinites and exinites (mainly spores, pollen grains and cuticles).

  Organic matter of continental origin is predominantly identified in the Bajocian series. Terrigeneous higher plant remains (Pteridophyte, spores, cuticles, ligneous tissues) are characteristically concentrated in these deposits.

  A medium oil genetic potential is recorded in the coaly levels in the SLEIPNER Formation.

  In a sandstone level (Bathonian), migrated hydrocarbons have geochemical characteristics different from syngenetical ones in the series, but which are akin to some Portlandian - Kimmeridgian syngenetical hydrocarbons encountered at 15/3 - 1, 3 and 4.

- The diagenesis survey of the Jurassic shows an increase from 0.60 % VRo (3808.50 m) to 0.80 % VRo (4046 m). This rank increase in about 280 metres is slightly higher than the normal rank evolution.

TABLE I - CARBON CONTENT AND PYROLYSIS RESULTS

AGE	Formation	Sample	Depth (m)	T.O.C	S1	S2	S3	100.S1/S1+S2	Tm	H.I	O.I
L. Cret.		Cutt.	3500	0.29							
		"	3530	0.40							
		"	3560	0.62							
		"	3590	0.62							
		"	3620	0.95							
		"	3650	0.60		< 0.1					
		"	3680	0.70							
		"	3710	0.96							
		"	3740	0.69							
		"	3800	0.61							
Upper Jurassic	Draupne	SWC. 6	3808.3	0.45	0.08	0.29	0.68	22	432	64	151
		7	3809	1.43	0.33	2.76	0.77	11	435	193	53
		8	3810.3	7.64	5.84	51.84	0.74	10	435	678	9
		9	3818	6.67	6.16	31.92	0.73	16	431	478	10
		10	3829	1.78	0.73	3.99	1.58	15	432	224	88
		11	3835	4.48	3.42	15.12	0.75	18	431	337	16
		12	3840	3.94	3.43	16.43	0.67	17	429	417	17
		13	3863	5.74	4.06	26.	0.68	14	435	452	11
		14	3866	5.88	3.14	22.80	1.14	12	434	387	19
		15	3870	4.85	2.81	16.	0.67	14	435	346	13
		Cutt.	3870	4.63	1.36	4.73	1.	22	437	102	21
		SWC.16	3874	7.05	4.27	35.68	0.74	11	438	506	10
	Heather	18	3882	2.45	0.71	3.46	1.38	17	439	141	56
		19	3886	3.42	0.83	3.15	1.02	14	440	150	29
		20	3895	2.37	0.36	1.75	1.46	17	437	73	61
		21	3897	3.51	0.65	3.15	1.09	17	436	89	31
		Cutt.	3900	2.73	0.37	0.40	1.06	49	442	14	38
		"	3905	2.50	0.32	0.27	1.23	55	440	10	49
		"	3910	2.08	0.28	0.32	1.68	47	439	15	80
		"	3915	1.87	0.20	0.32	1.12	38	425	17	59
		"	3920	2.14	0.29	0.51	1.33	36	428	23	62
		"	3925	2.43	0.44	0.76	1.16	36	439	32	47
		"	3930	2.27	0.45	1.06	1.17	30	441	46	51
Middle Jurassic	Sleipner	Cutt.	3935	16.11	5.34	41.34	0.92	11	438	256	5
		"	3965	62.00	16.31	148.72	4.09	10	441	239	6
		"	3970	2.04	1.63	3.68	0.86	31	435	180	42
		Core 1	3974.4	1.72	0.66	2.37	1.02	22	446	137	59
		" 1	3978.5	1.79	0.89	2.28	0.74	28	447	127	41
		" 2	3990.7	2.49	1.04	6.49	0.23	14	447	260	9
		" 2	3996.6	2.69	1.04	5.80	0.30	15	447	215	11
		Cutt.	4019	6.28	1.56	12.64	2.72	11	437	201	43
		Core 3	4022.5	5.58	1.48	12.	0.25	11	446	215	4
		3	4026.7	23.60	7.76	91.92	0.68	8	442	389	2
		Cutt.	4046	10.28	2.44	20.08	5.44	11	436	195	52
		"	4058	7.41	0.58	4.82	5.52	11	422	65	74
		"	4070	1.94	0.23	0,86	2.39	21	444	44	123
	Redshales	"	4090	0,85	0.13	0.61	1.14	18	439	71	134
		"	4110	0.42					-		
		SWC.24	4113	0.06							
		" 25	4118.5	0.08							

ABREVIATIONS AND UNITS

TOC	Total organic carbon (% weight of rock)
S1	Hydrocarbons present in the rock (mg HC/g rock kg H/tonne)
S2	Hydrocarbons produced by pyrolysis (mg HC/g rock kg H/tonne)
HI	Hydrogen index (mg HC/g TOC)
OI	Oxygen index (mg CO2/g TOC)
Tm	Temperature at the top of S2