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REPORT TITLE

SOURCE ROCK ANALYSES OF WELL 34/10-6

CONTRACTOR

Statoil

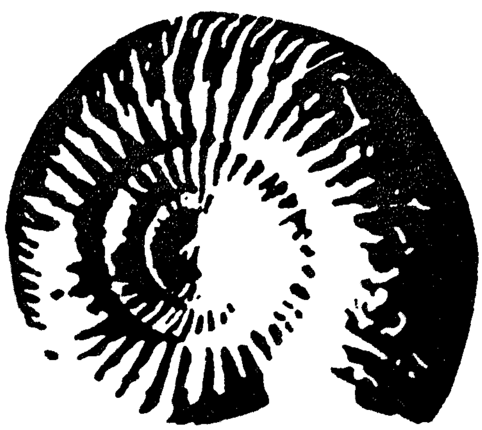
UND — ARKIVET
Nr.: 14

CONTRACTORS REF.:

Bjørn Rasmussen

JOB. NO.:

IKU



INSTITUTT FOR
KONTINENTALSOKKELUNDERSØKELSER

Continental Shelf Institute

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Bjørn Rasmussen	

SCIENTIST	DATE	PROJECT NO.
M. Bjorøy, T.M. Rønningsland, J.O. Vigran	14.3.80	0-256/1/80
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Organic Geochemistry		
	RESPONSIBLE SCIENTIST: Malvin Bjorøy	

SUMMARY

The section from 1760 - 2104 m was analysed. The whole section is found to be immature. The samples were of a poor quality and a tentative estimation of richness and type of source rock are:

Upper 100 m: Poor potential as a source rock for gas.

Lower part: Fair/good potential as a source rock for gas.

KEY WORDS

Source rock.

EXPERIMENTAL

Total Organic Carbon (TOC)

The various selected samples were crushed on a centrifugal mill and sieved. The portions with a particle size between 0.125 mm and 0.063 mm were used in the further work. Aliquotes of the samples were treated with hot 6N HCl to remove carbonate and washed twice with distilled water to remove traces of HCl, then placed in a vacuum oven at 50^{o}C, evacuated to 20 mm Hg for 12 hrs. The samples were then analysed on a Leco E C 12 carbon determinator, to determine the total organic carbon (TOC).

Extractable Organic Matter (EOM)

From the TOC results samples were selected for extraction. Of the selected samples, approximately 100 gm of each was extracted on soxhlet apparatus for 48 hrs using dichloromethane (DCM) as solvent. The DCM used as solvent was distilled in an all glass apparatus to remove contaminants. The paper thimbles used in the soxhlet apparatus were previously washed with DCM on a large soxhlet apparatus for 48 hrs. to remove any soluble components.

Activated copper foil was used in the flasks to remove any free sulphur from the samples.

After extraction, the solvent was removed on a Bućhi Rotavapor and transferred to a 50 ml flask. The rest of the solvent was then removed and the amount of extractable organic matter (EOM) determined.

Chromatographic Separation

The extractable organic matter (EOM) was separated on chromatographic columns, packed with silica, Riedel & Hähn, 0.063 mm, using the slurry method with hexane as solvent. On top of the silica, small amounts of alumina, approximately 2 cm, was added. The EOM, after it was "taken up" on alumina, was transferred to the top of the columns, which were then eluted with predistilled hexane, benzene and methanol using a ratio of 200 ml of each solvent pr. gm of EOM.

The various eluants were removed on a Buchi Rotavapor and the samples transferred to vials and dried at 40°C in a stream of dry nitrogen, and the amount of the various fractions, saturated, aromatic and NSO fraction (Nitrogen, Sulphur, Oxygen), determined. The saturated fractions were analysed gas chromatographically on a 25 m OV 101 glass capillary column with He as carrier gas (0.7 ml/min.) using the splitless injection technique. The glass capillary column was mounted in a Carlo Erba F V 2150 gas chromatograph.

Vitrinite Reflectance

Samples, taken at various intervals, were sent for vitrinite reflectance measurements at Geoconsultants, Newcastle-upon-Tyne. The samples were mounted in Bakelite resin blocks; care being taken during the setting of the plastic to avoid temperatures in excess of 100°C. The samples where then ground, initially on a diamond lap followed by two grades of corundum paper. All grinding and subsequent polishing stages in the preparation were carried out using isopropyl alcohol as lubricant, since water leads to the swelling and disintegration of the clay fraction of the samples.

Polishing of the samples was performed on Selvyt cloths using three grades of alumina, 5/20, 3/50 and Gamma, followed by careful cleaning of the surface.

Reflectance determinations were carried out on a Leitz M.P.V. microphotometer under oil immersion, R.I. 1.516 at a wavelength of 546 nm. The field measured was varied to suit the size of the organic particle, but was usually of the order of 2 micron diameter.

The surface of the polished block was searched by the operator for suitable areas of vitrinitic material in the sediment. The reflectance of the organic particle was determined relative to optical glass standards of known reflectance. Where possible, a minimum of twenty individual particles of vitrinite was measured, although in many cases this number could not be achieved.

Processing of Samples for Evaluation of Visual Kerogen

The rock samples were crushed and afterwards treated with hydrochloric and hydrofluoric acids to remove the minerals. A series of microscopic slides was mounted in glycerine jelly:

T-slide represents the total acid insoluble residue.
O-slide represents the residue screened through 15 sieves.
N-1,2,3 slides contain palynodebris remaining after flotation (Zn Br_2) to remove disturbing heavy minerals.
X-1,2,3 slides contain oxidized residues, when oxidizing is required due to high coalification or much sapropel.

