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REPORT TITLE

BIOSTRATIGRAPHY AND ORGANIC GEOCHEMISTRY OF NORWEGIAN NORTH SEA WELLS 18/11-1, 17/12-1 AND 17/12-2.

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SUMMARY

Fairly uniform claystone sequences in Norwegian North Sea Wells 18/11-1, 17/12-1 and 17/12-2 are mostly of earliest Cretaceous to Late/Middle Jurassic age though some older sediments may be present. A complete organic geochemical including oil source rock correlation was carried out and showed only poor correlation between potential source rocks and the oils recovered.

KEY WORDS

Norw. blocks 17 & 18

Biostrat./Source rock

Jurassic

C O N T E N T S

contd...........

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 Buchi 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.

Palynology

Standard techniques were employed using HCl, HF, flotation in zinc bromide where necessary, and screening through 15 μ nylon nets. Minimal oxidation with HNO_3 was carried out on some samples to provide cleaner residues.

PART ONE: BIOSTRATIGRAPHY

PART ONE: BIOSTRATIGRAPHY

As the available material was in some cases limited it was decided palynology would provide the most effective means of dating the intervals. The following account is based largely on the occurrence of dinoflagellate cysts. Definitive dating of the sequences (i.e. assigning an unqualified age) is not always possible due to the restrictions which the material imposes.

Caved contamination was a problem encountered in all of the wells under consideration, particularly in the uppermost part as there is no control on the sections above the intervals described below. The most serious problems were met in well 17/12-2, and the proposed biostratigraphy of this well is rather uncertain. Detailed descriptions of the lithology of individual cuttings samples can be found in the geochemical part of this study under the total organic carbon (TOC) results for each well.

Well 18/11-1 Biostratigraphy 1530 - 2060 m

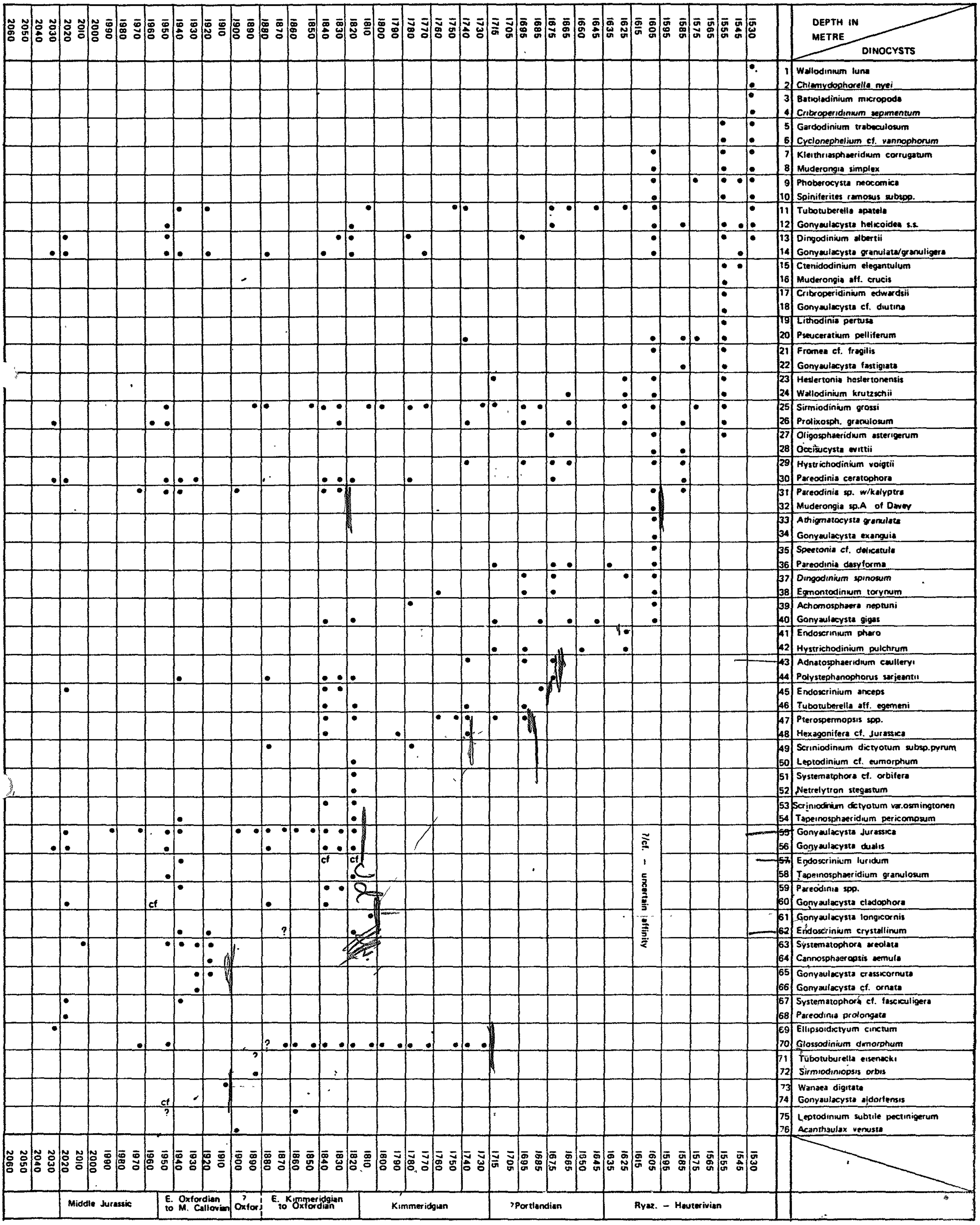
This well provided the best overall stratigraphic control. Biostratigraphy is based on stratigraphically significant dinocysts assemblages and is refined by distintive changes in kerogen composition and lithology.

1530 - 1635 m. Ryazanian to ?Hauterivian

Lithology

The lithology of this interval consists largely of grey claystones with varying amounts of sandstone. At the top of the interval up to about 30 % of the cuttings fraction consists of medium to coarse sands in which glauconite was observed. Sand decreases rapidly downwards though there are sporadic and significant influxes at 1550 m (15 %), 1565 (20 % fine to medium) 1610 (15 % medium to coarse) 1635 (25 % fine to medium) and 1645 m (10 %). Small amounts of limestone occur throughout most of the interval. Glauconite is frequent towards the lower part of the interval around 1565 - 1575 m and 1595 - 1610 m. Also of note are shell fragments recovered from the 1575 and 1585 m samples.

Fig.1, Distribution of palynomorphs in well 18/11-1.



Palynology

Palynomorph productivity is medium to high in the samples from 1530 to 1625 m. At 1635 and 1645 m the productivity is low and the sample at 1650 m is almost barren. Preservation is good to very good.

A number of stratigraphically significant species are present between 1530 and 1625 m (species no. 1-42, figure 2). They are all characteristic of the Lower Cretaceous (Ryazanian-Hauterivian). Gardodinium trabeculosum (5), Ctenidodinium elegantulum (15), Muderongia aff. crucis (16), Cribroperidinium sepimentum (4), Lithodinia pertusa (19) and Gonyaulacysta fastigiata (22) represent an Hauterivian element in the uppermost part of the unit. The occurrence of Tuboterella apatela (11) at 1530 m suggests, however, that the presence of these younger elements may be due to caving and that the true age for this interval may be slightly older, i.e. Valanginian.

The first downhole occurrence of Pareodinia dasyforma (36), Dingodinium spiosum (37) and Egmontodinium torynum (38) in association with the lowermost occurrences of Phoberocysta neocomica (9) and Pseudoceratium pelliferum (20) at 1605 m further suggests that we are close to the Ryazanian - Valanginian boundary and that the lower part of the interval (below 1605 m) may be of Ryazanian age. Endoscrinium pharo (41) is present at 1625 m.

These observations together with the general composition of the assemblages are regarded as evidence for the presence of the Ryazanian and Valanginian and possibly the Hauterivian stages within unit I.

The base of the interval is not definitely established though we here prefer to set this at 1635 m on lithological grounds.

Environment

Shallow marine, probably fairly close to shore, possibly with slightly restricted conditions towards the base.

5362.8

1635 - 1715/20 m - ?Portlandian

Lithology

Grey silty claystones, micaceous in part are the predominant lithology though in the upper part these grade to clayey siltstone (1665 - 75 m). Small amounts of white limestone are a fairly consistent component of the cuttings fraction throughout most of the interval though this is slightly more common around 1690 m. The uppermost occurrence of white limestone fragments is at 1635 m. The 1635 and 1645 m samples are also highly pyritic. Minor, but noteworthy influxes of sand occur at 1670, 1690 and 1720 m. Other minor components include glauconite at 1710 m, sporadic occurrences of pyrite and light grey marls around 1715 - 20 m.

Palynology

The evidence for the age of this unit is here rather tentative as palynomorph productivity is only medium between 1665 and 1695 m and low in the remaining interval. Preservation is fair.

The first appearance of Adnatosphaeridium cauleryi (43), Endoscrinium anceps (45) and Tubotuberella cf. egemenii (46) and the persistent occurrence of Pareodinia dasyforma (36) and Dingodinium spinosum (37) between 1665 and 1695 m suggest a possible Portlandian age Also of note in the presence of Pterospermopsis sp. Further evidence is the absence of a number of species characteristic of the above interval.

Environment

Shallow marine conditions with some restriction in circulation are suggested. The uppermost part of this interval contains considerable amounts of pyrite which, if indigenous suggests rather poor circulation, possibly poor in oxygen. Otherwise the dinoflagellate assemblages recovered suggest a shallow marine environment.

1730 - 1810 m. Kimmeridgian

Lithology

Dark grey to grey claystones are the predominant lithology with small amounts of white or brownish limestones. The claystones are somewhat darker than in the above interval. Glauconite was observed at 1760 m. Shell fragments are recorded from the base of the interval. The cuttings fraction of this interval is strongly contaminated by mud additives, particularly in the upper part.

Palynology

The palynological productivity is low within this unit. However, there is a distinct change in the kerogen composition which is very characteristic.

The occurrence of Glossodinium dimorphum (70) at 1730 m and below, the absence of such species as Pareodinia dasyforma is evidence of a Kimmeridgian age.

Environment

Shallow marine conditions possibly with some restriction in circulation are suggested.

1830 - 1890 m. Early Kimmeridgian to Oxfordian

Lithology

Considerable contamination by mud additives is again noted at the top of this interval. The upper part of the interval consists of dark grey and grey claystones similar to those of the above interval. Small amounts of brownish and greybrown siltstones and clayey siltstones are also recorded.

Palynology

The consistent occurrence of Gonyaulacysta jurassica (55) from 1820 m and

A number of other species, e.g. Leptodinium cf. eumorphum, Scriniodium dictyotum var osmingtonense (53) and Gonyaulacysta cladiphora (60) also make their first downhole occurrence in this interval. These are corroborative evidence of an Early Kimmeridgian/Oxfordian age.

The consistent occurrence of Glossodinium dimorphum in all samples down to 1879 m and possibly in 1880 m further suggests that the whole of this interval may be of Kimmeridgian age. However, this could be caved from the above deposits and without sidewall control a Kimmeridgian age cannot be confirmed.

The evidence for an Oxfordian age lies in the occurrence of a single poorly preserved specimen of Endoscrinium crystallinum (62) and a possible record at 1870 m. This species is usually common in Oxfordian deposits though it is known to extend up to the basal Kimmeridgian. This cannot be considered as particularly strong evidence for an Oxfordian age and may be due to reworking. Other species common in the Oxfordian (e.g. Endoscrinium galleritum are lacking.

In summary, the fossils present in this interval favour a Kimmeridgian rather than an Oxfordian age though as we cannot exclude the possibility that these are caved into poorly fossiliferous Oxfordian deposits we leave open a possible Oxfordian age.

Environment

Shallow marine possibly with somewhat restricted circulation.

1890 - 1900 m. ?Oxfordian

Lithology

Dark grey to black claystones and light grey to light brown clay/siltstones to siltstones, grading to very fine sandstone.

Palynology

Fossils are sparse in this interval though G. jurassica (55) is recorded. The absence of G. dimorphum below 1870/80 m may suggest a pre-Kimmeridgian (i.e. ?Oxfordian) age for 1890/1900 m. This is however rather tentative.

Comment

he main reason for recognising this interval is the distinctive lithology.

Environment

Probably shallow marine to deltaic.

1905 - 1955 m. Early Oxfordian to Late/Middle Callovian

Lithology

Fine to medium, angular to subangular sands, light grey in colour, together with dark grey claystones are present in the uppermost part of the interval. At 1920 m considerable amounts (40 %) of silt/claystone to siltstone are also recorded. Below this level dark grey claystones (mostly strongly contaminated by mud additives) are dominant.

Palynology

This interval contains similar forms to the above interval though a number of new elements are present such as Systematophora areolata, Ctenidodinium cf ornatum etc. The record of Wanaea digitata at 1910 m may however, be taken as evidence of an earliest Oxfordian to Late or possibly Middle Callovian age. The record of G. dimorphum (70) towards the base of the interval is thought to be due to caving.

It should be pointed out however, that the assemblages recorded here are noteably poorer than is usually encountered in rocks of this age. Of particular note is the continued absence of abundant specimens of E. crystallinium (62) and E. galleritum. Occasional specimens of E. crystallinum (62) are recorded though these are uncommon and sporadic.

Environment

Shallow marine, possibly coastal to deltaic. The environment of this interval may explain the relatively poor dinoflagellate cyst assemblages.

1960(?)/1970 - 2020 m. Middle Jurassic. ?Bathonian to Bajocian

Lithology

The 1960 and 1965 m samples, consist of coal and mud additive. They are thought to belong to this interval. Dark grey to black and some brownish claystones, micaceous in parts together with sands and the dominant lithologies. The proportion of clay to sandstones varies somewhat; claystone rich horizons are recorded at 2000 m and 2020 m. In the upper part of the interval claystones rapidly give way (downwards) to sandstones with minor coals. Notable occurrences of coarse or very coarse sands are recorded in the lower part of the interval.

Palynology

Dinoflagellate cysts are less common in this interval and most of those present may be caved (e.g. Dinogodinium alberti (13) at 2020 m).

There are few certain occurrences of stratigraphically significent forms though the somewhat uncertain records of Gonyaulacysta cf. aldorfensis and ?Leptodinium subtile subsp. pectinigerum at 1950 m may possibly suggest a Bathonian age at this level. The record of Pareodinia prolongata at 2020 m may also suggest a Bathonian age though once again the possibility of caving from younger strata (this species extends up to the Callovian) cannot be excluded.

The evidence for the age of this interval is not conclusive though it seems that a Bathonian age is the more likely. A Bajocian age can not be excluded. A Callovian age is possible though seems rather less likely.

The spores and pollen recorded from this interval are mostly long ranging and of little stratigraphic significance at this level. They are indicative of a Middle or Late Jurassic age.

Environment

Probably deltaic with marked marine influxes at times.

2025 - 2060 m. Indeterminate

Lithology

Sands and claystones are again the predominant lithologies. The claystones are dark grey, grey, green, yellowgreen and brown in colour. The uppermost occurrence of green claystones is at 2025 m which is designated as the upper limit of this interval.

Palynology

This interval is more or less barren of indigenous palynomorphs though occasional evidently caved forms are recorded.

Comment

There is more or less no evidence for the age of this interval which is defined on lithological criteria. A Triassic age seems possible though no truly "red" beds are encountered. Moreover if the minor amounts of coal recorded are in situ and not caved/mud additives a Middle Jurassic age would seem likely. However, if this were the case, we would expect somewhat richer spore/pollen assemblages. The 2050 and 2060 m samples are completely barren.

Well 17/12-1 - Biostratigraphy 6200 - 8000 feet

This well shows a somewhat more uniform sequence than 18/11-1 and the distribution of significant dinocysts is more sporadic. Sample coverage for biostratigraphic studies in the uppermost part is also poorer than in 18/11-1.

6200' - 6400' - Ryazanian to ?Valangian

Lithology

Silty grey claystones, micaceous in parts are the main lithology down to 6325' below which silty grey, dark grey and some lighter grey claystones are present. Pyrite is observed sporadically.

Palynology

Palynomorph productivity is high at 6200' and 6300', but low at 6400'. Preservation good.

A number of species at 6200' and 6300' again point to an early Lower Cretaceous age for this horizon. Gonyaulacysta exanguia (2), Muderongia simplex (3), and Pseudoceratium pelliferum (4) in association with Tubotuberella apatela (8), Occisucysta evittii (14), and Egmontodinium torynum (15) at 6200' and 6300' show a Ryazanian or possibly early Valanginian age. The sample at 6400' yielded a poor assemblage, and we are uncertain if this should be assigned to the Cretaceous or the Jurassic. In this respect the incoming of somewhat darker shales at 6325' may be of significance. However, we prefer to include this 6400' sample on the basis of a slight change in the kerogen composition and preservation, and an abrupt change in total organic carbon content between 6400' and 6500'.

Comment

The change in total organic carbon referred to above takes place between 6425' - 6450'. However, there was insufficient material for both geochemical and biostratigraphic studies.

Environment

A shallow marine environment is suggested on the basis of the dinoflagellate cysts.

*(6500') - 6775' - Portlandian

Lithology

Grey to dark grey claystones predominate, though some lighter grey and brownish claystones are present at some horizons, noteably from 6625' to the base of the interval. The claystones are often silty and grade to clayey siltstones around 6575'.

Palynology

The upper boundary for this unit is not marked by any distinct change in dinocyst assemblage. Between 6500' and 6650' extremely poor assemblages were recorded. At 6675', 6700' and 6725' there is a higher productivity with the first downhole occurrence of Adnatosphaerdium cauleryi (25) and Tubotuberella cf. egemenii (32). Dingodinium spinosum (24) is present in assemblages from 6600' and 6725' but was not recorded from the Cretaceous in this well.

Also of note is the consistent occurrence of Pareodinia dasyforma in the lower part of this interval from 6700' and below. This species is known to be particularly common in the Early Portlandian.

The data is not completely conclusive though a Portlandian age seems likely for this interval.

Comment*

This interval probably extends to up 6450'. See comment for the above interval.

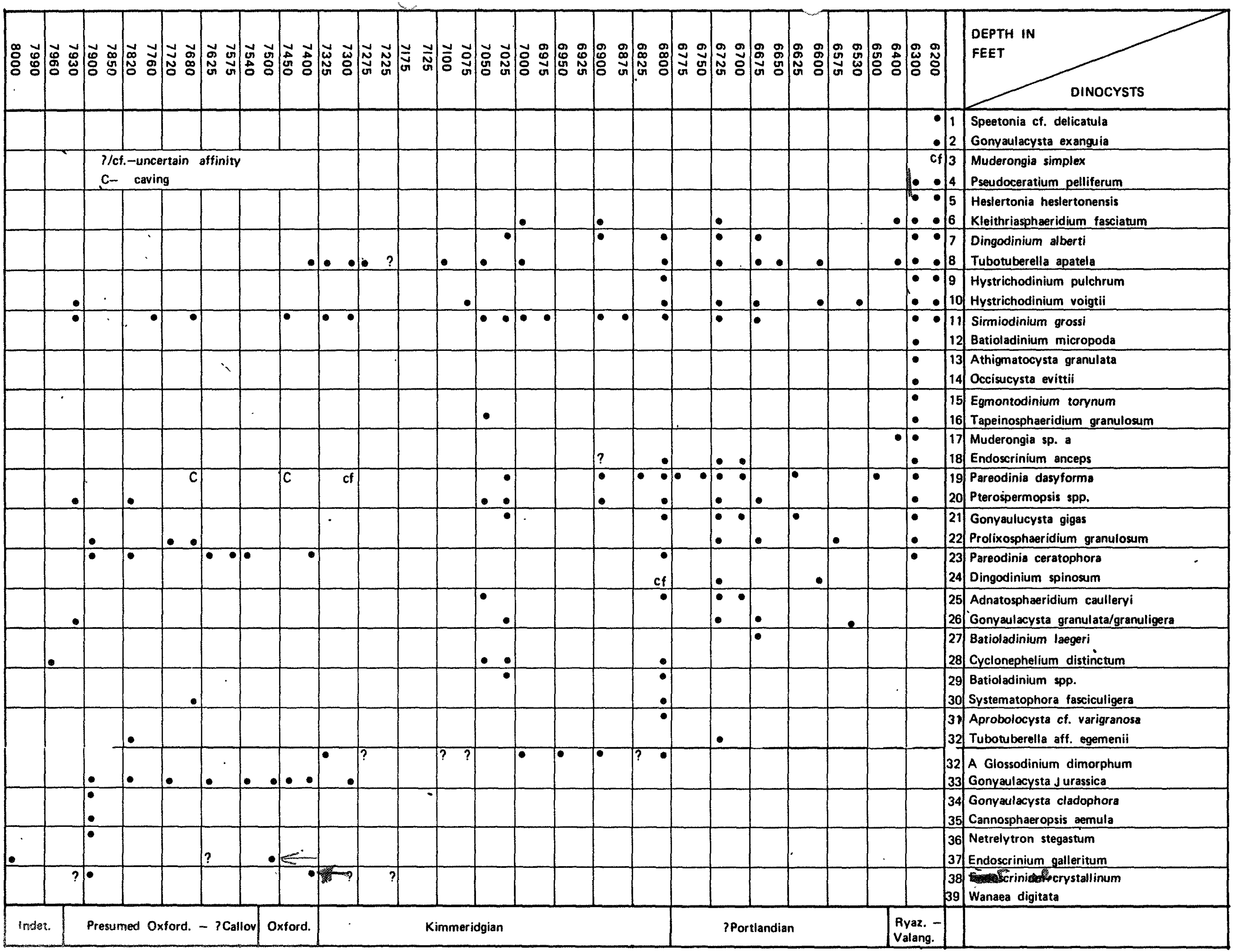


Fig.2, Palynomorph distribution in well 17/12-1.

6800' - 7325' - Kimmeridian

Lithology

Grey to dark grey claystones predominate over the greater part of this interval. At 7200' small amounts (3 %) of marl are recorded. At 7225-30' the claystones are fissile. Below this and to the base of the interval grey to dark grey claystones, slightly micaceous are again present.

Palynology

The uppermost occurrence of Glossodinium dimorphum at 6800' is taken as evidence of the penetration of Kimmeridgian deposits. The distribution of this species is more sporadic than in 18/11-1 though it seems to be present down to the base of the interval at 7325'. Gonyaulacysta jurassica is recorded from the 7300' sample suggesting an Early Kimmeridgian age at this level.

Environment

A shallow marine environment, possibly with slightly restricted circulation is suggested.

7400' - (7530')* - ?Oxfordian

Lithology

Dark grey to black claystones are present in this interval. The 7530'* (see comment) sample consists of c. 50 % brownish light grey to light brown claystone to silt/sandstone.

Palynology

The evidence for the age of this interval is rather speculative. The rare presence of Scriniodinium crystallinium (40) and Endoscrinium galleritum (32A) suggest an early Kimmeridgian or Oxfordian/Callovian age. The absence of Glossodinium dimorphum (32) further suggests a pre-Kimmeridgian age.

This is tentative as the occurrence of this species is rather erratic. However, the consistent presence of Tubotubunella apateta (8) to 7400' suggests an age no older than Oxfordian as this species is uncommon in deposits older than Oxfordian. However, this is also tentative as the record of T. apatella could be due to caving.

Comment*

This interval is extended down to 7530' on lithological grounds. No sample was available at 7530' for palynology.

7540' - 7930, - Presumed Oxfordian to ?Callovian

Lithology

Dark grey to black claystones dominate the whole of this interval. The upper part of the interval down to about 7600' is rather shaly with intercalations of micaceous sandstones, silts and white limestone. Coal laminae present in some of the claystones and coals make up to 10 % of the cuttings fraction in some samples, noteably from 7720' and below. Grey and browngrey claystones are a minor component at several horizons, particularly in the lower part of the interval.

Palynology

The evidence for the age of this interval is also tentative. The consistent record of Gonyaulacysta jurassica (33) throughout the interval suggests an Oxfordian or possibly a Callovian age. Caved contamination is recorded from most levels. Sporadic occurrences of Scriniodinium crystallinum (38) and possibly Endoscrinium galleritum (37) also support a general Oxfordian-Callovian age.

Moreover, Wanaea digitata (39) is recorded from 8000'. If this is in situ, a lowermost Oxfordian or possibly latest Callovian age is likely at this level (i.e. the interval below). This would inply an Oxfordian age for the present (7540' - 7930') interval. However, we are reluctant to exclude the possibility of a Callovian age for the present interval on the basis of a single specimin, suggesting an Early Oxfordian to ?Late Callovian age for the interval below.

Consequently we leave the dating of this interval rather open as presumed Oxfordian to ?Callovian.

Environment

Fairly rich spore/pollen assemblagees are noted at several horizons within this interval suggesting increased terrestrial input. Occasional dinoflagellate cysts however, indicate some marine influence. We suggest a very shallow marine environment, close to shore with considerable input of terrestrial material.

7960' - 8000' - Indeterminate, ?Early Oxfordian/?Late Callovian, ?Middle Jurassic

Lithology

Fine to medium and coarse/very coarse greyish sands together with dark grey to black claystones are the main lithology. The lowermost sample (8000') contains (36 %) slightly silty/sandy redbrown claystones, greenish and lightgrey to browngrey claystones in addition to the dark grey to black claystones observed higher in the interval. Smaller amounts of brownish grey and redbrown claystones are also observed higher in the interval.

Palynology

The only significant fossil recovered from this interval (8000') is a single specimen of Wanaea digitata. If in situ this would imply an Early Oxfordian (or possibly latest Callovian age.). However, in the absence of supporting evidence, we are reluctant to restrict the dating of this interval. The 8000' sample also contains a fairly rich spore/pollen assemblage of Middle or early Late Jurassic age. If not caved this provides supporting evidence for the suggested dating.

Environment

Probably inshore deltaic to shallow marine.

Well 17/12-2 - Biostratigraphy 6500 - 7350 feet

This well provided the least satisfactory results of the three wells under consideration. Presumed caved palynomorphs of latest Jurassic or earliest Cretaceous age occur throughout the well.

6560' - 6640' - Ryazanian to Valanginian

Lithology

The lithology of this interval consists of grey to dark grey claystones, slightly micaceous in parts. Some lighter grey claystones occur towards the base.

Palynology

Palynomorph productivity is medium to high and preservation good to excellent within this interval.

Assemblages recorded between 6560' and 6620' include a number of species characteristic of the lower part of the Lower Cretaceous (1-33, figure 3). They have many species in common with the assemblages recorded between 1605 and 1625 m in 18/11-1 and show an upper Ryazanian or lower Valanginian age for this interval. Most significant is the presence of Pseudoceratium pelliferum (2), Occisucysta evittii (4) and Tubotuberella apatela (23). The first downhole occurrence of Endoscrinium pharo (13) and Dingodinium spinosum (14) is recorded from 6580' and Egmontodinium torynum (33) appears at 6620'.

Environment

A shallow marine environment seems likely from the abundance of dinoflagellate cysts.

6680' - 6900' - ?Portlandian

Lithology

Dark grey claystones sometimes slightly brownish or micaceous are the predominant lithology though in the upper part (down to c. 6720') lighter grey and grey claystones are recorded.

Palynology

At 6680' we find the first downhole occurrence of Tubotuberella cf. egemenii (37), Endoscrinium anceps (38) and Adnatosphaeridium caulleryi (39). Dingodinium spinosum (14) and Egmontodinium torynum (33) are persistent constituents of the assemblages at 6680', 6700' and 6820', while several characteristic species from above have disappeared. P. dasyforma occurs consistently in samples down to 6900', below which its record is more erratic. This could indicate that the 6900' sample is close to the base of the Portlandian.

Environment

A shallow marine environment is suggested.

6940' - 7140' - ?Kimmeridgian

Lithology

The lithology of this interval is similar to that of the above and consists largely of dark grey claystones, slightly micaceous in parts though some grey and light grey slightly silty claystones are present around 7040' - 7060'. From 7080' and below, the claystones are more fissile.

Palynology

The evidence for the age of this interval is rather weak. The uppermost sample yielded no significant palynomorphs and presumed caved palynomorphs are common throughout the rest of the interval. At 7020' & 7060' extremely poorly preserved specimens, possibly referable to Glossodinium dimorphum (50)

Fig.3, Palynomorph distribution in well 17/12-2.

R—reworked species

No.	DINOCYSTS \ DEPTH IN FEET	7350	7340	7300	7260	7220	7180	7140	7100	7060	7020	6980	6940	6900	6860	6820	6780	6740	6700	6680	6640	6620	6580	6560
1	Systematophora fasciculigera																						●	●
2	Pseudoceratium pelliferum																					●	●	●
3	Kleithriasphaerdium sp.																			●	●	●	●	●
4	Occisucysta evittii																					●	●	●
5	Fromea cf. fragilis																						●	
6	Meiourogonyaulax stoverii																						●	
7	Spiniferites ramosus subspp.																						●	
8	Speetonia cf. delicatula																						●	
9	Gonyaulacysta fastigiata																					●	●	
10	Muderongia simplex																			●		●	●	●
11	Heslertonia heslertonensis																●			●		●	●	●
12	Kleithriasphaeridium cf. corrugatum																●			●		●	●	●
13	Endoscrinium pharo																			●		●	●	
14	Dingodinium spinosum															●				●		●	●	
15	Hystrichodinium pulchrum													●			●			●			●	●
16	Wallodinium krutzschii											●		●			●						●	●
17	Hystrichodinium voigtii	●	●	●	●									●			●			●		●	●	●
18	Dingodinium albertii	●	●	●										●			●	●		●		●	●	●
19	Pareodinia dasyforma	●	●	●	●		●			●		●		●	●	●	●	●	●	●	●	●	●	●
20	Gonyaulacysta helicoidea	●		●	●															●		●	●	●
21	Gonyaulacysta granulata/granuligera	●												●						●			●	●
22	Prolixosphaeridium granulosum	●												●						●		●	●	●
23	Tubotuberella apatela			●	●			●		●				●	●		●			●	●	●	●	●
24	Sirmiodinium grossi	●	●	●	●		●			●	●	●		●	●		●			●	●	●	●	●
25	Tapeinosphaeridium pericompsum	●												●			●					●	●	●
26	Pterospermopsis spp.	●		●	●	●		●		●	●	●		●		●	●					●		●
27	Hystrichosphaeridium pachydermum				●												●							●
28	Batioladinium cf. jaegerii											●		●			●			●		●	●	
29	Pareodinia ceratophora	●		●										●			●			●		●	●	
30	Netrelytron stegastum																					R		
31	Systematophora cf. areolata																			●		●		
32	Fromea sp.																●			●	●	●		
33	Egmontodinium torynum																●		●		●	●		
34	Kleithriasphaeridium fasciatum																			●	●			
35	Batioladinium cf. jaegerii sensu Duxbury -77																●			●				
36	Athigmatocysta granulata																			●				
37	Tubotuberella cf. egemenii																●			●				
38	Endoscrinium anceps											●		●		●	●			●				
39	Adnatosphaeridium caulleryi	●			●									●			●			●				
40	Paragonyaulacysta sp.																●							
41	Aprobolocysta varigranosa																●							
42	Gonyaulacysta gigas	●	●	●	●									●										
43	Gonyaulacysta cladophora		●		●	?																		
44	Polystephanophorus cf. paracalathus	●		●																				
45	Gonyaulacysta Jurassica		●		●	●	●																	
46	Gonyaulacysta dualis	●																						
47	Endoscridium luridum	●																						
48	Leptodinium cf. subtile	●																						
49	Wanaea sp.	?																						
50	Glossodinium dimorphum		●							?	?													

?E.Oxf. – ?Callovian	?Oxf. ?E.Kim	?Kimmeridge	?Portlandian	Ryaz. – Valang

were recovered. This rather weakly suggest the possibility of a Kimmeridgian age, at least for this level. There is little positive evidence for the rest of the interval, and the dating should be regarded as highly tentative.

Environment

A marine environment, probably fairly shallow is indicated.

7180 - ?7220 - ?Oxfordian to ?Early Kimmeridgian

Lithology

Dark claystones, sometimes grading to black, and black claystones are the main lithologies though some brown and browngrey claystones are also recorded.

Palynology

Gonyanlacyta jurassica (45) was recorded from this interval. This may indicate penetration of Early Kimmeridgian, Oxfordian or even Callovian deposits though the latter seems less likely. There is however little supporting evidence for either a Kimmeridgian or an Oxfordian age, and the most obvious aspect of the assemblages are presumed caved Portlandian to Early Cretaceous palynomorphs.

Comment

In both 18/11-1 and 17/12-1 the occurrence of black claystones is associated with sediments in which the evidence seems to point to an Oxfordian rather than a Kimmeridgian age. This may also be the case here though we do not have fossil evidence to support this. The lower limit of this interval is uncertain du to mud contamination.

Environment

A shallow marine to deltaic environment seems likely

7260' - 7360' - ?Early Oxfordian to Callovian

Lithology

The uppermost sample from this interval consists of dark grey, grey and black claystones together with fine to coarse angular to subangular sands (20 %). Below this dark grey and light browngrey claystones with minor sands (5 %) are present down to 7300'/7320'. These give way (downwards) to dark grey to black micaceous claystones which at 7340' are fissile. There is considerable mud contamination within this interval, and the lithology is difficult to interpret. The upper limit of the interval is uncertain.

Palynology

Presumed caved palynomorphs are again the most obvious aspect of the assemblages. Presumed indigenous forms are for the most part very poorly preserved and certain identification is difficult. For this reason we do not dismiss the possibility that they are reworked.

Nevertheless, Polystephanophorus cf. paracalatus (44) is recorded from 7300' and 7350' and two extremely poorly preserved specimens which may represent ?Wanaea sp. were recovered from the 7350' sample. If truly indigenous these would suggest an Early Oxfordian or Callovian age from at least 7300'.

Comment

This interval is extended upwards from 7300' to 7240' on grounds of lithology as the 7240' sample in the uppermost occurrence of sands. We have recorded no convincing fossil evidence either for or against this adjustment.

Environment

A shallow marine to dèltaic environment of deposition is suggested.

Correlation of wells 18/11-1, 17/12-1 and 17/12-2

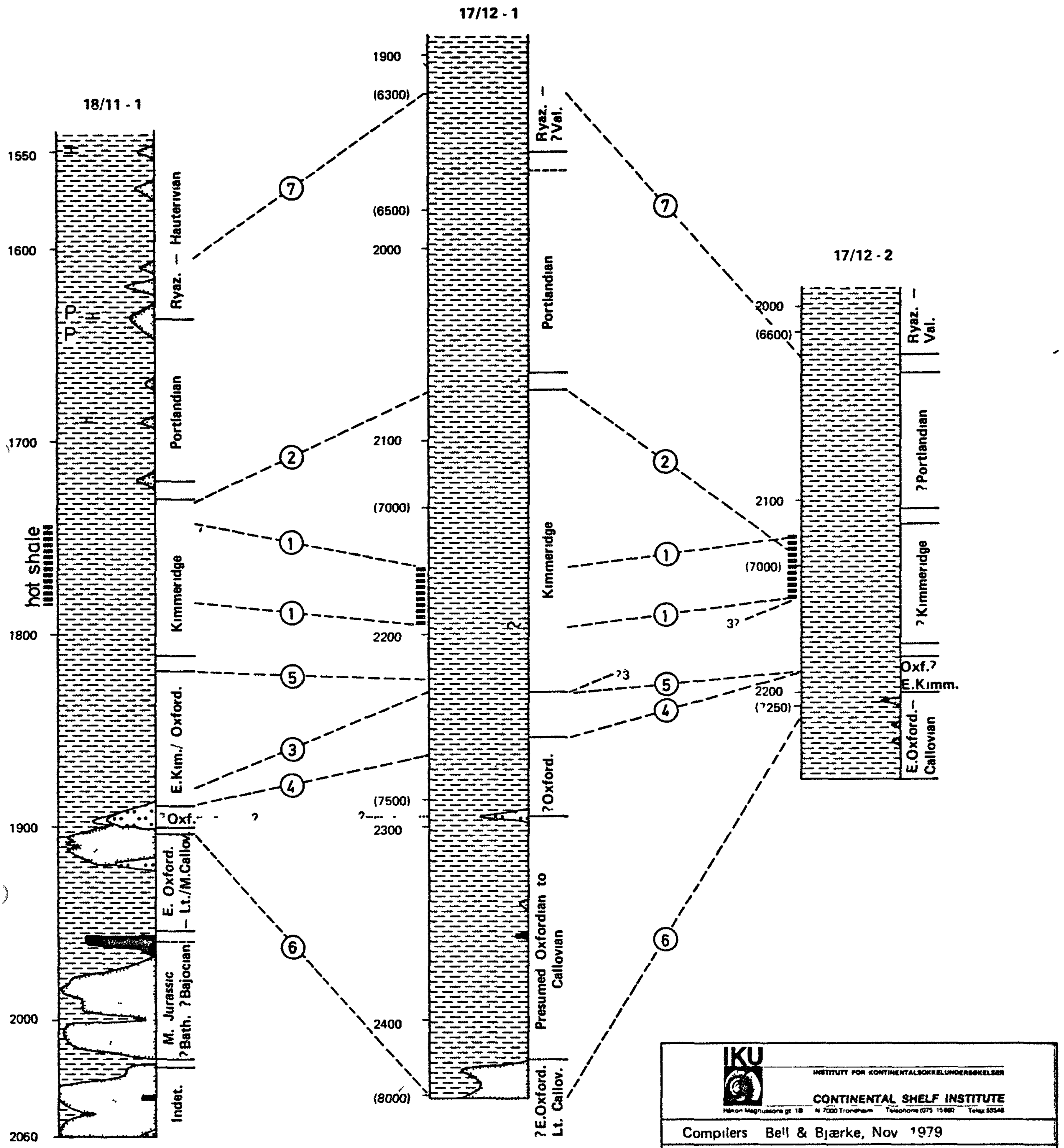
As noted above, electric logs were not available for the study though the location of the "hot shale" in each well was released. This correlation is therefore based purely on fossil and lithological criteria. This enables only the broad outline to be worked out.

Fossil correlations should always be considered with caution, and we here point some of the general principles and limitations. Any correlation is based on the occurrence or non occurrence of a fossil species. In an ideal case assuming an uniform unbroken (marine) sequence, the uppermost occurrence of a (marine) fossil which occurs commonly and consistently in the sequence below is taken as the "extinction point" i.e. the point in the sequence at which the fossil probably died out. This "extinction point" is then compared to the known extinction point in an established sequence.

There are a number of severe restrictions to this method. The non-record of a species may be due to misidentification of the species, failure to recognice the species due to poor preservation, or the fact that large numbers of other (e.g. caved) fossils obscure indigenous fossils. The latter is particularly relevant to palynological fossils on which this correlation is based. The use of the lower limit of a fossil as a fixed stratigraphic point is generally less reliable in well analyses due to the possibility of caving. An additional factor is that a fossil may occur above it's supposed "extinction point" due to reworking.

In the following suggested correlation, we have selected some few distinctive species in an attempt to establish the most significant aspects of the stratigraphy of the wells under consideration. The following factors have been taken into account.

1. The occurrence of "hot shale".
2. The top occurrence of Glossodinium dimorphum.
3. The base of G. dimorphum.
4. The uppermost occurrence of "black" claystones.
5. The top of Gonyanlacysta jurassica.
6. The occurrence of Wanaea spp. + Polystephanophorus cf. paracalatus.
7. The lowermost occurrence of Pseudoceratium pelliferum.



POSSIBLE CORRELATIONS OF NORTH SEA

WELLS 18/11 1, 17/12 1 and 17/12 - 2

Depths in parenthesis are in (feet), other depths are in metres

IKU

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CONTINENTAL SHELF INSTITUTE

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Compilers Bell & Bjærke, Nov 1979

Ref. P 249/ fig 4 — 18/11 - 1, 17/12 1, 17/12 2

Coal — Claystone — Marl
P Pyrite — Sandstone — Siltstone
Limestone

CORRELATION LINES

1. "Hot shale"
2. Top Glossodinium dimorphum
3. Base G dimorphum
4. Top black claystone
5. Top Gonyaulacysta jurassica
6. Occurrence of Wanaea spp + Polystephanophorus cf paracalatus.
7. Base Pseudoceratium pelliferum

Portlandian 17/12 - 1 See notes

A critical examination of these correlations and the occurrence of fossils in the different units of the three wells, may enable some refinement of the proposed age datings and possibly establish the time equivalence of units described under slightly different age limits. However, we refrain from this proceedure on the grounds that contamination is evident in many samples and prefer to retain the age units described in the preceeding section.

(7) Base of PSEUDOCERATIUM PELLIFERUM

The lower limit (base) of P. pelliferum is generally believed to be Late Ryazanian (= c. Berriasian). The non-occurrence of this common species below 1605 m in 18/11-1 and 6300' in 17/12-1 may indicate that the sequences immediately below these levels and above the Portlandian are of Ryazanian age. A low confidence is given to this correlation due to the possibility of caving. In 17/12-2 this species occurs down to 6620' possibly due to caving.

(1) Occurrence of "Hot Shale"

This is an extremely useful correlation datum andis given high confidence. It is assumed to be roughly time equivalent in each of the wells.

(2) The top occurrence of GLOSSODINIUM DIMORPHUM

Glossodinium dimorphum is normally associated with Kimmeridgian deposits. It may extend into the Early Portlandian such that the exact age limit of the "Kimmeridgian" as here recognised may be subject to discussion. This is however not relevant to its use as a stratigraphic datum in this correlation.

If the occurrence of "hot shale" and G. dimorphum are considered together in wells 18/11-1 and 17/12-1 assuming that the hot shale represents a time plane, then the occurrence of G. dimorphum in 17/12-1 is much higher than in 18/11-1.

Assuming that the non-record of this species in 18/11-1 is not due to non-recognition or other factors (see above), then the "post hotshale Kimmeridgian" is in the order of 100 m in 17/12-1 and in the order of 10 m in 18/11-1.

This suggests that this sequence is much reduced or absent in 18/11-1 compared with 17/12-1.

