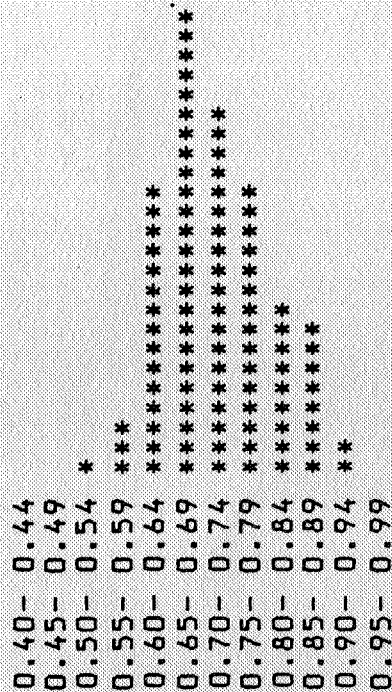


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A coal petrographical investigation of the well 2/11-1

Interpretation and implications for the maturity and quality of possible petroleum source rocks



DGU
Geological Survey of Denmark

1984

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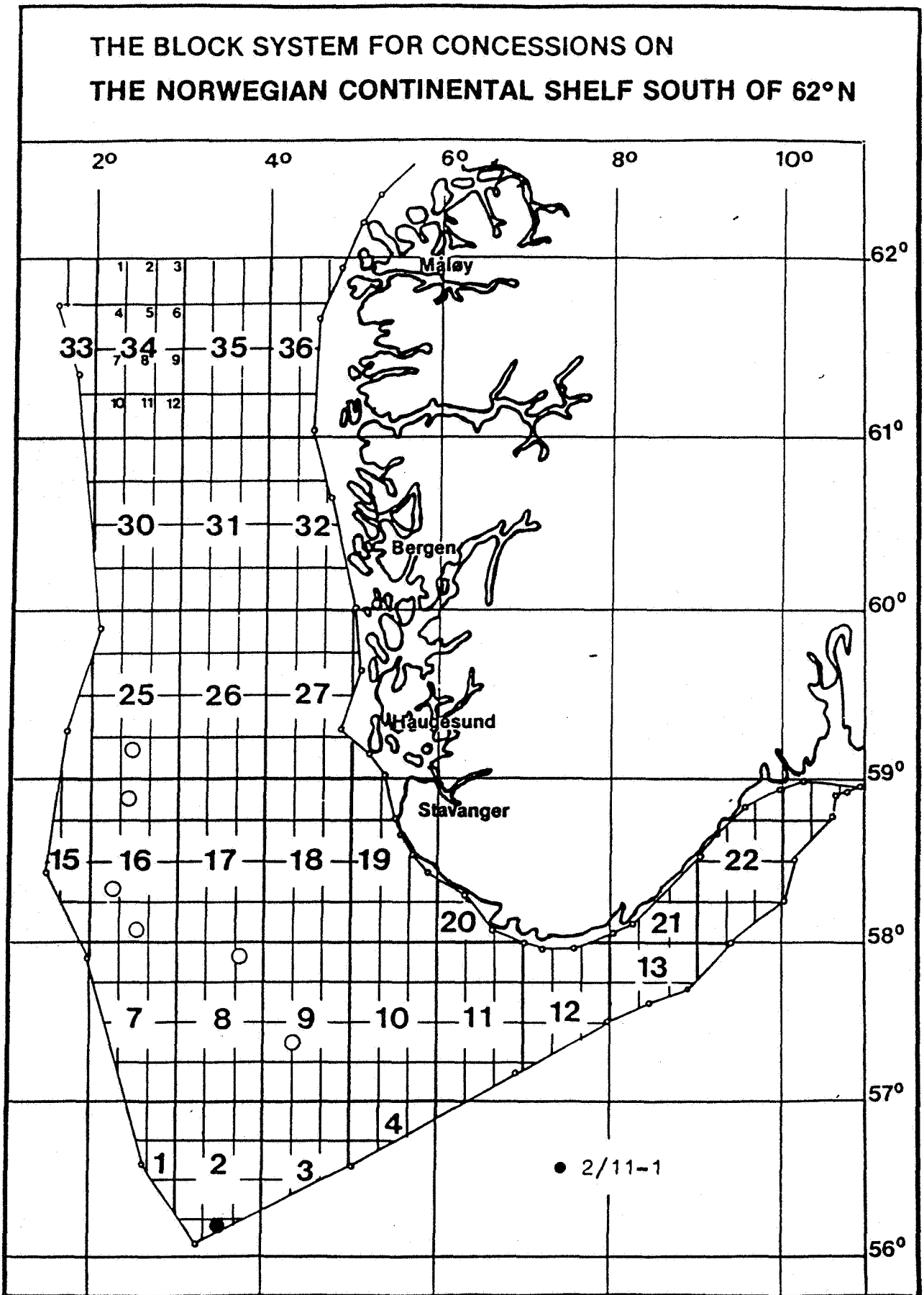


Fig. 1 Locality map

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Summary

Samples from the Cenozoic - Mesozoic sequence in the well 2/11-1 drilled in the southernmost part of the Central Graven on the Norwegian continental shelf, have been subjected to coal petrographical analyses with special emphasis on the maturity and quality of possible petroleum source rocks of Late Jurassic age.

Favourable liptinitic organic matter, dominated by alginite and bituminite, was especially recorded in the interval 12010' - 13020' (ca. 3660 - 3970 m). The Kimmeridgian sequence is rated mature with respect to oil generation, approaching the zone of actual oil expulsion at a depth of ca. 12800' (ca. 3900 m) and reaching the zone of maximum oil generation in the interval below ca. 13800' (ca. 4200 m).

The interval with the most favourable type of organic matter is not yet fully within the zone of actual oil expulsion, however, the apparently favourable load-bearing capacity of the liptinitic organic matter, will probably lead to expulsion at lower maturity levels.

Introduction

As part of an agreement between DGU and NPD the well 2/11-1 has been subjected to a coal petrographical analysis in order to study the maturity and the type of organic matter with special emphasis on deposits of Late Jurassic age.

Cuttings samples from the Cenozoic - Mesozoic interval supplemented with core samples from the Kimmeridgian have been analysed for vitrinite reflectance. Supplementary maturity determinations were carried out on samples rich in liptinite using spectral scanning.

The organic matter in the samples from the Mesozoic was rated qualitatively using normal-reflected light supplemented with blue-light induced fluorescence.

Geological setting

The 2/11-1 well is located in the Norwegian part of the Central Graven, i.e. its southernmost part close to the border to the Danish area (fig. 1). The well was drilled on the eastern flank of an anticlinal structure, referred to as the Valhall structure, with the objective to test all horizons down to Permian Rotliegendes, however, was bottomed in rocks of Late Jurassic age (NPD paper no. 7). The well penetrated almost 1200 m of fine grained sediments reaching TD at 4691 m. Radiolarians in this sequence indicate a Late Jurassic age, however, the great thickness of the Late Jurassic may partly be due to repeated sections in a fault zone (fig. 2).