T & O slides are necessary to evaluate kerogen composition/palynofacies which is closely related to sample lithology.

Screened slides are normally required to consentrate the larger fragments, and to study palynomorphs (pollen, spores and dinoflagellates) for paleo-dating and colour evaluation.

So far visual evaluations of kerogen have been undertaken from residues mounted in glycerine jelly, and studied by Leitz Dialux in normal light (halogene) using x10 and x40 objectives.

Rock-Eval Pyrolyses

100 mg crushed sample was put into a boat whose bottom and cover are made of sintered steal and analysed on a Rock-Eval pyrolyser.

RESULTS AND DISCUSSION

Samples from 1760 - 2104 m were received for source rock studies. The lids on the cans were not sealed properly, and gas analysis was therefore not performed. The samples from the upper part of the sequence contained hardly any cuttings, only mud additives (nutshells) and the results from this part are very uncertain, it was very difficult to pick out any true material.

The TOC values vary from 0.5 - 1.5% throughout the whole analysed sequence, and it will not be divided into separate zones. Seven samples from this sequence were extracted. The TOC values of the three lower extracted samples are high compared to the TOC values on a few picked cuttings. This might be due to contamination, i.e. the picking of the large amount of cuttings for extraction has not been as selective as the picking for TOC measurements. Another possibility could be that the cuttings used for TOC measurements are downfall, and that the true value is higher. The upper two samples, 1828 - 1873 m and 1909 - 1918 m are found to have a poor abundance of extractable hydrocarbons. The samples from 1987 - 1996 m have a rich abundance while the next three samples (Table III) have a fair abundance of extractable hydrocarbons. The lowermost sample has a good abundance of extractable hydrocarbons.

The gas chromatograms of the saturated fractions vary considerably. The two uppermost samples both show a bimodal distribution with a large unresolved envelope in the sterane/triterpane interval. The next sample has a normal distribution for a mature sample. This sample might be slightly contaminated by migrated hydrocarbons.

The gas chromatograms of the saturated hydrocarbon fractions of the three next samples have a distribution normally associated with immature, terrestrial sediments. The lowermost sample varies from the others in that pristane is the dominant peak. The whole pattern indicates immature woody material (coal).

Vitrinite Reflectance measurements

Vitrinite reflectance measurements were undertaken on eight samples: In the following each sample is described, and together with the reflectance data, other information from the analyses are given.

Sample K1821, (1760 m): Mudstone, Ro = 0,42 (8).
The sample has only a trace of organic material with small specks of reworked vitrinite being dominant. Only a few particles of inertinite and true vitrinite, UV light shows a yellow/orange to mid-orange fluorescence from spores and a low exinite content.

Sample K1824, (1805m): Shale and carbonate, Ro = 0,45 (6)
The sample has a very low organic content with small particles, mostly of reworked material together with some inertinite. Only a trace of true vitrinite. UV light shows a yellow/orange to mid-orange fluorescence from spores and a low exinite content.

Sample K1829, (1855 m): Shale and carbonate, Ro = 0,45 (6).
The sample has a very low organic content with small particles, mostly of reworked material together with some inertinite. Only a trace of true vitrinite. UV light shows a yellow/orange to mid-orange fluroescence from spores and low exinite content.

Sample K 1829, (1855 m): Shale, Ro = 0.37 (10).
The sample has a low organic content with small particles of reworked material being dominant. Only a trace of true vitrinite and particles of inertinite. UV light shows a yellow/orange and mid-orange fluorescence from spores together with a trace of exinite.

Sample K 1834, (1900 m): Shale and carbonate, Ro = 0.37 (7) and Ro = 0.97 (2)
The sample has a low organic content, mostly reworked particles. Some inertinite and a trace of true vitrinite particles. UV light shows a yellow/orange and dull, deep orange fluorescence from spores together with a trace of exinite.

Sample K 1841 (1960 m): Mixed shale lithologies, Ro = 0,43 (12).
The sample has a low organic content with small particles, mostly reworked together with some inertinite. Only a trace of true vitrinite particles. UV light shows a yellow/orange and a dull, deep orange fluorescence from spores together with a trace of exinite.

Sample K 1847 (2014 m): Shale and Carbonate, Ro = 0.39 (15).
The sample has a low orgnaic content with particles of reworked material being dominant with inertinite as subordinate. Only a trace of true vitrinite particles. UV light shows a yellow/orange to mid-orange fluorescence from spores and a low to moderate exinite content.

Sample K1852 (2059 m): Shale and Carbonate, Ro = 0.34 (22).
The sample has a very low organic content apart from a few loose coal fragments. Particles of reworked material are dominant. Only a trace of particles of true vitrinite and inertinite. UV light shows a yellow/orange and a dull, mid-orange fluorescence from spores together with a moderate to rich exinite content.

Sample K 1857 (2104 m): Coal, Ro = 0,32 (24).
The sample is a normal coal, rather fractured and brecciated. Quite rich in inertinite and rather dirty. UV light shows a yellow/orange fluorescence from spores and a moderate exinite content.

Visual kerogen examination

The interval 1760 m to 2114 chosen for source rock/maturation studies is of Middle Jurassic age according to information from Statoil.

The analysed samples, 1760 m, 1805 m, 1855 m, 1900 m, 1960 m, 1847 m, 2059 m and 2104 m, showed not to be suitable for kerogen analysis, and the results are very unreliable.

The total acid insoluble residues are finely dispersed. They seem to consist of amorphous as well as terrestrial remains but the distinction is difficult due to the size of the particles.

