ORGANIC FACIES IN THE SABLE SUBBASIN, SCOTIAN SHELF

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ABSTRACT

Fifty-two organic-rich and organic-lean cutting and core samples from three boreholes (S. Venture O-59, Venture B-43, and Louisbourg J-47) from the Scotian Basin were analyzed by transmitted and incident light microscopy, elemental analysis, and Rock-Eval pyrolysis to determine organic facies and source-rock potential of these sediments. Fluorescence and vitrinite reflectance data suggest mature sediments below 4000m. Fluorescence data indicate a possible extension of oil/wet gas floor in the overmature zone because of overpressuring.

Most of the cutting samples are contaminated with lignite, pipe dope, fibre, asphalt etc. which created problems for the identification of source rocks by chemical methods.

Six organic facies were defined which included different proportions of terrestrial, mixed, and marine organic matters. Organic facies determined four oil-prone (Type IIA-IIB) and several condensate/minor oil-prone (IIB) mature source rocks in S. Venture O-59 borehole in both Missisauga and Mic Mac Formations (Oxfordian to Turonian age); these are mainly deposited in a restricted prodelta environment. Venture B-43 sediments contain mainly condensate/minor oil-prone (Type IIB) mature source rock in Oxfordian to Turonian age; these are mostly deposited in a partially restricted shallow marine environment. Contradictory to earlier report, sediments in the borehole Louisbourg J-47 are mainly gas-prone (Type IIB-III and III) source rocks.

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INTRODUCTION

Administrative Aspect

This research proposal was requested by Supply and Services of Canada, Dartmouth, Nova Scotia at the initiation of the Eastern Petroleum Geology Division, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Accordingly, we submitted the research proposal on October 18, 1988. The proposal was accepted by SSC, Dartmouth, Nova Scotia on October 28, 1988. Research work was started from Novemver 1, 1988. COGLA, Halifax on our request, permitted us to collect fifty samples (ten conventional cores and forty unwashed cuttings) from three boreholes (S. Venture O-59, Venture B-43, and Louisbourg J-47) from the COGLA Repository facility at the Bedford Institute of Oceanography, Dartmouth, N.S.

Scientific Aspect

The Sable subbasin, an integral part of the Scotian Basin, is a major depocenter for Mesozoic-Cenozoic sediments (Jansa and Wade, 1975; Grant et al., 1986). Sable subbasin sediments contain major condensate and gas deposits; sediments below 4500m are mostly geopressured.

Since 1974, several researchers studied kerogen quality (by transmitted light microscopy), thermal history, and geochemistry of crude oil and condensates by using organic geochemical parameters (Hacquebard, 1974; Bujak et al., 1977, Cassou et al., 1977; Rashid and McAlary, 1977; Purcell et al., 1978; Powell and Snowdon, 1979; Barss et al., 1980; Powell, 1982, 1985; Grant et al., 1986). With a few exceptions (Bujak et al., 1977; Barss et al., 1980), most of these works used indirect chemical methods (gasoline-range hydrocarbon ratio, elemental analysis; C15+ GC data etc.). Except biomarkers (no study was made in the Scotian Basin), other chemical parameters are not suitable to illustrate source-rock potential when the sediments are beyond 0.8% R_o and studied with a contaminated cutting sample. Because dehydrogenation, homogenization, and cracking reactions are associated with the advanced maturation, most of the chemical methods, therefore, are not very suitable to evaluate the subtle difference between various organic facies and eventually source-rock types. This is especially difficult when the sediments are affected by contamination in the cuttings sample. On the other hand, microscopic technique using only transmitted-light kerogen smear slides, is not enough to differentiate between oil-prone and non-oil-prone amorphous organic matters (example: amorphogen of Bujak et al., 1977), which are mostly the major constituents in marine and deltaic source-rocks. Improved microscopic techniques use a combination of transmitted white light and incident white/blue (fluorescence) light to study kerogen smear slide, kerogen polished plug, and whole-rock polished plug together. This technique is more useful in differentiating any variation in organic facies within source or non-source rocks especially at higher maturation (Teichmuller and Ottenjann, 1977; van Gijzel, 1981; Mukhopadhyay et al., 1985; Senftle et al., 1986; Teichmuller, 1986; Jones, 1987; Dow et al., 1988; Mukhopadhyay, 1989).