The Late Jurassic sequence is mainly characterised by organic-rich silty shales considered as "hot shales". A Kimmeridgian age is considered for the main part of the drilled sequence below 3550 m, while Portlandian sediments probably are present above approximately 3550 m. The Jurassic/Cretaceous boundary cannot be accurately defined due to a poor microfauna, but the fauna and correlations with neighbouring wells suggest somewhere within the interval 3325 - 3490 m. The Early Cretaceous sediments exceed 375 m and both the paleoenvironments and the logs indicate a continuous deposition from the Late Jurassic

into the Cretaceous. The fine grained calcareous Cretaceous deposits indicate a low energy depositional environment, which also is reflected by the Late Jurassic sediments (NPD paper no. 7).

Shows of hydrocarbons were encountered in Paleocene sandstones and in Maastrichtian carbonates where testing yielded 38 barrels of oil/hour.

Methods

Type of organic material and maturation level can be determined with reflected-light microscopy supplemented with fluorescent light techniques. The maturity level of sedimentary organic matter can be determined by measurements of vitrinite reflectance. This technique, that has proved to be a very sensitive maturity parameter, is at present one of the most widely applied maturity parameters in petroleum exploration (Hunt 1979, Tissot & Welte 1984).

If vitrinite particles are absent or scarce, the fluorescence properties of liptinite can be used as a maturity parameter. Fluorescence is intense in immature samples and decreases during diagenesis and catagenesis accompanied with a shift of the fluorescence colour towards higher wavelengths. At the end of the oil generation zone, the oil "death line", the fluorescence properties of liptinite disappears. This change can be quantified by measurements of the emission spectrum between 400 and 700 nm, and expressed in numerical values (Ottenjann et al. 1974, Teichmüller & Ottenjann 1977, Ottenjann 1980, 1981). Of special interest is the red/green ratio (Q) = relative intensity at 650 nm divided by the relative intensity at 500 nm and the position of the maximum wavelength (λ_{max}), which is an expression of the wavelength with the maximal relative fluorescence intensity. These parameters have been correlated with huminite/vitrinite reflectance (fig. 3) and can thus be applied as a maturity parameter on sedimentary liptinitic organic matter such as algae or spores and pollen.

A total of 29 cutting samples from the Cenozoic-Mesozoic

sequence and 6 samples from the cored interval (3863,9 - 3877,7 m) of Kimmeridgian age were available for analysis.

Reflectance and fluorescence measurements have been carried out on whole rock samples, i.e. core and cutting samples crushed to a grain size of 2 - 3 mm, embedded in a synthetic resin which is cold setting, followed by grinding and polishing using 1/4 mikron diamond powder for the final polish.

Reflectance measurements have been carried out on two microscope systems:

A reflected-light Zeiss photomicroscope equipped with a MPO3 photometer and digital readout, using a 40x Epi-pol oil immersion objective, working with a plane-glass reflector. Data are collected and processed by a MPS 3000 microcomputer.

A Leitz MPV3 reflected-light microscope equipped with a pol-opak illuminator, plane-glass reflector and a 32x oil immersion objective. Data are collected and processed by a MINC 11/23 microcomputer.

Illumination is for both systems through a green filter with peak transmission at 546 nm. The photomultipliers are calibrated against standards with reflectance values of 0.515 and 1.26 %R₀.

The readings, i.e. random reflectance, for each sample are grouped at intervals of 0.05 %R₀ and plotted as histograms (fig. 4). For the group of reflectance measurements regarded as being representative for the autochthonous (indigenous) vitrinite population representing maturation within the host rock, arithmetic mean and standard deviation are calculated. Coal and coal-rich samples, if present, are used as marker horizons.

The quantitative fluorescence measurements are carried out on the Zeiss microscope system, equipped with a continuous-filter monochromator and a 100W high-pressure mercury lamp equipped with a stabilized power supply. For UV-excitation the Zeiss F1 fluorescence reflected-light illuminator is used working with a 25x neofluar objective.

The readings are displayed as spectrograms showing the distribution of the relative fluorescence intensities from 400 to 700 nm together with the resulting Q and lambda-max

values (fig. 5).

The rating of the organic matter was carried out on the Leitz system using an automatic Ploem-opak illuminator, equipped with a plane-glass reflector and a blue-light filter combination for work in normal-reflected-light and UV-light; working with a 10x and 25x oil immersion objective. Photographs were taken with a OM-2 camera using Fujichrome 100/36 dias films.

Terminology and methods according to the outlines in Stach et al. 1982.

Reflectance

The results of the reflectance measurements are presented in table 1.

The greatest difficulty in maturity/rank determinations on disseminated sedimentary organic matter, lies in the choice of particles whose rank represents maturation within the host rock. A sedimentary rock may contain organic particles derived directly from plants, particles somewhat altered chemically and/or physically during transportation and deposition, and finally recycled particles from older sedimentary rocks. In addition caving and the use of coal as a drilling mud additive provide complicating factors when working with cuttings. Those huminite/vitrinite particles which had the lowest degree of alteration when incorporated in the sediment, indicate the degree of thermal alteration of the sediment as measured by rank. They are selected by first eliminating constituents of the liptinite group, identified by low reflectance, morphology and fluorescence properties in low rank stages. This includes the recognition of solid bitumen which easily can be misinterpreted as vitrinite. The remaining particles represents material corresponding to the huminite/vitrinite and the inertinite maceral groups. Among the huminite/vitrinite particles a low reflecting group can be identified, which is considered representative of the indigenous population, representing maturation within the host rock. The higher reflecting huminite/vitrinite represents natural transitions to the inertinite group (pseudovitrinite - semi-inertinite) and/or reworked particles, the

latter often identified as rounded particles with oxydation rims. With huminite particles care is taken that the reflectivity of the huminite B types are measured and not that of the relatively weakly reflecting A types of huminite. This situation is also encountered with respect to vitrinite impregnated with bituminite, commonly observed in source rocks, which can lead to a lowering of the reflectance values in the order of 0.2 to 0.4 %R_o (Robert 1981). This type of vitrinite can normally be identified by its fluorescence properties which also is the case for huminite A.

Generally the measurements have been carried out on small wisps and splinters of huminite and vitrinite. Apart from a few samples from the Cenozoic (378A & 384A) and a few of the core samples of Kimmeridgian age (311A, 313A & 316A), the samples have low contents of vitrinite. The reflectograms in general exhibit broad distributions of the reflectance values. This can be attributed the presence of reworked material and/or low rank material from overlying intervals. Significant contributions of macerals transitional to inertinite, i.e. pseudovitrinite and bitumen-impregnated vitrinite will also lead to a spread of the reflectance values. Fluorescence studies reveal that significant proportions of the vitrinite is impregnated with fluorescent compounds and thus unsuitable for reflectance measurements. This is especially frequent in the samples from the Kimmeridgian in the depth interval below ca. 11650'. As stated above a few of the core samples yielded significant proportions of suitable vitrinite for measurements, however, in general the samples from the Mesozoic have low contents of suitable vitrinite which highly reduce the reliability of the reflectance measurements.