The screened residues contain mainly cysts of marine derivation. The only fossil restricted to the Middle Jurassic is cf. Wanea acollaris. All other fossils, mainly dinoflagellate cysts, are either long ranging or restricted to the Tertiary or Cretaceous or more rarely to the Upper Jurassic.

The post Middle Jurassic material, in this interval represents the dominanting part of all the samples (after screening of the residues). These can not be distinguished from indigenous material.

Rock-Eval Pyrolysis

Seven samples were analysed (Tabel VIII), and were all found to have a low hydrogen and high oxygen index, showing kerogen type III.

Conclusion

The samples from the analysed sequence were rather difficult to work with, due to a large proportion of mud additives and downfall. Based on the available results, the following conclusion is given.

The whole sequence is immature.

The estimation of source rock richness and type will be highly tentative, due to the problems outlined above. The results from the various analyses indicate the upper part of the analysed sequence to have a poor potential as a source rock for gas while the lower part, from approximately 1850 m, has a fair to good potential as a source rock for gas.

TABLE I

LITHOLOGY AND TOTAL ORGANIC CARBON

IKU No.	Depth	TOC	Lithology
K 1821	1760	0.54	15% Claystone, some silty, grey-greengrey, some slightly brownish grey (with Coal), green 85% Nut shells
K 1822	1775	0.50	60% Claystone, as above 40% Nut shells sm.am. Limestone, white; Pyrite, obs. Gravel/coarse Sand (Gneiss of Quartz and Biotite, subrounded to rounded Quartz grains)
K 1823	1790	0.55	50% Claystone, grey-greygreen, some green 50% Nut shells obs Limestone, white/light grey; Pyrite, coarse rounded Quartz Sand; brown hard Limestone, ?sideritic
K 1824	1805	0.92	20% Claystone, as above 80% Nut shells
K 1825	1810	0.74	95% Cement 5% Claystone, as above
K 1826	1828	0.69	3% Claystone, silty, greenish grey, obs pockets of white Silt 97% Nut shells
K 1827	1837	1.14	sm.am. Claystone, as above 100% Nut shells
K 1828	1846	1.42	sm.am. Claystone, as above, some green 100% Nut shells
K 1829	1855	1.19	obs. Claystone, as above; Limestone, brownish white 100% Nut shells

IKU No.	Depth	TOC	Lithology
K 1830	1864	0.88	sm.am. Claystone, grading to clayey Siltstone, grey-greyish green 100% Nut shells
K 1831	1873	1.26	sm.am. Claystone, as above 100% Nut shells
K 1832	1888	1.30	sm.am. Claystone, grey to dark grey, greenish 100% Nut shells and some Mica
K 1833	1891	0.94	sm.am. Claystone, some silty, grey to light green 100% Nut shells and some Mica, cement
K 1834	1900	1.17	sm.am. Claystone grading to Siltstone, grey/ light grey to light greenish obs. very coarse subrounded Quartz; Gneiss 100% Nut shells and some Mica, cement
K 1835	1909	0.87	sm.am. Claystone, grey, greenish 100% Nut shells,
K 1836	1918	1.50	3% Claystone, grey, greenish grey-green 97% Nut shells obs Quartz, rounded, coarse
K 1837	1927	0.87	5% Claystone, as above, obs dark grey/black 95% Nut shells
K 1838	1951	0.80	40% Claystone, grey, greenish, some green obs Pyrite; Siderite/Dolomite, greybrown,hard 60% Nut shells and some Mica
K 1839	1936	1.19	50% Claystone, grey, some light green/green sm.am. slightly brownish dark grey ?Siderite hard; Pyrite (rare) 50% Nut shells (some Mica)

IKU No.	Depth	TOC	Lithology
K 1840	1942	1.03	25% Claystone, some grading to clayey Siltstone, grey, greengrey, obs with Coal fragments, Pyr obs. obs Marl, light grey/white, loose 75% Nut shells and some Mica, cement
K 1841	1960	0.67	30% Claystone, grey (silty, with Coal fragments) grading to light green 70% Nut shells, some Mica, cement
K 1842	1969	0.86	40% Claystone, some silty grey, light greenish-green 60% Nut shells, some Mica, cement
K 1843	1978	0.84	50% Claystone, silty, as above 50% Nut shells and some Mica, cement
K 1844	1987	1.21	50% Claystone, partly silty, grey, greenish 50% Nut shells
K 1845	1996	0.79 0.29	15% Claystone, as above 10% Limestone, white (brownish), some light browngrey 75% Nut shells
K 1846	2005	0.79 0.23	60% Claystone, grey, some brownish, dark grey fissile obs 15% Limestone, white to brownish white, slightly sandy obs sm.am. ?Siderite, browngrey, brown, hard obs. Pyrite 25% Nut shells
K 1847	2014	0.75	65% Claystone, grey, light grey partly silty, pyritic, some micaceous, some green 5% Limestone, as above sm.am. Limestone, brownish dark grey/grey, hard; obs Pyrite; rounded Quartz; Siderite, hard; Coal 30% Nut shells