A recent report on Rock-Eval pyrolysis of the sediments from the borehole Louisbourg J-47 suggests several thick zones of oil-prone source-rocks in the Jurassic-Cretaceous section of the Scotian Basin. This research work was therefore, initiated to evaluate the variability in organic facies and source-rock potential of selected organic-rich and some organic-lean sediments from three boreholes (S. Venture O-59, Venture B-43, Louisbourg J-47). Improved microscopic techniques were used for all samples, which is supplemented by elemental analysis and Rock-Eval pyrolysis on a selected samples especially from the deeper part of the boreholes.

SAMPLES AND METHODS

Samples

A total of fifty samples were collected from three boreholes. Out of which, forteen samples are chosen from borehole S. Venture O-59 (depths between 4010 and 6171m), twelve samples are from Venture B-43 (depths between 4560 and 5871m), and twenty-four samples are from borehole Louisbourg J-47 (depths between 1030 and 6000m). Two additional samples (4845m and 5655m) from borehole Louisbourg J-47 were also analyzed microscopically (only from kerogen smear slides supplied by AGC). All samples were washed and crushed to -20 and +40 mesh for whole rock polished plug preparation, -40 mesh for kerogen isolation for some of the samples, and -60 mesh for Rock-Eval pyrolysis.

Analytical Methods

Kerogen isolation was done by Atlantic Geoscience Centre according to the method after Barss and Williams (1973). We received kerogen smear slide and polished kerogen plugs from the Atlantic Geoscience Centre. Whole rock polished plugs were prepared and maceral analysis were done according to Stach et al., (1982). For maceral point counting, all three types of preparations (kerogen smear slide, kerogen polished plug, and whole rock polished plug) were taken using transmitted white light for the smear slides, incident white light for both kerogen and whole rock plugs, and incident blue-light (fluorescence) for kerogen smear slde/polished plug and whole rock polished plug. Five hundred point counts were made for each sample. For some of the samples from Louisbourg J-47, only kerogen smear slides and polished whole rocks were utilized, because kerogen polished plugs were not available from the Atlantic Geoscience Centre.

The maceral terminology used in this report, are taken from Stach et al., (1982), Mukhopadhyay et al., (1985), and Mukhopadhyay (1989). Equivalent terms of different maceral types are taken from Teichmuller and Ottenjann (1977), van Gijzel (1981), Senftle et al., (1986), and Hutton (1987). Vitrinite reflectance was measured using a Zeiss Universal Microscope; however, most of the data were taken from Avery (1983, 1988).

Rock-Eval pyrolysis was performed on five samples using a Delsi Oil Show Analyzer (after Espitalie, 1985). TOC was determined by Leco Carbon Analyzer after acid treatment.

Elemental analysis (carbon, hydrogen, oxygen, and nitrogen) was done on twenty-two isolated kerogens using a Carlo-Erba Elemental Analyzer (model 1106) as described by Howarth (1977).

RESULTS AND DISCUSSION

Location and Lithology

Figure 1 shows the location of three boreholes (A = S. Venture O-59; B = Venture B-43; C = Louisbourg J-47). Boreholes A and B are within the Sable subbasin and borehole C is in the NE corner of Scotian basin (outside the Sable subbasin).

Except a few samples in the borehole Louisbourg J-47 (1030m, 3105m etc.), most of the analyzed samples are gray/black shale or marl/limestone with or without variable proportions of green marl, green shale, sandstone, and dolomitic limestone (Table 3). Figure 2 shows a generalized stratigraphy showing age, lithology, and Formations. Except one sample in borehole Louisbourg J-47 (1030m), all other samples are within Callovian and Turonian age.

Organic Petrography

a. Maceral composition

A systematic definition of different maceral types is given in the appendix. Table 1 illustrates the maceral composition (volume percent in mineral-free basis) and their fluorescent characteristics of fifty-two samples from three boreholes. In order to clarify maceral terminology and amorphous liptinites, equivalent terms and possible hydrocarbon generation characteristics, are shown in the footnote of Table 1. Core samples are marked as (c); all other samples are cuttings. None of these samples contain any amorphous liptinite I (see appendix for definition). Because of the advanced maturation, all the amorphous liptinite, alginite, exinite, and particulate liptinite A contain an appreciable amount of secondary macerals (example: granular vitrinite, micrinite, clustered micrinite, rank-alginite etc. (Stach et al., 1982; Mukhopadhyay et al., 1985; Dow et al., 1988). Original macerals were identified from the morphology as seen in the transmitted light and the change in morphology as seen in the incident light microscopy.