In 17/12-2 the significance of this fossil is much reduced as it is recorded only sporadically and in a very poor state of preservation (no certain in situ occurence was recorded). Nevertheless, if we accept the Portlandian dating of 17/12-2, then the top of the "hot shale" is more or less coincident with the top of the Kimmeridgian. We tentatively suggest that this sequence is also absent or reduced in 17/12-2.

(3) The base of GLOSSODINIUM DIMORPHUM

This is given a lower confidence rating due to the possibility of caving. It is nevertheless of significance when considered in conjunction with the occurrence of Gonyaulacysta jurassica (datum 5, see below). The lower limit of this species is generally believed to be earliest Kimmeridgian or latest Oxfordian. If the record of G. dimorphum in 18/11-1 is not due to caving, this suggests that the greater part of the interval described as "early Kimmeridgian to Oxfordian" in this well is in fact of Kimmeridgian age.

(4) The uppermost occurrence of "black" claystones

We note here that this datum seems to be associated with the occurrence of suspected Oxfordian. In 18/11-1 and 17/12-1 these claystones are associated with siltstones. In 17/12-2 minor amounts of sand are recorded immediately below the interval described as "?Oxfordian ?Early Kimmeridgian".

(5) The top occurrence of GONYAULACYSTA JURASSICA

The upper limit of the occurrence of common Gonyaulacysta jurassica is generally thought to be Early Kimmeridgian though sporadic records are known from higher in the Kimmeridgian.

In 18/11-1 the top record of this species is at about 1820 m. This is well above the lower limit of G. dimorphum and also above the occurrence of "black" claystones in this well. In 17/12-1 the first downhole occurrence of this species is roughly coincident with the base of G. dimorphum and to top of the "black" claystones. It is possible that non-recognition etc. accounts for the absence of this species in 17/12-1.

However, if the top occurrence of this species is a reliable datum in 17/12-1, we tentatively suggest that some of the interval described as Early Kimmeridgian/Oxfordian in 18/11-1 is reduced or absent in 17/12-1.

In 17/12-2 serious caving problems were encountered, and the reliability of the top G. jurassica datum is even more in doubt. Nevertheless, it is again approximately coincident with the uppermost occurrence of "black" claystones. This gives some grounds for suggesting that the Early Kimmeridgian/Oxfordian interval of 18/11-1 is also reduced in 17/12-2.

(6) Occurrence of WANAEA SPP. and POLYSTEPHANOPORUS of PARACALATUS

These species are members of a suite of species which have a top occurrence in earliest Oxfordian deposits and extend down into the Callovian. They are therefore considered together as a single datum.

We are unable to rate this correlation datum highly as it is based on specimens which are mostly in an extremely poor state of preservation making positive identification difficult. In addition they are rare in the sequences examined (one or two tentative identifications in each well) such that the possibility of non-observation is rather high.

In 18/11-1 the record of these species is at the top of the sand body at 1910 m, immediately below siltstones of presumed Oxfordian age. In 17/12-1 a single specimen assigned to Wanaea digitata is recorded from the lowermost sample (8000') which is also a sand body. This is well below the occurrence siltstones (see fig. 7) of presumed Oxfordian age.

This suggests that the sequence of claystones occurring in 17/12-1 between 7530' and 7940' may be absent in 18/11-1.

This sequence is arbitarily assigned a presumed Oxfordian to Callovian age in 17/12-1 and need not imply time equivalence with the Early Oxfordian to Late/Middle Callovian interval (c. 1905 - 1950 m) in 18/11-1. The two sand bodies in these wells (c. 1905 - 1920 m in 18/11-1 and ca. 7960' in 17/12-2) may therefore be lateral equivalents.

In 17/12-2 P. cf. paraculatus and Wanaea sp. are suspected at 7300' and 7350' respectively. The poor state of preservation suggests reworking, and we are unwilling to propose a correlation though, we do note that if these specimens are indigenous, they imply that the "presumed Oxfordian to Callovian" claystone sequence of 17/12-1 may also be reduced or absent in 17/12-2.

It also seems possible that the siltstone unit in 18/11-1 at ca. 1890/1900 m may correlate with the siltstone unit of 17/12-1 at ca. 7530'.

PART TWO: SOURCE ROCK STUDIES

RESULTS AND DISCUSSION

A: Well 18/11-1

Total Organic Carbon (TOC)

Samples above approximately 1500 m were very few and of a poor quality. None of these samples were analysed. From 1530 m to terminal depth a good suite of samples were received, and these were analysed extensively. Most of the samples were mainly claystone. Where more than one lithology was registered, all lithologies, except sandstones, were analysed for total organic carbon.

On the basis of total organic carbon measurements, the analysed sequence of the well can be divided into zones.

Zone A: - 1730 m:
This seems to be a very homogeneous sequence with only small variations in the TOC values, around the 1.0 % mark.

Zone B: 1735 - 1820 m:
At approximately 1740 m the TOC value changes sharply from 1.0 % in zone A to approximately 3.5 %. The TOC values are rather constant over an interval of approximately 80 m, then drop sharply.

Zone C: 1825 - 1900 m:
The TOC values in this zone are intermediate in value to the two zones above, approximately 1.5 %.

Zone D: 1905 - 1920 m:
Only two readings on claystone in this zone with results similar to the zone above. This zone is, however, separated out from the zone above due to the change in lithology to siltstone and sandstone. The claystone cuttings might be downfall from the zone above.

Zone E: 1925 - 1960 m:
At approximately 1925 m the TOC value again changes sharply to approximately 3 %. This high value is found for most of the analysed samples.

Zone F: 1960 - 2060 m:
This zone consists mainly of sandstone with thin claystone sequences in between. The TOC values vary considerably within this zone, and it is believed that this large variation is partly due to a contamination by other lithologies (sandstone) in the analysed samples. The samples were of a poorer quality in this part of the well than higher up.

Extraction and Chromatographic Separation

Zone A: Three samples from this zone were analysed, all showing a fair abundance of extractable hydrocarbons. The ratio between saturated and aromatic hydrocarbons are approximately 1 for all three samples. The gas chromatograms of the saturated hydrocarbon fractions vary only slightly from sample to sample. The n-alkanes are not very abundant while the steranes/triterpanes are very abundant. The large proportion of steranes/triterpanes indicates an input of terrestrial material and that the n-alkanes are destroyed by bacterial activity after sampling.

Biostratigraphic examination suggests that the Cretaceous/Jurassic boundary is approximately at 1635 m. We do not find a change either in the TOC measurements or in the extraction and further examination of the various fractions.

Zone B: Three samples from zone B were extracted, all showing a fair abundance of extractable hydrocarbons, and with a saturated/aromatic and HC/TOC ratio similar to the samples from the zone above. The gas chromatograms of the saturated hydrocarbon fractions vary considerably. The sample from 1730-35 m has a distribution similar to those from the zone above while the sample from 1765-70 m has a large abundance of isoprenoids, pristane and phytane being larger than nC_{17} and nC_{18}, and a pronounced, more unresolved sterane hump. The most pronounced difference from the samples higher up in the well is that phytane is more abundant than pristane. This indicates that the environment of deposition has been strongly reducing.

The lowermost sample in this zone, 1805 - 1815 m also has a low abundance of n-alkanes, especially in the higher m.w. range. The isoprenoids are pronounced but not as pronounced as in sample 1765 - 1770 m, and the pristane/phytane ratio is almost equal to unity. It should, however, also be pointed out that n-C_{14} is very pronounced in this sample.

Zone C: Two samples from zone C were extracted. The upper sample shows a good abundance of extracted hydrocarbons, while the lower sample shows a fair abundance. The ratio of saturated/aromatic hydrocarbons is similar to the ratio found in the samples in zone A and B.

The gas chromatograms of the saturated fractions vary from sample to sample. In upper sample, 1835 - 1840 m, a pronounced unresolved sterane hump is seen, and the n-alkanes, nC_{15} to nC_{21}, are far more abundant than the isoprenoids.

The gas chromatogram of the saturated hydrocarbon fraction of the next sample, 1875 - 1880 m, is different. A large unresolved sterane hump is found, but with a distinct pattern of n-alkanes with a high CPI value. Again the n-alkanes, nC_{15} to nC_{21}, are more pronounced than the isoprenoids. The most pronounced feature in this gas chromatogram is, however, the very large abundance of compounds in the nC_{13} - nC_{15} area. This abundance is so great, that it is probably due to a contamination either of migrated medium weight hydrocarbons, a condensate, or by a mud additive. If ordinary diesel had been used in the mud, a greater abundance of n-C_{15} - n-C_{20} would have been expected.

Zone D: No samples from this zone was extracted.

Zone E: One sample, 1925 - 30 m, from this zone was extracted, showing a good abundance of extractable hydrocarbons.

The gas chromatogram of the saturated hydrocarbon fraction shows the strong abundance of hydrocarbons in the n-C_{13} to n-C_{15} area as found in the lowermost sample in zone C. A large unresolved sterane hump is also found for this sample. The heavy n-alkanes, showing a high CPI value, is clearly distinguished in this sample.

Zone F: Two samples from this zone were extracted both showing a rich abundance of extractable hydrocarbons. The abundance of heavy n-alkanes varies in the two samples. In the upper sample, 1970 - 1975 m, the heavy n-alkanes cannot be distinguished, while in the lowermost sample the heavy n-alkanes are very pronounced with a high CPI value. This would indicate an input of mainly terrestic material and that the samples have been exposed to a various degree of bacteriological activity.

Most of the examined samples have signs of bacteriological activity, probably after sampling. In some of the samples this bacteriological activity has been rather strong, and almost all the n-alkanes are destroyed, while it has a lighter degradation in other samples. Due to this the abundance of extractable hydrocarbons is less than the true value would be, and these data are not reliable. In the source rock rating more emphasis is put on the total organic carbon than normally in our evaluation.

Rock-Eval Pyrolysis

A total of eighteen samples were pyrolysed on a Rock-Eval instrument. The analysed samples in zone A have a low hydrogen index and a very high oxygen index, i.e. typical kerogen type III kerogen. The samples from zone B and C have generally a higher hydrogen index than the samples from Zone A, but still with a very high oxygen index. These samples do, however, show a good petroleum index, in contrast to the samples from zone A.

All the analysed samples from zone D, except the sample from 1965 - 1970 m, have a low hydrogen index and a high oxygen index, which indicates kerogen type III.

Other analyses have shown these samples to be badly biodegraded, and this would strongly effect the pyrolysis results. Due to this the amount of free hydrocarbons will be reduced at the same time as the hydrogen index and oxygen index will be affected. We would normally get a strong reduction in the S_2 readings, which will reduce the hydrogen index at the same time as we would get an increase in the S_3 readings, which will increase the oxygen index. Due to this it is difficult to draw certain conclusions from these analyses apart from that zones A and F are definitely type III kerogen and that there are indications that zone E is also probably of type III kerogen. Zone B and C are difficult to classify, but it is believed that these two zones are of type II kerogen, and that the hydrogen index has been strongly reduced at the same time as the oxygen index has been strongly increased due to bacteriological activity.

The T_{max} values are low for all the analysed samples, and the whole analysed sequence must be classified as immature.

Vitrinite Reflectance

Sixteen samples were analysed for vitrinite reflectance. In the following each sample is described, and together with the reflectance data, other information from the analyses are given.

490 m: Shale, siltstone and carbonate, R_o = 0.36(9).
The sample has a low organic content with a good deal of bitumen staining and wisps. Otherwise a few intertinite and reworked particles with a trace of vitrinite. UV light shows a light orange fluorescence from spores and a low exinite content.

1180 m: Calcareous shale, R_o = 0.35(21).
The sample has a low organic content, apart from overall bitumen staining. Small particles of vitrinite with about equal proportions of inertinite and reworked material. UV light shows a light orange fluorescence from spore specks and a trace of exinite.

1320 m: Calcareous shale and carbonate, R_o = 0.34(21).
The sample contains small particles of vitrinite with about equal proportions of reworked material and inertinite. Some bitumen staining and interstitial material. UV light shows a light orange fluorescence from spore traces and hydrocarbon specks together with a trace of exinite.

1470 m: Sandstone and siltstone, R_o = 0.41(15).
The sample contains some interstitial bitumen and staining. Otherwise traces only of small particles of vitrinite and inertinite, mostly reworked. UV light shows fluorescence from hydrocarbon traces and no definite exinite.

1535 m: Shale, R_o = 0.36(20).
The sample has a low organic content with some good particles of vitrinite with about equal proportion of inertinite and reworked particles. UV light shows yellow/orange to mid-orange fluorescence from spores, and a trace of exinite.

1595 m: Carbonate and pyrite, R_o = 0.33 (21).
The sample which contains large pyrite masses, has a low organic content with a few loose coal fragments, wholly vitrinite plus some smaller vitrinite particles. A little bitumen staining and interstitial areas. Some particles of inertinite and reworked material. UV light shows a variable carbonate fluorescence with hydrocarbon traces and light orange spores together with with a trace of exinite.

1645 m: Mixed lithologies, sandstone, shale and carbonate, Ro = 0.34(21).
The sample has a low organic content with bitumen staining and interstitial areas. A few particles of reworked material and inertinite together with a trace of vitrinite particles. UV light shows a light orange fluorescence from spores and hydrocarbon traces together with a trace of exinite.

1695 m: Calcareous shale and siltstone, R_o = 0.29(9).
The sample has a low organic content with bitumen staining. Small particles, mostly of inertinite and reworked material. Doubtful fragments of true vitrinite. UV light shows a light orange fluorescence from spores and variable carbonate together with a low exinite content.

1750 m: Shale, R_o = 0.29(20).
The sample has a low organic content with a few loose coal cuttings - wholly vitrinite. The shale contains a few small inertinite particles and bitumen wisps. UV light shows a light orange fluorescence from spores and variable carbonate together with a low to moderate exinite content.

1800 m: Shale, R_o = 0.34(20).
The sample has a low to moderate organic content with bitumen particles, wisps and staining. Particles of inertinite and reworked material together with a few particles of true vitrinite are recorded. UV light shows a yellow to light orange fluorescence from spores and hydrocarbon traces together with a low to moderate exinite content.

1850 m: Calcareous shale, R_o = 0.39(21).
The sample shows an overall bitumen staining, otherwise a low content of small particles of vitrinite with reworked material and inertinite dominant. UV light shows a variable carbonate fluorescence plus light and mid-orange fluorescence from spores together with a low exinite content.

1900 m: Calcareous shale, R_o = 0.35(22).
The sample has a low organic content. Particles of reworked material and inertinite are dominant, but with a good proportion of vitrinite as particles and wisps. Bitumen wisps and heavy staining are recorded in some cuttings. UV light shows a light orange fluorescence from spores and hydrocarbon traces together with a low exinite content.

1950 m: Calcareous shale, R_o = 0.36(22).
The sample has a low organic content, with isolated particles and wispy particles of vitrinite. A few coal fragments, wholly vitrinite. Only a trace of inertinite. UV light shows a light orange fluorescence from spores and a low exinite content.

2000 m: Calcareous shale and siltstone, R_o = 0.35(20).
The sample has a low - moderate organic content, very variable. A few inertinite and reworked particles, loose coal and vitrinite fragment. Variable bitumen staining and wisps. A few particles of vitrinite. UV light shows a light orange fluorescence from spores and a low exinite content.

2035 m: Mixed lithologies, R_o = 0.39(21).
The sample contains a few loose coal fragments and a few inertinite and reworked particles. Most of the measurements are on loose material. UV light shows a light orange fluorescence from spores and a trace of exinite.

2060 m: Sandstone, R_o = 0.35(15).
Interstitial bitumen, but measurements on loose coal fragments and vitrinite particles in a few shale fragments. Graphite plentiful in drilling grease. UV light shows fluorescence from hydrocarbon traces and a yellow/orange fluorescence from spores together with a trace of exinite.

Visual Kerogen

Fiftytwo samples were processed for palynological investigations and for evaluation of palynofacies/kerogen composition and colour/maturity of this well.

Three main intervals can be distinguished, 1530 - 1665 m, 1675 - 1930 m, and 1940 - 2060 m, but further subdivision is possible.

1530 m to 1605 m:
Sapropel is dominant in the interval. But terrestic remains, mostly indeterminate finely dispersed material, form up to 50 % in the samples between 1585 m and 1605 m. Dark coal fragments are present and indicate reworking in most samples.
Colour index: -2 down to 1545 m, 2 from 1555 to 1605 m.

1615 m to 1665 m:
Herbaceous material is in part dominating in this interval of finely dispersed residues. Aggregates indicate presence of carbonate. Up to 20 % coaly fragments were noted in some of the samples.
Colour index: -2/2. Probably a low energy marine area close to coast.

1675 m to 1750 m:
Fairly small residues dominated by sapropel. Aggregates are common between 1705 m and 740 m. 1750 m is distinguished by slightly coarser herbaceous material and includes cuticular fragments.
Colour index: 2.

1760 m to 1780 m:
Rich residues which are dominated by sapropel obscuring other fossils. Aggregates are present.
Colour index: 2+. Apparently slightly increased compared with the above interval.

1790 m to 1890 m:
Sapropel dominates. Palynomorphs are fairly common and are well preserved especially in the interval 1870 m to 1890 m, which also contains cuticular fragments.

Colour index: 2. Probably a low energy marine area of deposition.

1910 m to 1930 m:
Sapropel seems dominant, but the residues are rich in undissolved minerals beside a minor part of terrestric remains.
Colour index: 2/2+. Perhaps a slightly too high index due to oxidation in a more high energy zone of deposition.

1940 m to 1960 m:
Sapropel is dominant. About 20 % terrestric material includes cuticles as well as woody remains and indeterminate herbaceous material. The remains seem sapropelized.
Colour index: 2/2+.

1970 m to 2060 m:
The interval is evaluated as dominated by terrestric material, either indeterminate herbaceous or woody. However, sapropel seems to dominate in some of the uppermost samples, but this may represent downfall from higher in the well.

Undissolved minerals disturb most residues especially from 2010 m to 2060 m.
Colour index: 2/2+, higher possibly due to oxidation between 2020 m and 2030 m.

Source Rock Evaluation

On the background of the above results, the whole analysed sequence of the well would be classified as immature.

Based on total organic carbon measurements, the analysed sequence is divided into four zones which will be given the following rating.

Zone A: 1530 - 1730 m: This zone is lean both in total organic carbon and extractable hydrocarbons, and with a relatively large abundance of terrestric material in the kerogen concentrate. With the background in the described analyses it will be rated to have a fair or fair/good potential as a source rock for gas.

Zone B: 1735 - 1820 m: This zone has a far greater abundance of organic carbon while the abundance of extractable hydrocarbons are low, probably due to bacteriological activity. The kerogen is almost 100 % sapropelic. This zone will be rated to have a rich potential as a source rock for oil and gas.

Zone C: 1825 - 1900 m: The abundance of organic carbon in this zone is far lower than in zone B, while the kerogen is found to be similar, i.e. mainly sapropelic. This zone will then be rated to have a good potential as a source rock for oil and gas.

Zone D: 1905 - 1920 m: This zone consists mainly of sand- and siltstone. Fluorescing hydrocarbons indicate migrated hydrocarbons in the sand - siltstone sequence.

Zone E: 1925 - 1960 m: The upper part of this zone has a kerogen composition as zones B and C, while in the lower part of the zone the kerogen shows a larger input of terrestric material. On the background of these results, this zone will be rated to have a good to rich potential as a source rock for gas and oil.

Zone F: 1960 - 2060 m: The main part of this zone consists of sandstone with some thin claystone lenses. The visual kerogen examination shows these to contain large proportions of terrestric material. The claystone in this zone has a good potential as a source rock for gas. Fluorescing hydrocarbons indicate migrated hydrocarbons in some of the sandstone lenses.

TABLE I

Lithology and Total Organic Carbon (TOC) measurements

Depth (m)	TOC	Lithology
420		Uncertain lithology, the material originate probably from drilling mud
490		100% Claystone, light grey to dark grey Mud contaminated
1180		100% Claystone, calcareous
1320		100% Claystone, calcareous
1470		100% Sandstone and Siltstone
1530	1.02	70% Claystone, grey 30% Sand, medium to coarse, subrounded to subangular, light grey, sm.am. Glauconite sm.am. sand
1535	1.30	100% Claystone, silty, grey, (brownish) light grey, micaceous, some light brown, sm.am. Sand.
1540	1.24	100% Claystone, grey sm.am.Sand; Limestone; Pyrite; Clay/Siltstone, light brown Contaminated by organic mud additives
1545	1.00	100% Claystone, gray, some light browngrey, some micaceous
1550	0.95	85% Claystone, grey 15% Sand sm.am Limestone, white, light brown; Pyrite
1560	1.04	100% Claystone, grey, light brown obs. sm.am Limestone, white
1565	0.96	75% Claystone, silty, grey 20% Sand,(fine-medium), some Glauconite and Mica 5% Silt/Claystone, light brown sm.am Limestone, white

Depth (m)	TOC	Lithology
1575	0.99	95% Claystone, silty, grey, some light brown, some micaceous 5% Sand, Glauconite sm.am Limestone, white; shell fragments
1580	1.04	100% Claystone, grey sm.am. Limestone and shell fragments, white; Sand; Pyrite
1585	1.16	100% Claystone, silty, grey, brown (more silty) (20%) sm.am Pyrite; Limestone; Siltstone; Sand; ? Dolomite
1590	1.0	100% Claystone, grey sm.am Limestone and shell fragments; Sand
1595	1.06	100% Claystone, grey, some brown (silty) sm.am Sand, with Glauconite; Limestone, white
1600	1.12	100% Claystone, grey sm.am Sand with some Glauconite; Limestone and shell fragments
1605		100% Claystone, grey
1610	1.16	85% Claystone, grey, browngrey 15% Sand, sm.am Glauconite sm.am Pyrite; Carbonate Contaminated by organic mud additives
1615	1.14	100% Claystone, silty, grey, some micaceous sm.am Clayey Siltstone, light brown; Pyrite; ?Dolomite; Limestone, brownish light grey
1620	0.91	70% Claystone, silty, grey, browngrey, light grey, partly pyritized 30% Sand, medium to coarse, light grey sm.am Pyrite

Depth (m)	TOC	Lithology
1625	1.08	100% Claystone, silty, grey, some micaceous sm.am Sand; Pyrite; Limestone; Siltstone; light grey; Silt/Claystone, light brown
1630	1.12	90% Claystone, grey 10% Sand, light grey sm.am Carbonate
1635	0.94	75% Silty Claystone grading to clayey Siltstone, grey, greatly pyritized 25% Sand, light grey, fine to medium sm.am Limestone, white; Clay/Siltstone, light brown
1645	0.86	87% Silty Claystone grading to clayey Siltstone, grey, greatly pyritized 10% Sand, as above 3% Limestone, white, brownish
1650	0.87	100% Claystone, grey, dark grey (micaceous) sm.am Marl, grey, brownish; Sand; Limestone, white
1665	0.94	100% Claystone, partly grading to clayey Siltstone, grey, some micaceous
1670	1.08	90% Claystone, silty, grading to clayey Siltstone, some pyritized 10% Sand sm.am. Limestone, white
1675	0.96	100% Silty Claystone grading to clayey Siltstone, grey, some micaceous sm.am Limestone, white

Depth (m)	TOC	Lithology
1680	1.04	100% Claystone, silty, grey, some pyritized sm.am Sand; Limestone, white Strongly mud contaminated
1685	0.82	100% Claystone, silty, grey, some micaceous sm.am Limestone, white
1690	0.79	82% Claystone, silty, grey, some light grey, some micaceous and pyritic 15% Sand 3% Limestone, white Strongly contaminated
1695	0.86	100% Claystone, silty, grey sm.am Sand; Limestone
1700	0.85	100% Claystone, silty, grey sm.am Limestone, white; Sand
1705	0.80	100% Claystone, silty, grey
1710	0.87	97% Claystone, grey, some light grey 3% Sand, with sm.am. Glauconite sm.am Limestone; Pyrite. Mud contaminated
1715	0.90	100% Claystone, grey, some micaceous sm.am Limestone, white; Marl, light grey
1720	0.91	80% Claystone, grey, some pyritized 20% Sand sm.am Limestone; white, brownish; Marl, light grey; clayey Siltstone, light brown

Depth (m)	TOC	Lithology
1725	0.94	100% Silty Claystone, partly grading to clayey Siltstone, grey
1730	1.14	100% Claystone, silty, grey
1735	1.31	100% Claystone, as above sm.am Sand; Limestone, white
1740	1.34	100% Claystone, silty, grey, sm.am Limestone, white Considerable amounts organic mud additives
1750	2.22	100% Claystone, as above sm.am Sand; Limestone, white, brownish
1755	3.41	100% Claystone, grey, some dark grey. Strongly contaminated by organic mud additives
1760	3.52	100% Claystone, dark grey to grey sm.am Sand, Glauconite obs; Limestone, white Contaminated by mud additives
1765	3.43	100% Claystone, as above, slightly brownish and micaceous
1770	3.32	100% Claystone, dark grey,some grey
1780	3.30	100% Claystone, as above
1790	3.21	100% Claystone, as above
1800	2.86	100% Claystone, as above sm.am Sand; Limestone, white
1805	2.05	100% Claystone, as above sm.am Limestone and shell fragments, white

Depth (m)	TOC	Lithology
1810	2.54	100% Claystone, as above
1815	2.42	100% Claystone, as above sm.am Limestone, brownish white; Claystone, brownish light grey, calcareous
1820	1.43	50% Claystone, as above 50% Additive (drilling mud or cement)
1825	1.56	75% Claystone, dark grey 25% Additive (drilling mud or cement)
1830	1.48	80% Claystone, dark grey 20% Additive (drilling mud or cement)
1835	1.58	100% Claystone, dark grey Contaminated by mud additives
1840	1.60	100% Claystone, dark grey, grey, partly slightly brownish, slightly micaceous
1845	1.61	100% Claystone, as above sm.am Claystone, brownish light grey, calcareous; Siltstone, light grey; Limestone, white
1850	1.64	100% Claystone, dark grey, grey, slightly micaceous sm.am Silt/Claystone, (brownish) light grey; Pyrite; Sand
1855	1.62	100% Claystone, as above obs. Sandstone, light grey, ? w Glauconite; Limestone; Claystone, silty, browngrey
1860	1.70	100% Claystone, as above obs. Silty Claystone, light brown

Depth(m)	TOC	Lithology
1865	1.78	100% Claystone, as above sm.am Silty Claystone, light brown, calcareous; Siltstone, grey
1870	1.90	100% Claystone, as above sm.am Clay/Siltstone, brown/browngrey to light grey, partly very micaceous
1875	1.86	100% Claystone, as above sm.am Dolomite, brown; Clay/Siltstone, brown
1880	1.91	100% Claystone, as above sm.am Claystone, partly silty, light brown to brown; Dolomite,brown
1890	1.60	85% Claystone, dark grey to black 15% Siltstone, partly clayey, grading to very fine sandstone, light grey; Sand; Limestone, white Strongly contaminated by mud additives
1895	1.57	55% Clay/Siltstone to Siltstone, sandy, light grey to light brown 40% Claystone, as above 5% Sandstone/Sand, light brey to light brown Contaminated by mud additives
1900	1.46	50% Claystone, dark grey 43% Silt/Claystone to Siltstone, light grey/white to brownish, calcareous 7% Sand/Sandstone Contaminated by mud additives
1905		85% Sand, fine to medium, angular to subangular, light grey 15% Claystone, dark grey sm.am Silt/Claystone to Siltstone

Depth (m)	TOC	Lithology
1910		85% Sand, as above
	1.76	15% Claystone, as above
		sm.am Silt/Claystone to Siltstone
		Mud contaminated
1920	1.74	40% Claystone, dark grey
		40% Silt/Claystone to Siltstone, light grey to brownish
		20% Sand and Sandstone
		Strongly contaminated by mud additives
1925	3.61	100% Claystone, dark grey
		sm.am Sand
		Consists mostly og mud and mud additives
1930	3.24	100% Claystone
		Strongly contaminated by mud additives
1935	3.06	100% Claystone, dark grey
		Strongly contaminated by mud and mud additives
1940	2.65	100% Claystone, dark grey
		Strongly contaminated by mud and mud additives
1945	2.96	100% Claystone, dark grey, partly silty.
		Half of the sample consist of mud and mud additives
1950	2.04	100% Claystone, dark grey
		Half of the material consists of mud and mud additives
1955	1.54	100% Claystone, dark grey
		obs. Sandstone; Siltstone.
		Mostly consisting of mud and mud additives
1960		75% Coal/Lignite
		25% Claystone, as above

Depth (m)	TOC	Lithology
1965		75% Coal
	7.19	25% Claystone, as above
1970	7.25	80% Claystone, dark grey to black, micaceous, some slightly brownish
		10% Sand
		10% Coal
1975	3.39	50% Claystone, dark grey to black
		43% Sandstone, light brown, clear to white
		7% Coal
1980		90% Sand/Sandstone, fine to medium,light grey to white
		7% Claystone, dark grey, grey
		3% Coal
1985		95% Sand, fine to very coarse, very angular to subangular
	3.16	5% Claystone
1990		75% Sand, as above
		25% Claystone, dark grey, grey, (brownish) light grey
		sm.am Coal
1995		75% Sand, fine to medium, some coarse/very coarse, very fine, subrounded to very angular, white, light brown
	2.29	25% Claystone, as above
2000	3.21	85% Claystone, as above, some yellow
		15% Sand
		Contaminated by mud/mud additives
2005		95% Sand, medium to very coarse, angular to very angular white to light grey
	1.09	5% Claystone
		sm.am Coal

Depth (m)	TOC	Lithology
2010		95% Sand, as above 5% Claystone
2015	1.19	80% Sand, as above 20% Claystone, grey, dark grey, yellow,light grey, sm.am Coal
2020	1.56	90% Claystone, dark grey 10% Sand About half of the sample consists of mud/cement
2025	1.28	70% Claystone, dark grey, grey, green 30% Sand Highly mud contaminated
2030		70% Sand, fine to coarse 30% Claystone, green, browngrey, grey, dark grey
2035	3.45	100% Sand, medium to very coarse, angular/very angular, light grey sm.am Claystone; Coal
2040		90% Sand, as above 10% Coal sm.am Claystone
2045	1.63	90% Sand, fine to medium, angular, light grey, white 7% Claystone 3% Coal
2050	1.70	65% Sand, medium to very coarse, angular to very angular, light grey 35% Claystone, green, light grey, dark grey, yellowgreen some yellow

Depth (m)	TOC	Lithology
2055		95% Sand, fine to very coarse, as above
	5.18	5% Claystone, green, yellow, brown
2060		90% Sand, light grey/white, green
	1.13	10% Siltstone, green to light grey, chloritic

TABLE II

Weight (mg) of EOM and chromatographic fractions
Well 18/11-1

Sample	Depth (m)	Rock extr. (g)	EOM(mg)	Sat(mg)	Aro(mg)	HC (mg)	Non HC (mg)	TOC %
K633-636	1530-60	16,13	13,2	1,7	1,4	3,1	3,6	1,13
K725-727	1605-25	7,06	9,6	1,3	0,7	2,-	1,6	1,16
K731-732	1670-90	14,51	11,3	1,6	0,9	2,5	2,9	1,11
K738	1730-35	4,03	3,7	0,1	0,3	0,4	1,5	1,31
K749	1765-70	40,10	19,4	4,3	2,4	6,7	6,-	3,43
K754	1805-15	23,78	19,8	2,9	1,3	4,2	4,7	2,05
K760	1835-40	48,76	32,6	11,-	4,6	15,6	8,8	1,58
K769	1875-80	38,67	15,5	3,8	1,8	5,6	4,8	1,91
K776	1925-30	40,24	42,4	11,4	7,6	19,-	12,8	3,61
K785	1970-75	51,82	144,1	27,1	29,-	56,1	55,8	7,25
K795	2020-25	70,35	78,8	27,6	12,8	40,4	17,-	1,56

TABLE III

Concentration of EOM and chromatographic fractions (Weight ppm of rock).
Well 18/11-1

Sample	Depth (m)	EOM	Sat	Aro	Total hydrocarb.	Non hydrocarb.
K633-636	1530-60	818	105	86	192	223
K725-727	1605-25	1359	184	99	283	226
K731-732	1670-90	778	110	62	172	199
K738	1730-35	918	240	74	314	372
K749	1765-70	483	107	59	167	149
K754	1805-15	832	121	54	176	197
K760	1835-40	668	225	94	319	180
K769	1875-80	400	98	46	144	124
K776	1925-30	1053	283	188	472	318
K785	1970-75	2780	522	559	1082	1076
K795	2020-25	1120	392	181	574	241

TABLE IV

Concentration of EOM and chromatograpic fractions (mg/gTOC).
Well 18/11-1

Sample	Depth (m)	EOM	SAT	Aro	Total hydrocarb.	Non hydrocarb.
K633-636	1530-60	72,4	9,3	7,6	17,0	19,7
K725-727	1605-25	117,2	15,8	8,5	24,4	19,5
K731-732	1670,80-90	70,1	9,9	5,5	15,5	18,0
K738	1730-35	70,0	18,3	5,6	23,9	28,4
K749	1765-70	14,1	3,1	1,7	4,8	4,3
K754	1805-15	40,6	5,9	2,6	8,6	9,6
K760	1835-40	42,3	14,2	5,9	20,2	11,4
K769	1875-80	20,9	5,1	2,4	7,5	6,5
K776	1925-30	29,1	7,8	5,2	13,0	8,8
K785	1970-75	38,3	7,2	7,7	14,9	14,8
K795	2020-25	71,8	25,1	11,6	36,8	15,4

TABLE V

Composition in % of the material extracted from the rock.
Well 18/11-1

Sample	Depth (m)	Sat / EOM	Aro / EOM	HC / EOM	Sat / Aro	Non HC / EOM	HC / Non HC
K633-636	1530-1560	12,8	10,6	23,4	121,4	27,2	86,1
K725-727	1605-1625	13,5	7,2	20,8	185,7	16,6	125,0
K731-732	1670,1680-90	14,1	7,9	22,1	177,7	25,6	86,2
K738	1730-35	2,7	8,1	10,8	33,3	40,5	26,6
K749	1765-70	22,1	12,3	34,5	179,1	30,9	111,6
K754	1805-15	14,6	6,5	21,2	223,0	23,7	89,3
K760	1835-40	33,7	14,1	47,8	239,1	26,9	177,2
K769	1875-80	24,5	11,6	36,1	211,1	30,9	116,6
K776	1925-30	26,8	17,9	44,8	150,0	30,1	148,4
K785	1970-75	18,8	20,1	38,9	93,4	38,7	100,5
K795	2020-25	35,0	16,2	51,2	215,6	21,6	237,6

TABLE VI

Tabulation of data from the gas chromatograms
Well 18/11-1

Sample	Depth (m)	Pristane/nc	Pristane / Phytane	CPI
K633-636	1530-60	0.68	1.30	1.60
K725-727	1605-25	0.68	1.20	1.40
K731-732	1670-90	0.56	0.91	NDP
K738	1730-35	0.58	1.06	1.20
K749	1765-70	1.42	0.81	1.73
K754	1805-15	0.97	0.92	NDP
K760	1835-40	0.39	0.61	NDP
K769	1875-80	0.58	1.16	1.20
K776	1925-30	0.97	1.39	NDP
K785	1970-75	1.10	2.10	2.45
K795	2020-25	0.69	0.96	NDP

NDP: No determination possible.

TABLE VII

Rock-Eval Pyrolysis Well 18/11-1

Sample	Depth	S_1	S_2	S_3	C_{org}	Hydrogen Index	Oxygen Index	Oil and gas content $S_1 + S_2$	Production Index $\frac{S_1}{S_1 + S_2}$	T_{max} °C
K635	1550	0.0	0.3	3.1	0.95	32	326	0.3	-	425
K641	1610	0.1	1.3	2.5	1.16	112	215	1.4	0.07	422
K647	1670	0.1	0.8	1.4	1.08	74	130	0.9	0.11	423
K739	1735	0.1	1.6	1.8	1.31	122	137	1.7	0.06	428
K746	1750	0.1	2.3	1.8	2.22	104	81	2.4	0.04	428
K749	1765	0.1	8.0	1.6	3.43	233	47	8.1	0.01	424
K754	1805	0.1	2.9	1.4	2.05	141	68	3.0	0.03	427
K757	1820	0.2	1.0	1.5	1.43	70	105	1.2	0.17	427
K761	1840	0.1	8.8	6.9	1.60	550	431	8.9	0.01	425
K766	1865	0.1	0.9	2.6	1.78	50	146	1.0	0.10	430
K776	1925	0.2	2.6	2.5	3.61	72	69	2.8	0.07	427
K779	1940	0.1	1.6	2.5	2.65	60	94	1.7	0.06	430
K784	1965	0.4	12.8	3.0	7.19	178	42	13.2	0.03	428
K786	1975	0.2	5.5	3.6	3.39	163	106	5.7	0.04	424
K792	2005	0.1	0.8	0.9	1.09	73	82	0.9	0.11	424
K794	2015	0.1	1.3	1.1	1.19	109	92	1.4	0.07	428
K798	2035	0.1	1.4	1.3	3.45	40	38	1.5	0.07	429
K800	2045	0.1	0.9	1.0	1.63	55	61	1.0	0.10	428
K802	2055	0.4	3.3	5.9	5.18	64	114	3.7	0.11	431
K803	2060	0.2	0.7	1.0	1.13	62	88	2.9	0.07	426

TABLE VIII

Vitrinite reflectance and visual kerogen measurements, well 18/11-1

Depth(m)	Vitrinite reflectance	Colour index	Type of organic matter
490	0.36(9)		
1180	0.35(21)		
1320	0.34(21)		
1470	0.41(15)		
1535	0.36(20)	-2	Am/He, W, Coal R!
1595	0.33(21)	-2	Am/He, W
1645	0.34(21)	-2/2	He, Am, Coal R!, W
1695	0.29(9)	2/2+	Am/He
1750	0.29(20)	2	Am/He, Cut, W, Poll
1800	0.34(20)	2	Am/He, W, Coal R!
1850	0.39(21)	2	Am/W, Poll-spor, Cysts
1900	0.35(22)	2/2+	Am/W, Poll-spor, Cysts
1950	0.36(22)	2/2+	Am/He, Cut, W, Poll-spor,W
2000	0.35(20)	2+	DFall.Am/He,W,Poll-spor Cyst
2035	0.39(21)	2+/3-	He, Am, W
2060	0.35(15)	2+/3-	W, He, CoalR!,Poll-spor/Am

B: Well 17/12-1

Total Organic Carbon

The samples from the upper part of the well, i.e. down to 6200' were of very poor quality, and only a few were received for analyses. From 6200' -8000' a good collection of samples were received and these were analysed extensively. This section of the well is divided into six zones on the background of the TOC analyses.

Zone I: - 6450':
The TOC values of this zone is relatively constant, approximately 1.0 %.

Zone J: 6450 - 6750':
The TOC value jumps sharply to approximately 1.5 % at 6450' and is relatively constant down to 6800' where another sharp increase is seen.

Zone K: 6800 - 7100':
At 6750' the TOC values increase sharply compared to the samples above and continue to increase slightly with increasing depth down to 7100' where the TOC values are approximately 2 %. Zone K is mainly separated from zone J due to the sharp increase at 6800' and the steeper increase in TOC values from 6800 - 7100' than in the zone above. We are not certain if this small change justifies a separate zone.

Zone L: 7100 - 7325':
The TOC values increase sharply at 7100' to approximately 4.0 % and are relatively constant throughout the zone.

Zone M: 7325 - 7400':
No samples available.

Zone N: 7400 - 7500':
The few samples in this zone have TOC values at approximately the same level as zone L.

Zone O: 7500 - 7960':
The TOC values in this zone are all very high but very erratic.

Zone P: 7960 - 8000':
The TOC values drop sharply in this zone, which also contains a large proportion of sandstone. A general drop in TOC values is also seen for the last 150' in zone E, but the readings are more erratic and it is therefore not separated out from zone E.

Extraction and Chromatographic Separations

Zone I: No samples from this zone were extracted, mainly due to very small amounts of cuttings in each sample.

Zone J: One sample, 6400 - 6500', was extracted. This sample has a rich abundance of extracted hydrocarbons. The hydrocarbon/total organic carbon (HC/TOC) ratio is rather high, which indicates contamination of migrated hydrocarbons. The gas chromatogram of the saturated hydrocarbon fraction shows a smooth front biased unimodal distribution, probably due to contamination of diesel from the drilling mud. The pristane/n-C_{17} ratio is larger than 1.0 and this is not common in destillation products. The gas chromatograms of the saturated hydrocarbon fraction of the oil from 17/12-1 have a completely different pattern to the chromatograms seen here, and due to this the analysed samples can not have been contaminated by this oil.

Zone K: No samples were extracted from this zone.

Zone L: One sample from zone L, 7150 - 7225', was extracted showing a rich abundance of extractable hydrocarbons. The HC/TOC ratio is lower for this sample than for the sample in zone B, while the saturated/aromatic ratio is increased. The gas chromatogram of the saturated hydrocarbon fractions varies only slightly, mainly in the n-C_{17} - n-C_{17} area from the sample in zone J. Due to this, we would not exclude contamination of free hydrocarbons similar to the sample in zone J, even if the HC/TOC ratio is that low that such a contamination is not evident.

Zone M: No samples available.

Zone N: One sample from zone N, 7400 - 7425', was extracted, showing almost identical results as the sample from zone L.

Zone O: Four samples from zone O were extracted, showing almost identical results as the samples from zones L and N.

Zone D: No samples from this zone was extracted.

Rock-Eval Pyrolysis

A total of 27 samples from this well were pyrolysed by the Rock-Eval method. All the samples have a low T_{max} value, indicating immature samples, increasing to moderate mature towards the lower end of the well.