IKU No.	Depth	TOC	Lithology
K 1848	2023	0.95	65% Claystone, as above sm.am. Limestone, white; Limestone, dark brown, hard, ? sideritic; Pyrite common (partly rods); sandy Siltstone, light grey 35% Nut shells
K 1849	2032	1.10	50% Claystone, grey sm.am. Limestone, white; Pyrite (common); Limestone/Marl, greybrown, hard obs. Glauconite; Siderite, dark brown, hard 50% Nut shells
K 1850	2041	0.92	50% Claystone, grey, some green sm.am. Limestone, dark greybrown, hard; Limestone, white; rounded coarse Quartz, Pyrite (rare); light brown?Siderite 50% Nut shells
K 1851	2050	1.06	50% Claystone, as above 50% Nut shells
K 1852	2059	0.86	40% Claystone, grey, some light grey (silty) and green sm.am. rounded Quartz; Limestone, dark brown, hard 60% Nut shells
K 1853	2068	1.22	25% Claystone, as above sm.am Limestone, white; obs Pyrite 75% Nut shells
K 1854	2077	0.37	50% Claystone, some silty, grey, some green, light and dark grey, (brown) sm.am. Coal; Pyrite (rare); coarse rounded Quartz Sand, obs Glauconite 50% Nut shells

IKU No.	Depth	TOC	Lithology
K 1855	2086	1.00	40% Claystone, as above sm.am. Coal; rounded coarse Quartz Sand; Limestone, brown, hard, sideritic 60% Nut shells and some Mica
K 1856	2095	0.90	30% Claystone, silty, grey, some light and brownish, some grading to clayey Siltstone, micaceous with some Coal, some light green minor: Marl, greybrown; Coal; Quartz, subrounded, coarse; Limestone, white, brownish grey (hard) 70% Nut shells and some Mica
K 1857	2104	1.04	70% Coal 5% Claystone, as above 25% Nut shells

TABLE II

WEIGHT (mg) OF EOM AND CHROMATOGRAPHIC FRACTIONS

IKU No.	Depth	Rock extracted (g)	EOM	Sat.	Aro.	HC	Non HC	TOC
K-1827	1828m-1873m	29.6	11.4	1.7	1.4	3.1	3.1	1.21
K-1836	1909m-1918m	31.6	9.0	1.2	1.5	2.7	3.0	1.23
K-1844	1878m-1996m	30.5	33.8	11.5	9.7	21.2	8.9	1.05
K-1847	2014m-2023m	60.5	17.2	5.2	5.6	10.8	5.5	0.79
K-1849	2032m	76.7	21.0	5.2	5.3	10.5	5.3	2.01
K-1853	2068m	60.1	16.9	4.5	4.7	9.2	4.8	2.02
K-1856	2095m	65.5	45.4	6.9	15.7	22.6	13.4	4.34

TABLE III

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS (Weight ppm of rock)

IKU No.	Depth	EOM	Sat.	Aro.	HC	Non HC
K-1827	1828m→1873m	385.-	57.-	47.-	105.-	105.-
K-1836	1909m→1918m	285.-	38.-	47.-	85.-	95.-
K-1844	1987m→1996m	1108.-	377.-	318.-	695.-	292.-
K-1847	2014m→2023m	284.-	86.-	93.-	179.-	91.-
K-1849	2032m	274.-	68.-	69.-	137.-	69.-
K-1853	2068m	281.-	75.-	78.-	153.-	80.-
K-1856	2095m	693.-	105.-	240.-	345.-	205.-

TABLE IV

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS (mg/g TOC)

IKU No.	Depth	EOM	Sat.	Aro.	HC	Non HC
K-1827	1828m→1873m	32.-	5.-	4.-	9.-	9.-
K-1836	1909m→1918m	23.-	3.-	4.-	7.-	8.-
K-1844	1987m→1996m	106.-	36.-	30.-	66.-	28.-
K-1847	2014m→2023m	36.-	11.-	12.-	23.-	12.-
K-1849	2032m	14.-	3.-	3.-	7.-	3.-
K-1853	2068m	14.-	4.-	4.-	8.-	4.-
K-1856	2095m	16.-	2.-	6.-	8.-	5.-

TABLE V

COMPOSITION IN % OF THE MATERIAL EXTRACTED FROM THE ROCK

IKU No.	Depth (m)	Sat / EOM	Aro / EOM	HC / EOM	Sat / Aro	Non HC / EOM	HC / Non HC
K-1827	1828m → 1873m	15.-	12.-	27.-	121.-	27.-	100.-
K-1836	1909m → 1918m	13.-	17.-	30.-	80.-	33.-	90.-
K-1844	1987m → 1996m	34.-	29.-	63.-	119.-	26.-	238.-
K-1847	2014m → 2023m	30.-	33.-	63.-	93.-	32.-	196.-
K-1849	2032m	25.-	25.-	50.-	98.-	25.-	198.-
K-1853	2068m	27.-	28.-	54.-	96.-	28.-	192.-
K-1856	2095m	15.-	35.-	50.-	44.-	30.-	169.-

TABLE VI

TABULATION OF DATAS FROM THE GASCHROMATOGRAMS

IKU No.	Depth (m)	Pristane/nC_{17}	Pristane/Phytane	CPI
K 1827	1828-1873	o.54	1.21	1.5
K 1836	1909-1918	0.70	1.50	1.5
K 1844	1987-1996	0.83	1.34	1.0
K 1847	2014-2023	0.86	1.39	1.3
K 1849	2032	0.86	1.46	1.3
K 1853	2068	0.82	1.43	1.3
K 1856	2095	1.68	2.46	1.6

TABLE VII

VITRINITE REFLECTANCE AND VISUAL KEROGEN MEASUREMENTS

IKU numbers	Depth (m)	Vitrinite reflectance	xxColour index	xType of organic matter
K 1821	1760	0.42 (8)	?	Am,He
K 1824	1805	0.45 (6)	?	Am,He
K 1829	1855	0.37 (10)	?	Am,He
K 1834	1900	0.37 (7) and 0.97 (2)	?	Am,He
K 1841	1960	0.43 (12)	?	Am,He
K 1847	2014	0.39 (15)	?	Am,He
K 1852	2059	0.34 (22)	-2 or -2/2	He,W,Cut'Poll-spor/Am,Cysts
K 1857	2104	0.32 (24)	?	He,Am

x type of organic matter composition of acidinsoluble residue. We estimate that most of the organic material is derived from caved material from higher up in this well, the recorded cysts of Tertiary and Cretaceous age are therefore not listed in the table.

xx Colour index. For the same reason as above; The colour estimates have probably been based on caved material and are not reliable.