The upper and lower reflectance range of the interpreted indigenous vitrinite population, representing maturation within the host rock, have been selected by determining the reflectance range of pseudovitrinite and bitumen-impregnated vitrinite/huminite A. In general the reflectance range selected for the cutting samples proved to be in good accordance with the reflectance range selected in the core samples. Hence, caving is not regarded as significant. In addition the frequent use of lignite as a drilling mud

additive, has not been observed in this well. Thus, in spite of the limited number of measurements in several intervals, the data are regarded as a fair expression of the rank/maturity conditions, which is sustained by the results of the quantitative fluorescence measurements.

Spectral fluorescence measurements

In this study spectral fluorescence measurements have been carried out on alginite. As the measurements are restricted to isolated alginite, the possibility of the presence of reworked or otherwise atypical material, not reflecting maturation within the host rock, cannot be eliminated. In order to visualize the spread of the values recorded and to control the influence of "allochthonous", caved or otherwise atypical material, as many algae are measured and the recorded Q values displayed as histograms. Using the principles achieved from the reflectance measurements, narrow, unimodal distributions of the Q values are taken as indicative for autochthonous alginite populations. In samples with polymodal distributions of the Q values, the population with the lowest range of Q is generally regarded as representative of the autochthonous population. The lambda-max value is calculated as the mean maximum wavelength for the spectra of the selected Q population. Apart from the limitations already stated, oxidation and/or bacterial degradation may change the fluorescence properties as demonstrated by Spiro & Mukhopadhyaya (1983). Furthermore liptinites of different botanical origin may exhibit different fluorescence properties as shown by van Gijssel (1967).

In this study the measurements were restricted to dinoflagellates in samples from the Cenozoic, while alginite of Tasmanites type were measured in the samples from the Kimmeridgian. Investigations by Thomsen (1980) show that these algae follow the same coalification track, hence the results are directly comparable. None of the samples yielded any distinct polymodal distribution of the Q values, however, a great scatter was frequently observed of the recorded values. Qualitative observations often showed the algae to be highly degraded, probably as a result of

bacterial degradation, hence higher values than indicative for the proper rank/maturity conditions are to be expected. However, by comparison with samples with rather narrow distributions of the Q values, no major deviations have been noted and the resulting Q values are regarded as fair to good expressions of the rank/maturity conditions. The results are presented in table 2.

The fluorescence measurements on alginite of Tasmanites type recorded in the samples from the Kimmeridgian, show a spread of the mean Q values in the order of 0.97 - 1.65 and lambda-max in the order of 560 - 630 nm. However, the two extreme values must be regarded as uncertain due to the low number of measurements. By comparison with results obtained by Teichmüller & Ottenjann (1977) on alginite of Tasmanites type from the German Posidonia Schiefer of Early Jurassic age, this range corresponds to a vitrinite reflectance range of approximately 0.50 - 0.90 %R_o (cf. fig. 3). Comparing this rank range with the results of the actual vitrinite reflectance values recorded in this study, i.e. 0.56 - 0.97 %R_o in the Kimmeridgian samples, there is a good correspondance between the two methods applied, which also is the case for the samples from the Cenozoic interval.

Maturity

The maturity or level of organic metamorphism is indicated by the huminite/vitrinite reflectance trend in fig. 6.

The reflectance trend reaches about 0.97 %R_o at a depth of ca. 4690 m, indicating a Cenozoic - Mesozoic sediment pile, which encompasses a rank range equivalent to lignitic - high volatile bituminous A coal rank.

Comparing this rank range in terms of vitrinite reflectance (0.27 - 0.97 %R_o), with the stages of hydrocarbon generation, one must be aware of the difficulties in defining a general maturity level for the onset of oil generation. Several attempts have been made (Vassoyvich et al. 1970, Robert 1973, Teichmüller 1974, Hood et al. 1975, Dow 1977, Tissot & Welte 1978, Heroux et al. 1979). The results of the investigations and reviews show that the oil birth line may vary between 0.35 and 0.70 %R_o.

The apparent difficulties in defining a general maturity

level for the onset of oil generation can be partly be explained by different ways of selecting vitrinite for measurement, partly by the use of different extraction methods and problems in controlling the potential influence of migrated oil. However, according to Tissot & Welte (1978) the main reason for the discrepancies is related to the kerogen type, since different types of organic matter have different composition and thus different rate of transformation in response to an increase of temperature.

In the Danish Subbasin coal petrographical investigations of Mesozoic deposits drilled in deep wells, show that several of the investigated wells have passed a maturity level of 0.50 %R_o, the value most commonly cited as the threshold value for the onset of oil generation. Fair amounts of favourable kerogen types can be found in this sequence (Thomsen 1980, Lindgreen & Thomsen 1982), however, none of the wells investigated yielded commercial hydrocarbons. Investigations in the Danish part of the Central Graben (Thomsen et al. 1983) indicate that the composition of source rock hydrocarbons only become crude-like in a reflectance range of 0.60 - 0.70 %R_o. This is in good accordance with the findings of Hood et al. (1975) and Dow (1977) and is further sustained by investigations of coals by Teichmüller (1974), who states that mobile compounds are generated in the high volatile C/B rank range corresponding to 0.55 - 0.70 %R_o.

Hence rating sediments with a rank of 0.50 - 0.60 %R_o premature and using 0.60 %R_o as a general threshold value, the interval below 3550 m, i.e. the Kimmeridgian, is rated mature with respect to oil generation. The interval below ca. 3900 m is within the zone of actual oil expulsion reaching the maximum of oil generation in the interval below ca. 4200 m.

Type of organic matter

In the investigated samples the influence of organic matter from the drilling mud have been noted where possible. This is normally the case with isolated particles of lignite, bituminous coal and graphite in intervals with rank conditions clearly different from the rank conditions as revealed by the isolated particles. None of the samples investigated, showed any significant influence of organic matter

from the drilling mud as revealed by microscopy. However, the use of diesel oil as a drilling mud additive will have a bearing on the results of organic geochemistry.

The organic matter recorded in the samples from the Late Jurassic, i.e. the Kimmeridgian, is generally characterised by varying contents of liptinite, associated with low contents of vitrinite and inertinite. Vitrinite is mainly represented by detritic, reworked particles and bitumen-impregnated detritic vitrinite. Stringers of vitrinite are generally bitumen-impregnated, hence, not suitable for reflectance measurements. The content of inertinite is generally higher than the content of vitrinite, mainly represented by inertodetrinite. The presence of coal and coal fragments have not been recorded, although the lithological log show the presence of black coal in the uppermost part of the Kimmeridgian interval. The detritic and oxidized nature of the land-derived organic matter indicate significant transport.