The samples have a relatively low hydrogen index except for a few samples between 7200' and 7400'. The oxygen index is high for the uppermost analysed samples down to 7000', while the interval between 7000' and 7970' has a low oxygen index. The two lowermost samples show again a high oxygen index. This would indicate type III kerogen in the upper interval, down to 7000', and in the last 30' of the well, while the interval between 7000' and 7970' is of kerogen type II. This is in contradiction to the visual kerogen estimation, which shows the whole analysed sequence, 6200' - 8000' to be dominated by amorphous material. The reason for this contradiction is not fully understood presently, but the upper part of the analysed sequence is found by the vitrinite reflectance measurements to contain a large proportion of reworked material. This will lower the hydrogen index and increase the oxygen index compared to the true material, and in such a way distort the measurements. Due to this, more emphasis is put on the visual kerogen than on the pyrolysis on this well in the evaluation of type of kerogen.

The Rock-Eval pyrolysis does, however, by the oil and gas content and the production index measurement, indicate oil detections throughout most of the measured interval. This can either be migrated oil or mud additives.

Vitrinite Reflectance

Twenty samples were analysed for vitrinite reflectance. In the following each sample is described, and together with the reflectance data, other information from the analyses are given.

1860': Calcareous shale and carbonate, R_o = 0.27(14).
The sample has a very low organic content with small vitrinite particles, mostly in carbonate. A trace of inertinite and reworked material. UV light shows a yellow/orange fluorescence from spores and carbonate together with a low exinite content.

4280': Calcareous shale, R_o = 0.34(290).
The sample has a low organic content with small particles of inertinite and reworked material, mostly reworked material and true vitrinite. UV light shows a yellow and yellow/orange fluorescence from spore specks and a low exinite content.

4750': Shale and carbonate, R_o = 0.34(20).
The sample has a low to moderate organic content with small particles mostly of inertinite and reworked material, only a trace of true vitrinite. UV light shows a yellow/orange fluorescence from spores and carbonate together with a low exinite content.

5225': Shale and carbonate, R_o = 0.42(21).
The sample has a moderate organic content, restricted to the shale. Particles of reworked material and inertinite are dominant, only a trace of wispy particles of true vitrinite. UV light shows a yellow to orange fluorescence from spores and a trace of exinite.

6075': Calcareous shale and carbonate, R_o = 0.40(21).
The sample has a low organic content with small particles of vitrinite and inertinite. A trace of small vitrinite wisps and bitumen traces are recorded. UV light shows a light orange fluorescence from spore specks and a trace of exinite.

6275': Shale and carbonate, R_o = 0.38(19).
The sample has a low organic content, mostly small particles of vitrinite and inertinite with bitumen wisps. A few vitrinite wisps, but the inertinite is dominant. UV light shows a light orange fluorescence from spores and carbonate together with a trace of exinite.

6375': Mixed shale lithologies, R_o = 0.34(20).
The sample has a low organic content with bitumen wisps and particles of vitrinite and inertinite in about equal proportions. UV light shows a light orange fluorescence from spores and a low to moderate exinite content.

6530': Shale, R_o 0.31(20).
The sample has a low organic content with small particles of inertinite and reworked material dominant. A few vitrinite wispy particles and a few included vitrinite lignite fragments in the shale matrix. UV light shows a light to mid orange fluorescence from spores, and a moderate to rich exinite content.

6650': Calcareous shale, R_o = 0.48(20).
The sample has a low organic content, nearly all reworked material and inertinite particles. Only a trace of wispy particles of vitrinite. UV light shows a light to mid-orange fluorescence and a moderate to rich exinite content.

6825': Shale and carbonate, R_o = 0.51(16).
The sample has a low organic content with reworked material and inertinite particles being dominant. A trace of possibly true vitrinite particles and occasional bitumen wisps. UV light shows a light orange fluorescence from spores and a moderate exinite content.

6975': Shale, R_o = 0.51(15).
The sample has a low to moderate organic content with small particles, almost entirely reworked material and inertinite. Only a trace of doubtful true material. UV light shows a light orange fluorescence from spores and a moderate exinite content.

7125': Shale, rather pyritic, R_o = 0.37(20).
The sample has a low organic content with small particles of vitrinite and inertinite with appreciable reworking. Plentiful bitumen wisps. UV light shows a yellow to orange and light orange fluorescence from spores and a moderate exinite content.

7250': Shale, R_o = 0.33(20).
The sample has a moderate organic content with small particles of vitrinite and inertinite dominating. Only a trace of true vitrinite, differentiation difficult. Some bitumen staining. UV light shows a light orange fluorescence from spores and a moderate to rich exinite content.

7325': Mixed shale and carbonate lithologies, R_o = 0.43(20).
The sample contains some cuttings which are rather rich in bitumen wisps and staining. Otherwise a low content of inertinite and reworked material. Only a trace of true vitrinite. UV light shows a yellow to orange and light orange fluorescence from spores, together with a moderate to rich exinite content.

7500': Shale, R_o = 0.44(12) and R_o = 0.56(8).
The sample has a moderate organic content with bitumen wisps and staining. Inertinite particles are dominant. Only a low content of poor vitrinite particles. UV light shows a light orange fluorescence from spores, and a low to moderate exinite content.

7600': Shale, rather pyritic, R_o = 0.48(21).
The sample is moderate to rich in organic material with an overall bitumen staining and wisps. Plentiful coal fragments and included particles of vitrinite and inertinite. UV light shows a light and mid-orange fluorescence from spores and a low to moderate exinite content.

7700': Shale, Ro = 0.50(20).
The sample has a moderate organic content with overall bitumen staining. Particles of inertinite are dominant together with some vitrinite particles and some coal fragments. UV light shows light and orange fluorescence from spores and a low exinite content.

7800': Shale, R_o = 0.47(21).
The sample is moderate to rich in organic material with an overall bitumen staining and wisps. Loose and included coal fragments together with plentiful vitrinite wisps and stringers with inertinite particles. UV light shows a light orange fluorescence from spores and a low exinite content.

7900': Mixed shale lithologies, R_o = 0.45(22).
The sample has a moderate organic content with loose coal fragments and included particles of vitrinite and inertinite, with the latter dominant. Only a trace of bitumen. UV light shows a light orange fluorescence from spores and hydrocarbon impregnation together with a low to moderate exinite content.

8000': Shale, R_o = 0.42(8), R_o = 0.54(11) and R_o = 0.70(1).
The sample has a moderate organic content with bitumen wisps and staining. A suggestion of some oxidation is seen. Particles of inertinite are dominant and only a trace of poor vitrinite particles and wisps are recorded. UV light shows a light/mid-orange fluorescence from spores and hydrocarbon traces together with a poor exinite content.

Visual kerogen

As in well 17/12-2, presence of undissolved minerals has to be considered to evaluate a suite of residues all dominated by amorphous (marine) material.

Forty-seven samples were processed for kerogen/maturation studies and for palynological investigation from 6200' down to 8000'.

There are few striking events through this well judged only from the organic residues; marine conditions prevail down to 7540', further down we suggest more deltaic conditions.

6200' to 6625':
Sapropel dominates and forms aggregates. The material could be derived from a carbonate lithology. 6530' and 6575' are apparently richer in herbaceous, sapropelized material, and 6575' is poorly preserved due probably to bacterial activity.
Colour index: -2/2, but increased due to oxidation. Palynomorphs in screened slides support the lower index.

6650' and 6675':
These samples are distinguished by small black coal fragments (6650'). The sapropel which dominates the residue sticks to and obscures the other palynomorphs and may be present in smaller amounts than estimated.
Colour index: -2/2, as above, increased due to oxidation.

6700':
30 % finely dispersed indeterminate herbaceous material along with sapropel. The residue is disturbed by remaining undissolved minerals.
Colour index: -2/2 (as for 62' to 6625').

6725' to 7540':
Sapropel dominates and palynomorphs are commonly recorded below 6800'. The sapropel is frequently recorded as aggregates between 6900' and 6950', at 7075' and between 7175' and 7540'.

At 7100' there is a sample with coarser material of terrestric plants including cuticular fragments. Undissolved minerals are more common in the lower part of the interval from 7175' to 7500'.
Colour index: -2/2.

7575' to 7720':
Though sapropel is dominant, land derived material; indeterminate herbaceous and woody material - is more common than above.
Colour index: 2 or -2/2.

7760' to 7930':
Sapropel dominates, partly as aggregates. Sample 7900' in this interval is distinguished by presence of undissolved minerals and by apparently reworked material.
Colour index: 2.

7960' to 8000':
Sapropel dominates finely dispersed residues. Terrestric material, 20 to 40 %, includes cuticles, woody structures and indeterminate herbaceous material. The material seems sapropelized. Reworked material is present. Colour index: 2+ or 2+/3-, may be a too high estimate based on oxidized material.

Analysis of oil from well 17/12-1

An oil sample from DST6, 7560 - 7530', was received from Phillips Petroleum, and a chromatographic separation together with gas chromatographic analysis of the saturated hydrocarbon fraction and of the whole oil was undertaken. The oil, which is rather waxy, has pristane/n-C_{17} and pristane/phytane ratios which is normally found for oils in the southern part of the North Sea, Table XXV. The most striking feature with this oil is the difference in the n-alkane distribution in the nC_{17}-nC_{26} region compared to the nC_{27}-nC_{32} region. The Carbon preference index (CPI) in the lower region is found to be low, 0.9 while the CPI for the upper region is found to be normal for a well mature oil.

The normal distribution in a crude oil is an odd predominance of n-alkanes, i.e. CPI 71, or with CPI 1.9, but an even predominance is not uncommon. It is reported from carbonate or evaporite sediments and occasionally from crude oils. This particular type of distribution is usually associated with a high phytane/pristane ratio, whereas an equal abundance of phytane and pristane or a pristane dominance is much more common in other sediments with an odd n-alkane predominance. Two interpretations of the even n-alkane predominance have been suggested. Welte and Waples (1973) suggested that in very reducing environments, reduction of n-fatty acids, alcohols from waxes, and phytanic acid or phytol is prevalent over decarboxylation, resulting in predominance of even-carbon-numbered n-alkane molecules over odd molecules ($CPI < 1$) and a predominance of phytane over pristane. In less reducing environments, decarboxylation results in a majority of odd n-alkanes ($CPI > 1$) and a predominance of pristane over phytane.

Skimoyama and Johns (1972) proposed an alternative interpretation of the even n-alkane predominance. They carried out experimental degradation of n-fatty acids in the presence of montmorillonite or calcium carbonate. The two minerals seem to have two different catalytical effects: decarboxylation with loss of one carbon atom is favoured by montmorillonite, while beta cleavage with loss of two carbon atoms is favoured by calcium carbonate. Therefore, an original even-carbon-numbered fatty acid would generate mostly an odd n-alkane in shales and an even n-alkane in carbonates.

The two interpretations proposed are not conflicting, as the mechanism proposed by Welte would occur during diagenesis in young sediment, whilst the interpretation of Shimoyang and Johns refers mostly to the catagenetic transformations occuring at depth.

The oil found in 17/12-1 differs from "normal" oil mainly in the low CPI value found for the medium weight hydrocarbons. At present the reason for this strange pattern is not known, but it could indicate that the oil is sourced from two different source rocks which have had different environments of deposition.

Source Rock Evaluation

On the background of the previous discussed results, the analysed sequence down to 7300' will be classified as immature, while the sequence from 7300' to 8000' is moderate mature.

Based on total organic carbon measurements, the analysed sequence is divided into six zones which will be given the following rating.

Zone I: - 6450': This zone has relatively constant TOC values, and no samples are extracted. The TOC values are very similar to those found for zone A in well 18/11-1 and will be given the same rating as this, i.e. fair or fair to good potential as a source rock for gas.

Zone J: 6450 - 6750': The abundance of total organic carbon in this zone is slightly higher than in zone I. The visual kerogen examination shows this zone to contain mainly amorphous material while the pyrolysis measurements indicate kerogen type III. As mentioned earlier we will put more emphasis on the visual kerogen measurements than the Rock-Eval pyrolysis, due to the large proportion of reworked material. This zone will therefore be rated to have a fair to good potential as a source rock for oil and gas. The samples in this zone is contaminated, either by migrated hydrocarbons or by mud additives.

Zone K: 6800' - 7100': The samples from this zone are also contaminated by hydrocarbons, and the steady increase of TOC values with increasing depth could be due to this contamination. If so, this zone should not be separated out from the zone above. However, it is believed that this increase is genuine increase due to a change in the amount of organic carbon in the sediments and this zone is rated to have a good potential as a source rock for oil and gas.

Zone L: 7100' - 7325': At 7100' in this well a similar change in TOC values as found at 1740 m in well 18/11-1. The samples are again contaminated with hydrocarbons, but this has not affected the TOC values to a large degree. This zone will be rated to have a rich potential as a source rock for oil and gas.

Zone M: 7325' - 7400': No samples available.

Zone N: 7400' - 7500': The kerogen composition and the richness parameters are similar to those found in zone L and this zone will be given the same rating, i.e. rich potential as a source rock for oil and gas.

Zone O: 7500' - 7960': The visual kerogen examination has shown this zone to contain more terrestric material than the zones above, and this is probably the cause for the very high, but erratic TOC values found for this zone. The extraction and the pyrolysis again show the samples from this zone to be contaminated by hydrocarbons. The whole zone is rated to have a rich potential as a source rock for gas and oil.

Zone P: 7960' - 8000': This zone is separated out from zone E due to the sharp drop in organic carbon at the same time as the lithology change to mainly sandstone. The claystone analysed will be rated to have a good potential as a source rock for gas and oil.

TABLE IX

Lithology and total organic carbon

Depth (ft)	TOC	Lithology
1860		100% Claystone, silty, grey, calcareous, grading to Marl, light grey to brown (with green clasts) sm.am Glauconite; calcareous Clay/Siltstone, light grey with green grains, Pyrite Considerable amounts mud additives and rosettes of ? Gypsum
4210		100% Sand, white/light grey, fine, and very fine brown Sandstone, micaceous, Glauconite Considerable amounts mud additives
4280	1.05	100% Claystone
4725	1.37	100% Silt/claystone, grey, micaceous sm.am Gypsum (? additive); Glauconite Mud contaminated
5225	2.28	50% Claystone, dark grey 50% Siltstone, clayey, light grey and brownish light grey (calcareous)
6075	0.84	100% Claystone, silty, grey, light brownish grey (more silty, calcareous) sm.am (?) Gypsum
6200	0.93	100% Claystone, silty, grey, some micaceous, some light brown sm.am Pyrite; ? Gypsum; mud additives
6225	0.84	100% Claystone, as above sm.am Pyrite; Marl, brownish light grey; Sandstone, light brown; mud additives

Depth (ft)	TOC	Lithology
6250	0.92	100% Claystone, silty, grey, some brownish observed, pyritic, with small Coal-fragments, light brown (silty) sm.am Pyrite; Marl/Limestone (brownish) light grey; Quartz, mud additives
6275	0.86	100% Claystone, silty, grey, some light brown sm.am Limestone, white; Pyrite; mud additives
6300	0.90	100% Claystone, as above sm.am ? Gypsum
6325	1.12	100% Claystone, grey, dark grey sm.am Limestone, white; ? Gypsum; mud additives
6350	1.13	100% Claystone, silty, grey, dark grey, light grey, with very small Pyrite crystals and Coal grains sm.am ? Gypsum
6375	1.16	100% Claystone, partly silty, grey, some light grey and dark grey, some micaceous sm.am ?Gypsum; mud additives
6400	1.26	100% Claystone, partly silty, grey, dark grey sm.am Limestone, white
6425	1.20	100% Claystone, silty, grey to dark grey, very small Coal fragments, some micaceous sm.am ? Gypsum; Pyrite (partly rods)
6450	1.54	100% Claystone, grey, dark grey, some light grey, light brown, some micaceous sm.am Pyrite; ? Gypsum

Depth (ft)	TOC	Lithology
6475	1.50	100% Claystone, grey to dark grey, some micaceous sm.am Pyrite; Quartz Sand; Coal
6500	1.48	100% Claystone, as above, some brownish sm.am Gypsum; Drilling mud obs. Limestone (Chalk), white.
6530	1.32	100% Claystone, silty, grey to dark grey, brownish light grey (more silty, calcareous)
6575	1.40	100% Claystone grading to clayey Siltstone, dark grey, light grey sm.am (?) Gypsum
6600	1.46	100% Claystone, silty, dark grey, light grey sm.am (?) Gypsum
6625	1.42	100% Claystone, dark grey, light grey to grey, brownish
6650	1.49	100% Claystone, grey, some brownish light grey (more silty, calcareous), some micaceous
6675	1.52	100% Claystone, dark gray, brownish light grey (silty, calcareous), some micaceous
6700	1.61	90% Claystone, partly silty, dark grey, some brownish light grey (calcareous) 10% (?) Gypsum
6725	1.49	100% Claystone, silty, grey to dark grey, some micaceous
6750	1.54	100% Claystone, as above sm.am Gypsum; Limestone, white
6775	1.40	100% Claystone, grey to dark grey, some brownish light grey (calcareous), some micaceous

Depth (ft)	TOC	Lithology
6800	1.70	100% Claystone, grey to dark grey, some micaceous
6825	1.76	100% Claystone, as above
6875	1.81	100% Claystone, as above sm.am Limestone, white
6900	1.79	100% Claystone, silty, as above
6925	1.85	100% Claystone, as above
6950		100% Claystone, as above
6975	2.02	100% Claystone, as above
7000	1.87	100% Claystone, as above
7025	2.02	100% Claystone, as above
7050	2.10	100% Claystone, as above
7075	2.28	100% Claystone, as above
7100	2.10	100% Claystone, as above
7125	3.64	100% Claystone, grey, slightly micaceous
7150	4.12	100% Claystone, grey, slightly brownish in part, slightly micaceous
7175	4.06	Claystone, as above
7200	4.14	94% Claystone, as above, very fissile 3% Marl 3% (?) Gypsum

Depth (ft)	TOC	Lithology
7225	4.22	100% Claystone, as above, silty, very fissile
7250	3.96	100% Claystone, as above, fissile sm.am (?) Gypsum
7275	3.92	100% Claystone, grey to dark grey, slightly micaceous
7300	3.84	100% Claystone, as above
7325	2.18	100% Claystone, as above
7400	5.70	100% Claystone, dark grey, (slightly brownish), grey, shaly (fissile), intercalation with white Limestone observed sm.am ? Gypsum
7425	5.60	100% Claystone, dark grey to black, shaly (fissile), intercalation with white Limestone observed
7450	4.44	100% Claystone, dark grey, shaly (fissile). Mud contaminated
7475	4.06	100% Claystone, dark grey, some black, intercalated Limestone observed, with Coal fragments
7500	6.35	100% Claystone, dark grey, shaly sm.am ? Gypsum; Limestone, White; Mud contamination
7520	7.34	100% Claystone, dark grey to black, shaly (very fissile) Coal fragments; Pyrite obs. sm.am ? Gypsum; Limestone, white
7525	6.44	100% Claystone, as above sm.am ? Gypsum Mud contaminated

Depth (ft)	TOC	Lithology
7530	3.24	50% Claystone, dark grey to black, shaly, intercalation with white Limestone obs
	0.26	50% Claystone to Silt/Sandstone, brownish light grey to light brown, with green and reddish clasts in sand size sm.am ? Gypsum
7540	7.75	95% Claystone, as above, obs. with Pyrite 5% Claystone to Silt/Sandstone, as above sm.am Limestone; ? Gypsum
7550	6.40	100% Claystone, dark grey to black, shaly, intercalation with white Limestone obs sm.am. Gypsum; Limestone, white; Claystone to Silt/Sandstone
7560	5.11	100% Claystone, dark grey to black,shaly, intercalation with micaceous Sandstone obs sm.am Limestone, white; ? Gypsum; Sandstone, white, light brown; micaceous Sand; Claystone to Sandstone, browngrey, with green clasts; Mica
7575	7.58	100% Claystone, dark grey to black, shaly, intercalation with white Limestone obs sm.am ? Gypsum
7600	7.91	100% Claystone, dark grey to black, some coal, partly micaceous, intercalation with Sand/Silt and Limestone obs. sm.am Limestone, white; Siltstone and Sandstone Claystone to Silt/Sandstone, browngrey, with green clasts; ? Gypsum
7625	12.2	100% Claystone, dark grey to black, some Coal sm.am ? Gypsum; silty fine Sandstone, brownish light grey

Depth (ft)	TOC	Lithology
7640	4.28	100% Claystone, as above, some grey sm.am Gypsum; Sandstone
7660	3.75	100% Claystone, dark grey to black, some grey, browngrey sm.am Sandstone, very fine - fine, brownish light grey
7680	3.74	95% Claystone, dark grey to black, some browngrey 5% Sandstone, as above
7700	4.98	80% Claystone, dark grey to black, some brownish and grey 20% Salt, white (? additive) sm.am Coal
7720	7.11	95% Claystone, dark grey to black, interlaminated white Limestone obs. 5% Coal sm.am Salt; Sandstone, white
7740	4.62	50% Claystone, dark grey/black, some grey and browngrey 50% Salt, as above (? additive)
7760	5.28	90% Claystone, dark grey to black, some light browngrey 10% Coal sm.am Sandstone, (brownish) light grey; Salt
7780	3.33	92% Claystone, dark grey to black (shaly), greybrown (thin Coal lenses/lamina obs), some dark brown, carbonaceous 8% Salt (? additive) sm.am Sandstone, white (brownish), fine; Coal; crs Quartz grains, rounded
7800	4.08	93% Claystone, dark grey grading to black, greybrown 7% Coal sm.am Salt; Sandstone

Depth (ft)	TOC	Lithology
7820	4.53	100% Claystone, dark grey to black (shaly), light grey to greybrown sm.am Salt; Coal; Sandstone
7830	4.00	75% Claystone, dark grey to black (carbonaceous) greybrown (coaly) 20% Salt (? additive) 5% Coal sm.am Sandstone, as above
7840	3.70	60% Claystone, dark grey/black and greybrown 40% Salt (with Quartz grains) (? additive)
7850		97 % Claystone, dark grey/black (carbonaceous) and grey-brown (thin Coal-lenses obs), some light grey (brownish) and dark brown 3% Coal sm.am Salt
7860	2.59	100% Claystone, dark grey, black (one brachiopod obs) (shaly), greybrown to brownish light grey (Coal or carbonaceous Claystone intercalation obs) sm.am Salt obs. Coal
7880	2.64	100% Claystone, dark grey to black (carbonaceous) grey to brown (with Coalfragments) (silt and very small Coal-fragments in some cuttings)
7900	3.40	100% Claystone, dark grey, brownish light grey to grey-brown The sample consists mostly of drilling mud

Depth (ft)	TOC	Lithology
7920	2.66	100% Claystone, dark grey to black (carbonaceous), grey-brown/brown to brownish light grey (with Coal) sm.am Coal; Sandstone/Sand, as above (with Mica); coarse Quartz grains; Pyrite; Mica; Chlorite observed Mud contaminated
7930	2.54	100% Claystone, dark grey to black, grey to grey-brown sm.am Sand/Sandstone, fine to medium,micaceous; Coal; Limestone, brownish light grey to white, partly sandy. Considerably mud contaminated
7940	2.15	100% Claystone, dark grey to black, greybrown, brown (with coalified plant tissues), light grey very sandy and micaceous sm.am Coal; Sandstone Considerable amounts mud additives
7950	2.08	100% Claystone, dark grey to black, (brownish) light grey to brown, some green sm.am Sand and Sandstone, fine/medium, some coarse/very coarse grains; Coal; Limestone, white Contaminated by mud additives
7960	2.00	70% Sand, fine - medium, some coarse 30% Claystone, as above
7970		55% Sand/Sandstone, fine-medium, coarse/very coarse, light grey, greenish obs. 30% Salt, white, with Sand grains (? additive) 15% Claystone, dark grey to black, brown/greybrown, some green. sm.am Coal Some mud additives

Depth (ft)	TOC	Lithology
7980		50% Sand and some Sandstone, as above, with some green grains
	1.85	45% Claystone, as above, some grey, brownish light grey, redbrown
		5% Salt, with Sand grains
		sm.am Coal; Limestone, white
		Some mud additives
7990		50% Sand/Sandstone, as above
	1.74	50% Claystone, as above
		sm.am Limestone, sandy, white; Coal; Salt
		Some mud additives
8000		65% Sand, fine, some medium/coarse, light grey, some green grains
	1.65	35% Claystone, redbrown (silty, sandy), dark grey to black, green, light grey to browngrey
		sm.am Limestone, white

TABLE X

Weight (mg) of EOM and chromatographic fractions
Well 17/12-1

Sample No.	Depth (ft)	Rock extracted (g)	EOM (mg)	Sat (mg)	Aro (mg)	HC (mg)	Non HC (mg)	TOC
K1040-1044	6400'-6500'	15,74	67,6	27,6	12,8	40,4	10,1	1,60
K 583-586	7150'-7225'	46,31	217,3	108,0	30,0	138,0	45,7	6,38
K1045/1046	7400'-7425'	76,00	308,7	188,0	41,2	229,2	50,7	4,74
K1053-1056	7540'-7560'	63,34	288,1	154,3	54,7	209,0	56,8	4,22
K1060/1061	7660'-7680'	48,62	249,3	151,7	29,1	180,8	41,0	4,74
K1067/1068	7800'-7820'	18,69	179,8	85,5	35,8	121,3	35,0	8,91
K1074/1076	7900'-7930'	68,18	321,5	155,0	49,0	204,0	63,7	3,02

TABLE XI

Concentration of EOM and chromatographic fractions (Weight ppm of rock)
Well 17/12-1

Sample No.	Depth (ft)	EOM	Sat	Aro	Tot. hydro-carb.	Non hydro-carb.
K1040-1044	6400'-6500'	4295	1753	813	2567	642
K583-586	7150'-7225'	4692	2332	648	2980	987
K1045/1046	7400'-7425'	4062	2474	542	3016	667
K1053/1056	7540'-7560'	4548	2436	864	3300	897
K1060/1061	7660'-7680'	5128	3120	599	3719	843
K1067/1068	7800'-7820'	9620	4575	1915	6490	1873
K1074/1076	7900'-7930'	4715	2273	719	2992	934

TABLE XII

Concentration of EOM and chromatographic fractions (mg/gTOC)
Well 17/12-1

Sample No.	Depth (ft)	EOM	SAT	Aro	Total hydroc.	Non hydroc.
K1040-1044	6400'-6500'	268	110	51	160	40
K583-586	7150'-7225'	74	37	10	47	15
K1045/1046	7400'-7425'	86	52	11	64	14
K1053-1056	7540'-7560'	108	58	20	78	21
K1060/1061	7660'-7680'	108	66	13	78	18
K1067/1068	7800'-7820'	108	51	22	73	21
K1074-1076	7900'-7930'	156	75	24	99	31

TABLE XIII

Composition in % of the material extracted from the rock
Well 17/12-1

Sample No.	Depth (ft)	Sat/EOM	Aro/EOM	HC/EOM	Sat/Aro	Non HC/EOM	HC/Non HC
K1040-1044	6400'-6500'	41	19	60	216	15	400
K583-586	7150'-7225'	50	14	64	360	21	302
K1045/1046	7400'-7425'	61	13	74	456	16	452
K1053-1056	7540'-7560'	54	19	73	282	20	368
K1060/1061	7660'-7680'	61	12	73	521	16	441
K1067/1068	7800'-7820'	48	20	68	239	19	347
K1074-1076	7900'-7930'	48	15	63	316	20	320

TABLE XIV

Tabulation of data from the gas chromatograms
Well 17/12-1

Sample	Depth (ft)	Pristane/nC_{17}	Pristane/ Phytane	CPI
K1040-1044	6400-6500	1,20	1,84	1,06
K-583-586	7150-7225	0,92	1,58	1,10
K1045/1046	7400-4425	1,09	1,80	1,10
K1053-1056	7540-7575	1,00	1,88	1,08
K1060/1061	7660-7680	0,97	1,85	1,10
K1067/1068	7800-7820	0,93	2,21	1,10
K1074-1076	7900-7930	1,24	1,71	1,12

TABLE XV

Rock Eval Pyrolysis Well 17/12-1

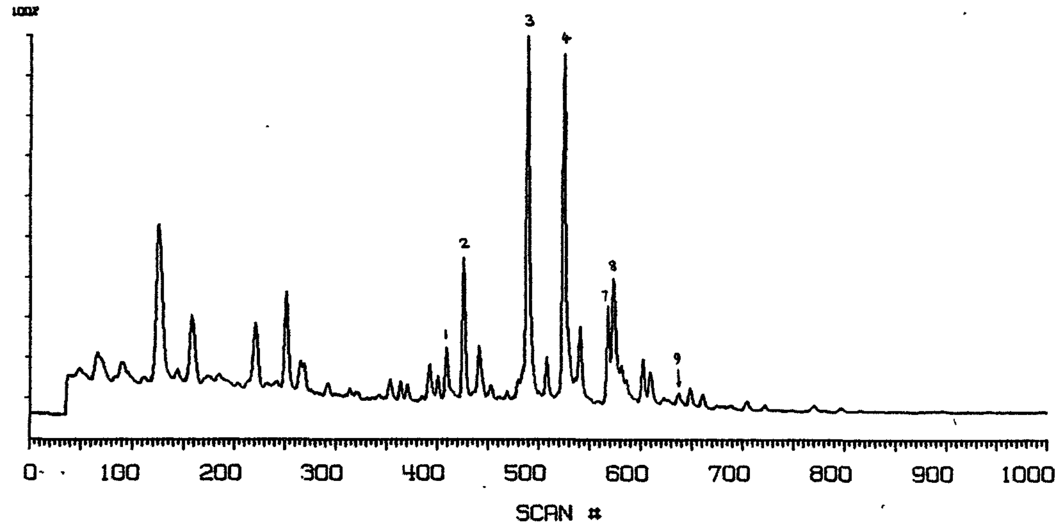
Sample	Depth (ft)	S_1	S_2	S_3	C_{org}	Hydrogen Index	Oxygen Index	Oil and gas content S_1+S_2	Production Index $\frac{S_1}{S_1+S_2}$	T_{max} °C
K555	4725	0,9	0,3	3,1	1,37	22	226	1,2	0,75	419
K557	5225	1,6	0,6	2,7	2,28	26	118	2,2	0,72	422
K1032	6225	1,1	0,5	1,7	0,93	54	183	1,6	0,69	420
K1036	6300	1,7	0,7	1,8	0,90	78	200	2,4	0,71	420
K1040	6400	1,2	1,1	1,1	1,26	87	87	2,3	0.52	425
K560	6530	1,6	1,1	1,6	1,32	83	121	2,7	0,59	424
K562	6600	2,0	1,5	1,1	1,46	103	75	3,5	0,57	424
K566	6700	1,9	2,2	1,5	1,61	137	93	4,1	0,46	423
K570	6800	2,2	2,1	0,7	1,70	123	41	4,3	0,51	426
K572	6875	2,2	2,3	1,7	1,90	121	89	4,5	0,49	422
K576	6975	3,2	2,6	0,8	2,02	129	40	5,8	0,55	425
K580	7025	2,5	4,3	0,9	2,88	149	31	6,8	0,37	425
K584	7175	3,1	33,9	1,3	4,06	834	32	37,0	0,08	418
K587	7250	1,7	22,7	1,5	3,96	573	38	24,4	0,07	419
K589	7300	2,6	4,8	1,4	3,84	125	36	7,4	0,35	423
K1045	7400	2,8	4,5	1,6	5,70	79	28	7,3	0,38	425
K1048	7475	3,2	4,2	1,0	4,06	103	24	7,4	0,43	425
K1054	7550	4,7	11,8	1,5	6,40	184	23	16,5	0,28	423

cont......

K 760 (4093) MASSPEC ANALYTICAL

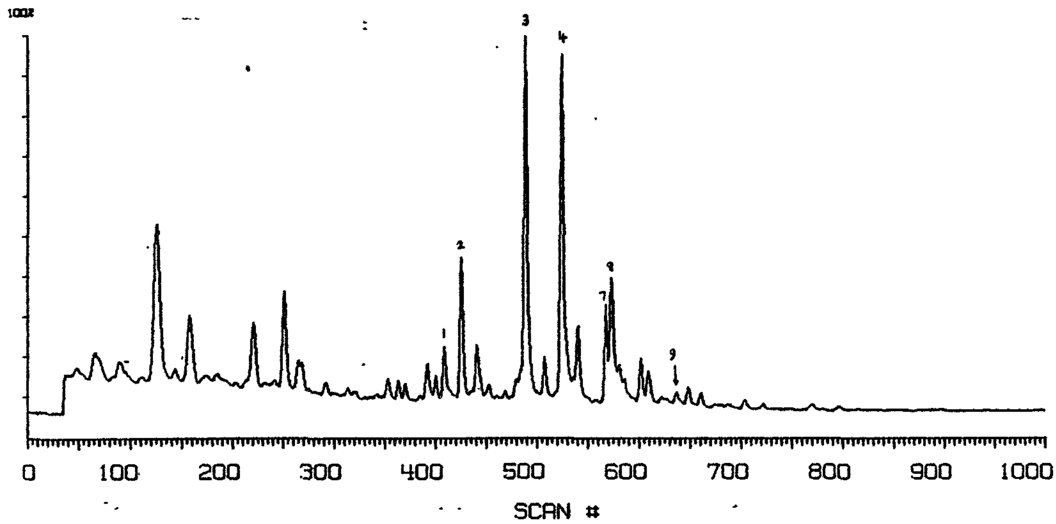
M/E 191 x 8 4 ION MID DATA

N-ALKANE # :



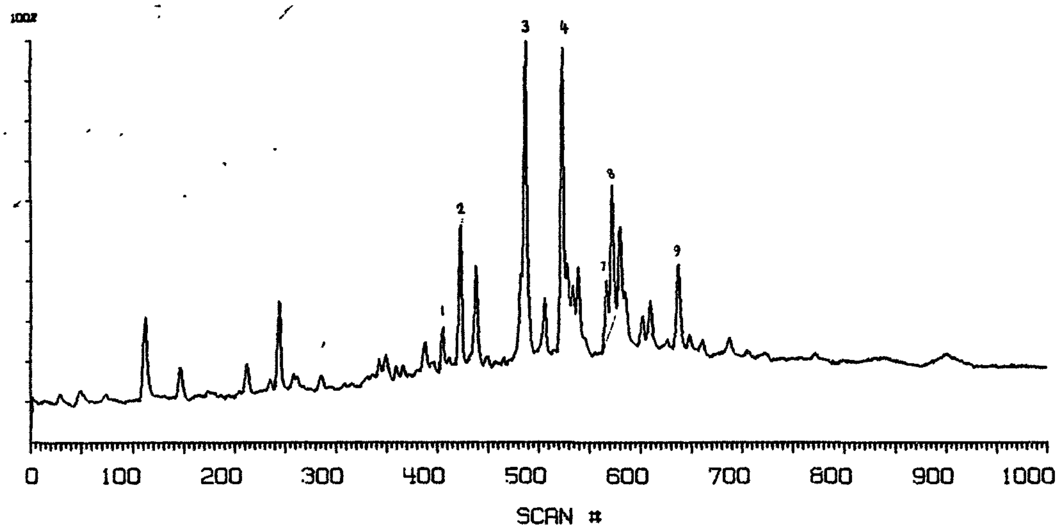
K 760 (4093) MASSPEC ANALYTICAL

M/E 191 x 8 4 ION MID DATA



K 769 (4098) MASSPEC ANALYTICAL

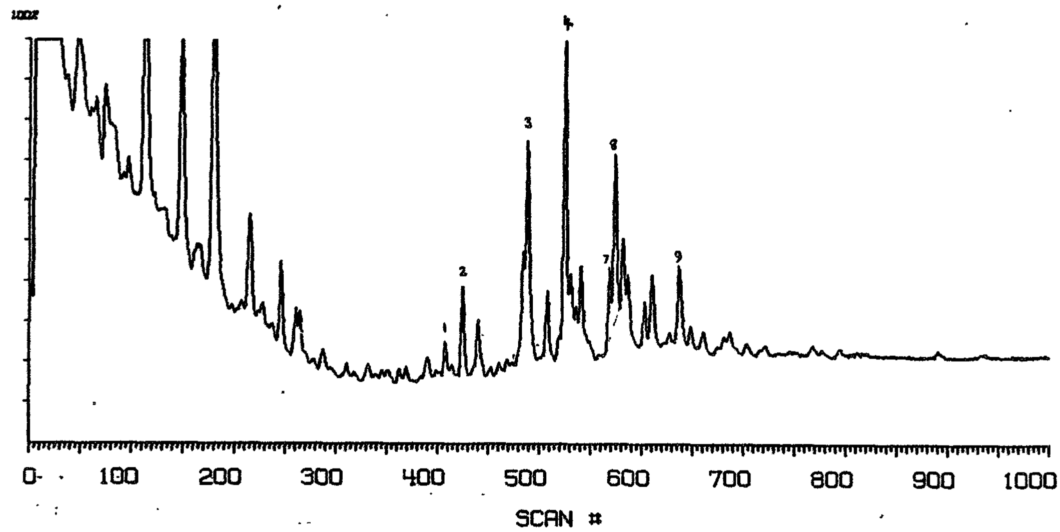
M/E 191 x 8 4 ION MID DATA



K 1042 (4100) MASSPEC ANALYTICAL

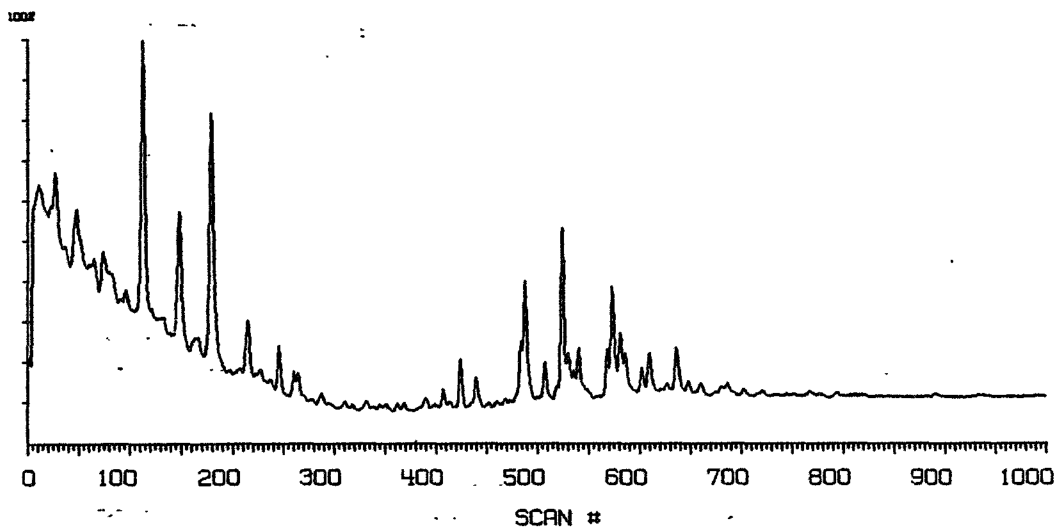
M/E 191 x 31 4 ION MID DATA

N-ALKANE # :



K 1042 (4100) MASSPEC ANALYTICAL

M/E 191 x 17 4 ION MID DATA



K 1045 (4102) MASSPEC ANALYTICAL

M/E 191 x 3 4 ION MID DATA

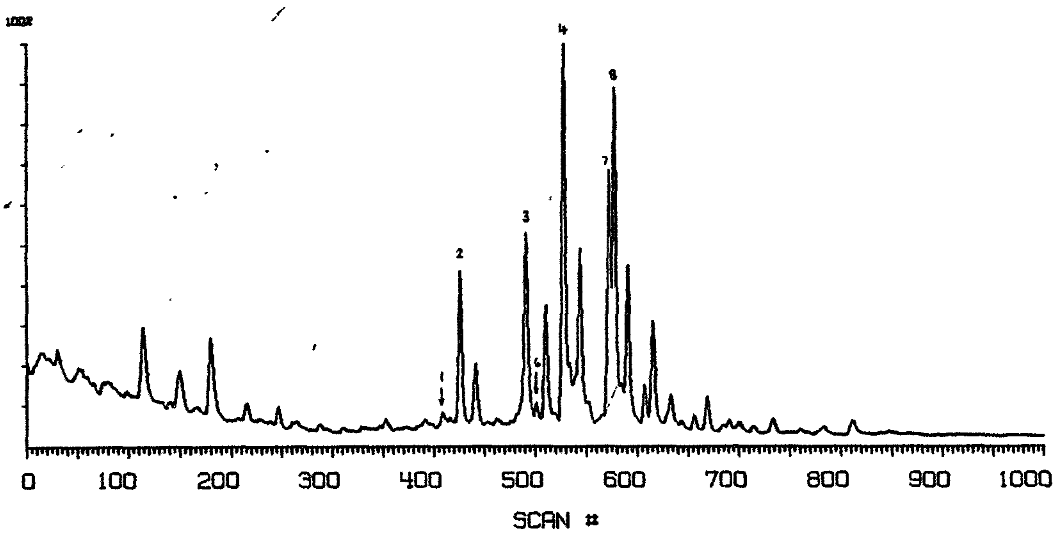


TABLE XV contd .....