TABLE VIII

ROCK-EVAL PYROLYSIS

Sample	Depth	S_1	S_2	S_3	C_{org}	Hydrogen Index	Oxygen Index	Oil of gas content $(S_1 + S_2)$	Production Index $\frac{S_1}{S_1 + S_2}$	T_{max} °C
K 1827	1837 m-1873 m	0.98	0.68	4.17	1.21	56.20	344.63	1.66	0.59	438°
K 1836	1901 m-1918 m	0.24	0.47	2.89	1.23	38.21	234.96	0.71	0.34	440°
K 1844	1987 m-1996 m	0.20	0.52	2.11	1.05	49.52	200.95	0.72	0.28	430°
K 1847	2014 m-2023 m	0.20	0.41	2.05	0.79	51.90	259.49	0.61	0.33	432°
K 1849	2032 m-2041 m	0.15	1.16	4.13	2.01	57.71	205.47	1.31	0.11	435°
K 1853	2059 m-2068 m	0.13	0.92	4.88	2.02	45.54	241.58	1.05	0.12	425°
K 1856	2095 m	0.30	3.45	5.13	4.34	79.49	118.20	3.75	0.08	432°

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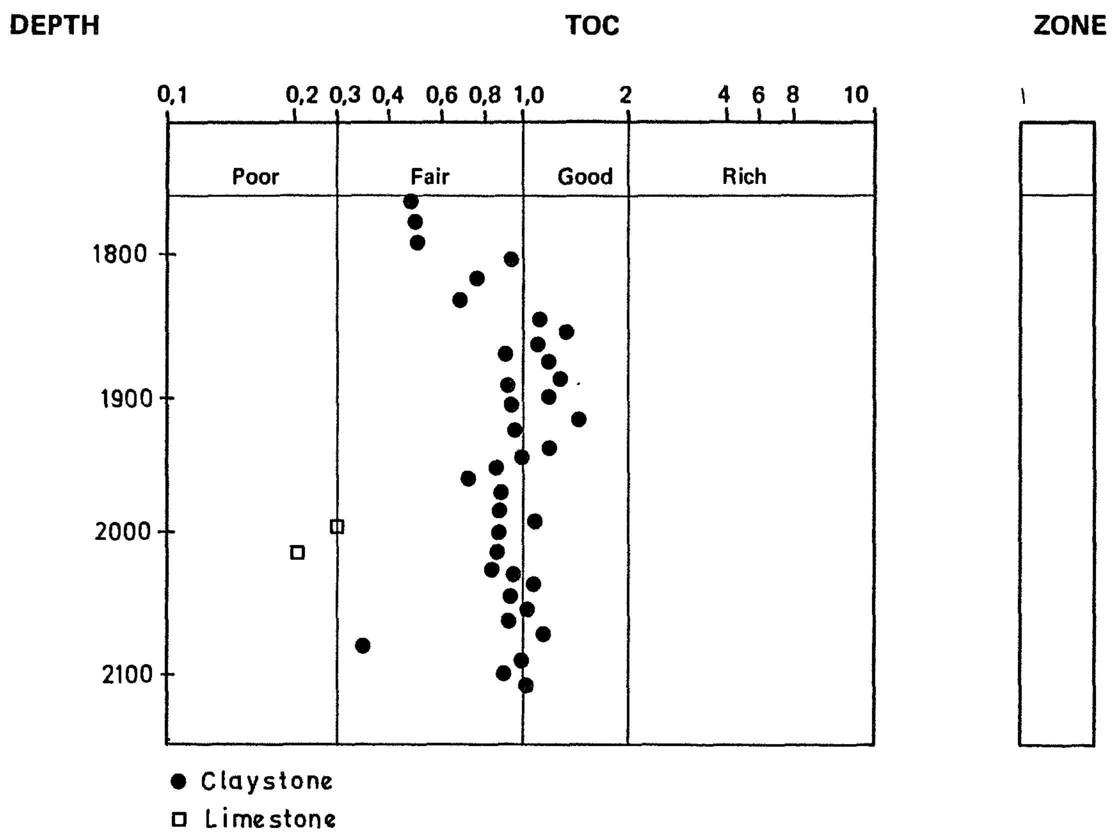
TOTAL ORGANIC CARBON (TOC)