The content of liptinite is varying. Fair amounts have been recorded in samples 385A and 386A, while high contents are present in samples 387A - 391A and in samples 311A - 317A. In the remainder of the samples investigated (392A - 397A) low contents of liptinite have been recorded. High contents of liptinite is primarily found in dark cutting types with high contents of syngenetic pyrite. Liptinite is mainly represented by alginite, bituminite, liptodetrinite and varying contents of sporinite. Part of the alginite can be classified as alginite of Tasmanites type (plate 2), identified by thick cell walls, size (100 - 200 mikrons) and strong fluorescence. The characteristic perforated cell walls were only observed in a few cases, which is attributed the degraded nature of several of the specimens. Thin walled alginite with the same fluorescence properties as alginite of Tasmanites type, is frequently observed (plate 1) and is tentatively attributed Leiosphaeridales, while small, microfilamentous algae are classed under Shizophyceae as suggested by Teichmüller & Ottenjann (1977). Sporinite (plate 1 & 2) is identified by morphology and weaker fluorescence as compared to alginite. The content is varying but significantly lower than the content of alginite in the sample investigated. Brown fluorescent, often lamellar, structureless organic matter

is frequent, locally amounting to dominance in some of the samples. This type of liptinitic organic matter has been classified as bituminite by Teichmüller & Ottenjann (1977), alginite B by Hutton et al. (1980), marine sapropelic groundmass by Robert (1981) and brown fluorescent structureless organic matter by Gutjahr (1983). In spite of the discrepancies concerning the terminology, it is generally accepted that this type of organic matter is one of the main precursors for liquid hydrocarbons.

Gutjahr (1983) put forward a classification scheme for petroleum source rocks based on incident-light microscopy. According to this classification several of the intervals in the Kimmeridgian can be classified as bacterial source rocks of type 2A, characterised by the presence of dull-yellow/brown fluorescent structureless organic matter associated with alginite. Vitrinite and inertinite are normally present as accessory components. This source matter is generally associated with abundant framboidal pyrite, indicative of bacterial reworking of the digestible organic matter.

The organic matter often shows a dense layered and/or lens-like distribution. Before maturity is reached, the full weight of the overburden is carried by the framework of sedimentary particles and its solid organic constituents. During maturation part of the organic matter becomes plastic and fluid is generated. Due to the resulting volume expansion, the weight of the overburden may be carried by the organic matter. The pressure will be transmitted by the organic matter causing fracturing followed by fluid expulsion. The framework of sedimentary grains again carries the full overburden until another expulsion phase is reached. According to Gutjahr (1983) the load-bearing character of the liptinites is a prerequisite for the efficient expulsion of oil. The presence of liptinite-rich networks in several of the samples investigated, indicate a good potential for effective generation of oil. Hence, part of the Kimmeridgian interval represented by samples 387A - 391A and 311A - 317A, corresponding to the depth interval 12010' - 13020' must be regarded as a good to excellent potential oil source rock, due to the high content of favourable liptinitic organic matter with the necessary load-bearing capacity for effective expulsion of liquid hydrocarbons.

Conclusion

Favourable type of organic matter dominated by alginite and bituminite is present in several intervals, especially the interval 12010'- 13020' (ca. 3660 - 3970 m). The Kimmeridgian sequence must be rated mature with respect to oil generation, approaching the zone of actual oil expulsion at a depth of ca. 12800' (ca. 3900 m) and reaching the zone of maximum oil generation in the interval below ca. 13800' (ca. 4200 m). However, since the content of liptinite in general appears to be low in the interval below 13800', the generative potential will be reduced.

The interval with the most favourable type of organic matter is not yet fully within the zone of actual oil expulsion, however, the apparently favourable load-bearing capacity of the liptinitic organic matter will probably lead to expulsion at lower maturity levels.

Judged from the vitrinite reflectance trend and the supplementary quantitative fluorescence measurements, no repeated sections of Late Jurassic age seem to be present, because of the distinct rank/maturity increase with depth.

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S

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Fig. 2:
Interpreted Seismic Record.



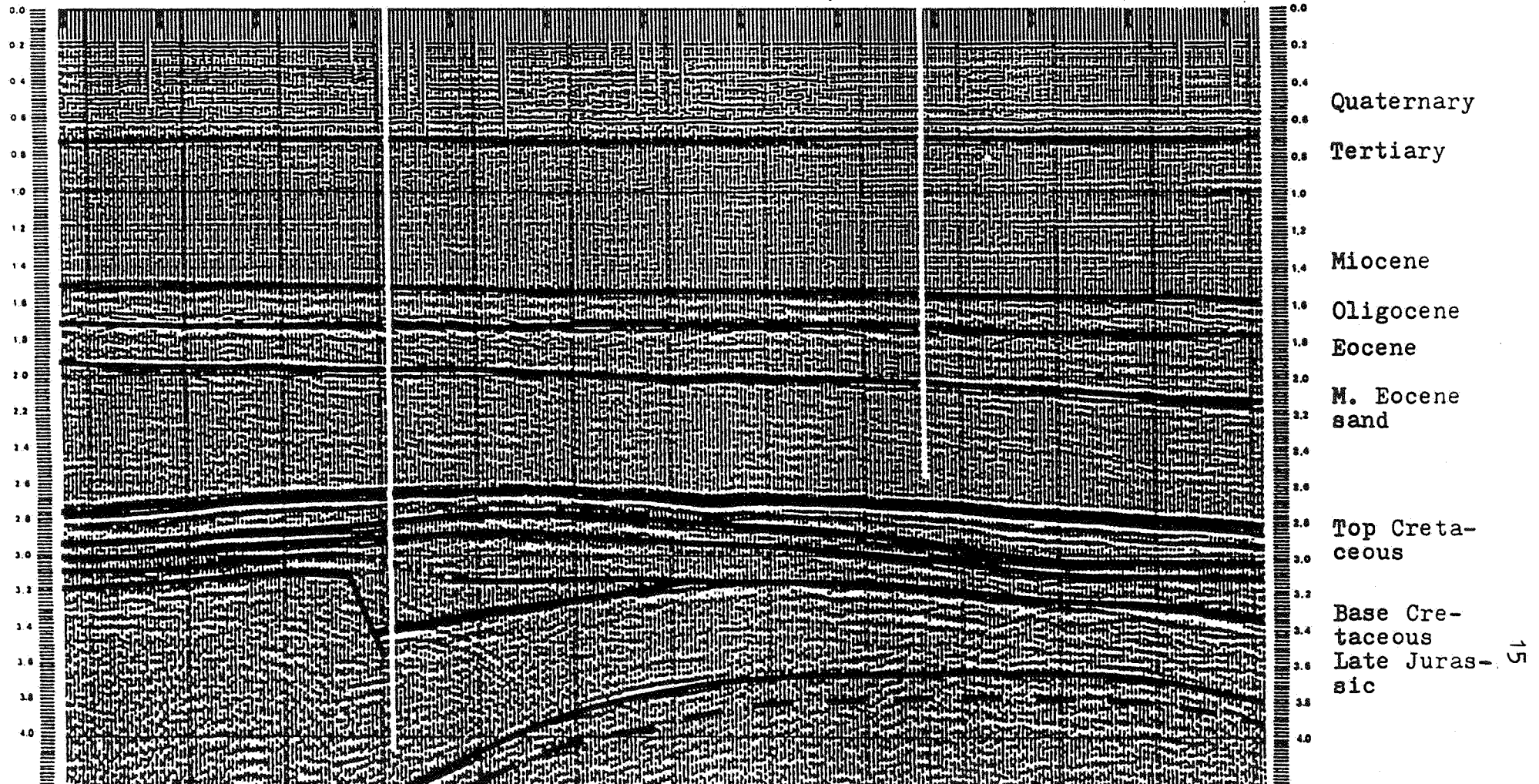
Line 70-17



AMOCO 2/11-1



AMOCO 2/8-1



S

N

Fig. 2:
Interpreted Seismic Record.