Except three samples, all samples in borehole S. Venture O-59 contain different proportions of amorphous liptinites (IIA, IIB, and III). Sample 4010m and 4130m contain mainly vitrinite (both allochthonous and autochthonous), exinite (sporinite and cutinite) (Fig. 3G, H, I, J); sample 4010m contains also amorphous liptinite III. Samples 4940m, 4980m, 5420m, 5590m and 6115m in borehole A contain a major proportion of marine-derived maceral types (amorphous IIA, particulate liptinite A, and alginite) (Fig. 4B, F, G, and H). However, mixed marine/terrestrially-derived amorphous liptinite (IIB) is the major maceral in most of the samples in borehole A (Fig. 4A, E, G, and I).

In the borehole A (S. Venture O-59), most of the cuttings samples are affected by contamination from lignite (Fig. 4D and H), asphalt, pipe dope (Fig. 4H), fibre, rubber, and paint. This contamination could be seen mainly in the kerogen concentrate and to some extent in the whole rock preparation. Maceral composition was calculated based on recognized non-contaminant maceral types. As an example, sample 6115m contains more than 40-50% ulminite (vitrinite) and 10-20% exinite from lignite contaminant. Excluding these contaminations, sample 6115m contains mainly marine organic matter.

According to fluorescence characteristics (yellow to red fluorescence), all analyzed samples in borehole A are within main phase of oil and wet gas generation (except samples below 6000m). Some contamination shows greenish yellow fluorescence. Some of the samples (4940m, 5590m, 6115m) contain anomalously high liquid and solid bitumen (pyrobitumen or impsonite).

In Venture B-43, there is a clear variation of maceral composition between 4560 and 5871m. Upper four samples contain either mixed organic matter (4560m and 4760m) or a dominant marine maceral types (4959m and 4962m). Between 5271 and 5871m, all samples contain dominant terrestrially-derived maceral types (except samples 5620m and 5770m). Three samples below 5800m contain more than 75% terrestrially derived maceral types (vitrinite, exinite, inertinite, and amorphous liptinite III).

Fluorescence data (yellow to red fluorescence) suggest that all samples from borehole B (Venture B-43) are within main phase of oil and wet gas generation. Sample 4962m contains abundant solid bitumen (weak dark brown fluorescence).

Except samples 4830m and 5655m, all samples from borehole C (Louisbourg J-47), have dominant (60-80%) terrestrially-derived maceral types (Fig. 3A, B, E. F). However, some samples (5437m, 5455m, 5580m, 5655m, and 5730m) contain more than 50% mixed marine/terrestrial maceral types (amorphous liptinite IIB and liptodetrinite) and some amount of marine maceral types (Fig. 3C, D). Most of the cuttings samples contain variable amounts of contaminations like lignite, fibres (Fig. 3D, possibly fresh wood (Fig. 3F), paint, and rubber. Compared to earlier reported Rock-Eval data (Snowdon and Fowler, 1988) showing several potential source rocks, most of the samples from the borehole C do not contain much marine maceral types of higher hydrocarbon potential. This suggests contamination effects on the cutting samples.

Fluorescence data suggest that main phase of oil generation started around 3700m and all samples are within oil/wet gas zone.

b. Vitrinite Reflectance

Table 3 shows the vitrinite reflectance of most of the samples from these three boreholes. In S. Venture O-59, analyzed samples have a maturity between 0.74 and 2.42% Ro which includes the boundary of oil, wet gas, and dry gas zone. Lower part of the section below 5590 should be considered overmatured and should not contain any fluorescence. However, fluorescence data suggest either retardation of maturity or an extension of liquid/wet gas zone until a maturity of 2.4% Ro, possibly due to overpressuring. Samples between 4560 and 5871m in the borehole Venture B-43 have maturity between 0.75 and 2.12% Ro which includes oil, wet gas and dry gas zone. A complete sequence of immature to mature sediments (0.25 to 1.81% Ro) were encountered in the borehole C (Louisbourg J-47).