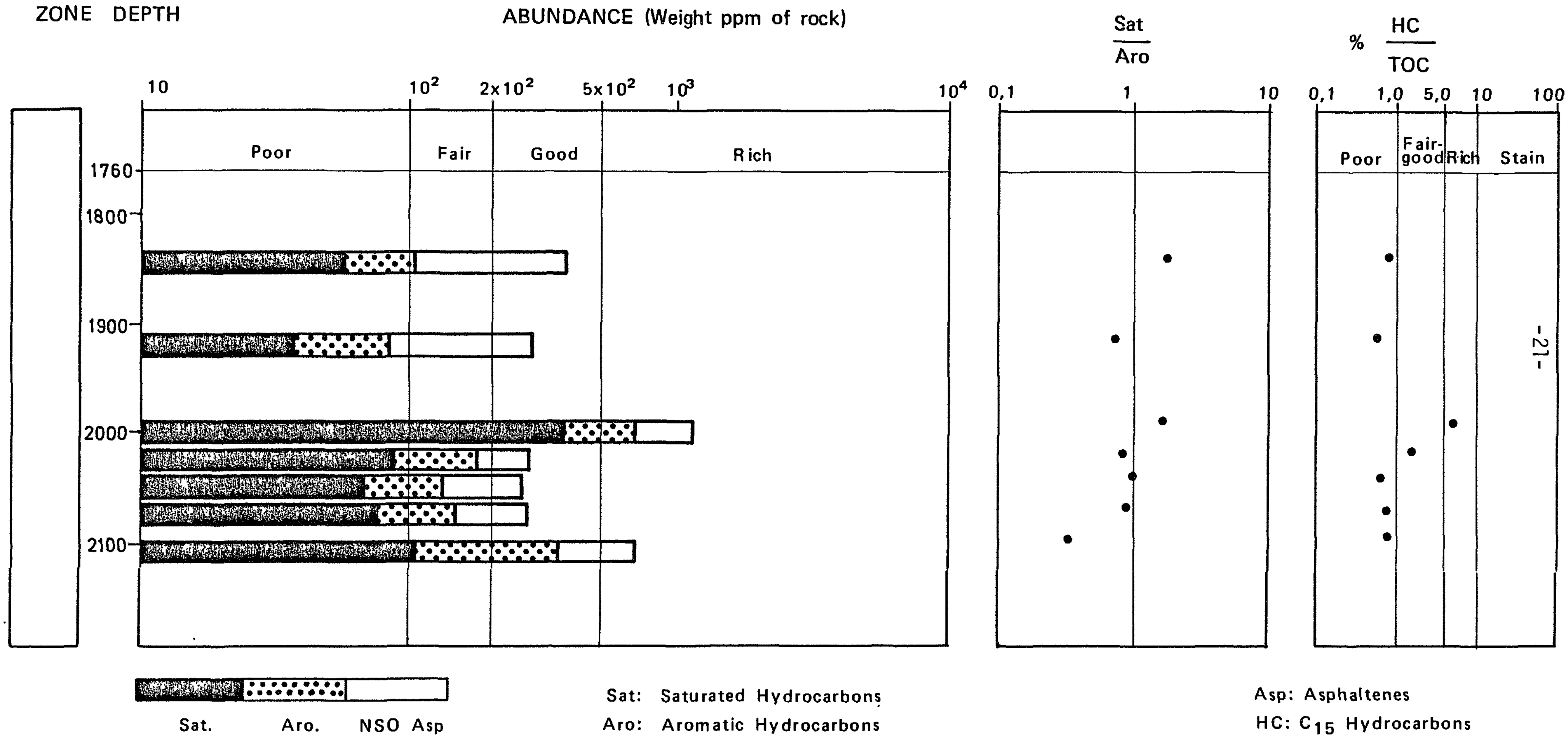
Presentation of Analytical Data



34/10-6

C_{15}^{+} HYDROCARBONS

Presentation of Analytical Data



Sat: Saturated Hydrocarbons

Aro: Aromatic Hydrocarbons

NSO: Nitrogen, Sulphur and Oxygen containing compounds

Asp: Asphaltenes