Sample	Depth (ft)	S_1	S_2	S_3	C_{org}	Hydrogen Index	Oxygen Index	Oil and gas content S_1+S_2	Production Index $\frac{S_1}{S_1+S_2}$	T_{max} °C
K1056	7575	3,2	9,5	2,2	7,58	125	29	12,7	0,25	427
K1059	7640	2,9	6,6	1,3	4,28	154	30	9,5	0,30	427
K1062	7700	3,4	7,1	1,1	4,98	142	22	10,5	0,32	427
K1065	7760	4,7	10,2	1,0	5,28	193	19	14,9	0,32	425
K1068	7820	4,4	4,5	1,9	4,53	88	42	8,9	0,49	429
K1073	7880	2,1	3,8	0,8	2,64	144	30	5,9	0,36	430
K1077	7940	1,2	2,7	0,8	2,15	126	32	3,9	0,31	431
K1081	7980	1,6	2,0	1,5	1,85	115	81	3,6	0,44	428
K1083	7990	0,6	1,2	2,6	1,74	69	149	1,8	0,33	429

TABLE XVI

Vitrinite reflectance and visual kerogen measurements, well 17/12-1

Depth (ft)	Vitrinite reflectance	Colour index	Type of organic matter
1860	0.27(14)		
4280	0.34(20)		
4750	0.34(20)		
5225	0.42(21)		
6075	0.40(21)		
6275	0.38(19)	2-/2	Am/He, W
6375	0.34(20)	2/2+	Am/He, W
6530	0.31(20)	2+/3-	Am/He, Poll-spor
6650	0.48(20)	2+/3-	Am/He
6825	0.51(16)	2+/3-	Am/He, Poll-spor, W
6975	0.51(15)	2+/3-	Am/He, W
7125	0.37(20)	2-/2	Am/He, W, Poll-spor, Cysts
7250	0.33(20)	2-/2	Am/He, W, Poll-spor, Cysts
7325	0.43(20)	2-/2	Am/He, Poll-spor, Cysts
7500	0.44(12)0.56(8)	2-/2	Am/He
7600	0.48(21)	2-/2	Am/He, W
7700	0.50(20)	2-/2	Am/He, W
7800	0.47(21)	2+/3-	Am/He, W
7900	0.45(22)	2+/3-	Am/He, Poll-spor, Coal R!
8000	0.42(8) 0.54(11) 0.70(1)	2+3/-	Am/Cut, He, W, Poll-spor

C: Well 17/12-2

Total Organic Carbon (TOC)

This well had a reasonable sample coverage of the sequence from 6600' to 7360', while only spot samples were available from higher up in the well. On the basis of the TOC measurements, the analysed sequence will be divided into three zones:

Zone S: - 6580':
Only a few measurements, showing very erratic values, due to lack of samples, especially in the upper part.

Zone T: 6580' - 6640':
The TOC values of this zone are quite constant, approximately 1.5 %.

Zone U: 6680' - 6720':
The TOC values start to increase slightly at 6680' and show a steady increase down to 6720'.

Zone V: 6750' - 7000':
At approximately 6750' the TOC values show a sudden jump and are found to vary between 2 and 2.5 % for this zone.

Zone W: 7020' - 7080':
At 7020' another sudden jump for the TOC values is found, and most of the TOC values in this zone are found to be approximately 4 %.

Zone X: 7100' - 7160':
At 7100' another jump in the TOC values are recorded and the samples in this zone are found to have TOC values at approximately 6 %.

Zone Y: 7180' - 7360':
At 7180' the TOC values drop to approximately 3 % with exceptance of sample 7220' which has a TOC value of 11.2 %. This is probably caused by contamination of small particles of coal or mud additive stuck to the claystone cuttings.

Extraction and Chromatigraphic Separation

No samples were extracted from zones S, T and U mainly due to the small amount and the qualities of the available samples.

Zone V: Sample; 6740' - 6820' was extracted showing a rich abundance of extractable hydrocarbons. The saturated/aromatic ratio is very high for the sample. The gas chromatogram of the saturated hydrocarbon fraction of the sample, shows a smooth, unimodal front biased distribution with a low pristane n-C_{17} ratio, and a relatively low pristane/phytane ratio. This is in sharp contrast to the analysed samples from well 17/12-1, which have pristane/n-C_{17} ratios larger or almost equal to 1.0. The pristane/phytane ratios are also found to be a lot larger in the samples from well 17/12-1 than in the analysed sample from zone V in well 17/12-2.

The total hydrocarbon/TOC ratio of this sample is rather high, and the sample might be contaminated with migrated hydrocarbons or diesel.

Zone W: One sample from this zone, 7000' - 7100' was extracted, showing a rich abundance of extractable hydrocarbons. The sample shows a high HC/TOC ratio which might indicate that this sample is contaminated by hydrocarbons. The saturated/aromatic ratio of this sample is approximately of the same value as that found for the sample in the zone above.

The gas chromatogram of the saturated hydrocarbon fraction is almost identical to the one from the zone above.

Zone X: One sample from this zone, 7120' - 7180', was extracted showing a rich abundance of extractable hydrocarbons.

The HC/TOC ration for this sample is a lot lower than in the samples from the zones above and there is also a large change in the saturated/aromatic ratio.

The gas chromatograms of the saturated hydrocarbon fractions of the sample are almost identical to those from the zones above.

Zone Y: Two samples from this zone, 7200' - 7260' and 7280' - 7360', were extracted both showing a rich abundance of extractable hydrocarbons. The uppermost sample is found to have almost identical parameters to the lowermost sample in zone W (7120' - 7180') while the lowermost sample, 7280' - 7360' is distinctly different both in the composition of hydrocarbons and in the HC/TOC ratio. These parameters are more like those found for the sample from zone V and the uppermost sample in zone W. The gas chromatograms of the saturated hydrocarbon fractions are, however, almost identical to the rest of the samples analysed from this well.

Rock-Eval Pyrolysis

A total of fifteen samples were pyrolysed by the Rock-Eval method. The results are very similar to those found for well 17/12-2 with low hydrogen index and hydrocarbon detection throughout the most of the analysed sequence. A similar contradiction between the visual kerogen examination and the Rock-Eval analyses as found for well 17/12-1 is found for this well, and the same restriction should be put on the Rock-Eval pyrolysis results from well 17/12-2 as was done on 17/12-1.

Vitrinite Reflectance

Fourteen samples were analysed for vitrinite reflectance. In the following each sample is described, and together with the reflectance data, other information from the analyses are given.

2210': Siltstone, R_o = 0.29(21).
The sample has only a trace of organic material, bitumen staining and a few small particles of vitrinite and inertinite. UV light shows a yellow to light orange fluorescence from spores and hydrocarbon specks together with a low exinite content.

3150': Calcareous shale, R_o = 0.34(14).
The sample has only a trace of organic material, bitumen staining and a few particles of vitrinite, inertinite and bitumen. Some reworking. UV light shows a yellow and yellow/orange fluorescence from spores together with a low exinite content.

5170': Shale, R_o = 0.35(7).
The sample has a low organic content with small particles of inertinite and reworked material with bitumen wisps. Only a trace of poor particles of vitrinite. UV light shows a yellow and light orange fluorescence from spores, and a trace of exinite.

5410': Shale and carbonate, R_o = 0.37(20).
The organic material is virtually restricted to shale with an overall moderate content. Particles of inertinite and reworked material with a trace of true vitrinite as wispy particles. UV light shows a light orange fluorescence from spores and hydrocarbon specks together with a trace of exinite.

5920': Shale, R_o = 0.38(11) and R_o = 0.63(1).
The sample has a low organic content, mostly reworked and inertinite particles. Some bitumen staining and a trace of true vitrinite particles. UV light shows a light orange fluorescence from spore fragments and a trace of exinite.

6320': Calcareous siltstone and carbonate, R_o = 0.38(5).
The sample has a low organic content with a few particles of inertinite and reworked material together with a trace of possible vitrinite particles. UV light shows a light orange fluorescence from spores and a low exinite content.

6560': Calcareous shale, R_o = 0.37(9).
The sample has a low organic content with particles of reworked material, and inertinite with bitumen wisps. Only a trace of true vitrinite as wispy particles and particles. UV light shows only a light to mid-orange fluorescence from spores and a low exinite content.

6600': Mixed shale lithology, R_o = 0.38(22).
The sample has a low to moderate organic content, mostly gnarled particles of reworked material and inertinite. Some bitumen wisps and wispy particles together with particles of true vitrinite are recorded. UV light shows a light orange fluorescence from spores and hydrocarbon specks together with a low exinite content.

6720': Shale, R_o = 0.37(20).
The sample has a moderate organic content with particles of reworked material and inertinite dominating. Bitumen wisps and a trace of small vitrinite particles are recorded. UV light shows a yellow to orange and light orange fluorescence from spores, rather dull, and a moderate exinite content.

6860': Shale and carbonate, R_o = 0.37(7).
The sample has a low organic content with bitumen wisps and small particles of inertinite and reworked material. Only a handful of small particles of doubtful vitrinite located. UV light shows a yellow/orange and light orange fluorescence from spores and a moderate exinite content.

7000': Shale, R_o = 0.38(7).
The sample has a moderate organic content with small particles of reworked material and vitrinite. Plentiful bitumen wisps and only a trace of doubtful true vitrinite particles. UV light shows a yellow to light orange fluorescence from spores and a moderate to rich exinite content.

7160': Coal, carbargillite and shale, R_o = 0.39(23).
The coal, wholly vitrinite, is rather scruffy, showing cell structure. In the carbargillite the inertinite particles is dominant, but with some good vitrinite wisps. UV light shows a yellow fluorescence from hydrocarbon specks plus light orange spores and a low to moderate exinite content.

7300': Calcareous shale, R_o = 0.43(21).
The sample has a low organic content, mostly particles of reworked material and inertinite. A little bitumen staining and a few coal fragments plus a trace of vitrinite particles. UV light shows a light orange fluorescence from spores and a low exinite content.

7360': Coal, carbargillite and shale, R_o = 0.39(22).
Vitrinite is dominant in the sample but very "scruffy" looking and with variable reflectance. UV light shows a yellow to orange and light orange fluorescence from spores and algae together with a moderate exinite content.

Visual Kerogen

Twenty-three samples were investigated to evaluate kerogen composition and maturity of the organic residues.

The finely dispersed residues are all such as derived from marine to shallow marine sites of deposition: Sapropel is dominant. Besides which is recorded 5-10 % finely dispersed terrestric remains down to 7100'. There are increased amounts of terrestric material in the lowest 200' of the well. To distinguish any zonation, also undissolved heavy minerals and possibly caved material or mud additives were considered since such factors may be of importance especially in intervals poor in indigenous organic material.

6560' and 6580':
Sapropel dominates, but remaining undissolved crystals distinguish the samples from the interval below (6620').
Colour index: -2.

6620' to 6640':
Sapropel dominates and is partly recovered as aggregates. Black coal fragments recorded, may represent mud additives.
Colour index: -2.

6680' to 6820':
Sapropel is dominant. The upper part of the interval is characterized by undissolved minerals, the lower 80' by aggregates.
Colour index: -2.

6860' to 6940':
Sapropel dominates. Palynomorphs are frequently observed.
Colour index: -2.

6980' to 7140':
Sapropel dominates and is often recorded as aggregates, increasing to 7100' and decreasing further up in the interval. Terrestric remains including cuticles are more frequent at 7100' and 7140'.
Colour index: -2/2.

7180' to 7220':
Sapropel dominates. Palynomorphs are frequent.
Colour index: 2.

7260' to 7350':
Sapropel dominates. Terrestric material includes cuticles and suggested reworked fragments. Undissolved minerals are present. The interval seems to give evidence of more deltaic conditions then above.
Colour index: 2.

Analysis of oil from well 17/12-2

An oil sample from well 17/12-2, 7078' - 7094', was also received and analysed in the same way as the oil from well 17/12-1. The gas chromatograms of the saturated hydrocarbon fraction and the whole oil are quite different from the sample from well 17/12-1. Firstly the amount of n-alkanes lighter than n-C_{15} are less in 17/12-2 than in 17/12-1, and a distinct maximum is seen at n-C_{16} for the oil from 17/12-2. The pristane/n-C_{17} ratio is larger than 1.0 in 17/12-2, while it was distinctly smaller in 17/12-1. The pristane/phytane ratio is almost equal to 1.0 in 17/12-2 while it was quite low in 17/12-1. The only similarity found between the two oils is their strange n-alkane distributions discussed previously. The difference in the composition of this sample compared to the sample from 17/12-1 could either be caused by a difference in thermal alteration for the two samples or that the percentage from the two suggested source rocks is different in 17/12-1 compared to 17/12-2.

Comparison between the Oils and the Sediment Extracts from Well 17/12-1 and 17/12-2

When the gas chromatograms of the saturated hydrocarbon fractions of the extracts from well 17/12-1 and 17/12-2 are compared with the gas chromatograms from the respective oils it is noted that the extracts from 17/12-1, which are found to be contaminated with either mud additive (diesel), migrated hydrocarbons or both, have a strong resemblence to the oil from 17/12-2, especially in the medium m.w. area (nC_{17} - nC_{20}), while there is a strong deficit of heavy n-alkanes in the extracts. Similar resemblance is also seen between the saturated hydrocarbon fractions of the extracts from the sediments in well 17/12-2 and the oil from well 17/12-1.

Due to this we cannot exclude an error in labelling on the two oil samples sent our institute. It has, however, been too short a time after analyses of these samples to get new samples from England and conduct new analyses.

Source Rock Evaluation

On the background of the previous discussed results, the analysed sequence of the well will be classified as immature.

Based on total organic carbon measurements, the analysed sequence is divided into four zones which will be given the following rating.

Zone S: -6580': Only a few samples were received from this interval. The TOC values are very erratic and there was not enough material for a complete study. Due to this a source rock rating will not be given.

Zone T: 6580' - 6640': The TOC values are quite constant for this zone, approximately 1.5 %. The visual kerogen show the zone to contain mainly amorphous material and the zone is rated to have a fair to good potential as a source rock for oil and gas. Fluorescing hydrocarbons in the lower part of this zone indicate migrated hydrocarbons.

Zone U: 6680' - 6720': This zone is separated out from the zone above due to a steady increase in the TOC values, it will, however, be given the same rating as zone T.

Zone V: 6750' - 7000': The TOC values in this zone are noticeably higher than in the zone above, approximately 2 - 2.5 %. The yield of extractable hydrocarbons indicates contamination by either migrated hydrocarbons or diesel, while the gas chromatogram of the saturated hydrocarbons favours the latter. The kerogen is completely dominated by amorphous material while the Rock-Eval pyrolysis shows a medium hydrogen index and a low oxygen index. The pyrolysis measurements also indicate that the samples from this interval are contaminated by hydrocarbons. Based on this, this zone will be rated to have a good to rich potential as a source rock for oil and gas.

Zone W: 7020' - 7080': The TOC values in this zone are found to be approximately 4 % while the extraction gives a rich abundance of extractable hydrocarbons. The yield is, however, noticeably lower, measured in mg HC/gTOC, than the zone above and the contaminations of free hydrocarbons is therefore believed not to be as pronounced as in zone V. The visual kerogen examination still shows the samples to be dominated by amorphous kerogen while the Rock Eval pyrolysis shows both a low hydrogen and oxygen index. Based on this, zone W will be rated to have a rich potential as a source rock for oil and gas.

Zone X: 7100' - 7160': The TOC values are somewhat higher for this zone than the zone above and the extraction shows a rich abundance of extractable hydrocarbons. The visual kerogen examination shows a larger impact of terrestric material than in the zone above. This zone will on the background of this be rated to have a rich potential as a source rock for gas and oil.

Zone Y: 7180' - 7360': The TOC values drop sharply at the start of this zone and are approximately 3 % for most of the zone. The kerogen composition changes in this zone compared to the zones above to a more terrestric origin. Based on these analyses, together with the Rock Eval pyrolysis and extraction results, this zone will be rated to have a rich potential as a source rock for gas and oil. Extraction and fluorescing hydrocarbons indicate migrated hydrocarbons in parts of this zone, probably mixed with diesel from the drilling mud.

TABLE XVII

Lithology and Total Organic Carbon (TOC) measurements

Depth (ft)	TOC	Lithology
3150	1.76	100% Claystone, dark grey and light grey Considerable mud contaminated
3200	1.43	100% Claystone, light grey to dark grey Largely consisting of mud products.
5110		Mainly drilling mud, but som glauconitic Sand
5140		Consists mainly of mud, and some glauconitic Sand, dark grey slightly micaceous Claystone, white Limestone, Pyrite.
5170	1.40	100% Claystone, silty, dark grey, micaceous sm.am. Limestone; (?) Gypsum; Pyrite. Considerable amounts drilling mud.
5200	1.37	Mostly drilling mud, but also dark grey Claystone and (?) Gypsum
5410	1.84	100% Claystone, grey to dark grey, brown sm.am. Limestone, white; (?) Gypsum. Considerable amounts drilling mud.
5500	2.65	100% Claystone, dark grey, micaceous
5920	2.43	100% Claystone, grey to dark grey, some micaceous
5980	0.93	95% Claystone, as above 5% Gypsum
6320	1.32	100% Claystone, partly silty, grey, slightly micaceous.
6380	1.20	100% Claystone, dark grey to grey
6580	1.36	100% Claystone, grey, dark grey

Depth (ft)	TOC	Lithology
6600	1.42	100% Claystone, grey to dark grey, light grey observed, slightly micaceous
6640	1.38	100% Claystone, grey to dark grey, light grey, slightly micaceous
6680	1.53	100% Claystone, grey, light grey, slightly micaceous
6700	1.64	100% Claystone, grey, some light grey
6720	1.86	100% Claystone, grey to dark grey, slightly micaceous
6740	2.25	100% Claystone, dark grey
6760	2.32	100% Claystone, dark grey, slightly brownish, slightly micaceous
6780	2.57	100% Claystone, as above
6800	2.42	100% Claystone, as above
6820	2.36	100% Claystone, as above
6840	2.06	100% Claystone, as above
6860	2.12	100% Claystone, as above
6880	2.36	100% Claystone, as above
6900	2.46	100% Claystone, as above sm.am. Gypsum
6920	2.41	100% Claystone, as above

Depth	TOC	Lithology
6940	2.48	100% Claystone, as above
6960	2.43	100% Claystone, as above sm.am. Gypsum obs. Pyrite
6980		100% Claystone, dark grey, slightly micaceous. Considerably mud contaminated.
7008	2.62	100% Claystone, as above sm.am. Gypsum
7020	4.15	100% Claystone, as above
7040	4.46	100% Claystone, dark grey, some grey, slightly micaceous sm.am. Gypsum
7060	2.50	100% Claystone, dark grey, some (brownish) light grey (silty) sm.am. Limestone
7080	4.52	100% Claystone, dark grey, fissile sm.am. Gypsum
7100	6.06	100% Claystone, as above sm.am Siltstone, light brown; Sand; Gypsum,
7120	5.74	90% Claystone, as above 10% Gypsum sm.am.Limestone, white, Pyrite
7140	5.85	100% Claystone, dark grey
7160	4.96	100% Claystone, dark grey
7180	3.60	100% Claystone, dark grey, grading to black, some brown sm.am. Sand; Siltstone and Sandstone, light brown

Depth	TOC	Lithology
7200	3.90	98% Claystone, dark grey, grey 2% Lignite
7220	11.20	100% Claystone, dark grey, grading to black, some light browngrey to brown sm.am. Sand; Coal Considerably mud contaminated
7240	3.10	80% Claystone, dark grey, some grey and black 20% Sand, fine to coarse, anguler to subangular sm.am. Limestone, white; Coal
7260	1.94	100% Claystone, dark grey, grading to black, some light browngrey and brown sm.am. Sand; Coal Mud contaminated
7280	3.15	95% Claystone, dark grey 5% Sand Half of the material consists of drilling mud.
7300	3.14	95% Claystone, dark grey and light browngrey 5% Sand sm.am. Siltstone, brown
7320	3.04	100% Claystone, as above Considerable mud contamination
7340	2.96	100% Claystone, dark grey - black, some micaceous. Considerable mud contaminated
7350	2.90	100% Claystone, dark grey, grading to black, very micaceous (?biotitic inpart) fragments observed, some light brown, fissile sm.am. Sand Strongly mud contaminated
7360	2.92	100% Claystone, dark grey to black sm.am. Coal

TABLE XVIII

Weight (mg) of EOM and chromatographic fractions
Well 17/12-2

Sample	Depth (ft)	Rock extr.(g)	EOM (mg)	Sat(mg)	Aro(mg)	HC(mg)	Non HC(mg)	TOC
K705-707	6740-6820	26,57	150,5	82,4	20,6	103,0	14,5	2,40
K712-714	7000-7100	24,20	130,4	73,1	15,8	88.9	18,3	3,16
K715-716	7120-180	39,74	234,8	110,8	37,3	148,1	33,7	5,69
K717-718	7200-260	32,88	255,2	122,6	37,2	159,8	32,4	5,15
K719-721	7280-360	33,70	259,7	151,1	35,1	186,2	30,8	2,65

TABLE XIX

Concentration of EOM and chromatographic fractions (weight ppm of rock)
Well 17/12-2

Sample	Depth (ft)	EOM	Sat	Aro	Total Hydroc.	Non Hydroc.
K705-707	6740-6820	5664	3101	775	3877	546
K712-714	7000-100	5388	3201	653	3674	756
K715-716	7120-180	5908	2788	939	3727	848
K717/718	7200-260	7762	3729	1131	4860	985
K719-721	7280-7320	7822	4552	1057	5608	928

TABLE XX

Concentration of EOM and chromatographic fractions (mg/gTOC)

Well 17/12-2

Sample	Depth (ft)	EOM	SAT	Aro	Total Hydroc.	Non Hydroc.
K705-707	6740-6820	236	129	32	162	23
K712-714	7000-7100	171	96	21	116	24
K715-716	7120-180	104	49	17	66	15
K717/718	7200-260	151	72	22	94	19
K719-721	7280-360	295	172	40	212	35

TABLE XXI

Composition in % of the material extracted from the rock

Well 17/12-2

Sample	Depth (ft)	Sat/EOM	Aro/EOM	HC/EOM	Sat/Aro	Non HC/EOM	HC/Non HC
K705-707	6740-6820	55	14	68	400	10	710
K617-619	7000-7100	56	12	68	463	14	486
K620/621	7120-7180	47	16	63	297	14	439
K717/718	7200-7260	48	15	62	330	13	493
K624-626	7280-7360	58	14	72	431	12	605

TABLE XXII

Tabulation of data from the gas chromatograms
Well 17/12-2

Sample	Depth (ft)	Pristane/ nC_{17}	Pristane/ Phytane	CPI
K705-707	6740-6820	0,46	1,20	1,06
K712-714	7000-7100	0,52	1,10	1,10
K715/719	7120-7180	0,50	1,18	1,18
K717/718	7200-7260	0,49	1,19	1,18
K719/721	7280-7360	0,46	1,09	1,05

TABLE XXIII
Rock Eval Pyrolysis Well 17/12-2

Sample	Depth (ft)	S_1	S_2	S_3	C_{org}	Hydrogen Index	Oxygen Index	Oil and gas content S_1+S_2	Production Index $\frac{S_1}{S_1+S_2}$	T_{max} °C
K600	5200	3,1	0,4	2,9	1,37	29	212	3,5	0,89	412
K602	5500	3,2	1,0	2,5	2,65	38	94	4,2	0,76	423
K605	6320	1,6	0,2	0,9	1,32	15	68	1,8	0,89	415
K607	6600	2,3	1,2	0,9	1,40	86	64	3,5	0,66	427
K609	6680	3,0	1,9	0,8	1,53	124	52	4,9	0,61	426
K610	6720	3,6	4,7	0,8	1,60	294	50	8,3	0,43	427
K706	6780	3,4	2,5	1,2	2,57	97	47	5,9	0,58	425
K613	6840	2,1	3,2	0,8	2,06	155	39	5,3	0,40	428
K709	6900	3,5	4,8	1,0	2,46	195	41	8,3	0,42	425
K616	6960	3,0	4,8	1,0	2,43	198	41	7,8	0,38	428
K712	7020	2,9	4,7	1,3	4,15	113	31	7,6	0,38	425
K714	7100	3,7	4,9	1,3	6,06	81	21	8,6	0,43	424
K715	7140	3,9	6,8	1,1	5,85	116	19	10,7	0,36	428
K716	7180	4,2	9,2	1,2	3,60	256	33	13,4	0,31	427
K719	7300	5,1	2,1	1,3	3,14	67	41	7,2	0,71	426
K626	7360	5,4	7,4	1,0	4,13	179	24	12,8	0,42	427

TABLE XXIV

Vitrinite reflectance and visual kerogen measurements, well 17/12-2

Depth(ft)	Vitrinite reflectance		Colour index	Type of organic matter
2210	0.29(21)			
3150	0.34(14)			
5170	0.35(7)			
5410	0.37(20)			
5920	0.38(11)	0.63(1)		
6320	0.38(5)			
6560	0.37(9)		-2	Am/W, CoalR', Poll-spor
6600	0.38(22)		-2	Am/He, Poll-spor, Cysts
6720	0.37(20		-2	Am/He, Cysts
6860	0.37(7)		-2	Am/He, Cysts
7000	0.38(7)		-2	Am/He, Poll-spor, Cysts
7160	0.39(23)		-2/2	Am/He, W, Poll-spor, Cysts
7300	0.43(21)		2/2+	Am/W, He, Poll-spor
7360	0.39(22)		2	Am/Poll-spor, He, Cut, W

TABLE XXV

Cromatographic separation of oils from

well 17/12-1 and 17/12-2.

IKU No	Sample	Weight of oil (mg)	Sat (mg)	Aro (mg)	HC (mg)	Non HC (mg)	Pristane / nC_{17}	Pristane / Phytane	CPI
K1338	17/12-1	998,9	437,3	223,2	660,5	87,9	0,59	1,42	1,05
K1337	17/12-2	996,3	270,6	308,5	579,1	111,1	1,21	1,21	1,04

Oil - Source Rock Correlation

Nine rock extracts together with the saturated hydrocarbon fraction of the two oil were sent to Masspec Analytical for GC-MC analysis, concentrating on the steranes and triterpanes which are most environmented indicative. The rock extracts were selected from various zones in the three wells which were found to have a rich enough potential to be possible source rocks for oil and gas.

Experimental

All fractions were examined as received (no urea clathration was performed) under the following conditions:

Instrument:	Finnian 3200/6100 CGCMS system
GC:	10 m x 0.3 mm OV-1 WCOT column programmed 150^{o} - $270^{o}C$ at $8^{o}C/min$.
MS:	300μA emission, 70 eV electron energy. Masses m/e 85, 191, 217 and 253 were scanned in M.I.D. mode (max. integration time 64 mS per ion) every 1 S.

Results

General

The primary data are enclosed in a separate appendix. The fragmentograms are grouped by m/e and arranged within each m/e group in the sample order listed in table XXVI.

Where fragmentograms plotted by the usual output procedures are normalized to a peak not in the "fingerprint region" (e.g. K1 042, m/e 217), an additional plot has been supplied in which data is re-normalized to the most intense peak in the "fingerprint region" and multiplication factors adjusted accordingly. The additional plots are produced by a newly developed Masspec program and are distringuished by the legend 'N-ALKANE NO.: ' written above the y-axis. (The legend concerns a program option which is not employed here).

Peak intensities were measured using the same peak nomenclature and criteria as for previous MID data. Additional peaks considered (triterpanes 7, 8, 9) are identified in table XXX. The peak intensities are listed in table XXVII.

Eight triterpane peak ratios were calculated and listed in table XXVIII together with thirteen sterane peak ratios, table XXIX.

Table XXX lists tentative assignments of the peaks primarily used for interpretation. The assignments are based on relative retention time (RRT), and comparison with assignments made in earlier correlation report for IKU.

Sterane peak ratios 8/17 and 12/17 (i.e. C_{27}/C_{29} regular cholestanes) and triterpane rations 3/4 (i.e. 17α(H) norhopane/17α(H) hopane) were chosen as the main indicators of environment of deposition for the purpose of this report. Similarly, sterane ratio 17/14 (20R/20S 14α(H)/17α(H) ethylcholestane) and triterpane ratios 9/4 (22R 17β(H) homohopane/17α(H) hopane), and 8/7 (22S/22R 17α(H) homohopane) were chosen as the main maturity indicators, the ethylcholestanes being selected because peaks 17 and 14 are in a less complicated region of the m/e 217 fragmentogram and are therefore more reliably measured than the peaks corresponding to the R and S epimers of 14α(H) 17α(H) cholestane and methylcholestane.

The chosen maturity-indicating ratios (triterpane 9/4 and 8/7 and sterane 17/14) all decrease with increasing maturity.

Comparison between samples: summary

The main indicator ratios described above are listed separately in table XXXI with comment on the principal deductions made from them, and with comment on other major features of the m/e 191 and 217 fragmentograms not reflected in the ratios.

<u>Comparison between samples: Triterpanes (m/e 191)</u>

(i) Oils, K1337 (17/12-2) and K1338 (17/12-1

The alkane fractions of the two oils, K1337 and K1338, displayed triterpane distributions typical of many crude oils. Peak 5 was observed in K1337 and peak 6 in K1338. The chosen ratios indicate a broadly similar depositional environment for the two oils, and that K1 338 is less mature than K1337.

(ii) K731, K749, K760 and K769

All are less mature than the oils. K731 and K749 are more similar to the oils in environment, ratio 3/4 being 0.67 and 0.70 respectively (oils, 0.53).

(iii) K1042 and K1045

Both extracts are less mature than the oils. An unidentified peak eluting halfway between peaks 3 and 4 is observed in K1042 (intensity 24 % peak 4) and K1045 (intensity 32 % peak 4). This peak is minor feature of the oils (<u>ca.</u> 8 % peak 4). Peak 6 is observed in K1045 but not in K1042. The ratio 3/4 is more similar to the oils (0.53) in K1045 (0.50) than K1042 (0.75).

(iv) K706, K713 and K715

All are less mature than the oils. The ratio 3/4 is similar to that of the oils (0.53) for each of this group (K715:0.54, K713:0.56, K706:0.67) but there is a major peak eluting immediately before peak 4 in all three fractions which is not observed for the oils. On the basis of RRT alone, this peak might tentatively be assigned the identity 18α(H) oleanane. If this assignment were correct, then K706, K713 and K715 are unlikely to be sources for the oils, and in any case do not appear to be sufficiently mature.

Comparison between samples: Steranes (m/e 217)

(i) Oils, K1337 and K1338

Ratios 8/17 and 12/17 indicate that both oils are from similar depositional environments (8/17 and 12/17 = 1.00 and 0.69 (k1337); 1.07 and 0.74 (K1338). Ratio 17/14 suggests that K1338 (1.04) is less mature than K1337 (1.39), but the relative abundance of C_{27} diacholestanes, peaks 1 and 2, is greater in K1338 than K1337.

(ii) K731, K749, K760 and K769

All are less mature than the oils. The ratio 17/14 indicates that maturity increases in the order K749-769-731-760, but it should be noted that C_{27} diacholestanes (peaks 1 and 2) are present in K760 and K769 and almost absent in K731 and K749. K749 is the most similar to the oils in depositional environment, comparing 8/17 and 12/17 together (table XXXI).

(iii) K1042 and K1045

Both are less mature than the oils. K1045 shows the highest value of maturity ratio 17/14 (8.80) of any of the samples studied, although it should be noted that C_{27} diacholestanes (peaks 1 and 2) are present in both samples.

(iv) K706, K713 and K715

K713 matches the oils most closely of any sample studied in the depositional environment ratios 8/17 and 12/17. All three samples are less mature than the oils when ratio 17/14 is considered, but all show the presence of C_{27} diacholestanes (peaks 1 and 2).

Comparison between samples: Monoaromatic Steranes (m/e 253)

Interpretation of the monoaromatic sterane results is complicated by the coelution in the "fingerprint region" (scans 300-450 approximately) of n-alkanes which contribute m/e 253 in an abundance which is sometimes significant compared with the abundance of m/e 253 in the spectra of presumed monoaromatic steranes. Peaks in the m/e 253 fragmentograms which are considered to have a possibly significant n-alkane contribution are arrowed.

Comparisons between samples, and correlations between the rock extracts and oils, have been restricted to visual "similarity ratings" (shown in table 7) because (i) n-alkane contributions to m/e 253 are significant for both the oils, and for some of the rock extracts, and (ii) monoaromatic steranes are less well understood as correlation parameters than are triterpanes and steranes.

Conclusions

1) All the rock extracts are less mature than the two oils (K1337 and K1338).

2) The greatest similarity to the two oils in environment of deposition (as assessed by triterpane ratio 3/4 and sterane ratios 8/17 and 12/17) is shown by K713. However, a triterpane suspected to be 18α(H) oleanane, which is source indicative, is present in K706, K713 and K715 and is absent in both oils. Therefore, K713 is unlikely to be the source of either oil. Also, K713 does not appear to be sufficiently mature.

3) K1045 and K749 show the next nearest similarities to K1337 and K1338 when the chosen depositional environment ratios are considered. Neither sample is sufficiently mature to be a direct source of the oils, but K1045 does show the presence of significant C_{27} diacholestanes whereas K749 does not. Triterpane 6 is observed in K1045, but not in K749.

4) Therefore, of the rock extracts studied, K1045 is the nearest match to the oils (particularly K1338) in depositional environment - although K1045 is not sufficiently mature to be a direct source for either oil.

TABLE XXVI

Information Supplied by I.K.U.

SAMPLE	WELL	DEPTH	WT mg	
K1337				Low CPI, ≃0.9 - reducing environment? But Pr/Ph ≃ 1.5 when<1 expected.
K1338				
+ K648	18-11-1	1680 m	1	No migratory H/C contamination expected, but biodegradation likely after sampling - cores stored 6 years in bags.
K749		1770 m	4	
K760		1840 m	5	
K769		1880 m	2	
K1042	17-12-1	6400'	50	On Pr/Ph and on n-alkane max C_{17} with steep decline to C_{20}, suspect contamination by diesel; but should not affect T/T, sterane distribs if diesel clean. No diesel sample available since 5 - 6 years ago.
K1045		7400'	∿100	
K706	17-12-2	6750'	∿40	
K713		7000'	∿30	
K715		7150'	∿60	

+ for K648 read K731 in tables XXVI to XXXII
The tables have been provided from Masspec Analytical

Table XXVII A

Peak Intensities

(Heights in mm)

TRITERPANES

Sample	Peak # 1	2	3	4	5	6	7	8	9
K 1337	5	15.5	44	83	7	1	37	25	0
K 1338	13	16	44	83	1.5	5	41	26	0
K 648	2	24.5	64	91	0	0	16	29	0
K 749	1	24	65	97	0	0	14	38	27
K 760	12	35	89	84	0	0	23	27	2
K 769	9.5	35	79	72	0	0	16	36	21
K 1042	7	22	54	72	0	0	19	43	19
K 1045	2	38	45	90	0	0	60	79	0
K 706	19	21	50	75	17	0	15	29	10
K 713	17	16	47	84	14.5	0	19	28	2
K 715	8	24	36	67	8	0	20	34	2

Table XXVII B

Steranes

Sample	Peak # 1	2	4	6	7	8	9	11	12	14	15	17
K 1337	66	43	28	68	73	64	39	42	44	46	48	64
K 1338	64	40	22	38	70	29	35	36	20	26	39	27
K 648	3	2	2	15	7	25	9	34	94	46	30	86
K 749	4	4	3	27	19	75	(15)	34	82	21	34	93
K 760	24	19	15	39	54	50	27	46	71	50	55	76
K 769	22	18	12	44	46	62	19	43	57	30	47	69
K 1042	41	26	16	30	38	51	23	35	43	19	37	77
K 1045	32	32	23	32	41	71	36	30	60	10	35	88
K 706	27	23	15	38	38	66	29	30	37	16	42	65
K 713	36	27	19	45	42	71	34	41	51	22	44	71
K 715	29	24	17	34	53	56	47	40	36	19	56	74

Table XXVIII

Triterpane Peak Ratios

Sample	Peak ratio 1/2	2/3	3/4	2/4	5/3	6/3	9/4	8/7
K 1337	0.32	0.35	0.53	0.19	0.16	0.02	0	0.68
K 1338	0.81	0.36	0.53	0.19	0.03	0.11	0	0.63
K 648	0.04	0.37	0.67	0.25	0	0	0	1.81
K 749	0.08	0.38	0.70	0.27	0	0	0.30	2.71
K 760	0.34	0.39	1.06	0.42	0	0	0.02	1.17
K 769	0.27	0.44	1.10	0.49	0	0	0.29	2.25
K 1042	0.32	0.40	0.75	0.31	0	0	0.26	2.26
K 1045	0.05	0.84	0.50	0.42	0	0	0	1.32
K 706	0.90	0.42	0.67	0.28	0.34	0	0.13	1.93
K 713	1.06	0.34	0.56	0.19	0.31	0	0.02	1.47
K 715	0.33	0.67	0.54	0.36	0.22	0	0.03	1.70

Table XXIX

Sterane Peak Ratios

Sample	Peak ratio												
	1/2	1/7	7/8	8/9	1/11	9/11	1/14	1/17	15/17	11/17	8/17	12/17	17/14
K 1337	1.53	0.9	1.1	1.6	1.6	0.9	1.4	1.0	0.7	0.7	1.00	0.69	1.39
K 1338	1.60	0.9	2.4	0.8	1.8	1.0	3.0	2.3	1.4	1.3	1.07	0.74	1.04
K 648	1.50	0.43	0.28	2.78	0.09	0.26	0.07	0.03	0.35	0.40	0.29	1.09	1.87
K 749	1.00	0.21	0.25	(5.00)	0.12	(0.44)	0.19	0.04	0.37	0.37	0.81	0.88	4.43
K 760	1.26	0.44	1.08	1.85	0.52	0.59	0.48	0.32	0.72	0.61	0.66	0.93	1.52
K 769	1.22	0.48	0.74	3.26	0.51	0.44	0.73	0.32	0.68	0.62	0.90	0.83	2.30
K 1042	1.58	1.08	0.75	2.22	1.17	0.66	2.16	0.53	0.48	0.45	0.66	0.56	4.05
K 1045	1.00	0.78	0.58	1.97	1.07	1.20	3.20	0.36	0.40	0.34	0.81	0.68	8.80
K 706	1.17	0.71	0.58	2.28	0.90	0.97	1.69	0.42	0.65	0.46	1.02	0.57	4.06
K 713	1.33	0.86	0.59	2.09	0.88	0.83	1.64	0.51	0.62	0.58	1.00	0.72	3.23
K 715	1.21	0.55	0.95	1.19	0.73	1.18	1.53	0.39	0.76	0.54	0.76	0.49	3.89
	1	2	3	4	5	6	7	8	9	10			
	Parameter												

Table XXX

Peak Assignments

Type	Peak # (marked on MID data)	Assignment	Basis
Triterpanes	5	17α(H), 18α(H) 28, 30 bisnorhopane	Relative retention time (RRT) + report 695/79
	3	17α(H) norhopane	RRT
	4	17α(H) hopane	RRT
	7	22S 17α(H) homohopane	RRT
	8	22R 17α(H) homohopane	RRT
	9	22R 17β(H) homohopane	RRT
Steranes	8	20R 14α(H) 17α(H) cholestane	RRT
	12	20R 14α(H) 17α(H) methylcholestane	RRT
	14	20S 14α(H) 17α(H) ethylcholestane	RRT
	17	20R 14α(H) 17α(H) ethylcholestane	RRT
	1	20S 13β(H) 17β(H) diacholestane	RRT
	2	20R 13β(H) 17β(H) diacholestane	RRT

Table XXXI

Comparison of Selected Depositional and Maturation Parameters

	Sample	Sterane Ratios			Triterpane Ratios			Comment
		8/17	12/17	17/14	3/4	9/4	8/7	
OILS	K1337	1.00	0.69	1.39	0.53	0	0.68	Oils generally similar, differing in maturity more than in depositional environment.
	K1338	1.07	0.74	1.04	0.53	0	0.63	
ROCK EXTRACTS	K648	0.29	1.09	1.87	0.67	0	1.81	All less mature than oils. Maturity increases in the order 749-769-648-760 comparing 17/14, 8/7 and 9/4, but note diacholestanes (1 and 2) present in 760 and 769 and absent in 648 and 749. Of this group, 749 is most similar to the oils in depositional environment (compare 8/17, 12/17 and 3/4).
	K749	0.81	0.88	4.43	0.70	0.30	2.71	
	K760	0.66	0.93	1.52	1.06	0.02	1.17	
	K769	0.90	0.43	2.30	1.10	0.29	2.25	
	K1042	0.66	0.56	4.05	0.75	0.26	2.26	Both less mature than oils. Diacholestanes (1 and 2) present in both samples. K1045 is more similar to the oils in depositional environment (ratios 8/17, 12/17, 3/4)
	K1045	0.81	0.68	8.80	0.50	0	1.32	
	K706	1.02	0.57	4.06	0.67	0.13	1.93	K713 is most similar to the oils in the chosen depositional environment ratios (3/17, 12/17, 3/4), but all three extracts show a triterpane eluting immediately before triterpane peak 4 which suggests that the similarity to the oils in ratios 8/17, 12/17 and 3/4 is coincidental.
	K713	1.00	0.72	3.23	0.56	0.02	1.47	
	K715	0.76	0.49	3.89	0.54	0.03	1.70	

Table XXXII

Visual Comparison of m/e 253 fragmentograms

Sample	Similarity rating to K1337/K1338
648	* *
749	*
760	* *
769	* *
1042	*(*)
1045	*
706	*
713	*
715	*

* * = fair to good similarity

* = less good similarity

PART THREE: SUMMARY AND CONCLUSIONS

DATA SUMMARY AND CONCLUSION

A direct correlation of the various zones in the three wells is difficult due to lack of necessary information, such as logs, etc. The various data from the three wells will be summed up and a final conclusion drawn from this.

The analysed sequences of the three wells are immature with exception of the lower 700' of well 17/12-1 which is moderate mature. Due to this the detected oil in well 17/12-1 and 17/12-2 cannot have been sourced by any of the penetrated sequences. Large parts of these sequences have, however, good or rich potentials as source rocks for oil and gas if they were mature enough. The zones with such possibilities would be zones A and B in well 18/11-1, J - N in well 17/12-1 and V and W in well 17/12-2. Zones T and U in well 17/12-2 would also be source rocks for oil and gas, but with a slightly lower potential. The upper part of the wells together with the lower part contain a larger proportion of terrestric material and are rated as possible source rock for gas (and oil).

To try to correlate the oils from wells 17/12-1 and 17/12-2 with possible source rock samples from various zones together with the two oil samples were analysed by GC-MS, concentrating on steranes and triterpanes. Some of the measured parameters are main indicators of environment, and as so will not change with increasing maturation, while others are typical maturity indicators. With the background in these analyses it is believed that the two analysed oils are sourced from the same source rock and the large difference seen in the whole saturated hydrocarbon fraction is only due to a difference in maturity of the two oils, with the oil from 17/12-1 being less mature than the oil from 17/12-2.