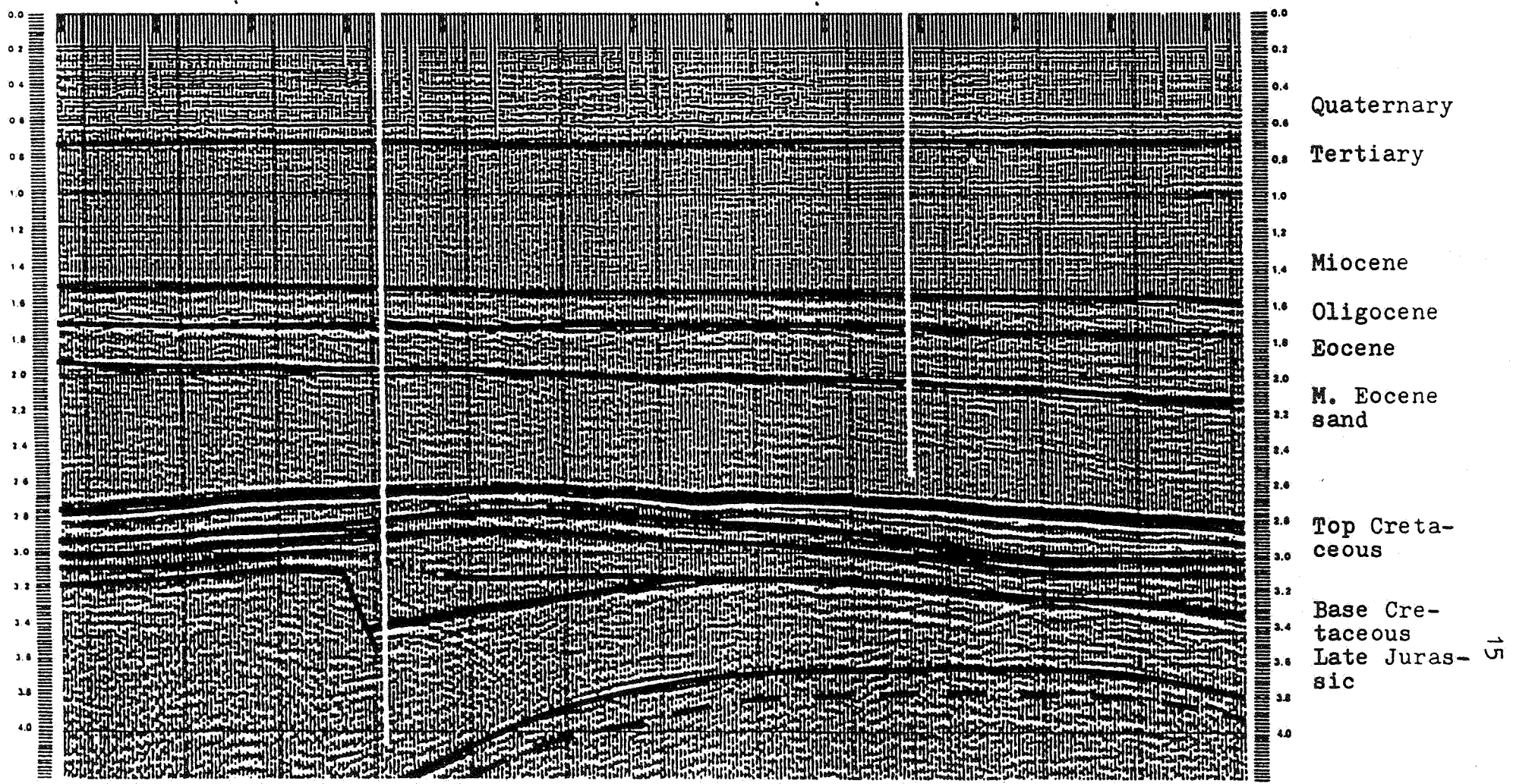
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AMOCO 2/11-1



AMOCO 2/8-1



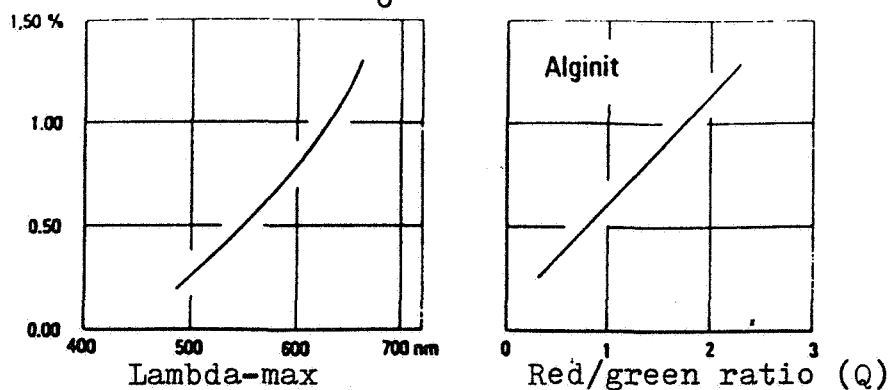
Vitrinite reflectance (R_o)

Fig. 3 Increase of the maximum wavelength (λ -max) and the red/green ratio (Q) with increasing maturity as expressed by vitrinite reflectance (after Ottenjann 1981).

SAMPLE : 378A

DATE : 831026

OPERATOR : CG

STANDARD : LEITZ

COMMENT : 2/11-1

COMMENT : 4410 - 4440

COMMENT :

COMMENT :

COMMENT :

SKALA : 1.0000

0.25- 0.29 ** 11.76

0.30- 0.34 ***** 41.18

0.35- 0.39 ***** 35.29

0.40- 0.44 ** 11.76

* = 5.88

TOTAL	USED	MIN	MAX	MEAN	VARIANS	STD	AFV
17	17	0.2900	0.4200	0.3447	0.0015	0.0391	
17	16	0.2900	0.4000	0.3400	0.0013	0.0354	

Fig. 4 Reflectogram, sample 378A, 2/11-1.
 $R_o = 0.34$.

SAMPLE : 387A
 DATE : 840827
 OPERATOR : CG
 OBJECT : ALGINITE
 COMMENT : 2/11-1
 COMMENT : 12010 -12020'
 COMMENT :
 COMMENT :
 COMMENT :

Wavelength (nm)	Relative Intensity (%)
400	0.00
410	0.00
420	0.00
430	1.40
440	1.59
450	1.77
460	1.98
470	2.17
480	2.40
490	2.57
500	2.78
510	2.99
520	3.15
530	3.32
540	3.51
550	3.66
560	3.78
570	3.79
580	3.83
590	3.86
600	3.89
610	3.78
620	3.67
630	3.54
640	3.38
650	3.21
660	3.06
670	2.84
680	2.63
690	2.40
700	2.19

* = 2.00 % rel
 Q_VALUE = 1.153
 TOTAL = 23
 USED = 20
 MIN = 560.0000
 MAX = 610.0000
 MEAN = 593.0000
 VARIANS = 181.0000
 STD AFV = 13.4536

Area blue (430 - 500 nm) = 20.0
 Area green (510 - 570 nm) = 29.1
 Area yellow (580 - 630 nm) = 27.1
 Area red (640 - 700 nm) = 23.7
 Area < Lambda-max = 60.7
 Area > Lambda-max = 39.3

Fig. 5 Spectrogram, sample 387A, 2/11-1. Lambda-max = 593 nm, Q = 1.15.