HC: C_{15} Hydrocarbons

TOC: Total Organic Carbon

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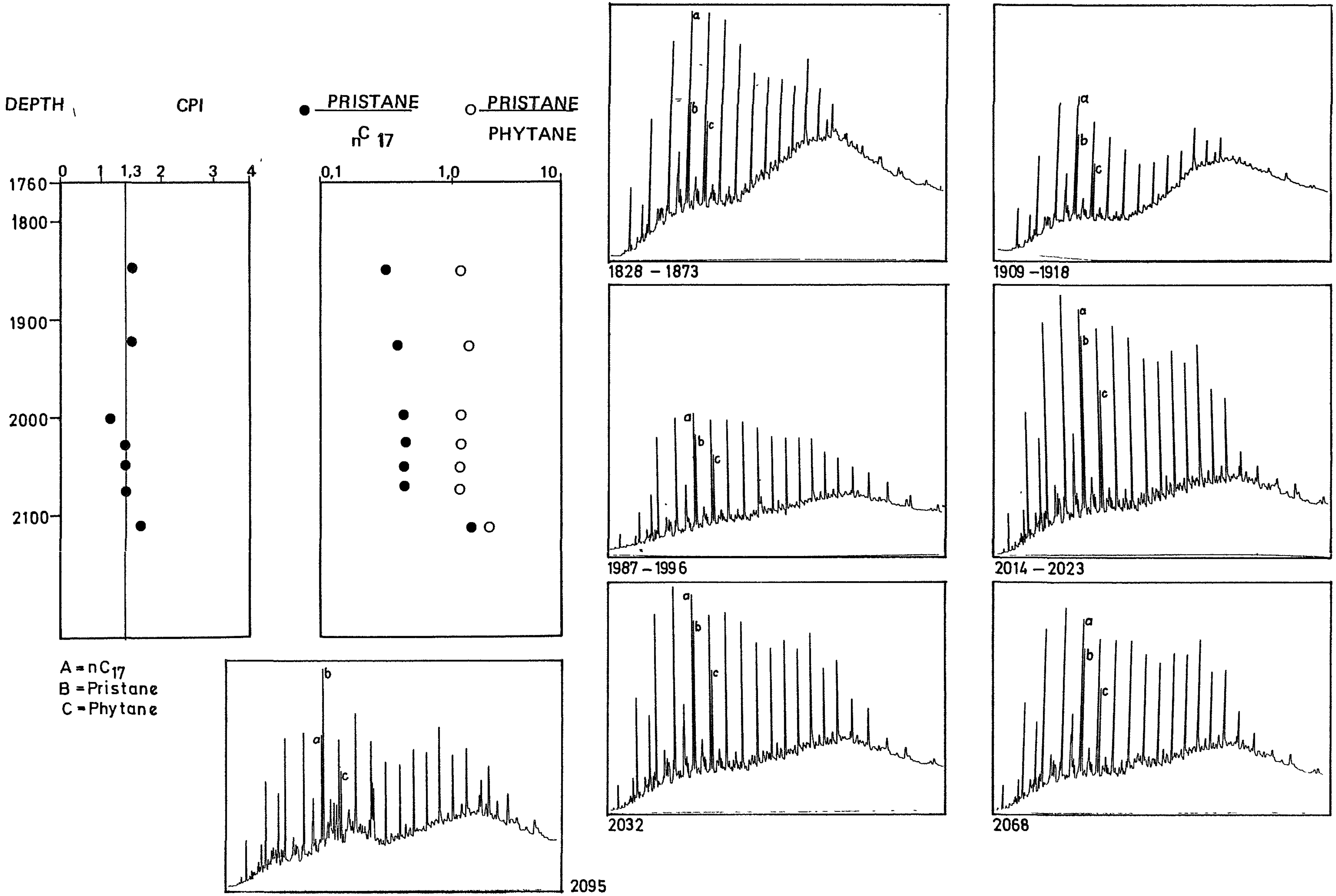
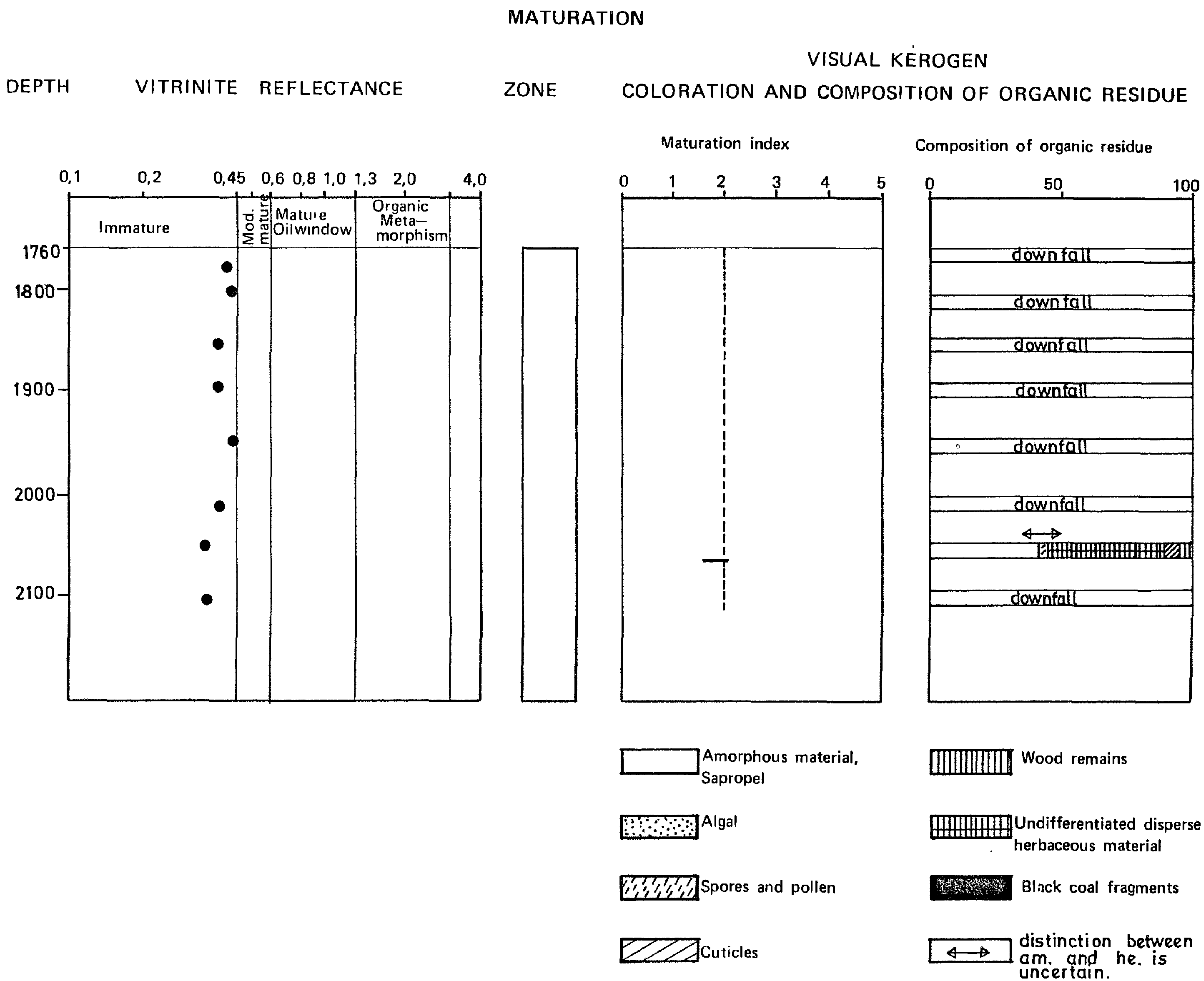
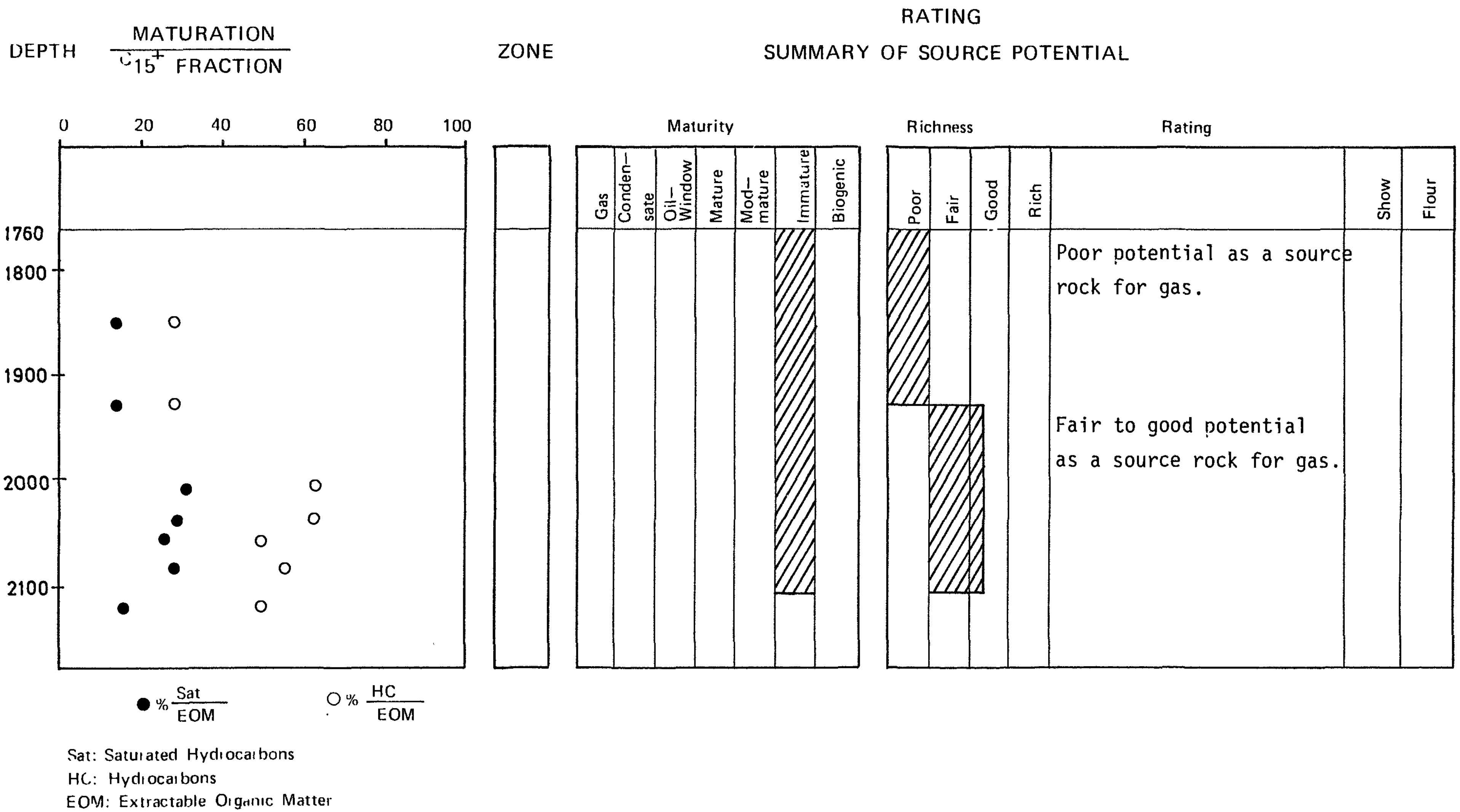
C_{15}^{+} SATURATED HYDROCARBONS