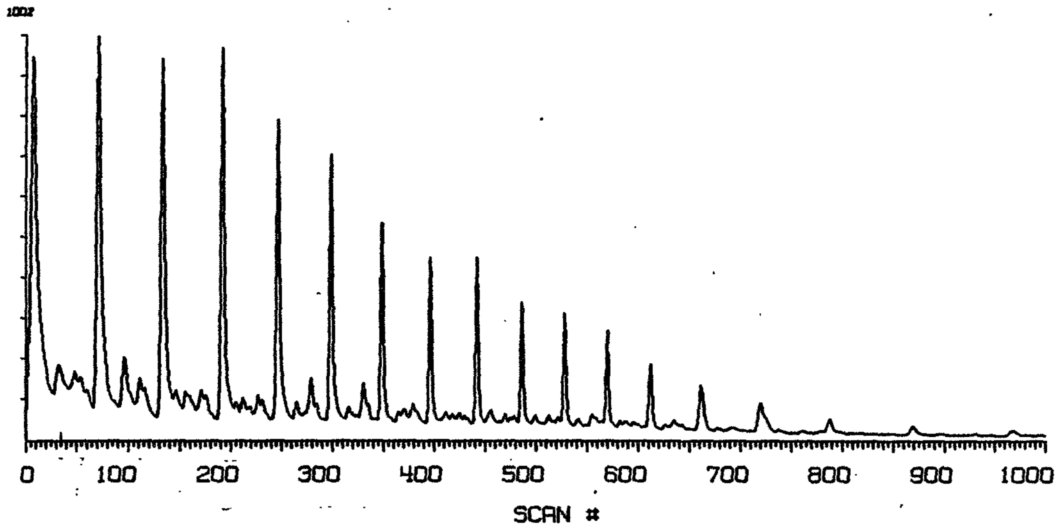
The correlation study between the two oils and the various sediment samples does not give any definitive correlating between any of the analysed sediment samples and the oils. Only one sample, K1045 (7400-7425') well 17/12-1, shows some kind of similarity. Therefore, although not a likely source rock, zone N can be said to be "the least unlikely".

As was mentioned previously, the sediments from both wells 17/12-1 and 17/12-2 are contaminated by diesel. Normally diesel will not contain triterpanes, but on the chance that the triterpane suspected to be 18α(H) oleane, found in all samples from 17/12-2 is from diesel or another mud additive than sample K713 (7000-7100', well 17/12-2) shows the greatest similarity to the two oils, and zones V and W would be likely source rocks for the oils where they have reached a high enough maturity.

APPENDIX: RESULTS FROM MASSPEC ANALYTICAL

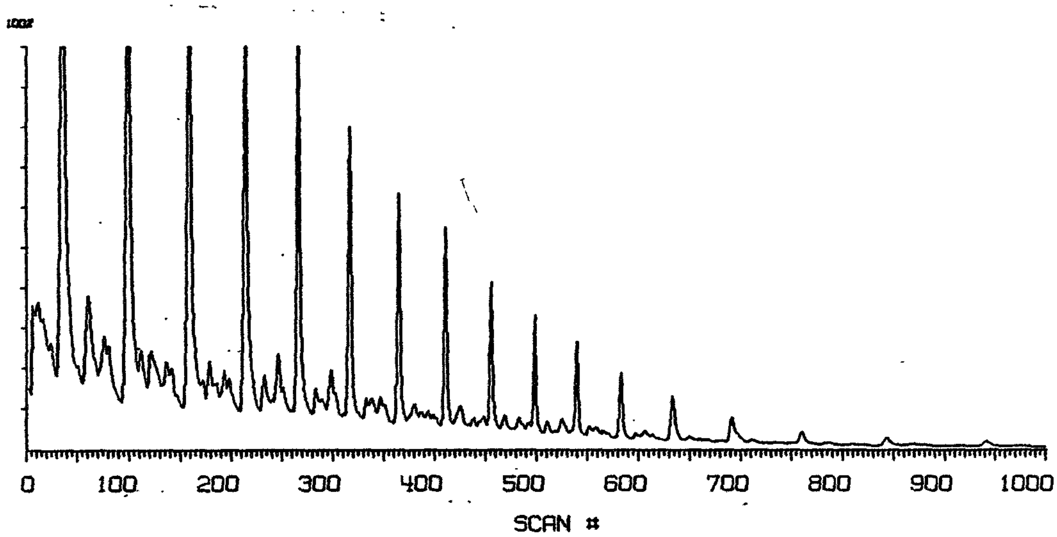
K 1337 (4095) MASSPEC ANALYTICAL

M/E 85 x 1 4 ION MID DATA



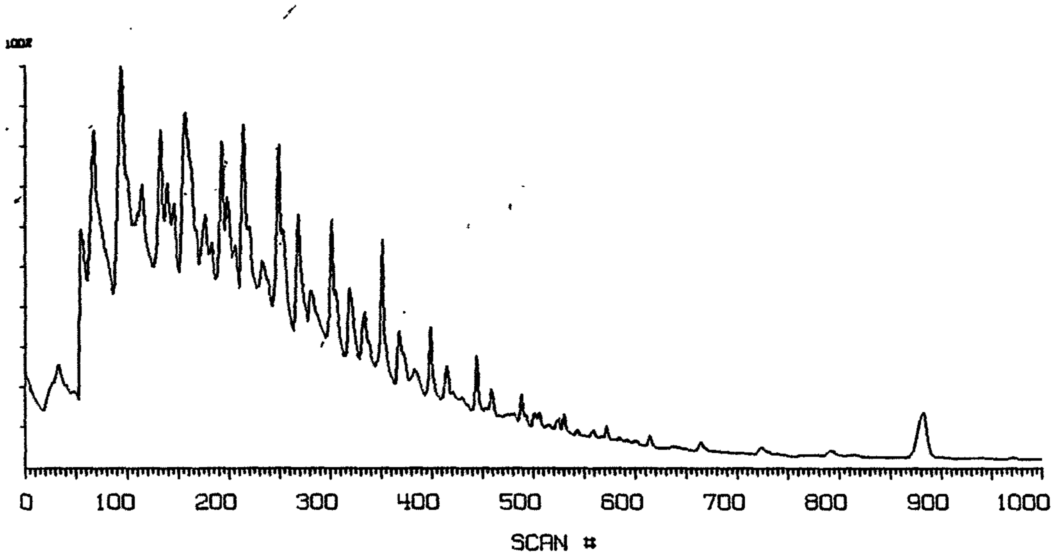
K 1338 (4096) MASSPEC ANALYTICAL

M/E 85 x 1 4 ION MID DATA



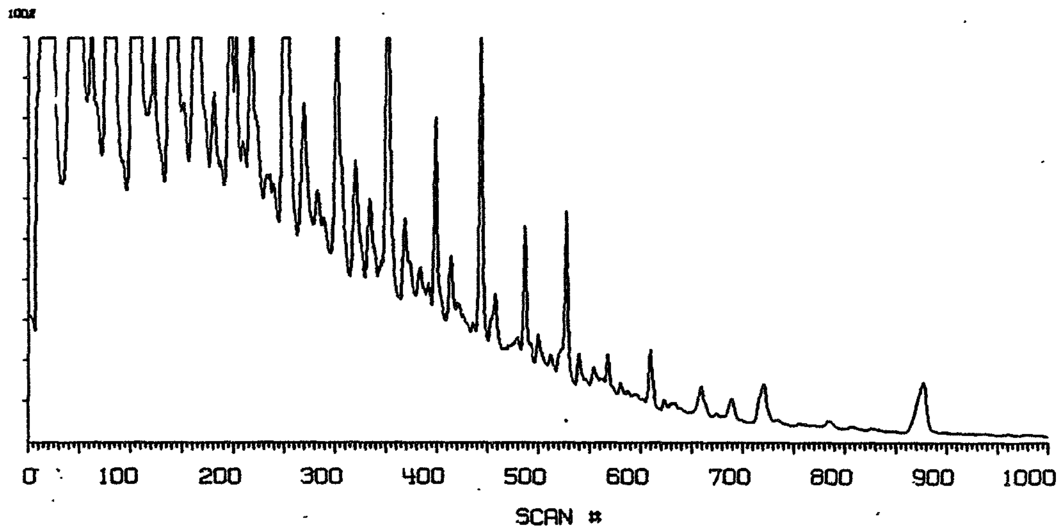
K 648 (4099) MASSPEC ANALYTICAL

M/E 85 x 1 FOR 648 READ 731. 4 ION MID DATA



K 749 (4094) MASSPEC ANALYTICAL

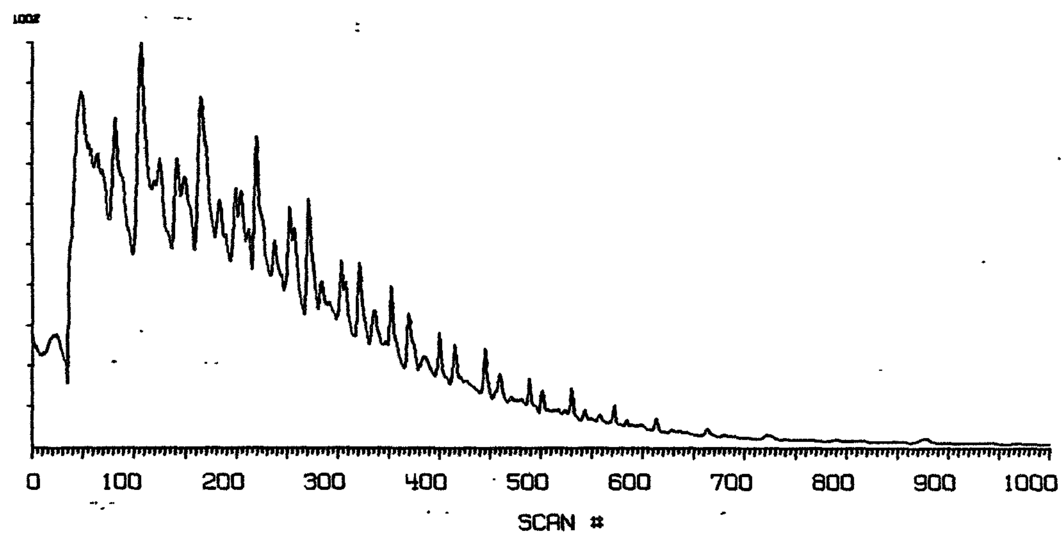
M/E 85 x 1 4 ION MID DATA



K 760 (4093) MASSPEC ANALYTICAL

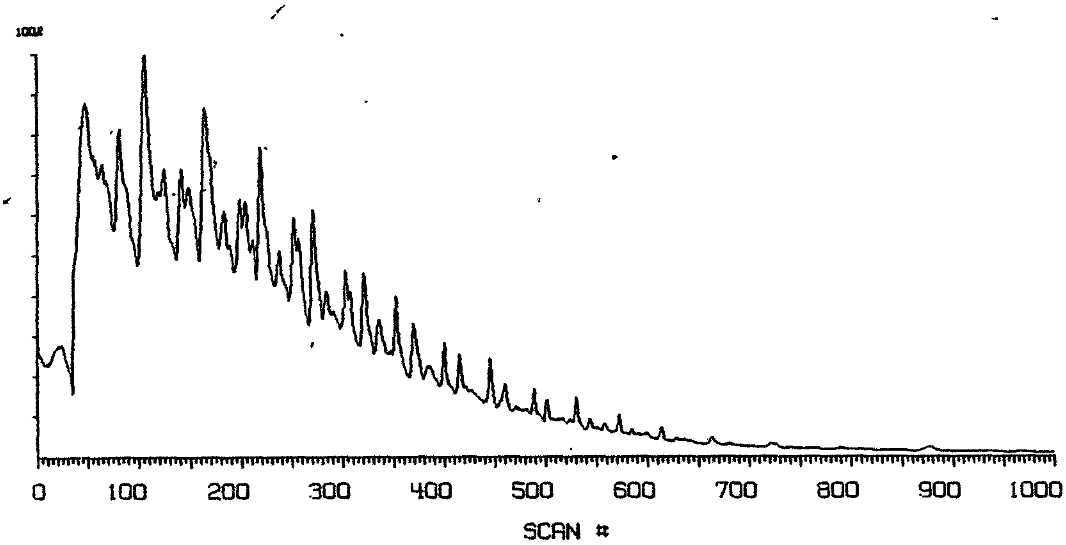
M/E 85 x 1 4 ION MID DATA

N-ALKANE # :



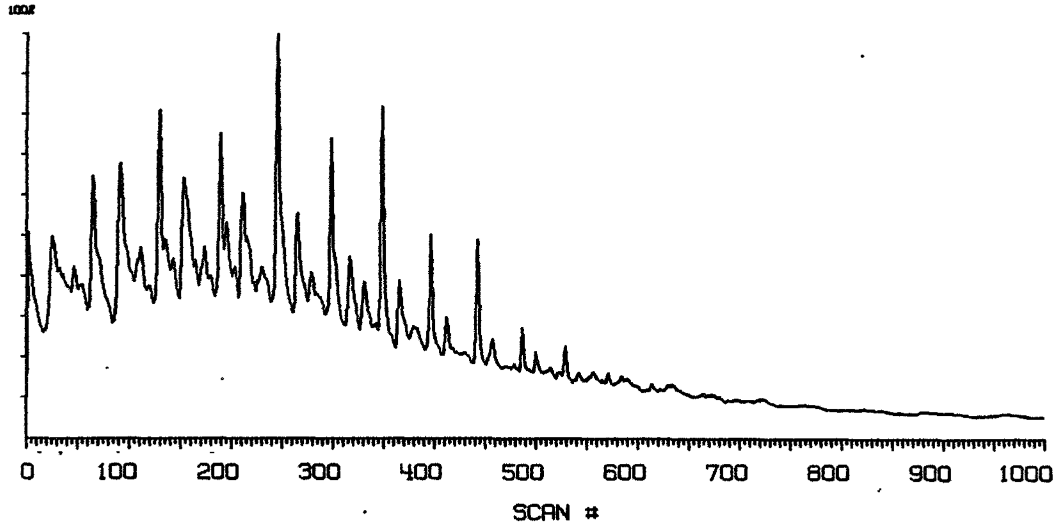
K 760 (4093) MASSPEC ANALYTICAL

M/E 85 x 1 4 ION MID DATA



K 769 (4098) MASSPEC ANALYTICAL

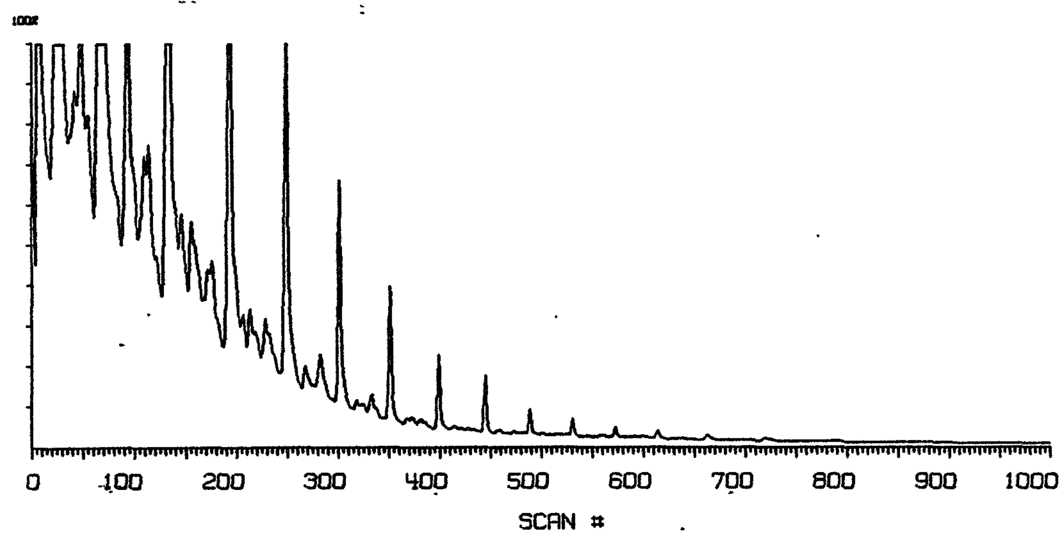
M/E 85 x 1 4 ION MID DATA



K 1042 (4100) MASSPEC ANALYTICAL

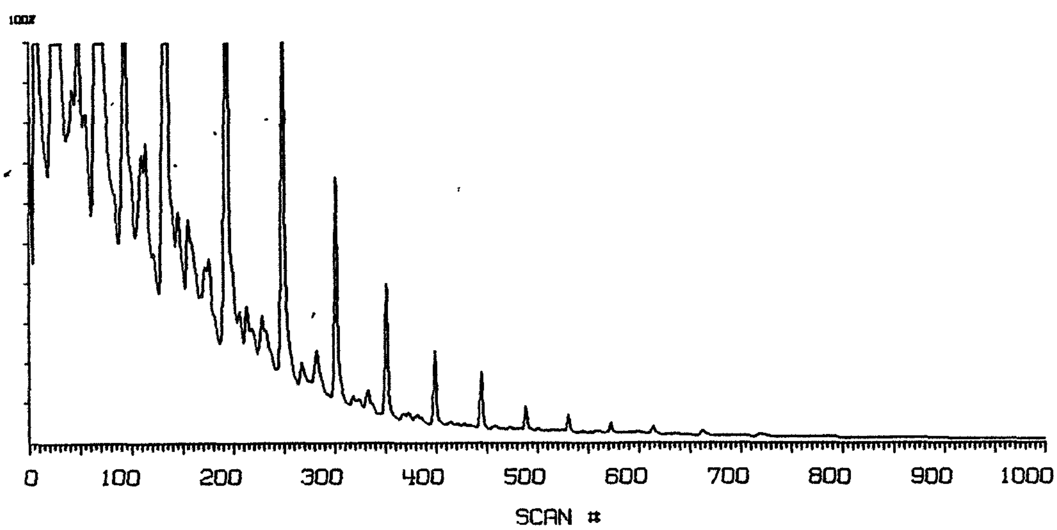
M/E 85 x 1 4 ION MID DATA

N-ALKANE # :



K 1042 (4100) MASSPEC ANALYTICAL

M/E 85 x 1 4 ION MID DATA

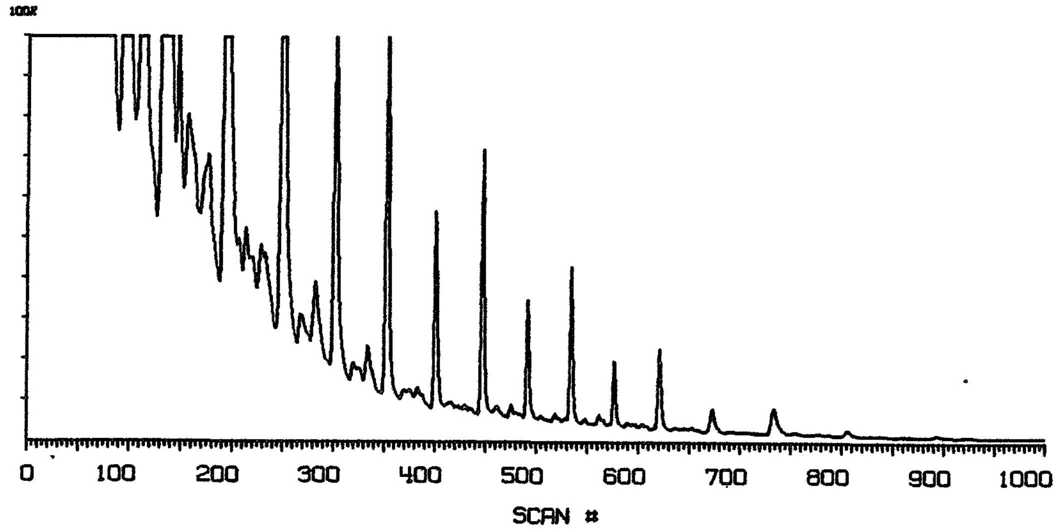


K 1045 (4102)

MASSPEC ANALYTICAL

M/E 85 x 1

4 ION MID DATA



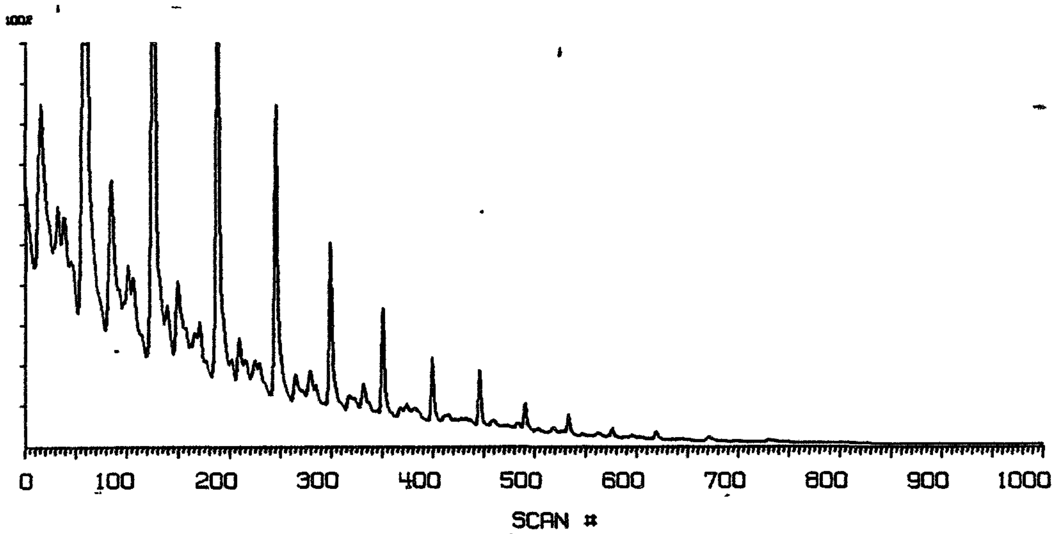
K 706 (4103)

MASSPEC ANALYTICAL

M/E 85 x 1

4 ION MID DATA

N-ALKANE # :

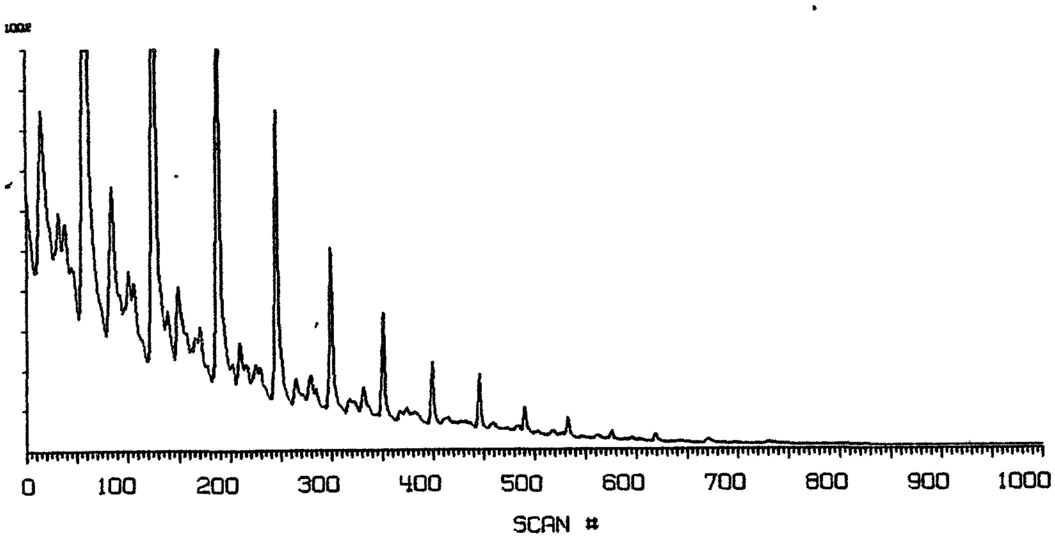


K 706 (4103)

MASSPEC ANALYTICAL

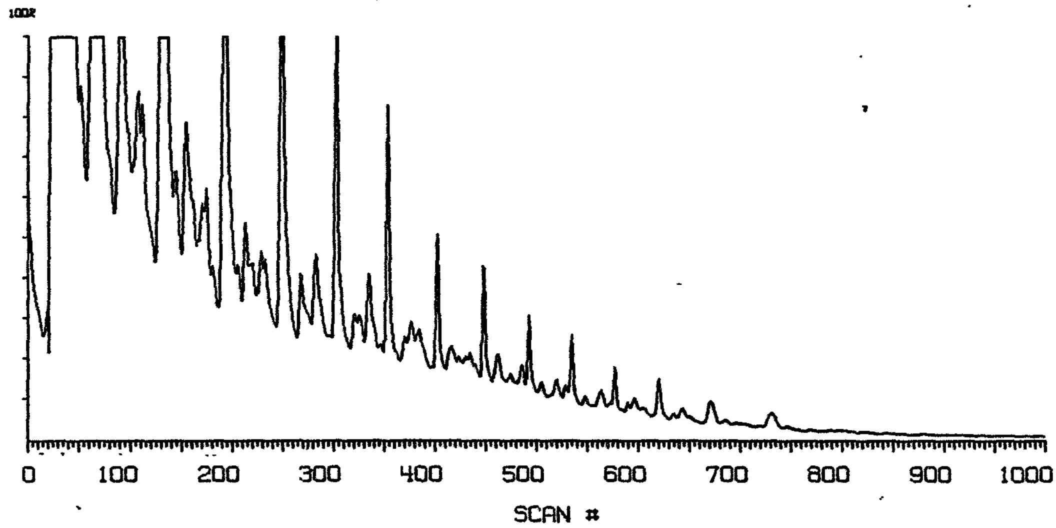
M/E 85 x 1

4 ION MID DATA



K 713 (4104) MASSPEC ANALYTICAL

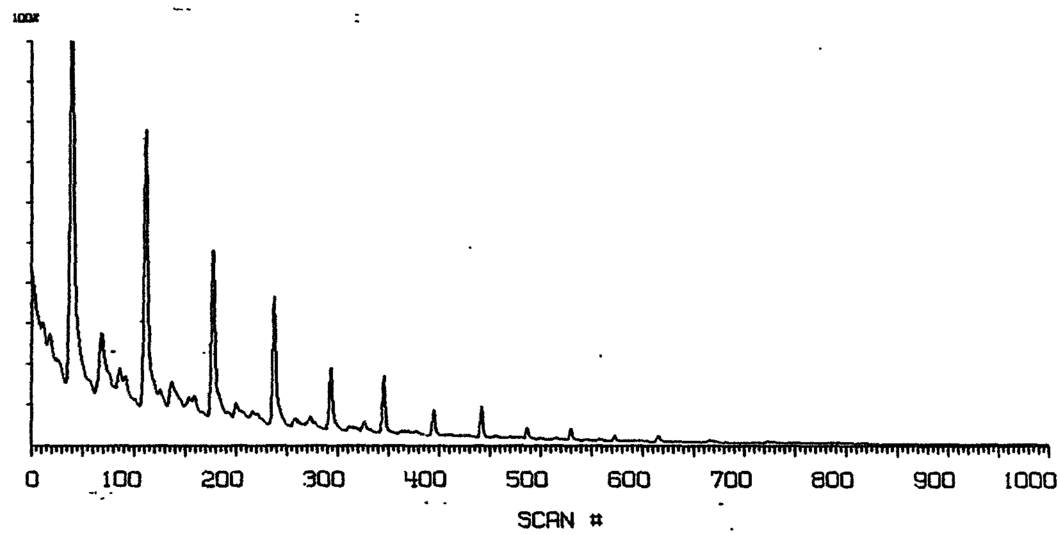
M/E 85 x 1 4 ION MID DATA



K 715 (4105) MASSPEC ANALYTICAL

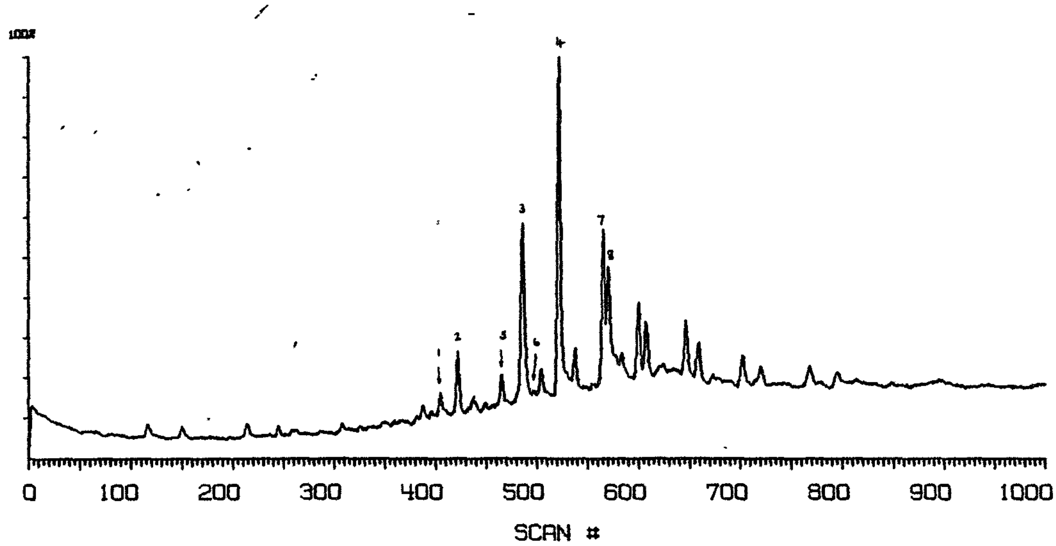
M/E 85 x 1 4 ION MID DATA

N-ALKANE # :



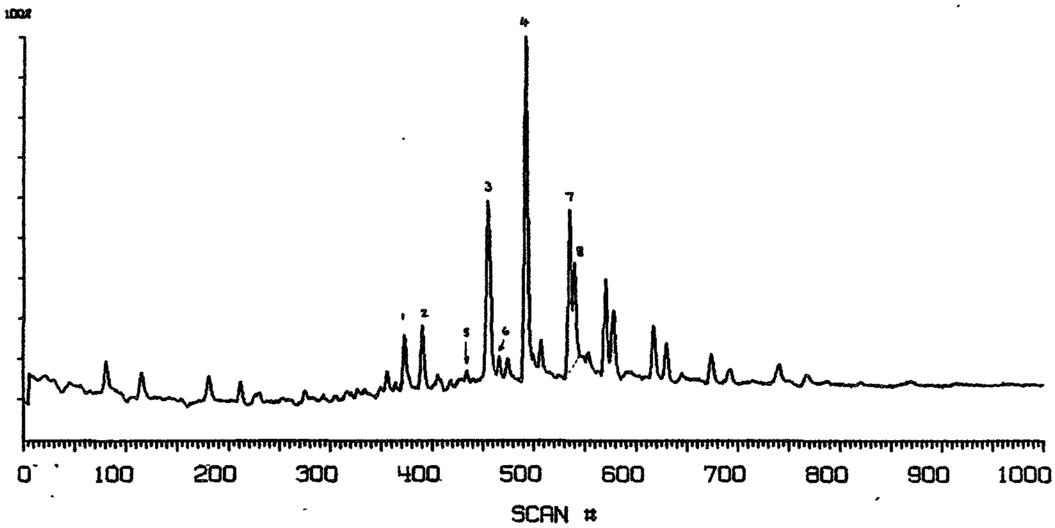
K 1337 (4095) MASSPEC ANALYTICAL

M/E 191 x 15 4 ION MID DATA



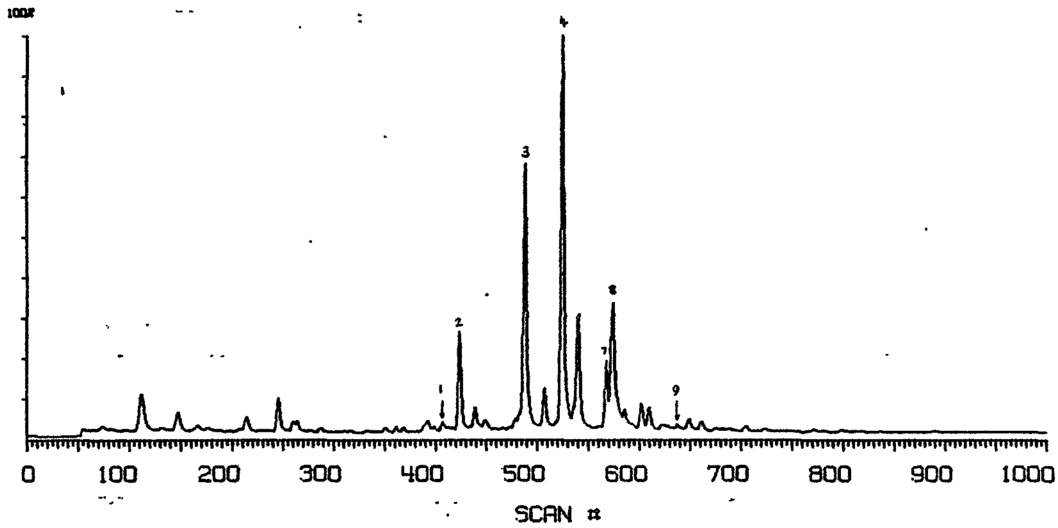
K 1338 (4096) MASSPEC ANALYTICAL

M/E 191 x 23 4 ION MID DATA



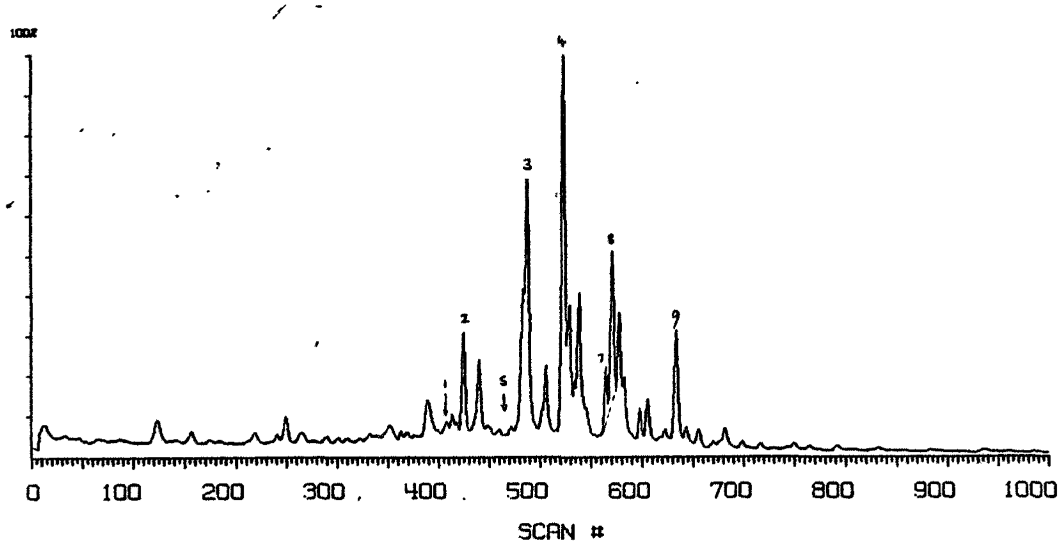
K 648 (4099) MASSPEC ANALYTICAL

M/E 191 x 1 FOR 648 READ 731. 4 ION MID DATA



K 749 (4094) MASSPEC ANALYTICAL

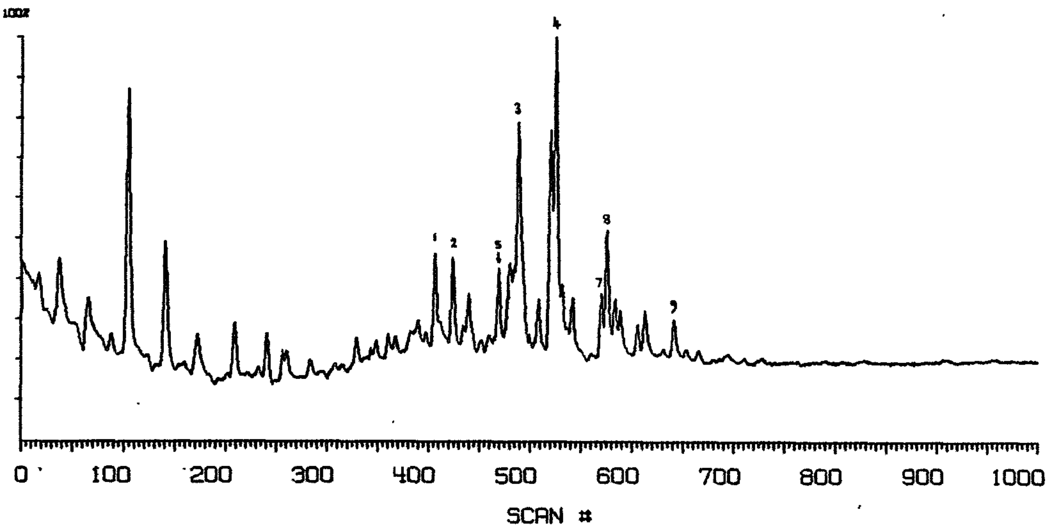
M/E 191 x 1 4 ION MID DATA



K 706 (4103) MASSPEC ANALYTICAL

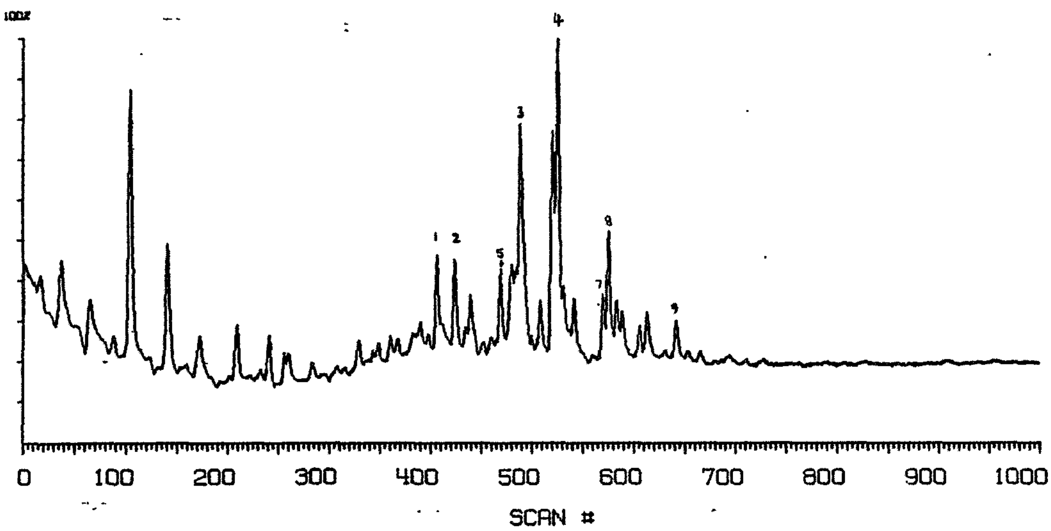
M/E 191 x 25 4 ION MID DATA

N-ALKANE # :