2/11-1
VITRINITE REFLECTANCE TREND

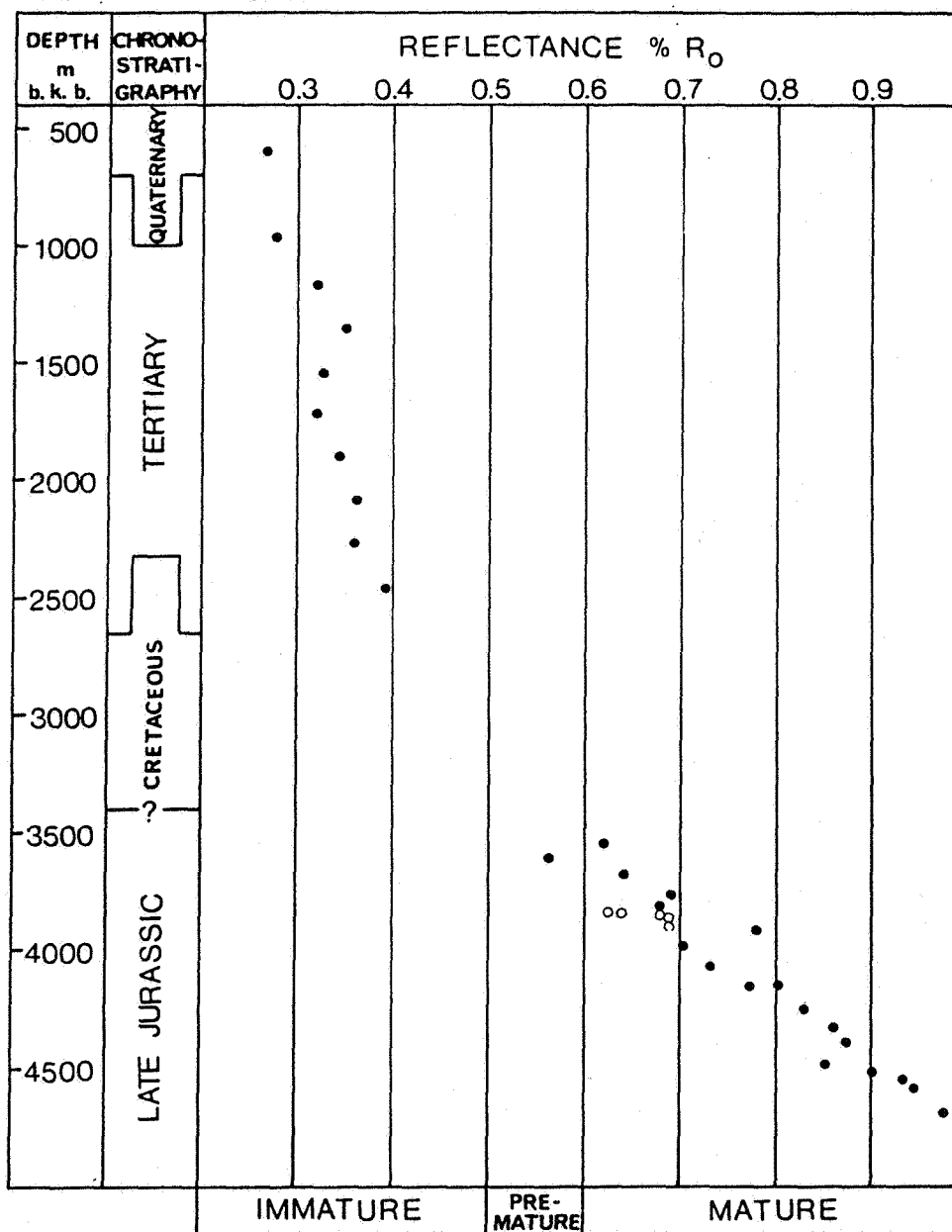


Fig. 6 Vitrinite reflectance trend, the 2/11-1 well.

TABLE 1

2/11-1

Vitrinite reflectance

Sample no.	Depth interval (feet)	Sample type	Mean reflectance	Standard deviation	Number of readings
374A	1920'- 1950'	Cuttings	0.27	0.03	14
375A	2550'- 2580'	Cuttings	n.d.		
376A	3120'- 3150'	Cuttings	0.28	0.04	11
377A	3810'- 3840'	Cuttings	0.32	0.03	10
378A	4410'- 4440'	Cuttings	0.35	0.06	33
379A	5010'- 5040'	Cuttings	0.33	0.04	16
380A	5610'- 5640'	Cuttings	0.32	0.05	24
381A	6210'- 6240'	Cuttings	0.34	0.04	13
382A	6810'- 6840'	Cuttings	0.36	0.07	6
383A	7410'- 7440'	Cuttings	0.36	0.05	8
384A	8010'- 8040'	Cuttings	0.39	0.07	42
385A	11615'- 11630'	Cuttings	0.62	0.03	4
386A	11810'- 11825'	Cuttings	0.56	0.05	18
387A	12010'- 12020'	Cuttings	0.64	0.04	12
388A	12310'- 12320'	Cuttings	0.69	0.06	12

TABLE 1 Continued

Sample no.	Depth interval (feet)	Sample type	Mean reflectance	Standard deviation	Number of readings
389A	12510' - 12520'	Cuttings	0.68	0.08	15
311A	12682' (41 - 54 cm b.t.)	Core	0.64	0.08	34
312A	12685' (17 - 23 cm b.t.)	Core	0.63	0.05	18
313A	12688' (47 - 55 cm b.t.)	Core	0.68	0.07	43
314A	12694' (73 cm b.t.)	Core	0.69	0.05	25
315A	12721' (73 - 76 cm b.t.)	Core	n.d.		
316A	12721' (37 - 43 cm b.t.)	Core	0.69	0.06	31
317A	12710' - 12720'	Cuttings	0.69	0.06	18
390A	12810' - 12820'	Cuttings	0.78	0.06	13
391A	13010' - 13020'	Cuttings	0.70	0.08	21
398A	13310' - 13320'	Cuttings	0.73	0.08	19
399A	13610' - 13620'	Cuttings	0.77	0.04	6
400A	13910' - 13920'	Cuttings	0.83	0.05	5
401A	14210' - 14220'	Cuttings	0.86	0.06	25
392A	14410' - 14420'	Cuttings	0.87	0.06	6
393A	14710' - 14720'	Cuttings	0.85	0.06	4
402A	14810' - 14820'	Cuttings	n.d.		