MATURATION
VISUAL KEROGEN
DEPTH
VITRINITE REFLECTANCE
ZONE
COLORATION AND COMPOSITION OF ORGANIC RESIDUE
Maturation index
Composition of organic residue
0,1 0,2 0,45 0,6 0,8 1,0 1,3 2,0 4,0
Immature
Mod. mature
Mature Oilwindow
Organic Meta– morphism
1760
1800
1900
2000
2100
0 1 2 3 4 5
0 50 100
downfall
downfall
downfall
downfall
downfall
downfall
downfall
Amorphous material, Sapropel
Algal
Spores and pollen
Cuticles
Wood remains
Undifferentiated disperse herbaceous material
Black coal fragments
distinction between am. and he. is uncertain.


RATING
DEPTH
MATURATION
C_{15}^{+} FRACTION
ZONE
SUMMARY OF SOURCE POTENTIAL
0 20 40 60 80 100
1760
1800
1900
2000
2100
Maturity
Gas
Conden-sate
Oil-Window
Mature
Mod-mature
Immature
Biogenic
Richness
Poor
Fair
Good
Rich
Rating
Show
Flour
Poor potential as a source rock for gas.
Fair to good potential as a source rock for gas.
% Sat/EOM
% HC/EOM
Sat: Saturated Hydrocarbons
HC: Hydrocarbons
EOM: Extractable Organic Matter