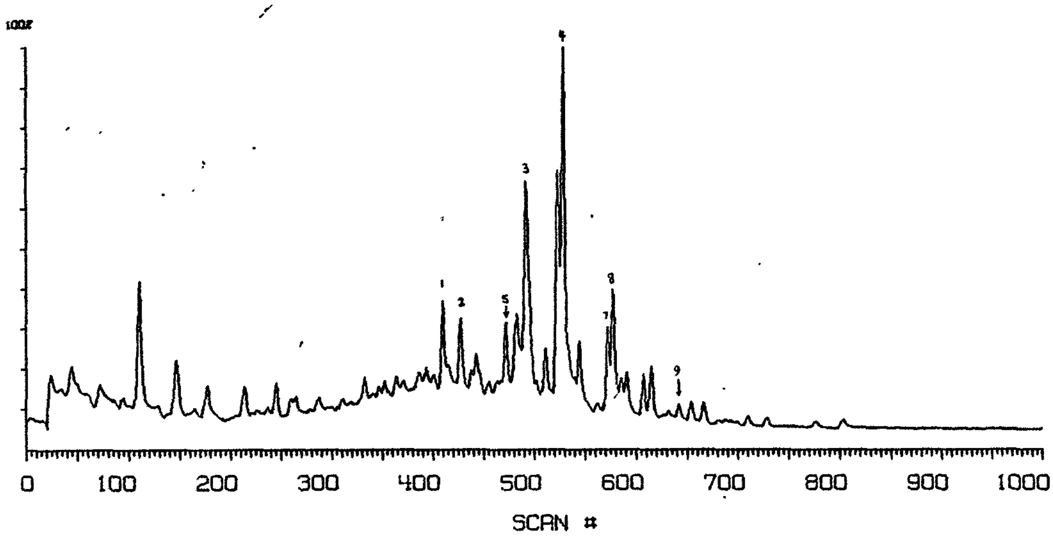
K 706 (4103) MASSPEC ANALYTICAL

M/E 191 x 25 4 ION MID DATA



K 713 (4104) MASSPEC ANALYTICAL

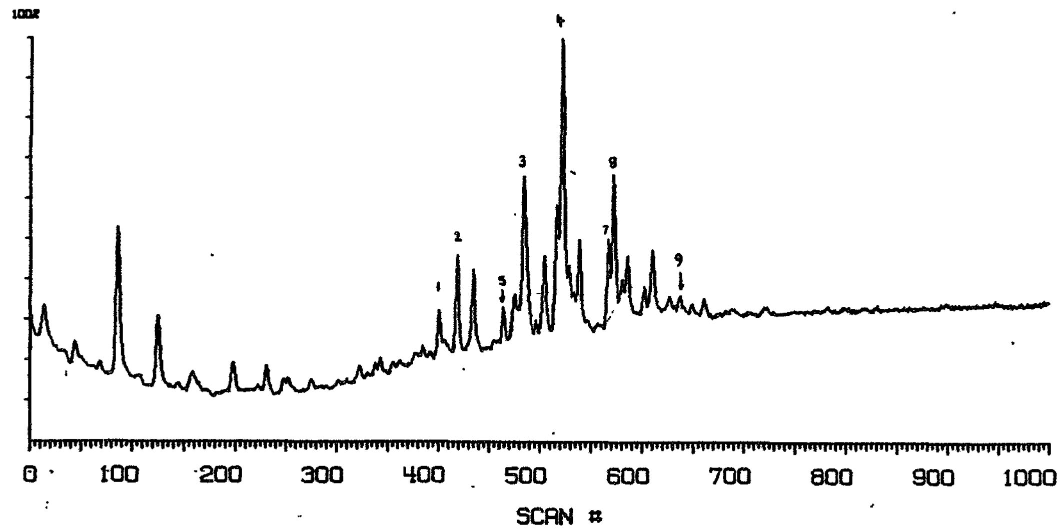
M/E 191 x 6 4 ION MID DATA



K 715 (4105) MASSPEC ANALYTICAL

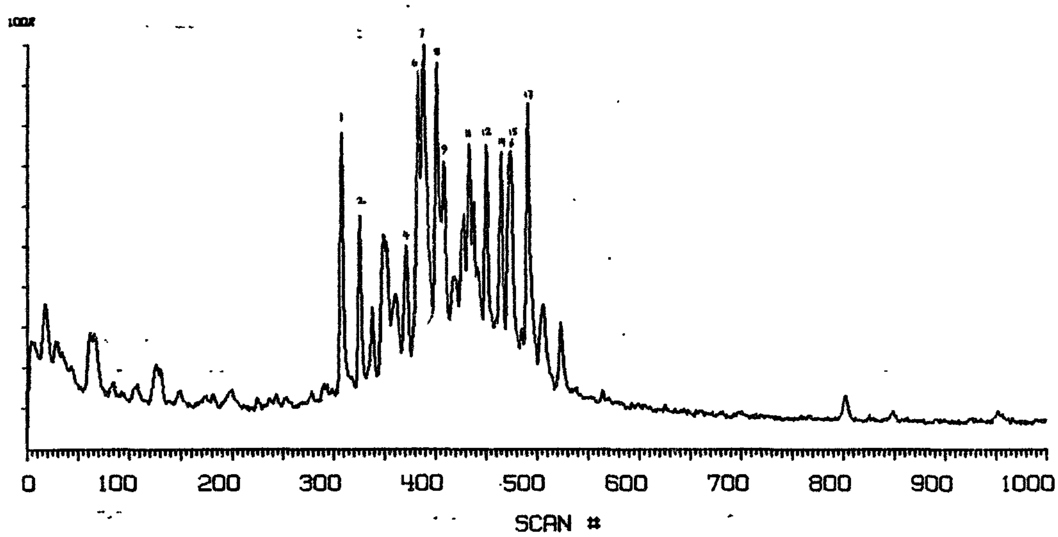
M/E 191 x 38 4 ION MID DATA

N-ALKANE # :



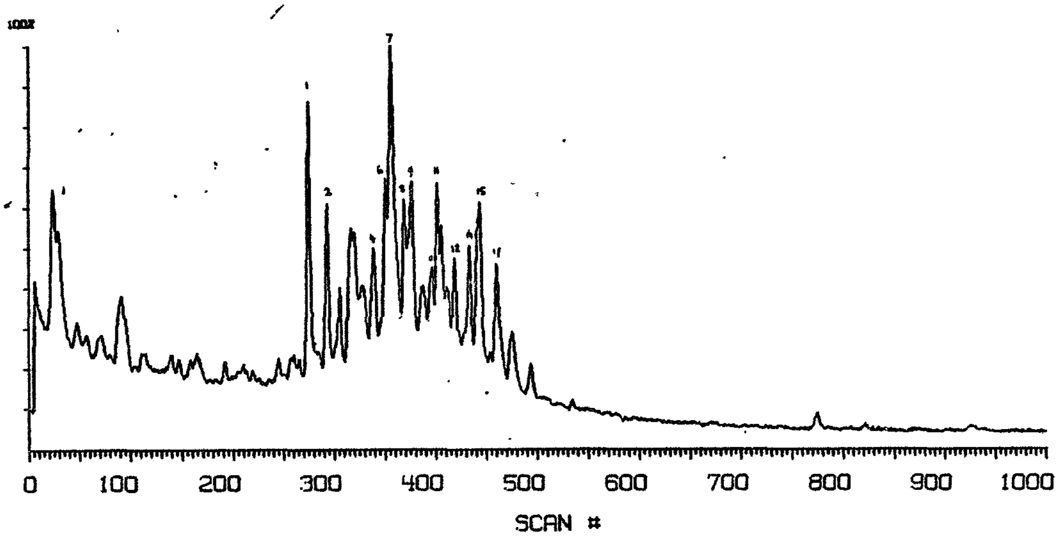
K 1337 (4095) MASSPEC ANALYTICAL

M/E 217 x 63 4 ION MID DATA



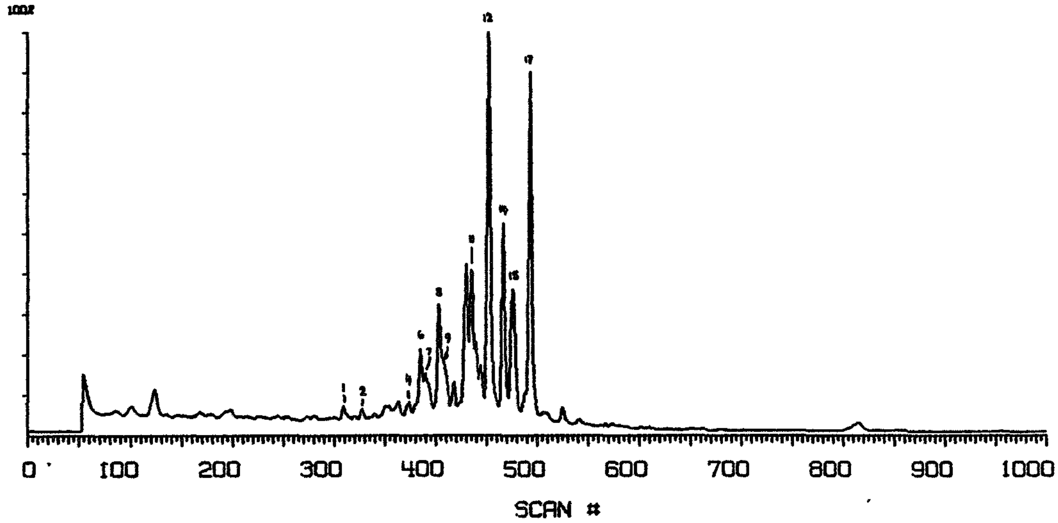
K 1338 (4096) MASSPEC ANALYTICAL

M/E 217 x 76 4 ION MID DATA



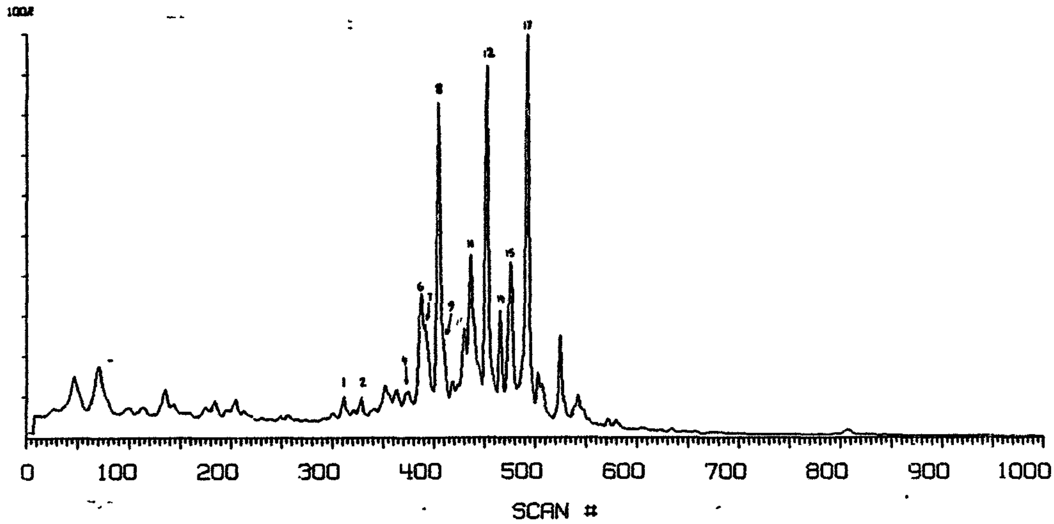
K 648 (4099) MASSPEC ANALYTICAL

M/E 217 x 6 FOR 648 READ 731. 4 ION MID DATA



K 749 (4094) MASSPEC ANALYTICAL

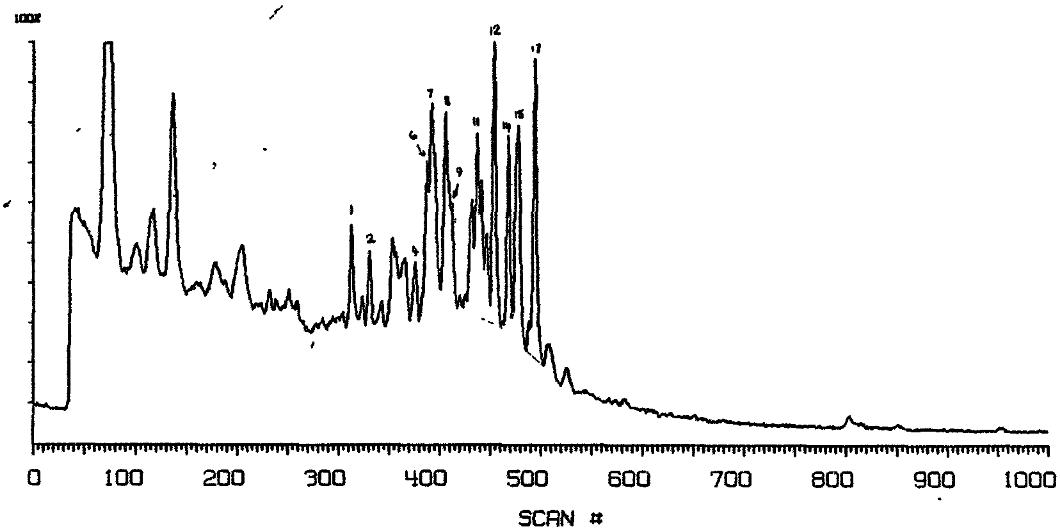
M/E 217 x 3 4 ION MID DATA



K 760 (4093) MASSPEC ANALYTICAL

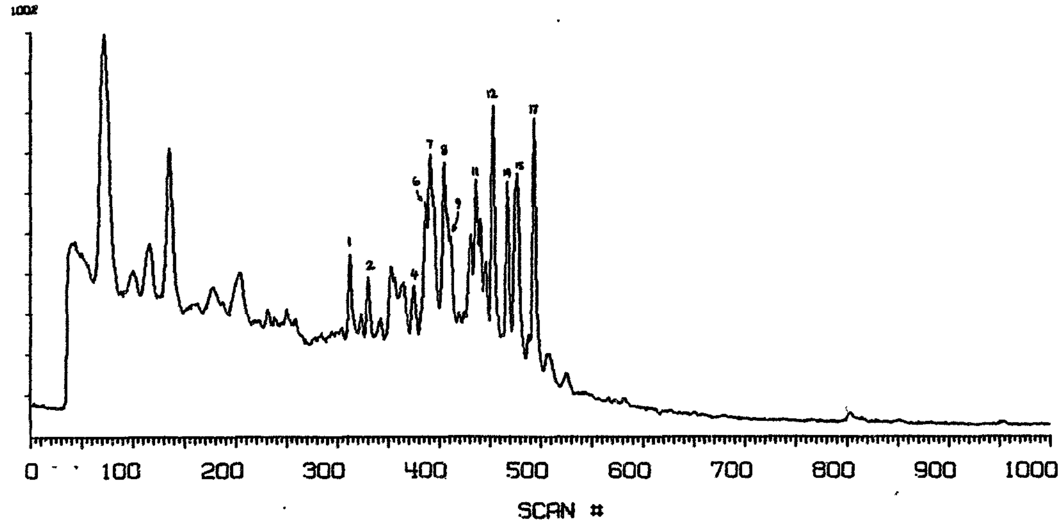
M/E 217 x 46 4 ION MID DATA

N-ALKANE # :



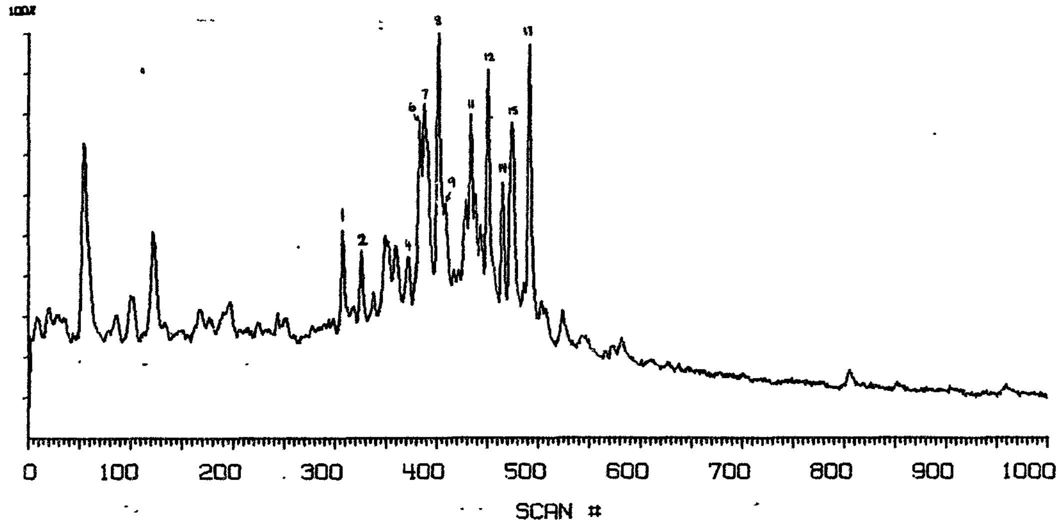
K 760 (4093)　　MASSPEC ANALYTICAL

M/E 217 x 38　　4 ION MID DATA



K 769 (4098)　　MASSPEC ANALYTICAL

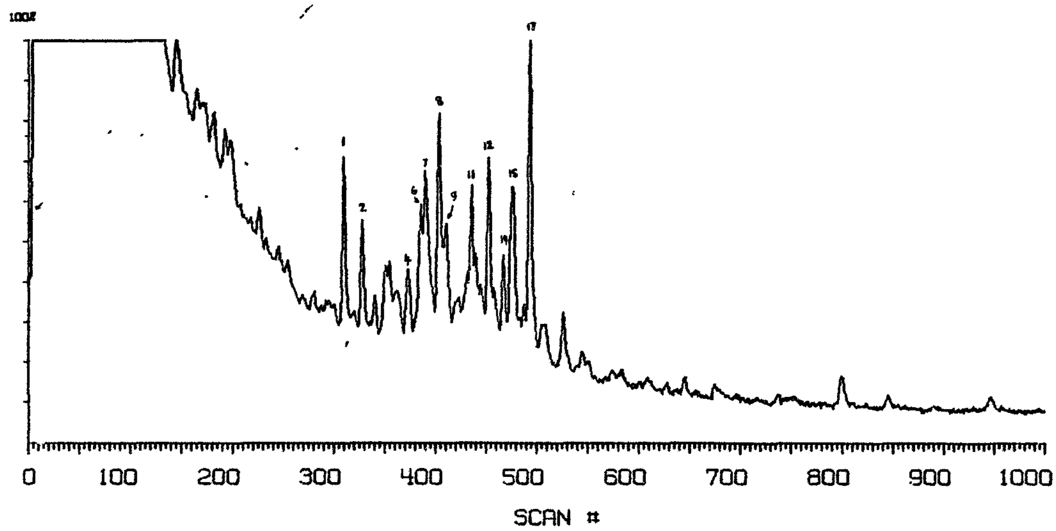
M/E 217 x 40　　4 ION MID DATA



K 1042 (4100)　　MASSPEC ANALYTICAL

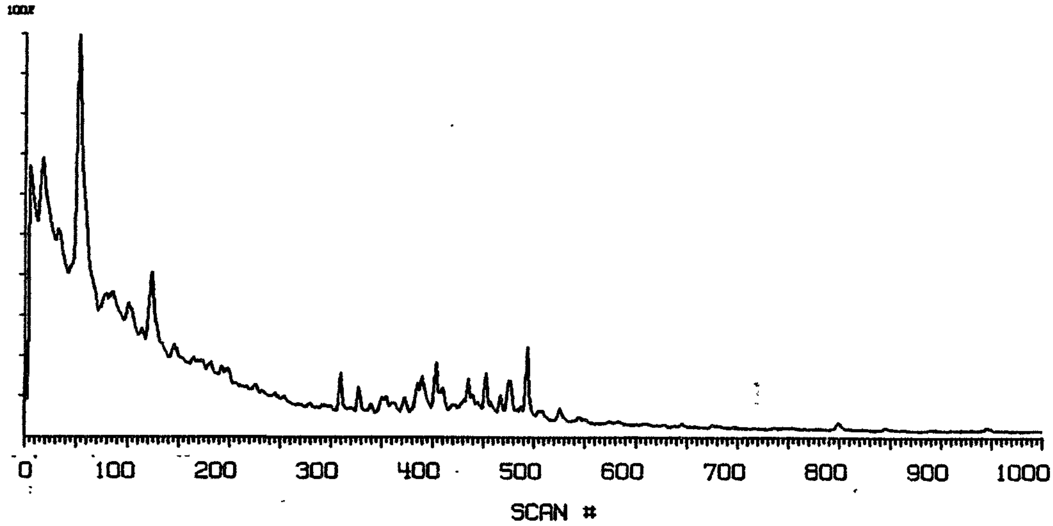
M/E 217 x 128　　4 ION MID DATA

N-ALKANE # :



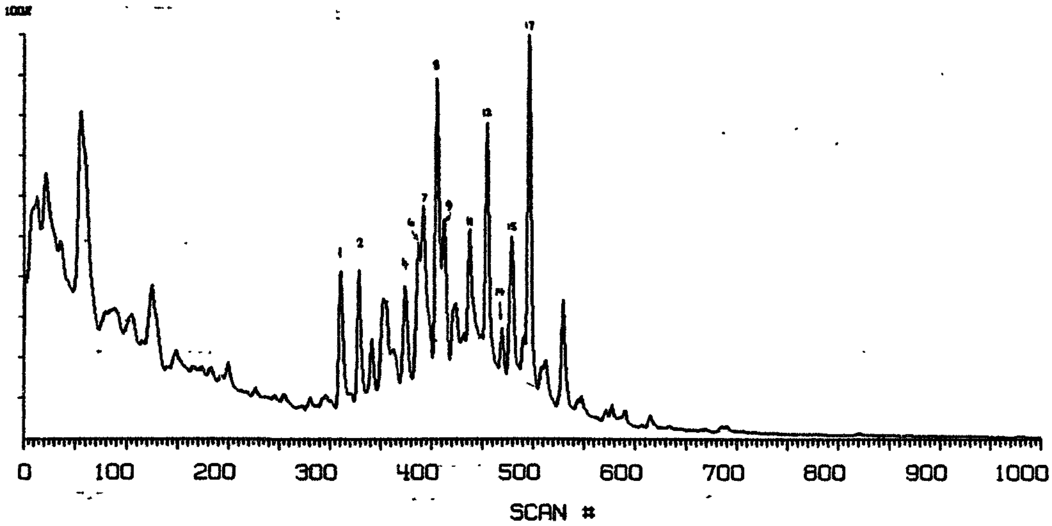
K 1042 (4100) MASSPEC ANALYTICAL

M/E 217 x 29 4 ION MID DATA



K 1045 (4102) MASSPEC ANALYTICAL

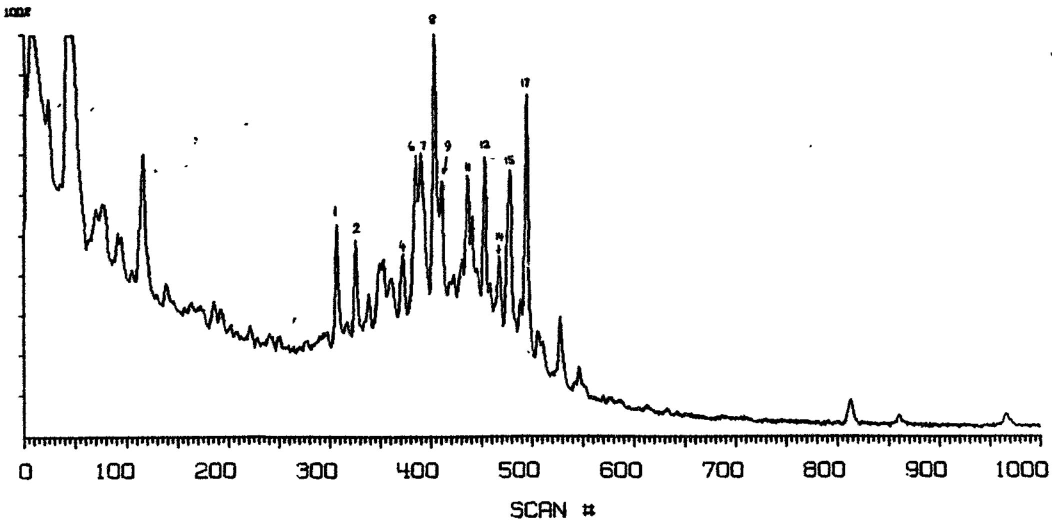
M/E 217 x 14 4 ION MID DATA



K 706 (4103) MASSPEC ANALYTICAL

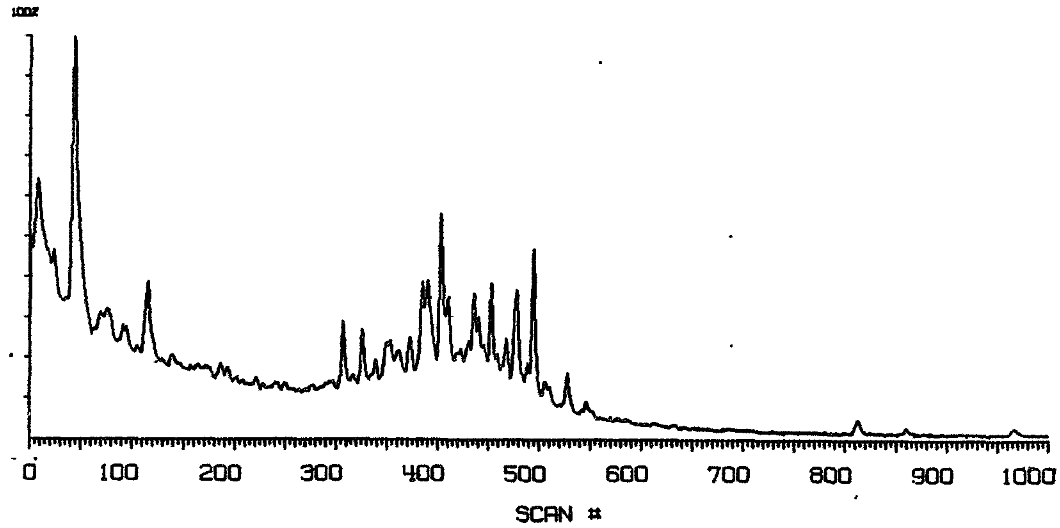
M/E 217 x 103 4 ION MID DATA

N-ALKANE # :



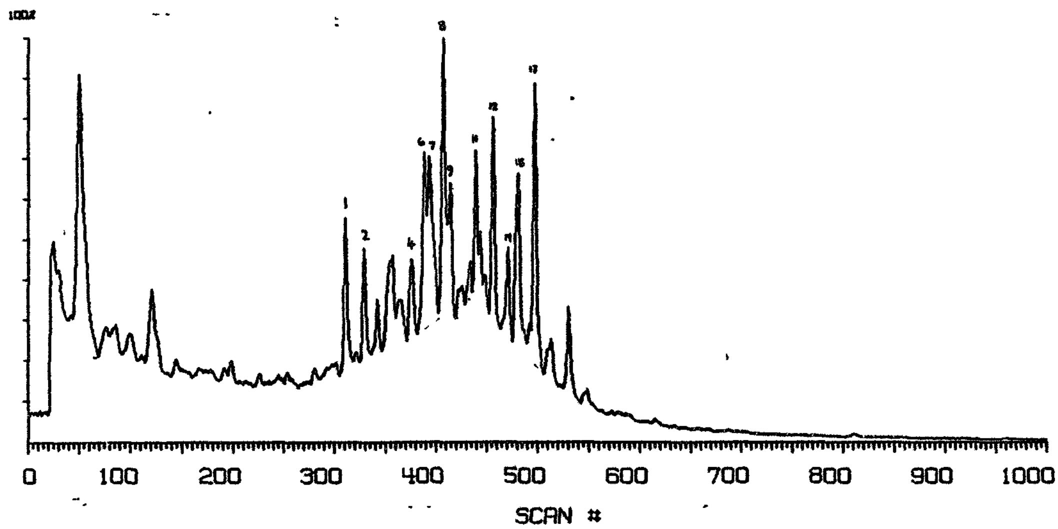
K 706 (4103) MASSPEC ANALYTICAL

M/E 217 x 58 4 ION MID DATA



K 713 (4104) MASSPEC ANALYTICAL

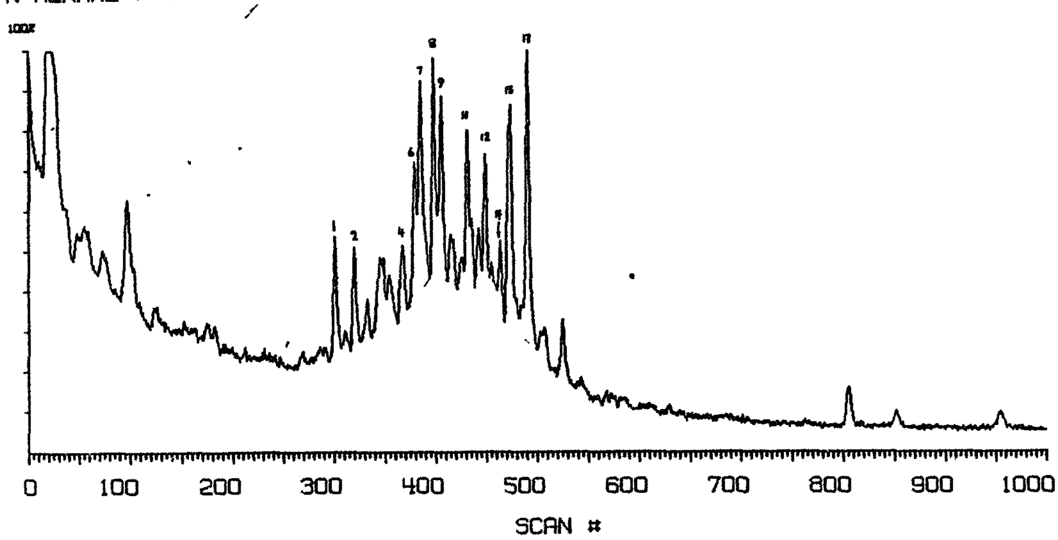
M/E 217 x 26 4 ION MID DATA



K 715 (4105) MASSPEC ANALYTICAL

M/E 217 x 220 4 ION MID DATA

N-ALKANE # :

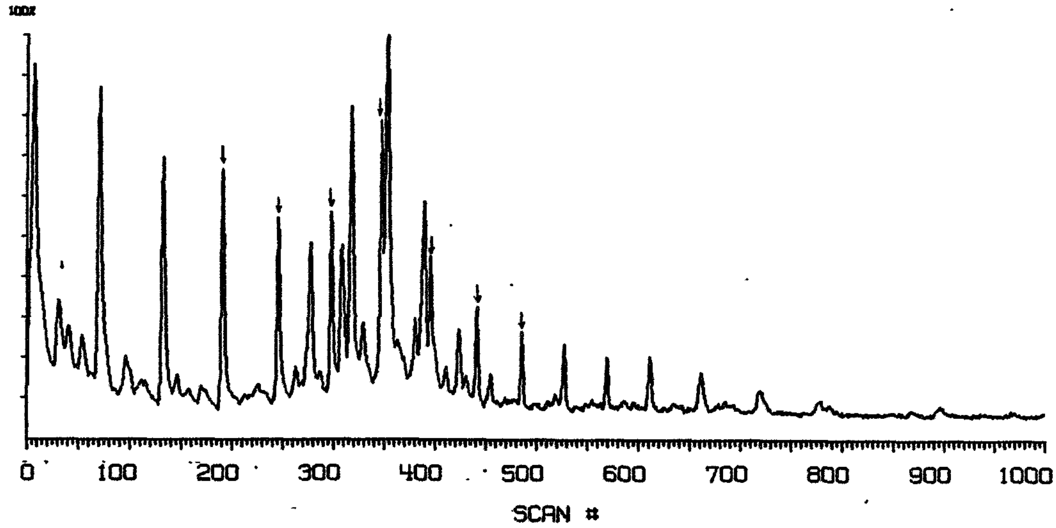


K 1337 (4095)

M/E 253 x 75

MASSPEC ANALYTICAL

4 ION MID DATA

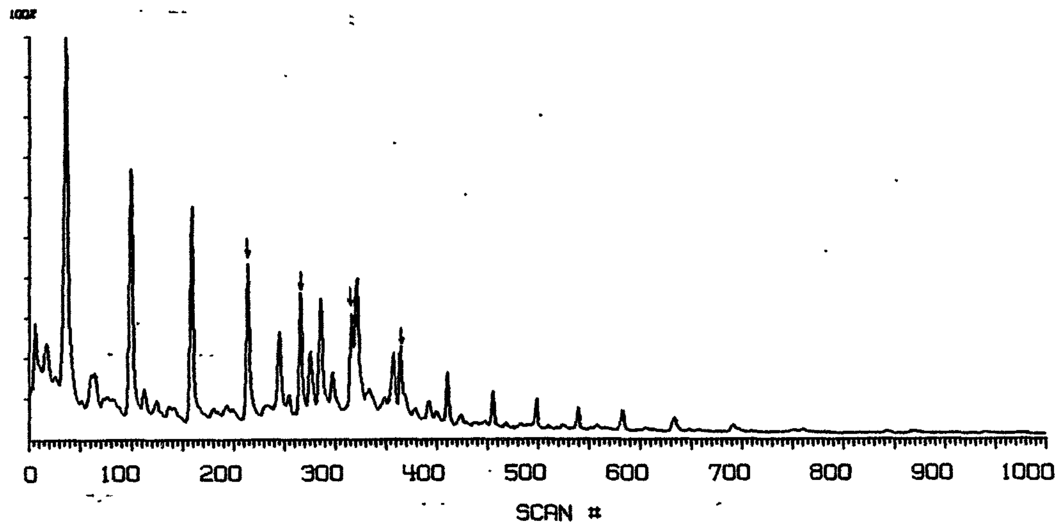


K 1338 (4096)

M/E 253 x 32

MASSPEC ANALYTICAL

4 ION MID DATA

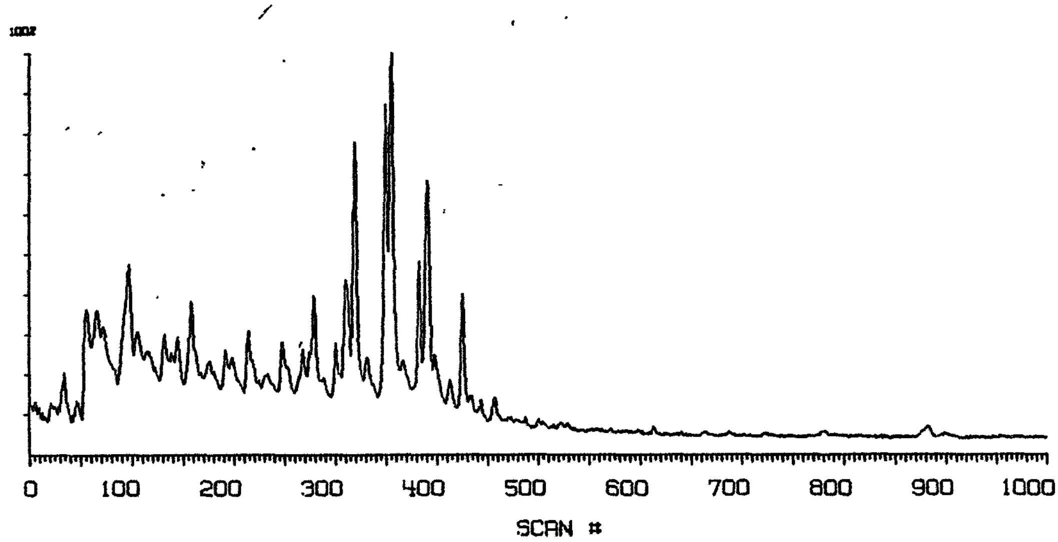


K 648 (4099)

M/E 253 x 37 FOR 648 READ 731.

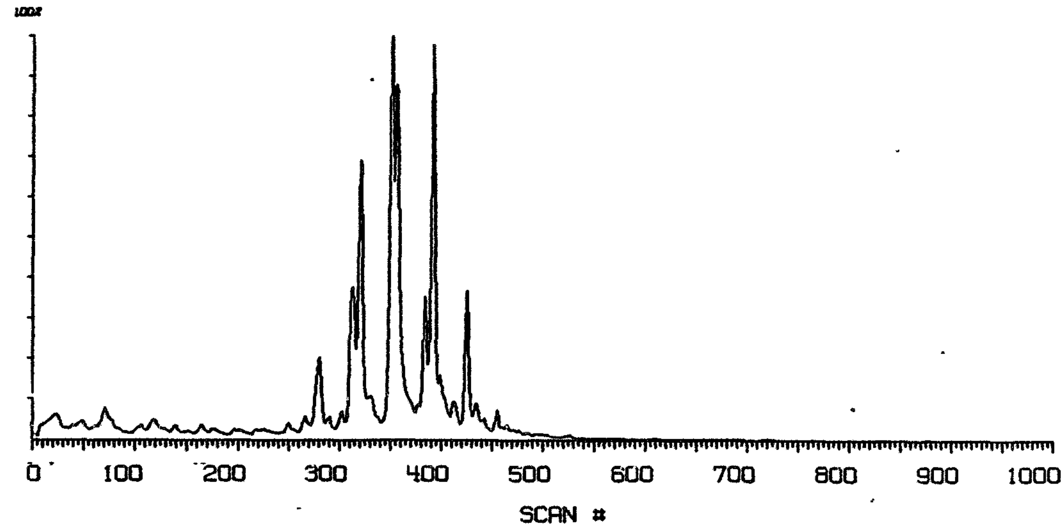
MASSPEC ANALYTICAL

4 ION MID DATA



K 749 (4094) MASSPEC ANALYTICAL

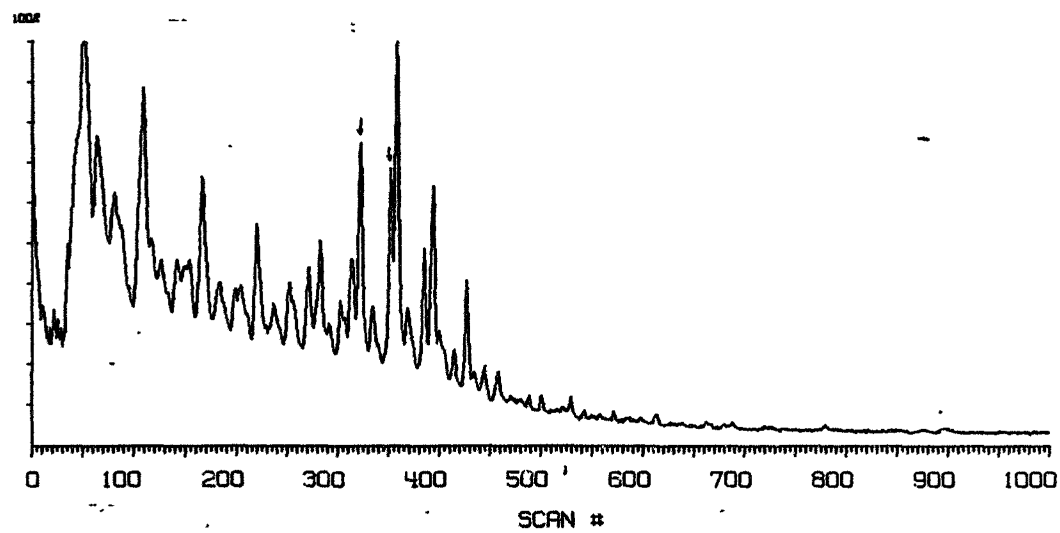
M/E 253 x 2 4 ION MID DATA



K 760 (4093) MASSPEC ANALYTICAL

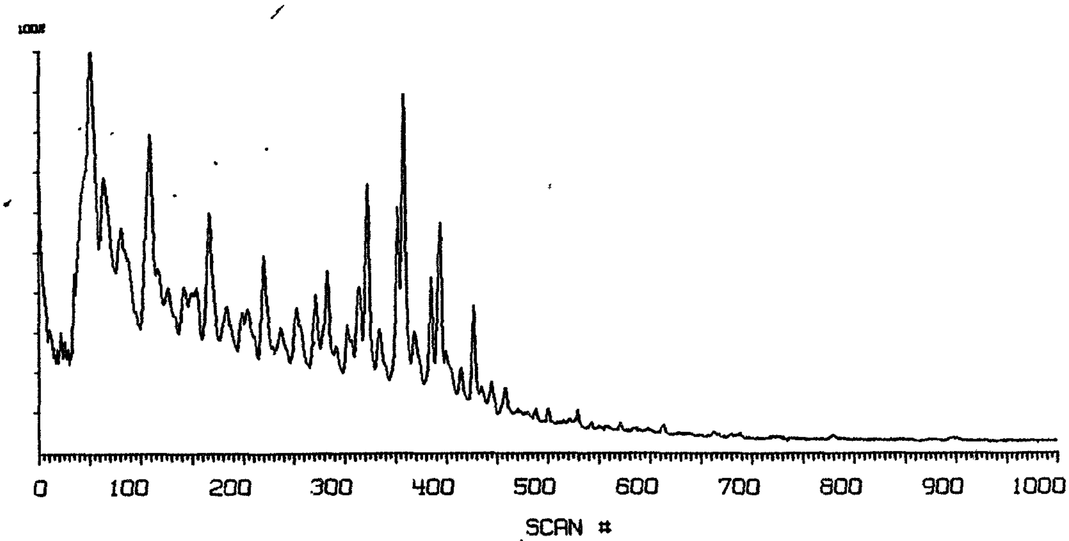
M/E 253 x 65 4 ION MID DATA

N-ALKANE # :



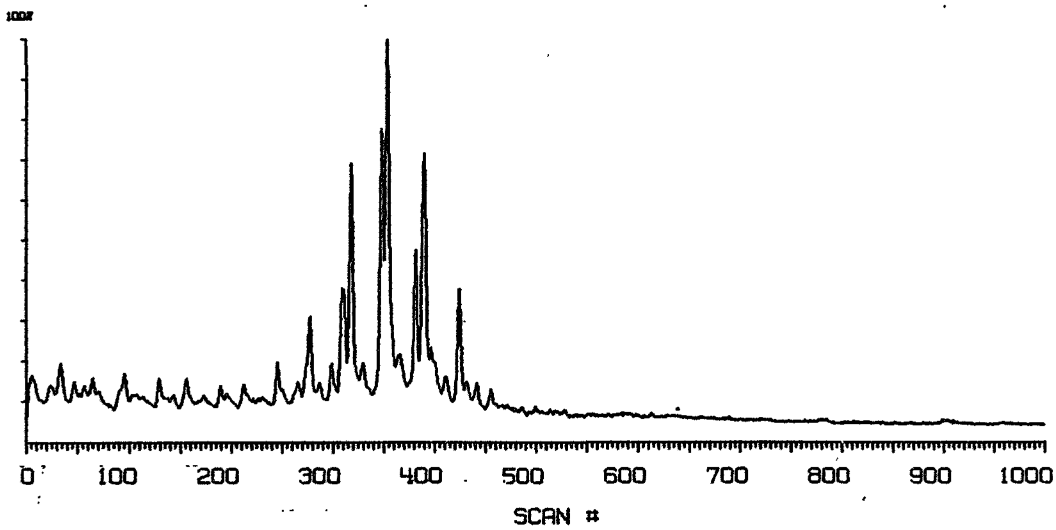
K 760 (4093) MASSPEC ANALYTICAL

M/E 253 x 58 4 ION MID DATA



K 769 (4098) MASSPEC ANALYTICAL

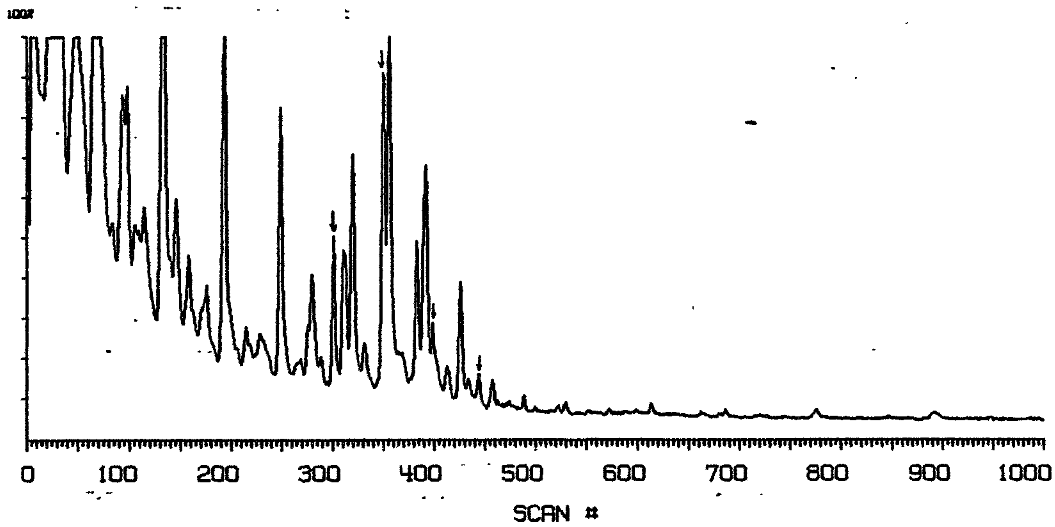
M/E 253 x 23 4 ION MID DATA



K 1042 (4100) MASSPEC ANALYTICAL

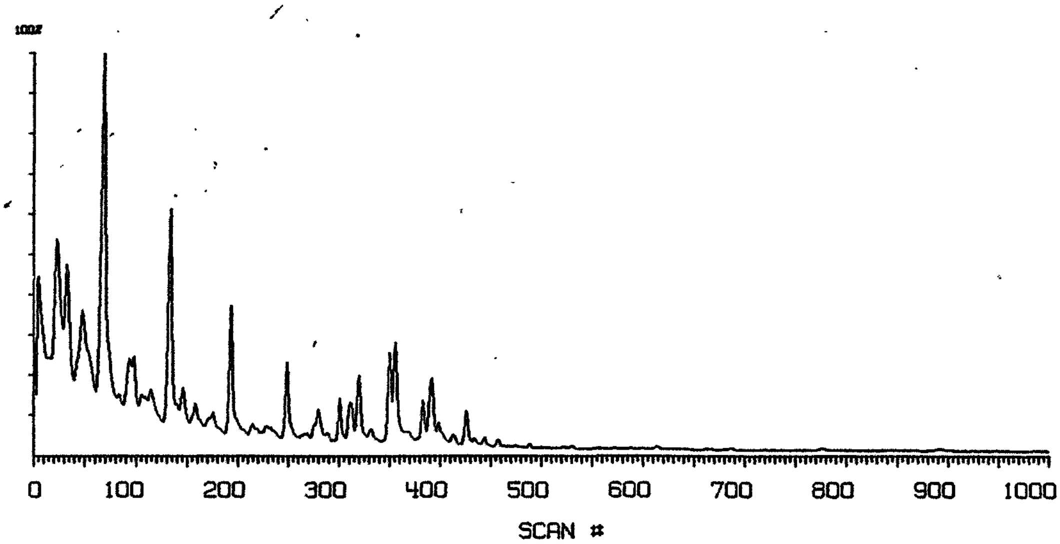
M/E 253 x 79 4 ION MID DATA

N-ALKANE # :