TABLE 1 Continued

Sample no.	Depth interval (feet)	Sample type	Mean reflectance	Standard deviation	Number of readings
394A	14910' - 14920'	Cuttings	0.90	0.08	16
395A	15010' - 15020'	Cuttings	0.93	0.08	6
396A	15310' - 15320'	Cuttings	0.94	0.06	13
397A	15390' - 15392'	Cuttings	0.97	0.06	10

TABLE 2

2/11-1

Spectral fluorescence data

Sample no.	Depth interval (feet)	Sample type	Red/green ratio (Q)	Lambda-max	Number of readings
374A	1920'- 1950'	Cuttings	0.42	492	16
378A	4410'- 4440'	Cuttings	0.42	503	3
385A	11615'- 11630'	Cuttings	0.97	560	1
386A	11810'- 11825'	Cuttings	1.04	571	18
387A	12010'- 12020'	Cuttings	1.15	593	20
388A	12310'- 12320'	Cuttings	1.07	579	11
389A	12510'- 12520'	Cuttings	1.30	605	6
311A	12682'(41 - 54 cm b.t.)	Core	1.14	589	38
312A	12685'(17 - 23 cm b.t.)	Core	1.35	604	48
313A	12688'(47 - 55 cm b.t.)	Core	1.32	603	31
314A	12694'(73 cm b.t.)	Core	1.33	603	59
315A	12721'(73 - 76 cm b.t.)	Core	1.29	599	14
316A	12721'(37 - 43 cm b.t.)	Core	1.35	601	26
317A	12710'- 12720'	Cuttings	1.32	600	13
390A	12810'- 12820'	Cuttings	1.19	592	11
391A	13010'- 13020'	Cuttings	1.17	590	5

TABLE 2 Continued

Sample no.	Depth interval (feet)	Sample type	Red/green ratio (Q)	Lambda-max	Number of readings
398A	13310'- 13320'	Cuttings	1.17	590	2
400A	13910'- 13920'	Cuttings	1.38	600	2
401A	14210'- 14220'	Cuttings	1.65	630	1

PLATES 1-2
Field width 140
mikron

Plate 1

Association of alginite (yellow objects), sporinite (brown objects) in a mineralous-bituminous groundmass dominated by matrix-bituminite and liptodetrinite. Greater algae are attributed alginite of Tasmanites type, while the thinwalled types with the same fluorescence properties are referred to Leiosphaeridales. Sporinite is identified by its weaker, brownish fluorescence and structures exine.

Sample 388A, $Q = 1.07$, $\lambda\text{-max} = 579$. Blue-light induced fluorescence.

Association of alginite of Tasmanites type and lamellar, brown fluorescent organic matter.

Sample 314A, $Q = 1.33$, $\lambda\text{-max} = 603$. Blue-light induced fluorescence.

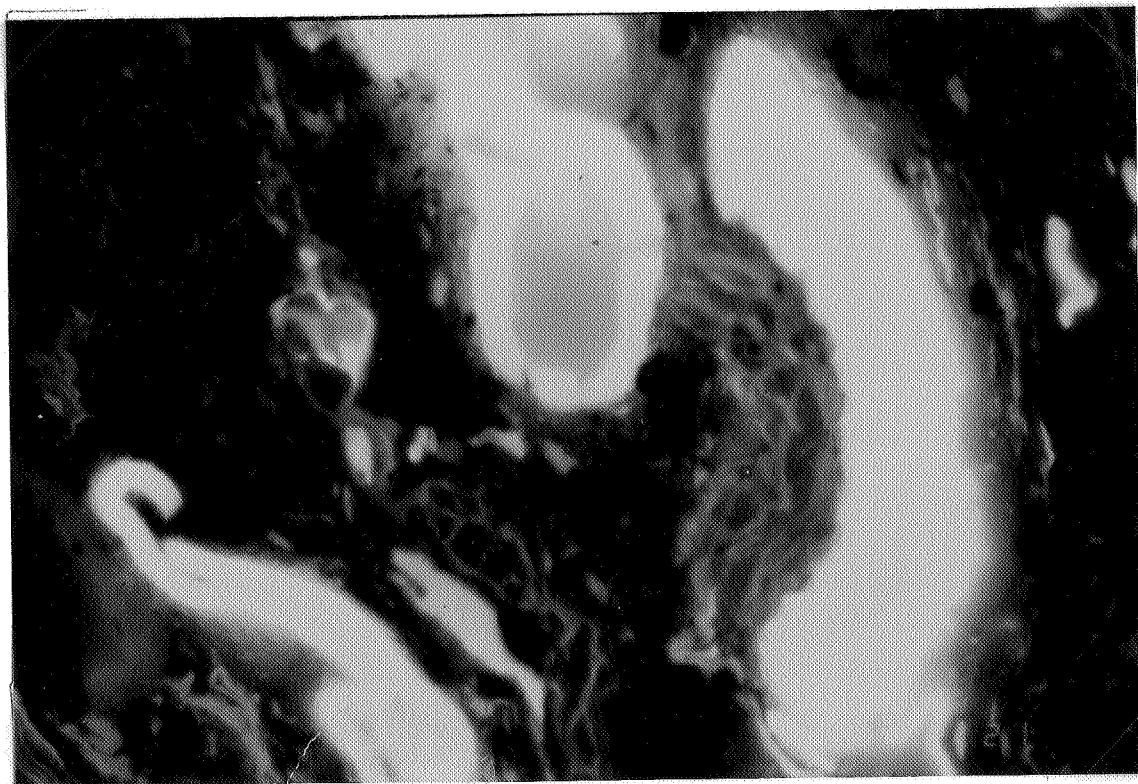
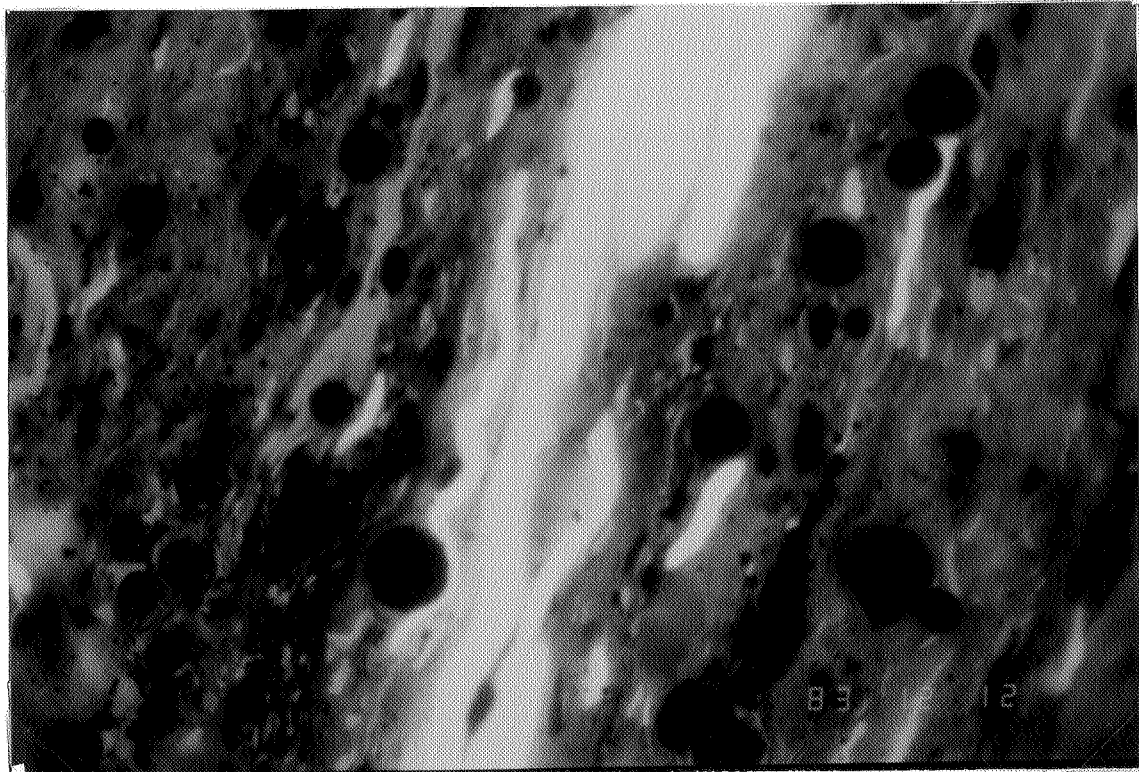


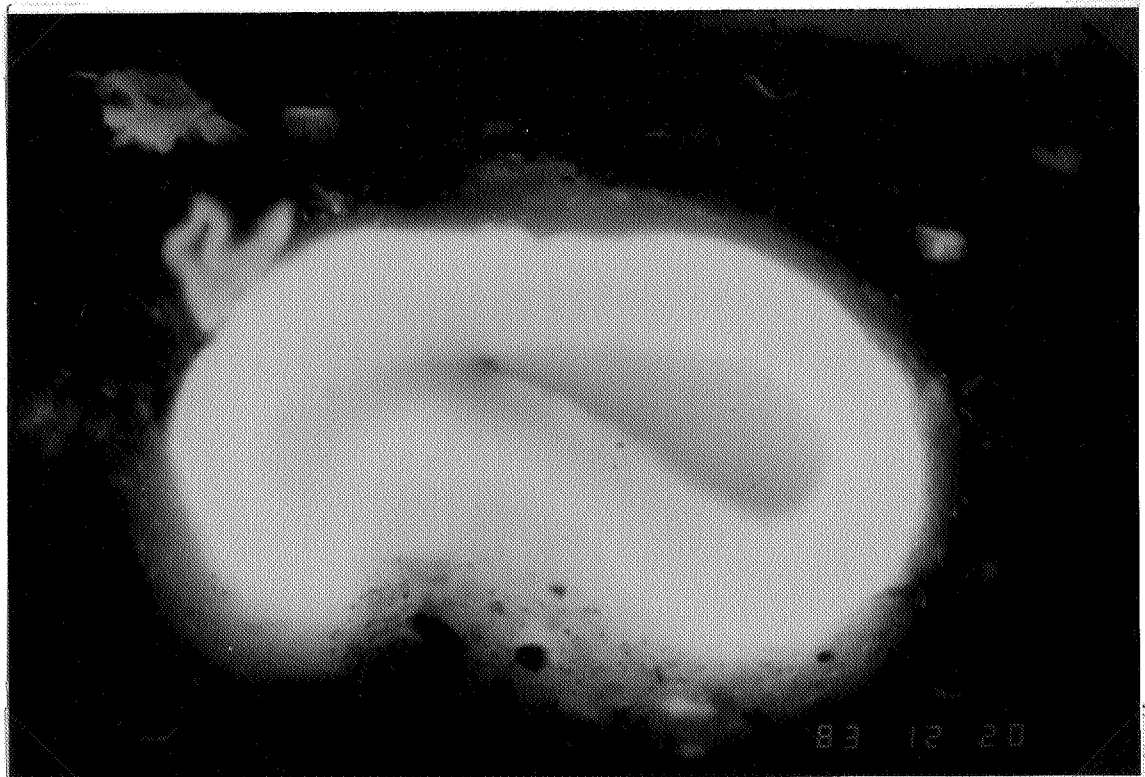
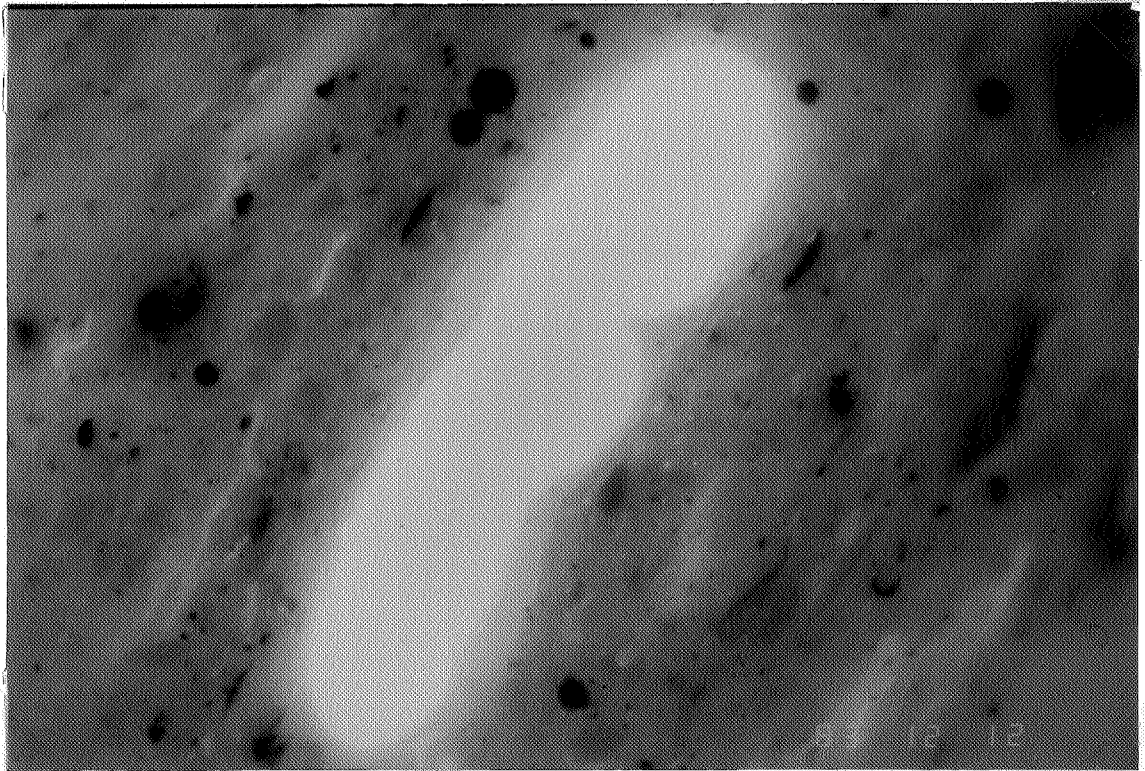
Plate 2

Strong fluorescent alginite of Tasmanites type orientated parallel to the bedding in a mainly mineralous groundmass, Diffuse, brown fluorescent organic matter represents matrix-bituminite.

Sample 387A, $Q = 1.15$, $\lambda\text{-max} = 593$. Blue-light induced fluorescence.

Deformed, disc-shaped alginite of Tasmanites type associated with sporinite and liptodetrinite.

Sample 314A, $Q = 1.33$, $\lambda\text{-max} = 603$. Blue-light induced fluorescence.



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