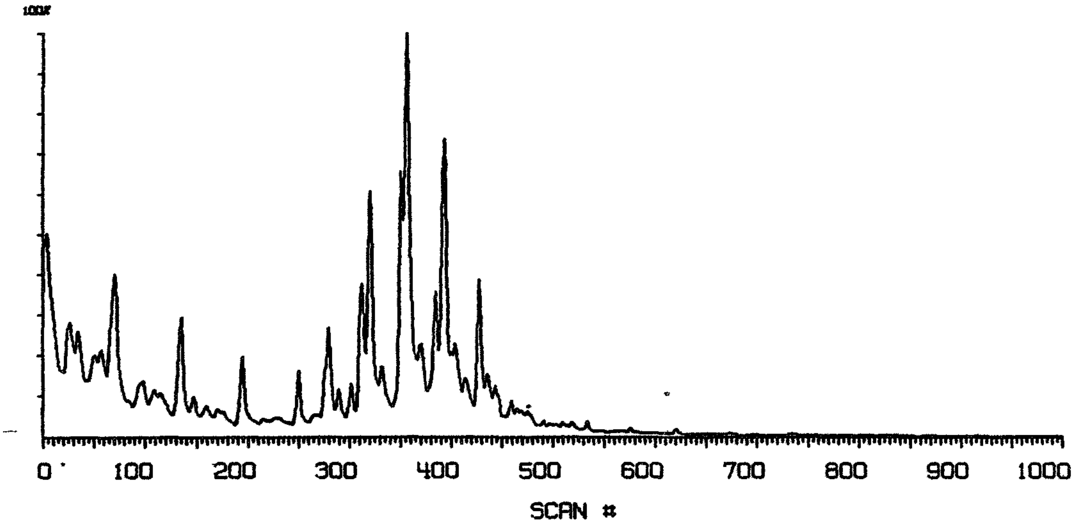
K 1042 (4100) MASSPEC ANALYTICAL

M/E 253 x 23 4 ION MID DATA



K 1045 (4102) MASSPEC ANALYTICAL

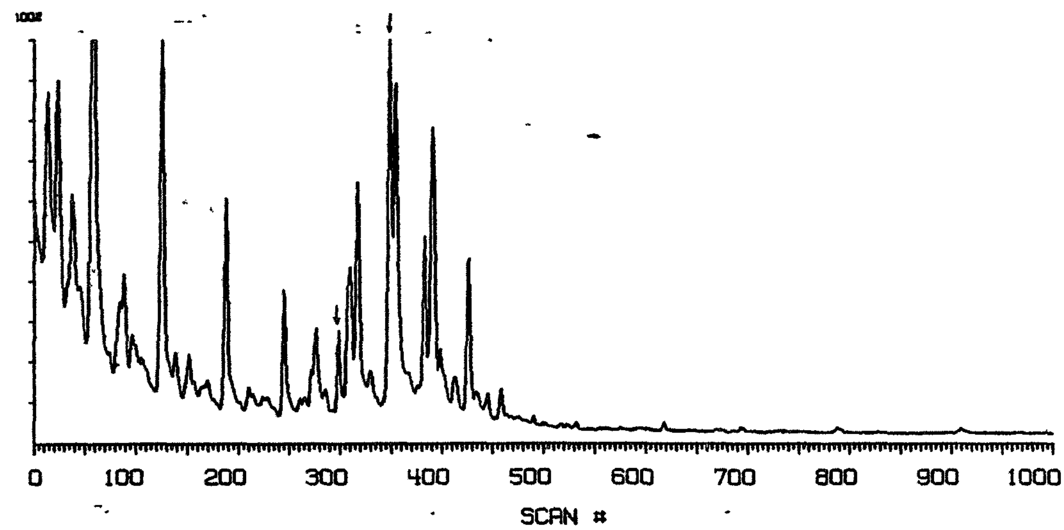
M/E 253 x 6 4 ION MID DATA



K 706 (4103) MASSPEC ANALYTICAL

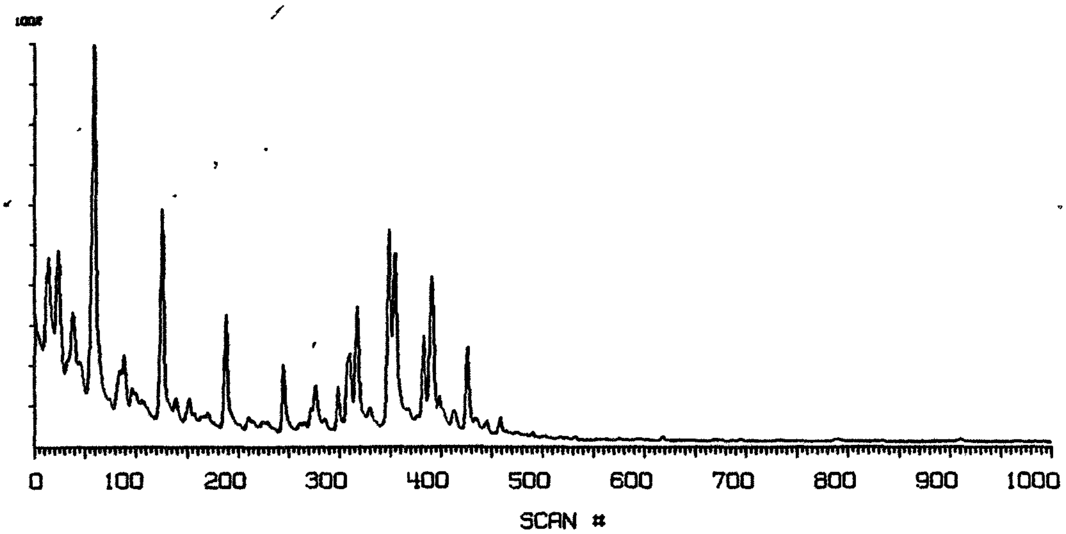
M/E 253 x 47 4 ION MID DATA

N-ALKANE



K 706 (4103) MASSPEC ANALYTICAL

M/E 253 x 26 4 ION MID DATA

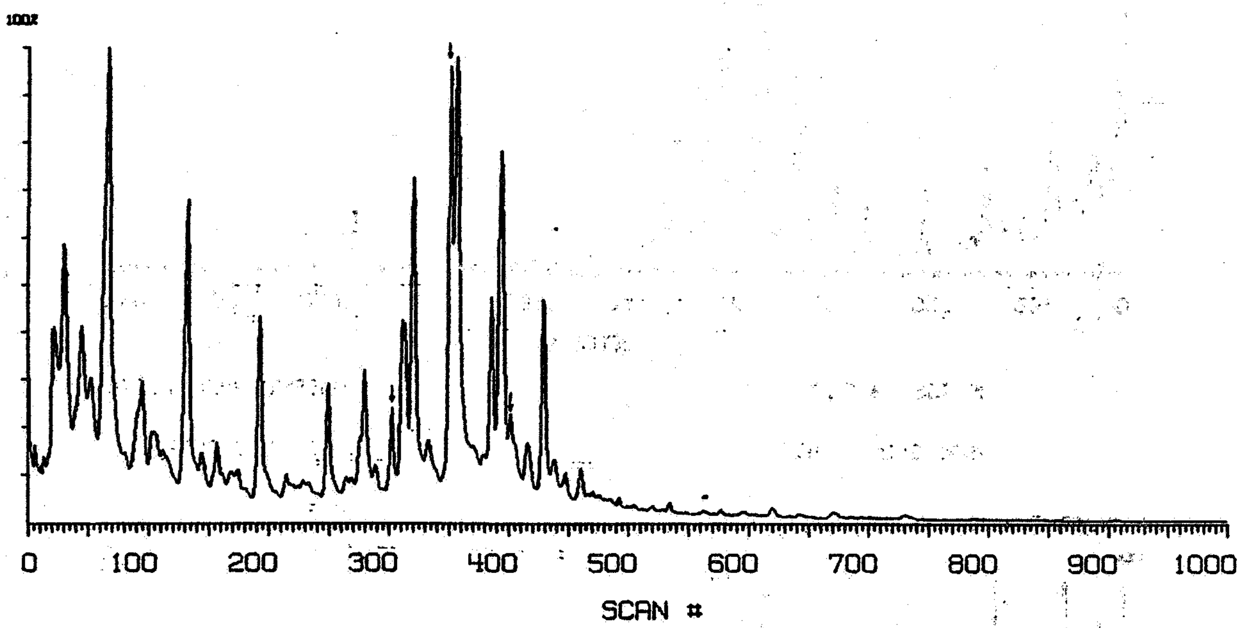


K 713 (4104)

MASSPEC ANALYTICAL

M/E 253 x 15

4 ION MID DATA



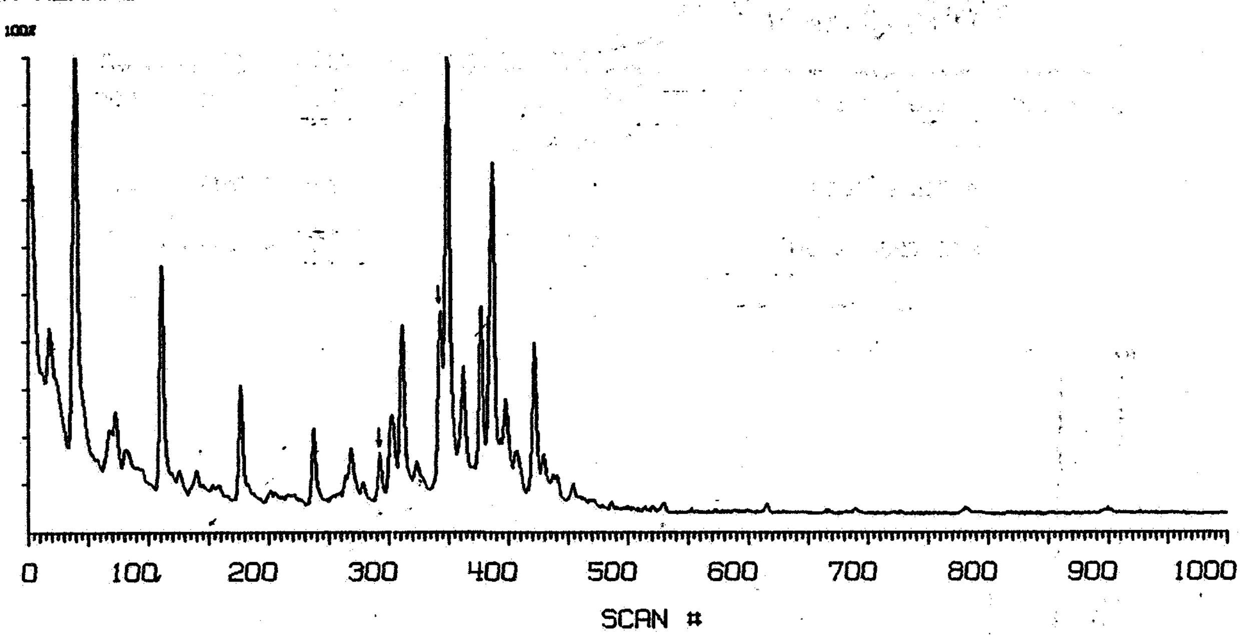
K 715 (4105)

MASSPEC ANALYTICAL

M/E 253 x 63

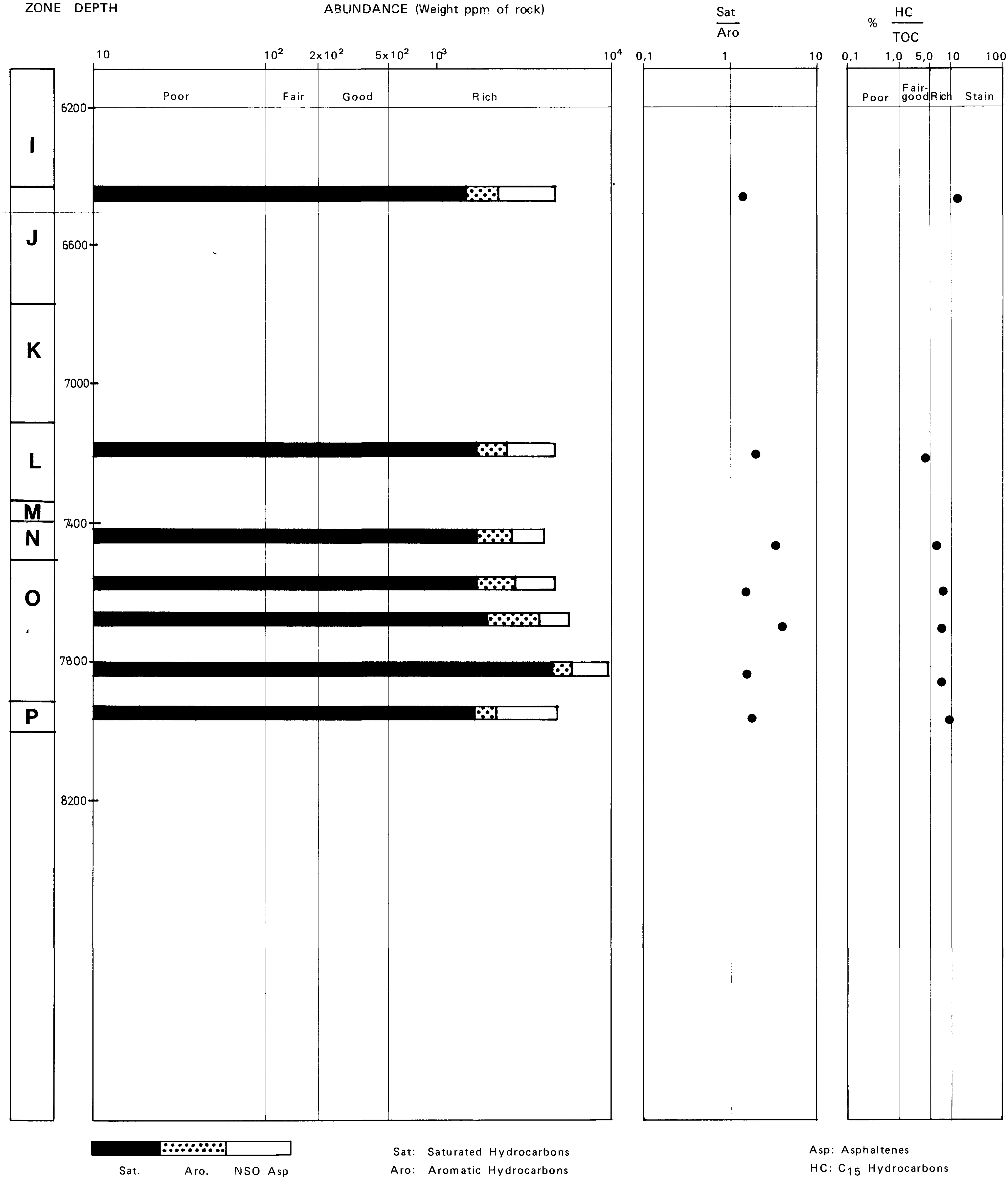
4 ION MID DATA

N-ALKANE # :



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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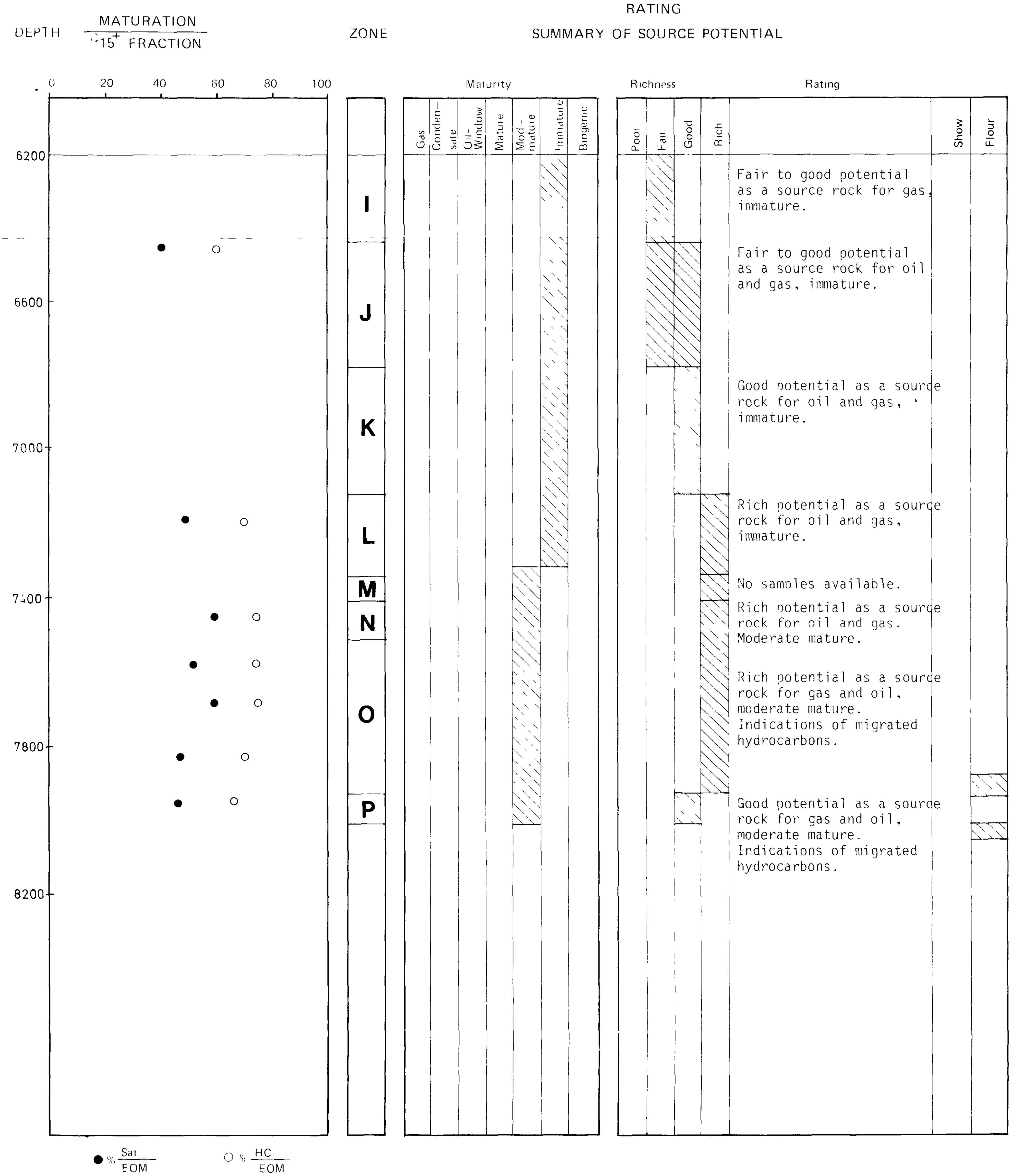
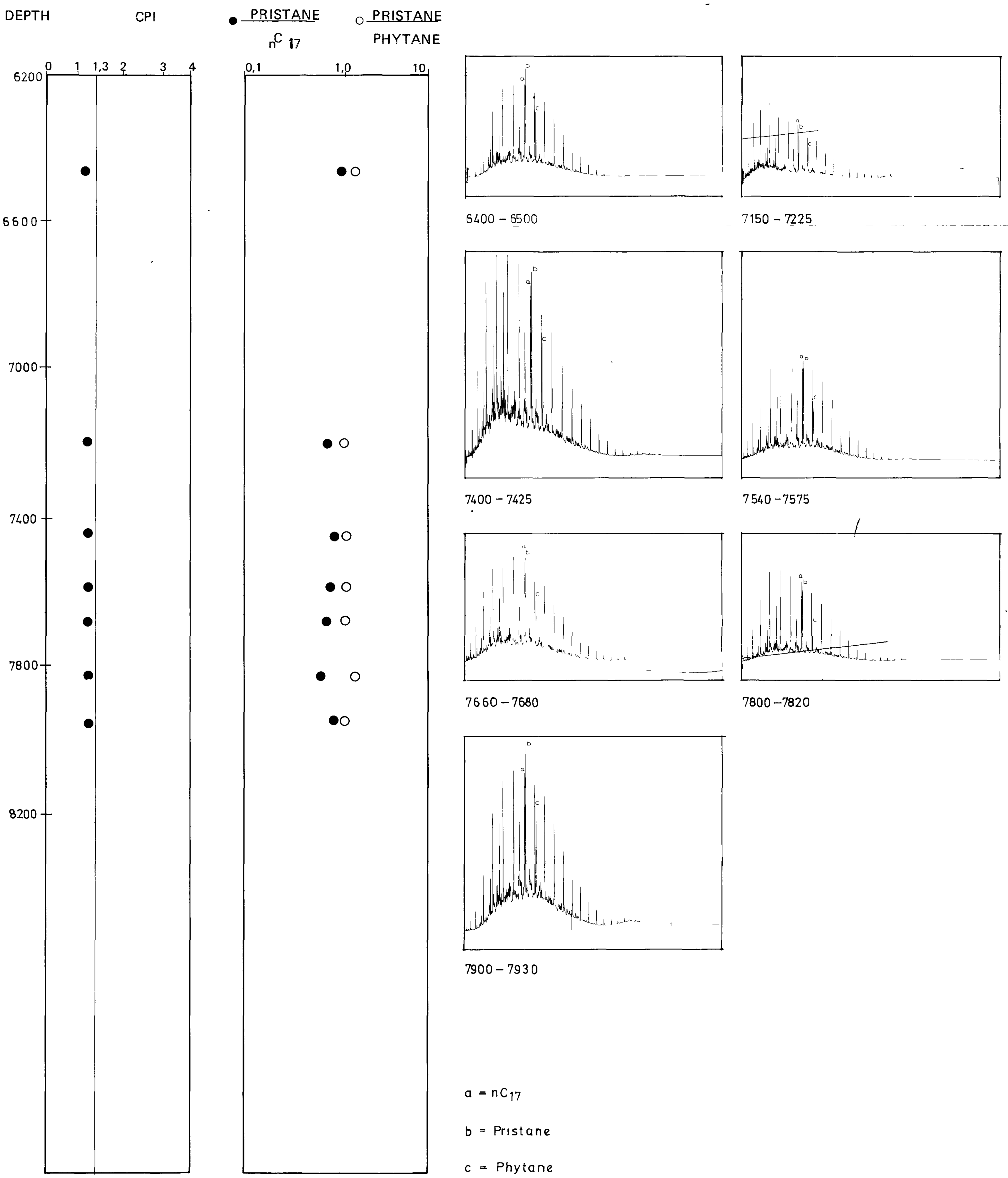
INTERPRETATION DIAGRAM

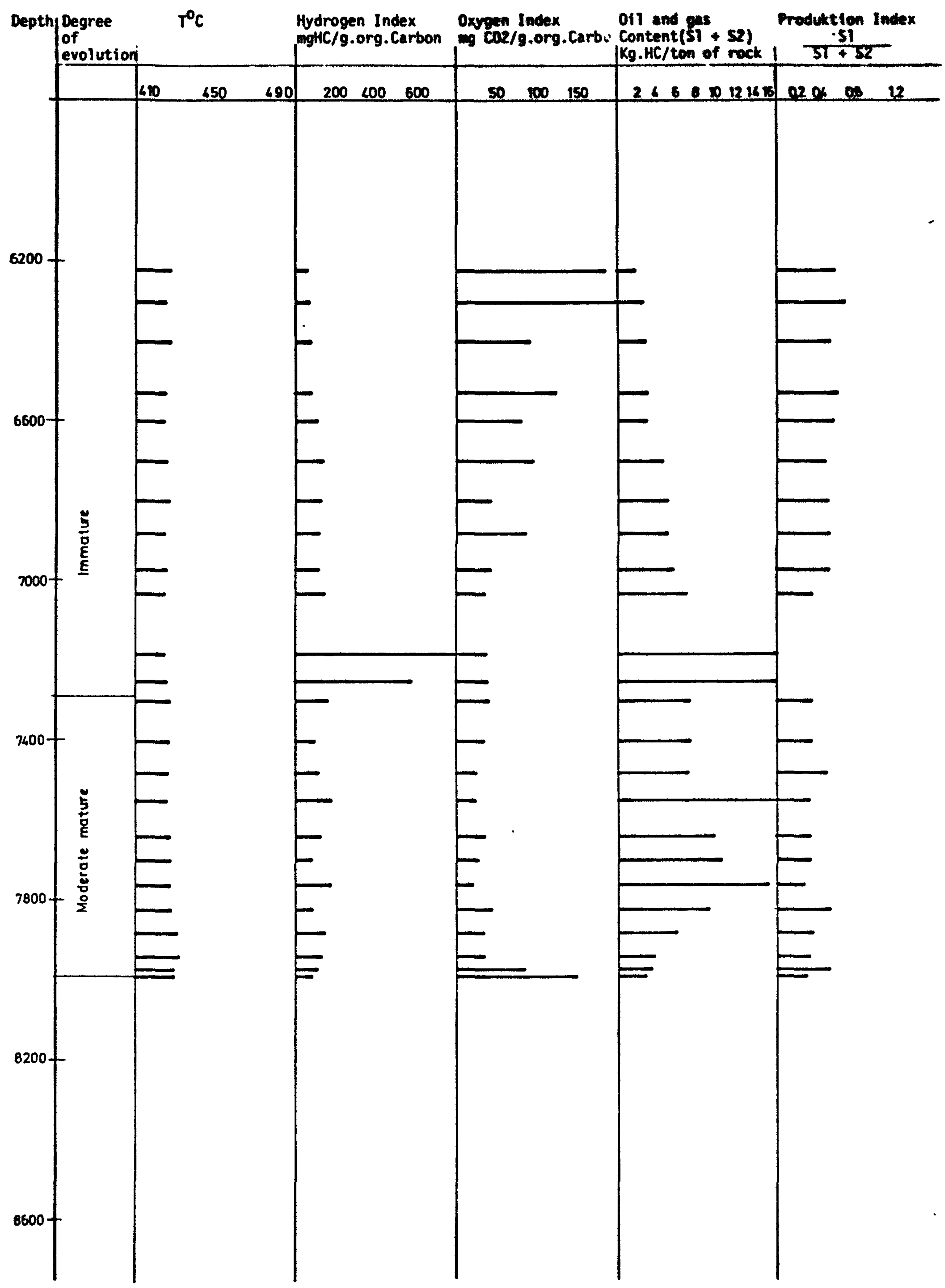


Sat Saturated Hydrocarbons
HC Hydrocarbons
EOM Extractable Organic Matter

C_{15}^{+} SATURATED HYDROCARBONS



ROCK EVAL PYROLYSIS



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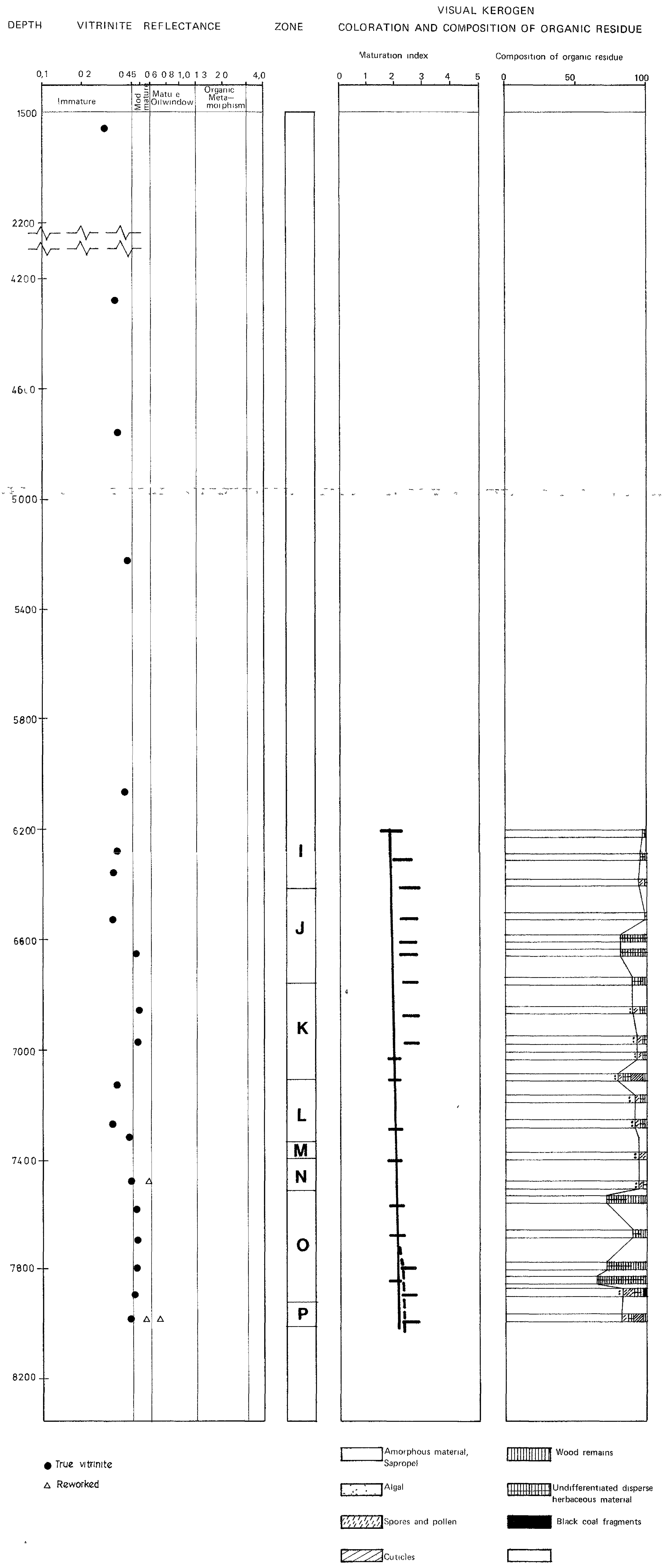
MATURATION



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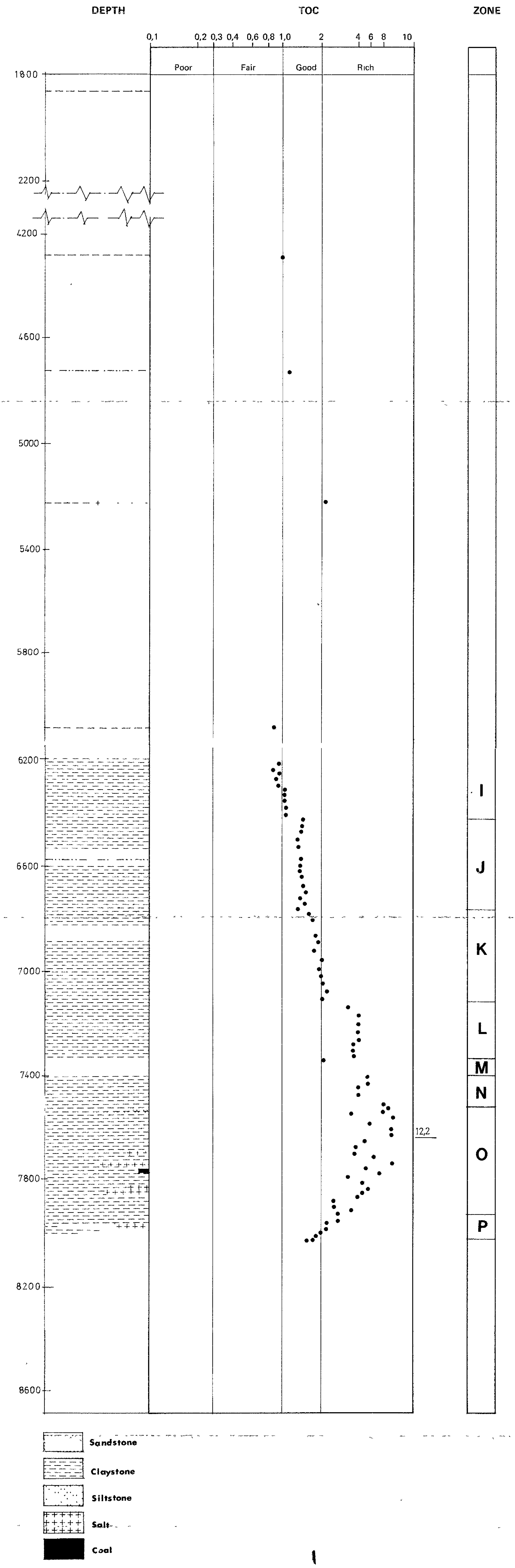
TOTAL ORGANIC CARBON (TOC)

Presentation of Analytical Data



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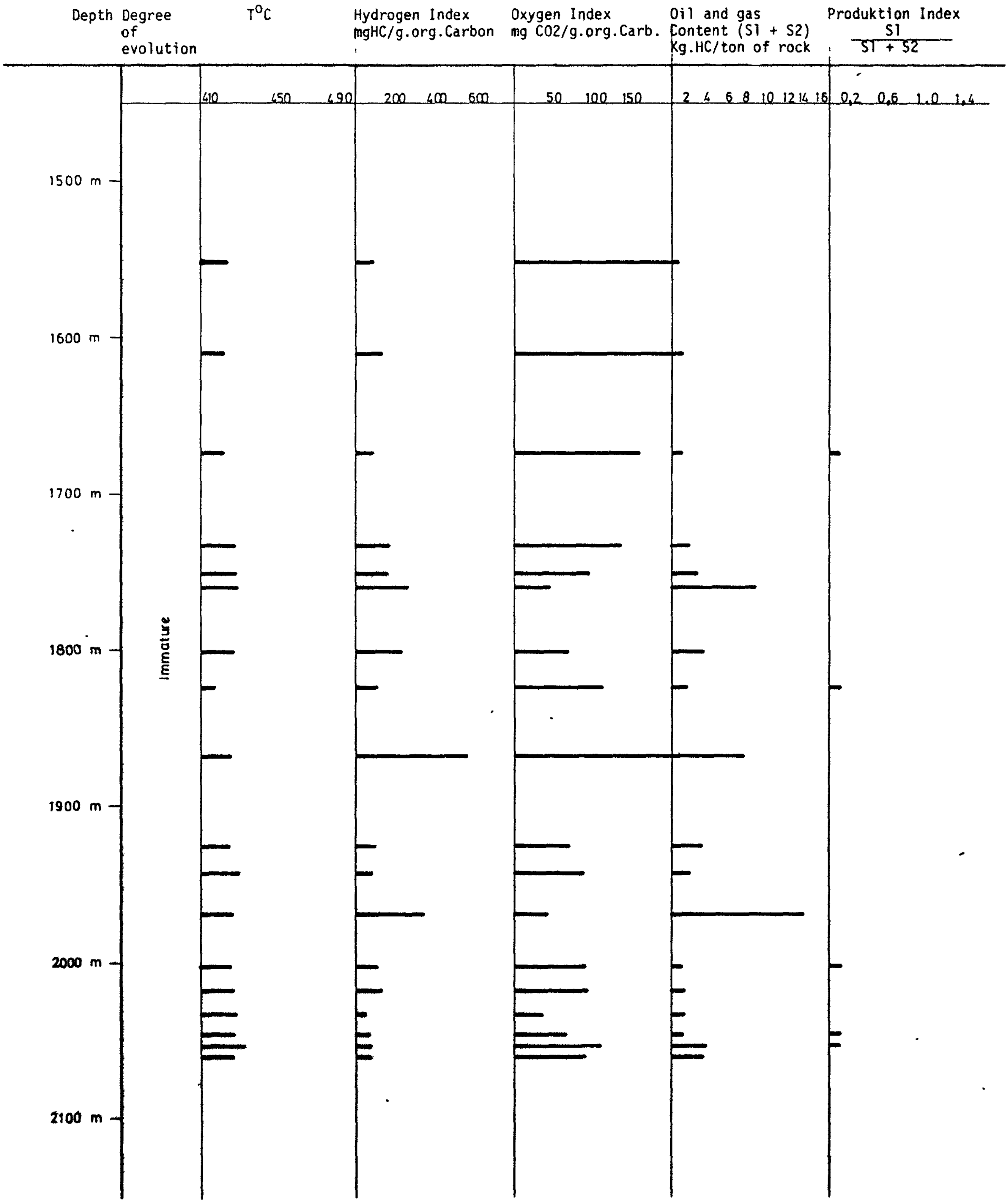
ROCK EVAL. PYROLYSIS



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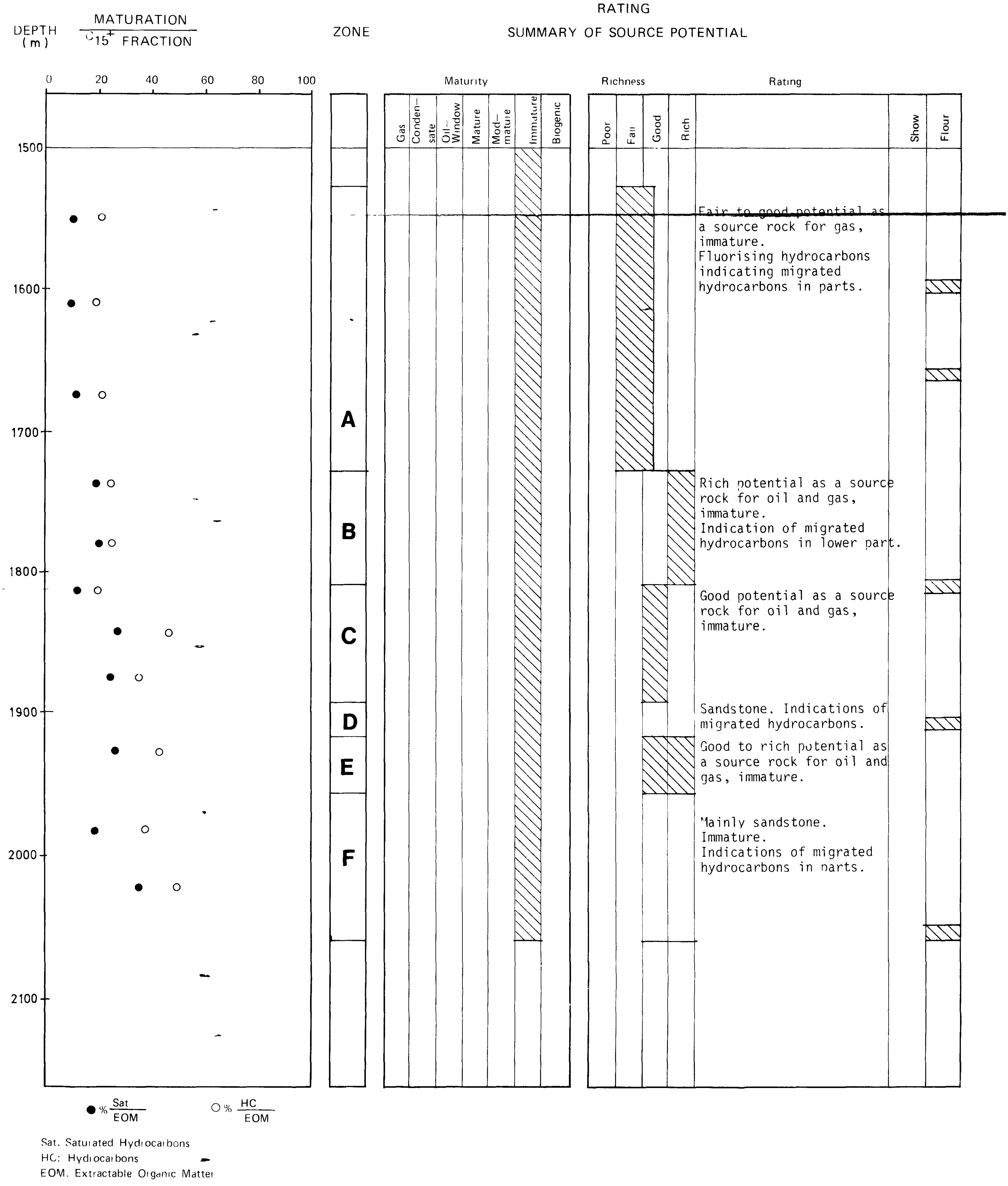
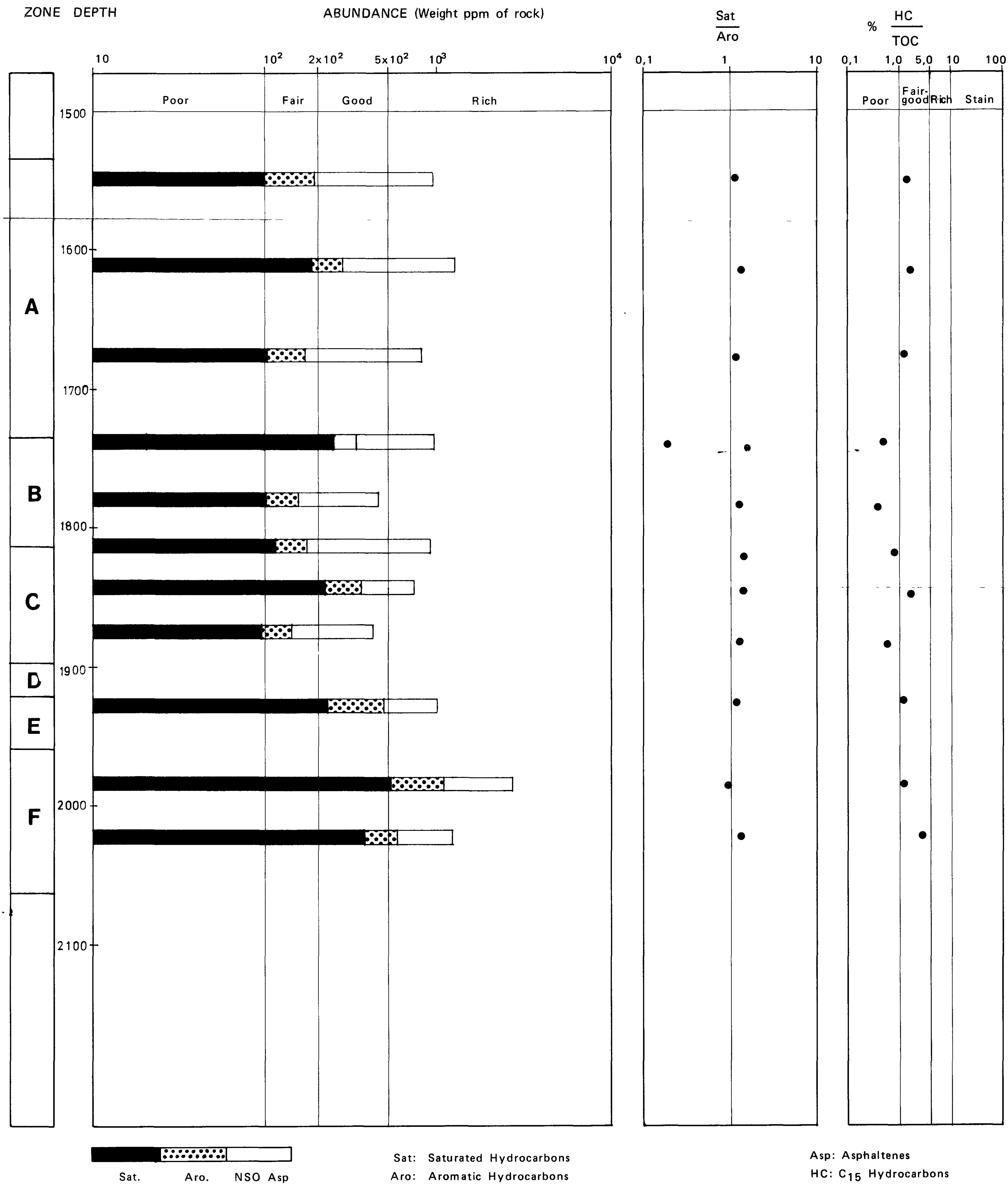
INTERPRETATION DIAGRAM



C_{15}^{+} HYDROCARBONS

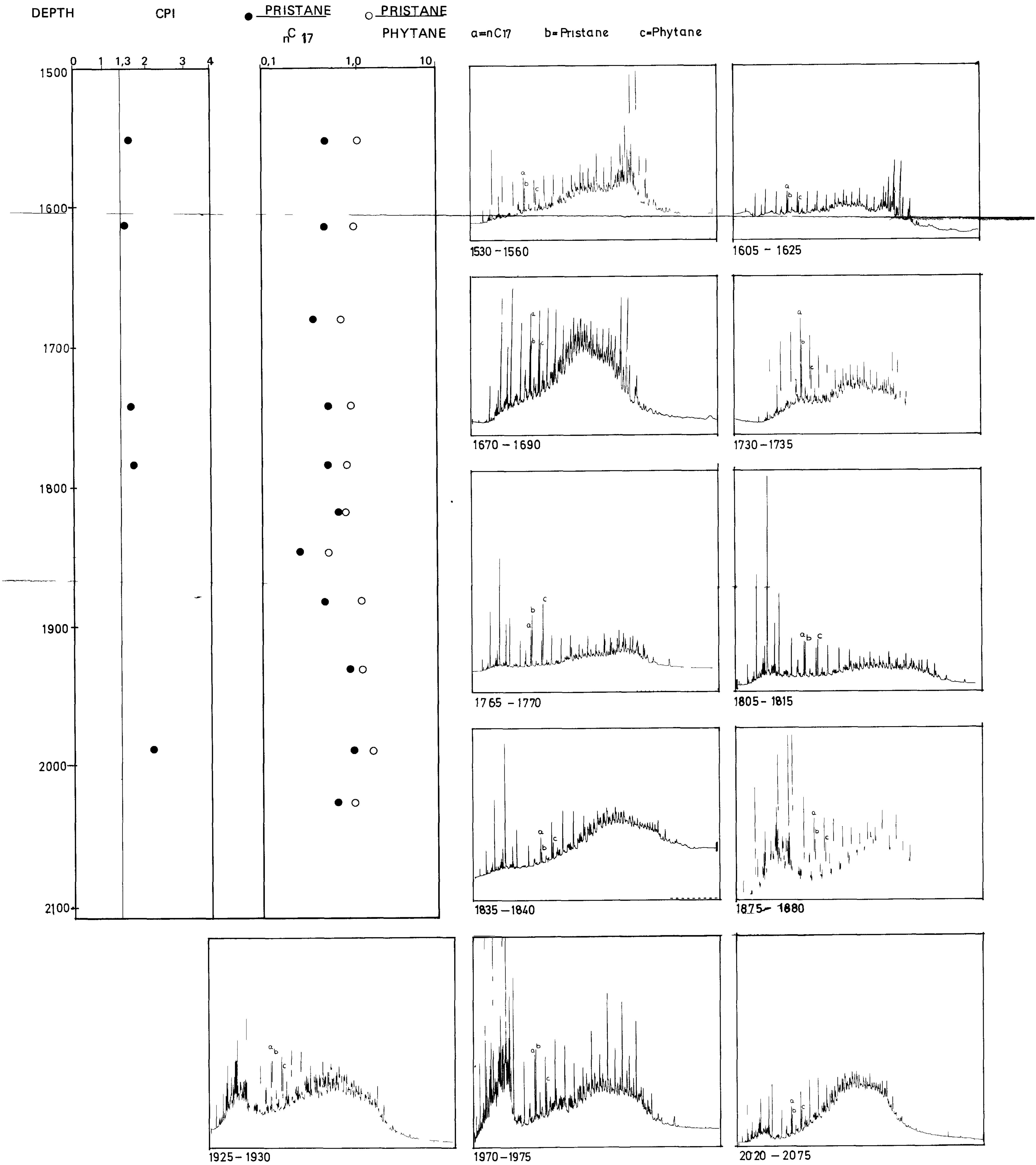
Presentation of Analytical Data



Sat: Saturated Hydrocarbons
Aro: Aromatic Hydrocarbons
NSO: Nitrogen, Sulphur and Oxygen containing compounds

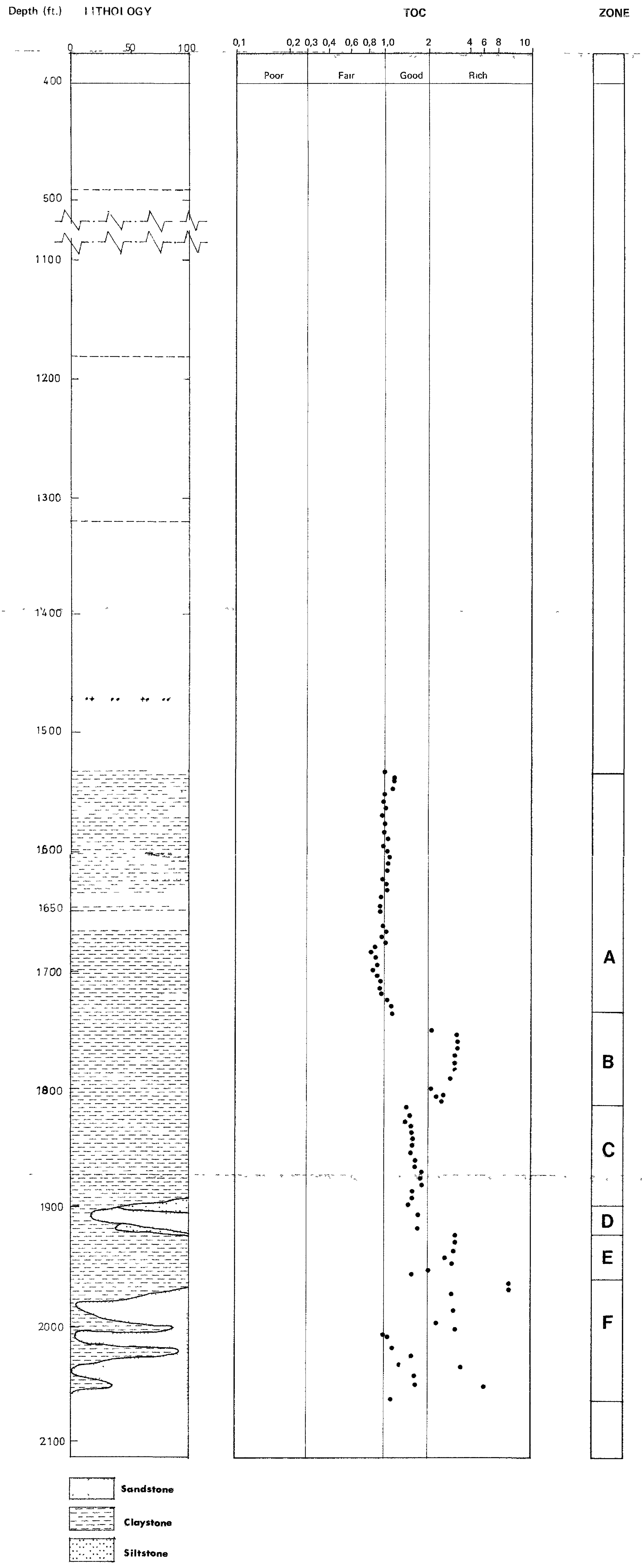
Asp: Asphaltenes
HC: C_{15} Hydrocarbons
TOC: Total Organic Carbon

C_{15}^{+} SATURATED HYDROCARBONS



TOTAL ORGANIC CARBON (TOC)

Presentation of Analytical Data



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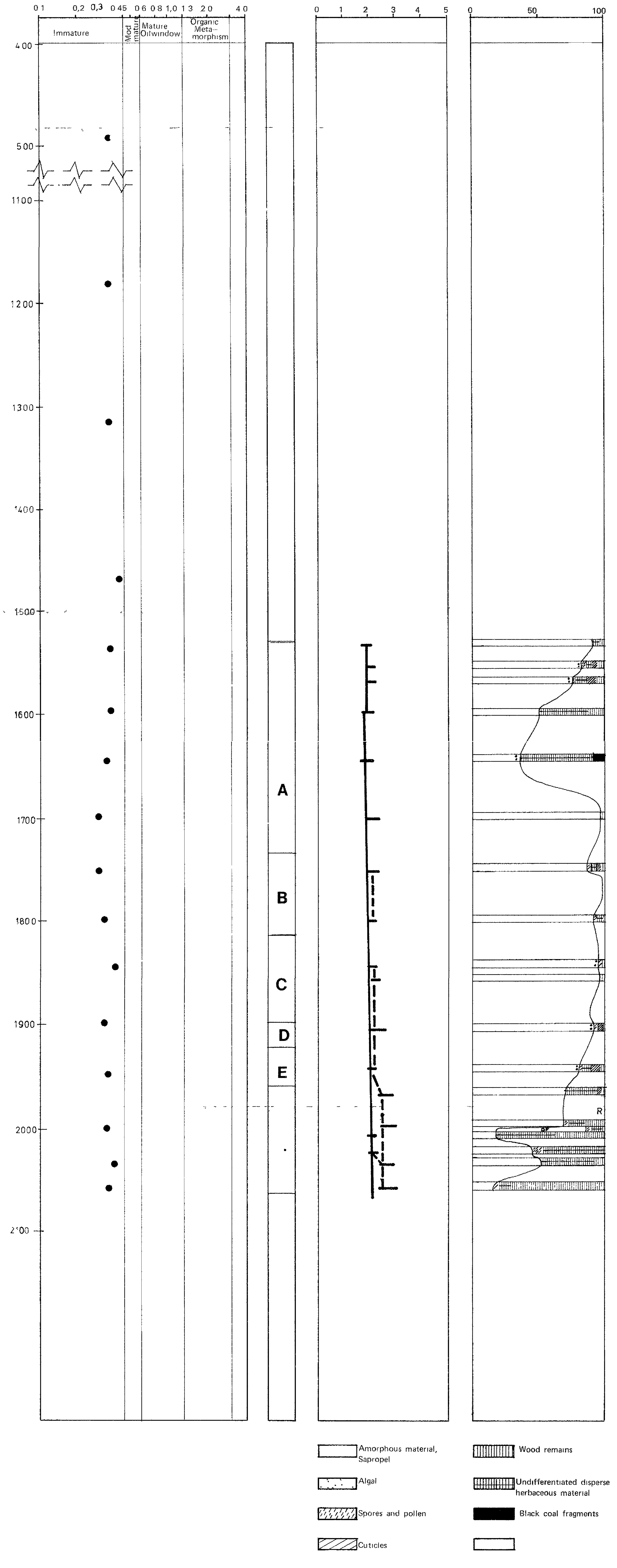
MATURATION

DEPTH | VITRINITE REFLECTANCE | ZONE | VISUAL KEROGEN COLORATION AND COMPOSITION OF ORGANIC RESIDUE



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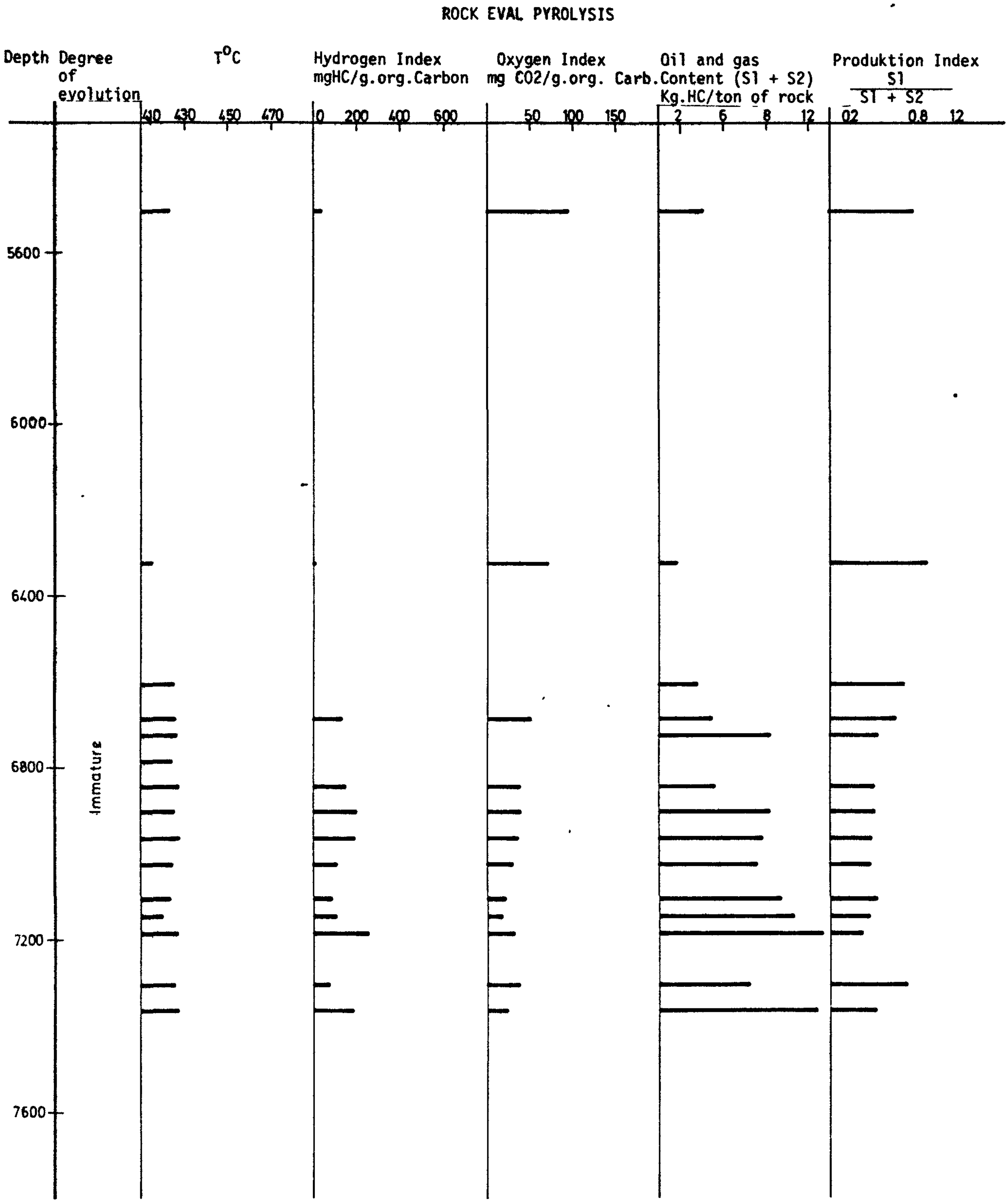
ROCK EVAL PYROLYSIS
Depth
Degree of evolution
T°C
410 430 450 470
Hydrogen Index mgHC/g.org.Carbon
0 200 400 600
Oxygen Index mg CO2/g.org. Carb.
50 100 150
Oil and gas Content (S1 + S2) Kg.HC/ton of rock
2 6 8 12
Produktion Index S1 / S1 + S2
02 0.8 12
5600
6000
6400
6800
7200
7600
Immature

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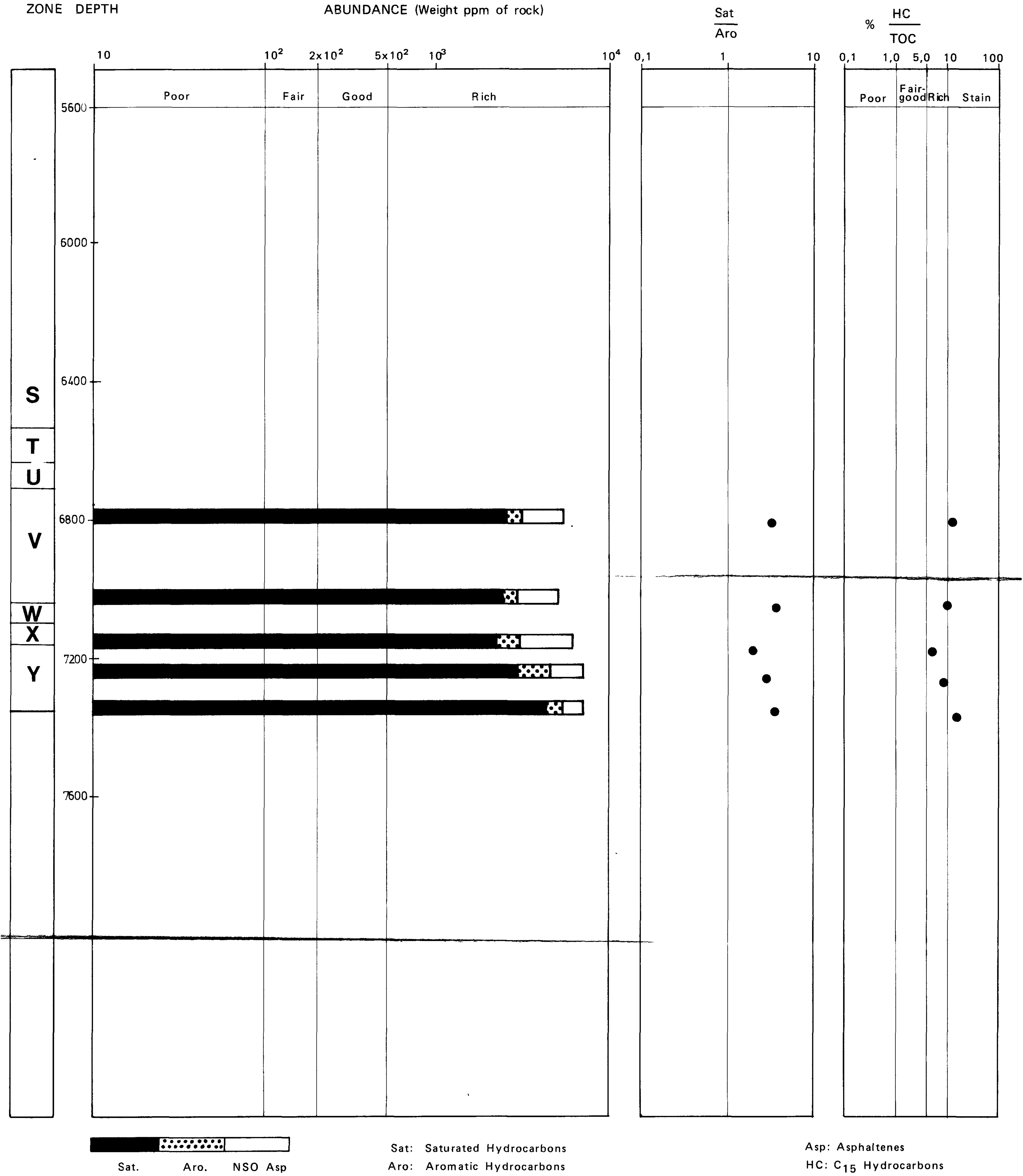
C_{15}^{+} HYDROCARBONS

Presentation of Analytical Data



Sat: Saturated Hydrocarbons

Aro: Aromatic Hydrocarbons

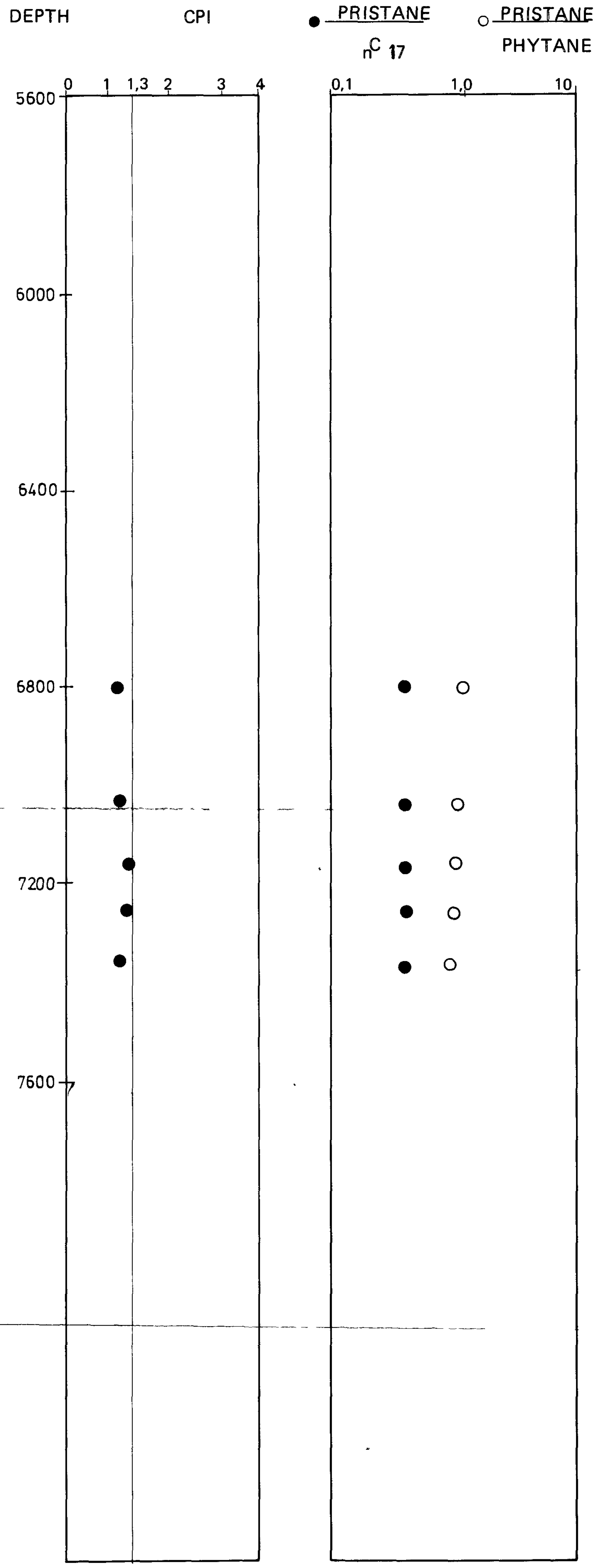
NSO: Nitrogen, Sulphur and Oxygen containing compounds

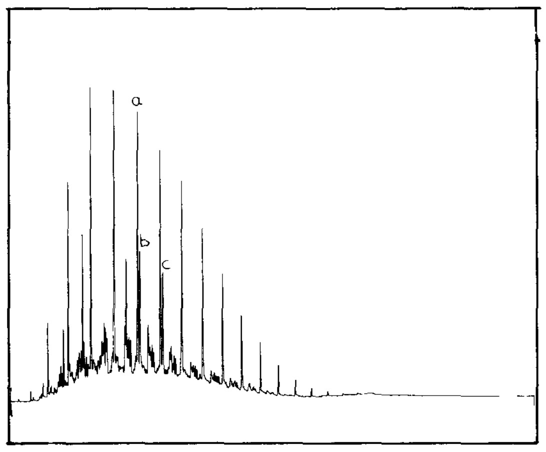
Asp: Asphaltenes

HC: C_{15} Hydrocarbons

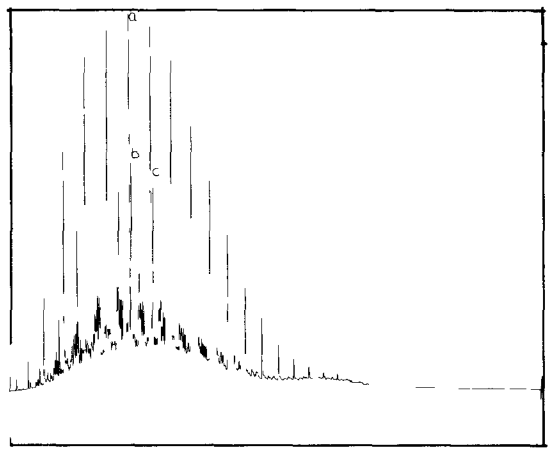
TOC: Total Organic Carbon

C_{15}^{+} SATURATED HYDROCARBONS

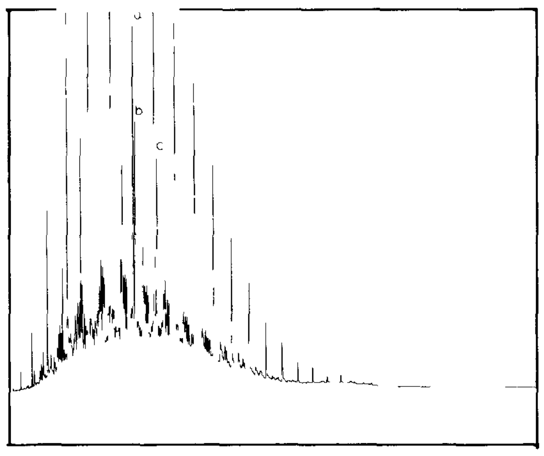




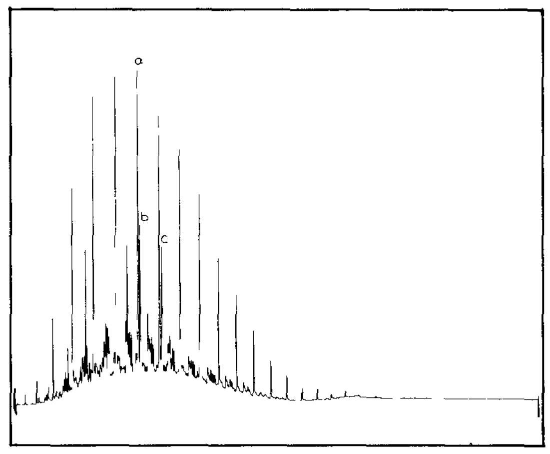
6780 - 6820



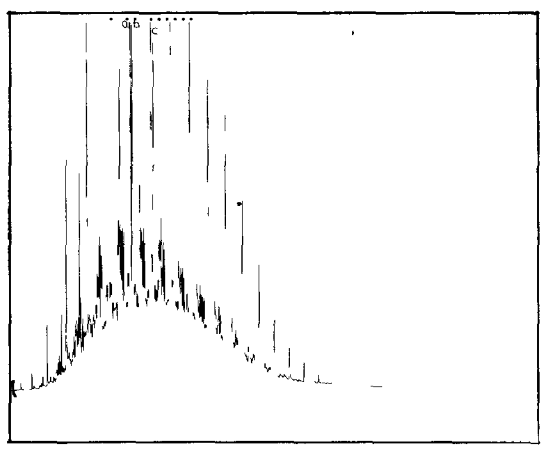
7000 - 7100



7120 - 7180



7200 - 7260



7280 - 7360

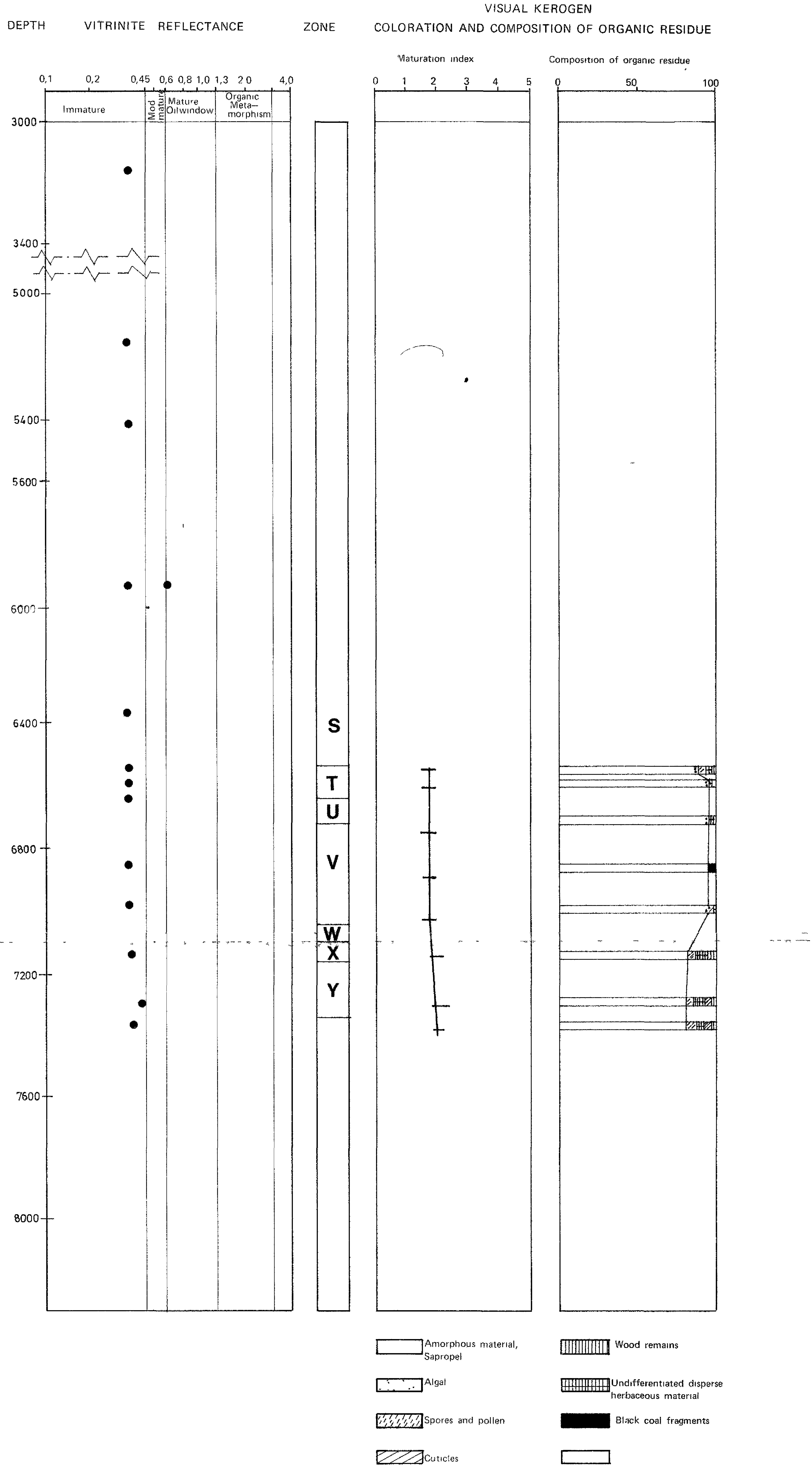
a = nC_{17}

b = Pristane

c = Phytane

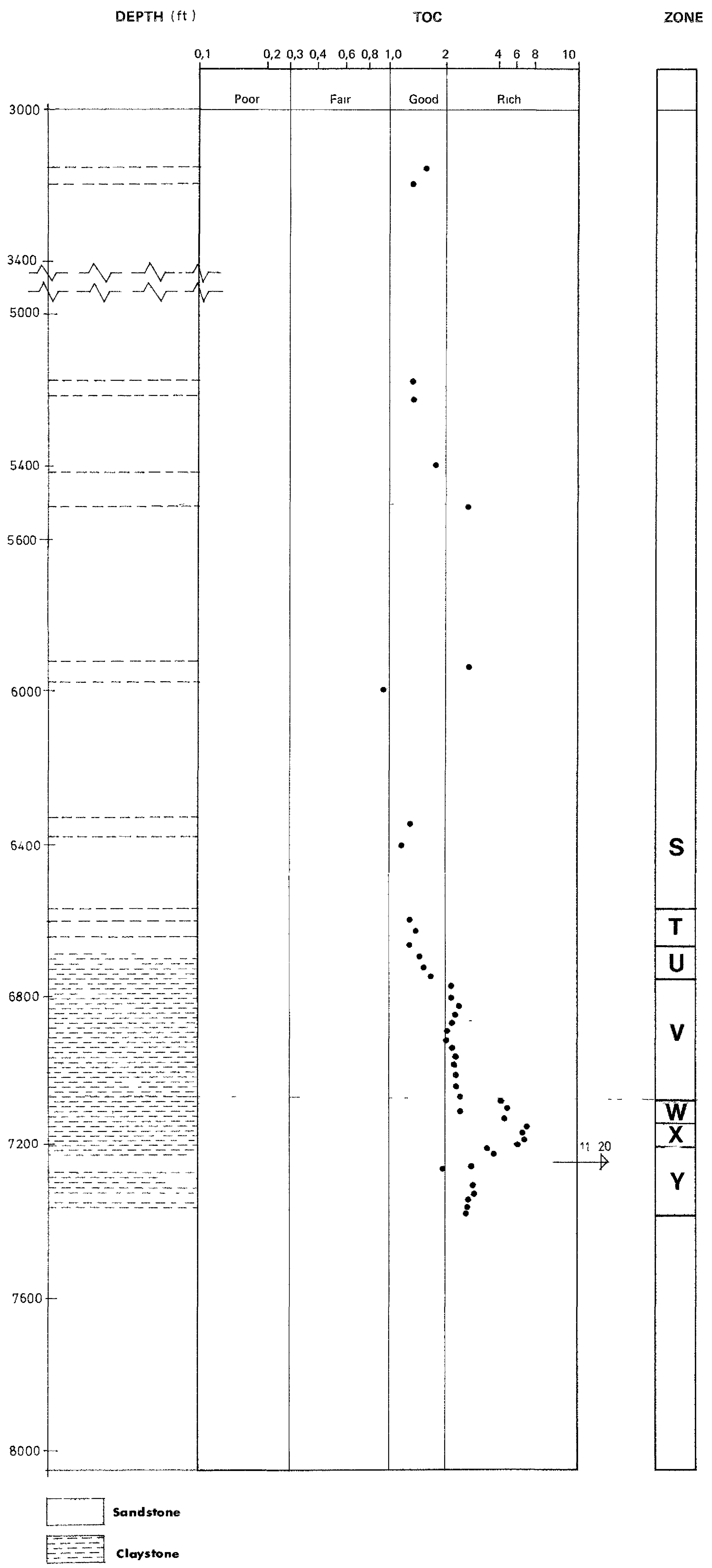
17/12-2

MATURATION



TOTAL ORGANIC CARBON (TOC)

Presentation of Analytical Data



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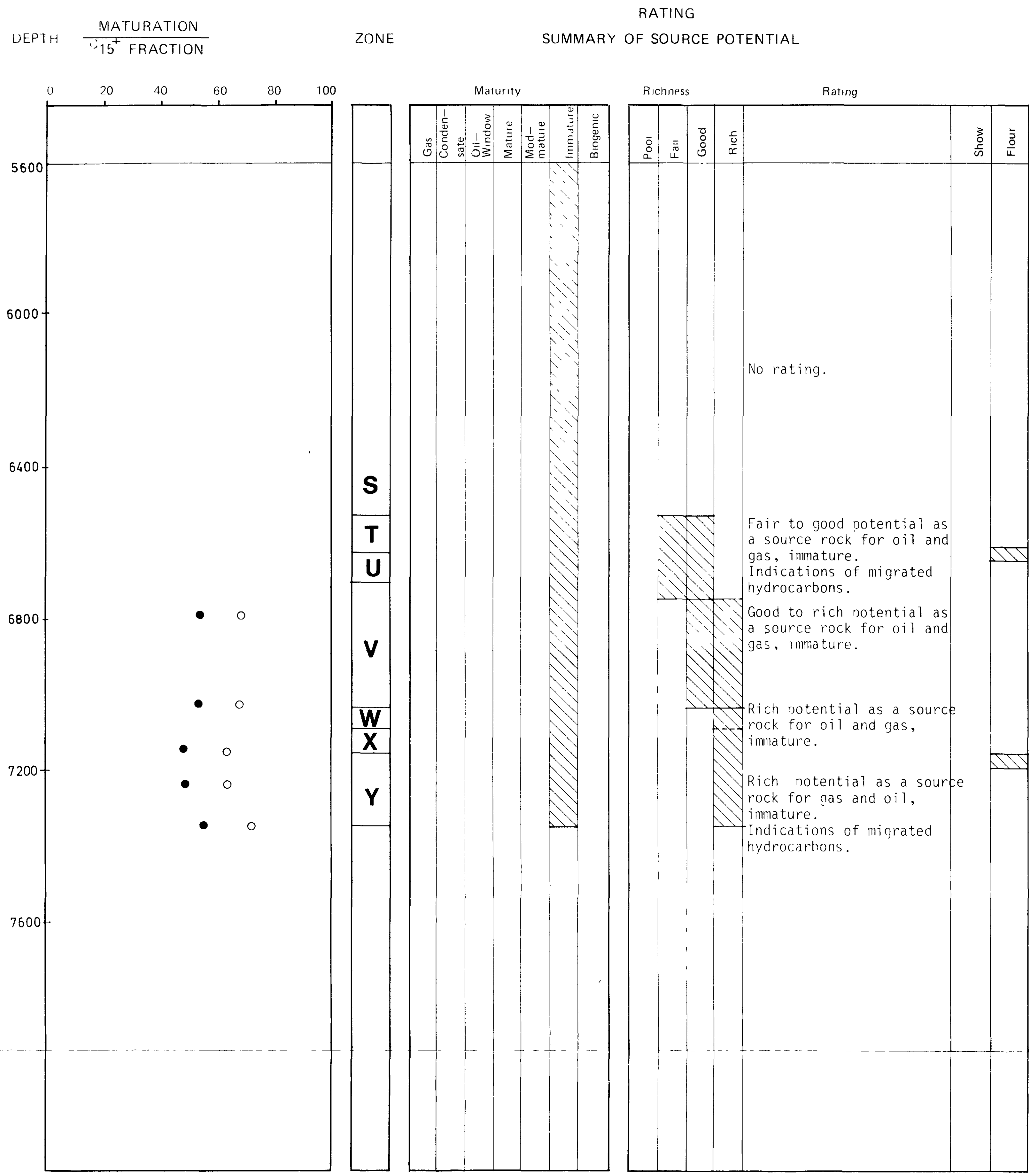
INTERPRETATION DIAGRAM



● % Sat / EOM　　○ % HC / EOM

Sat. Saturated Hydrocarbons
HC Hydrocarbons
EOM Extractable Organic Matter