Elemental Analysis

Table 2a shows the nitrogen, carbon, hydrogen, and oxygen (by direct determination) content and atomic H/C and O/C ratios of twenty-two samples from three boreholes. Except samples 4010m and 4130m, all samples from borehole S. Venture O-59 show anomalously high oxygen content compared to their advanced maturity. Low carbon content in sample 5175m (S. Venture O-59) indicate major sandstone rather than black shales were taken during kerogen isolation. Anomalously high H/C and O/C ratios compared to maturation for all samples (except 4010m and 4130m), suggest possible contamination in the kerogen concentrates.

Oxygen content, atomic H/C and O/C of all core samples from both Venture B-43 and Louisbourg J-47 show normal sequence of mature source rocks as revealed by organic petrography. On the other hand, cuttings sample 5570m (Venture B-43) contains much higher oxygen content compared to its maturity and suggests contamination.

Rock-Eval Pyrolysis

Three core samples and one hand-picked cutting samples from boreholes A, B, and C show higher Tmax (between 457 and 503), production index, and low hydrogen index (31 to 56 mg HC/G TOC). TOC content of three samples are more than 1%. Comparing production index and Tmax for Kerogen Type II-III or III source rocks (Espitalie, 1985), this data indicate that all four samples have maturity more than 1.0% R_o. One cutting sample (6115m) from S. Venture O-59, which could not be hand-picked, shows low Tmax (431^{o}C) suggesting contamination and high bitumen content.

ORGANIC FACIES AND SOURCE-ROCK POTENTIAL

The term 'Organic facies' was earlier elaborated by Rogers (1980) and was defined by Jones and Demaison (1982) (appendix). Jones (1987) elaborated seven different organic facies characteristics based on H/C ratio and Rock-Eval pyrolysis (Fig. 5a and table therein). Twenty-two samples from three boreholes were plotted on H/C and O/C according to the organic facies plot of Jones (1987) (Fig. 5b). O/C ratio of organic facies plot of Jones (1987) was limited to 0.25, which is normal for evaluating different kerogen maturation paths. Except samples 4010m and 4130m, all samples from S. Venture O-59 and one sample from Venture B-43 (5570m) are outside the normal O/C ratio (beyond 0.25). These samples are therefore considered contaminated by drilling mud additives and cavings and can not be evaluated by the method adopted by Jones (1987). Two samples from S. Venture O-59 and one sample from Venture B-43 (4962m), and three samples from Louisbourg J-47 (2695m, 4411m, and 4420m) lie within Organic Facies C (terrestrial, some oxidation) having a possible hydrogen index of 125-250 (mg HC/g TOC) in the immature stage. One sample from Venture B-43 (4959m) lie within Organic Facies BC (mixed; some oxidation, possible HI 250-400 in the immature stage). Five other samples from Louisbourg J-47 are too mature for the proper evaluation of Organic Facies according to Jones (1987).

It is therefore observed that the method adopted by Jones (1987) for evaluating 'Organic Facies' and source-rock potential is not suitable for mature/overmature sediments and the rocks which are contaminated by drilling mud additives or cavings. In order to evaluate 'Organic facies' and source-rock potential, petrographic morphological characteristics and oxidation features are utilized (Mukhopadhyay et al., 1983; Mukhopadhyay et al., 1985; Dow et al., 1988). Six different organic facies were considered from the maceral analysis to evaluate the analyzed samples on a bitumen-free basis (Table 3). Oxidation level was considered according to the morphologic characteristics of macerals and pyrite (Table 3). In evaluating kerogen types and their source-rock potential, organic facies, oxidation level, and organic input are considered. Similarly depositional environment can be predicted from the association of organic facies, oxidation level, and organic input. Organic input was evaluated from the percentages of maceral types of similar affinity. As an example, terrestrial input is considered when an organic matter has more than 60% vitrinite, inertinite (excluding micrinite), exinite, and amorphous liptinite III. Appendix B illustrates the source-rock potential and hydrocarbon types of different organic facies (after Mukhopadhyay, 1989). Main oil-prone source rocks (>60-80% oil) are associated with Organic Facies 1 (both A & B), 2 (both A & B), and 3 (both A & B), which form Type I, IIA, and IIA-IIB source rocks. Type IIB source rock generates mainly condensate (>60%) with minor oil (20%) and gas. Type IIB-III generates mainly gas (>60%) with condensate; Type III yields major gas with very minor liquid hydrocarbons. Type III-IV and IV is a non-source for generating hydrocarbons.

Table 3 shows a comprehensive picture of organic facies distribution, maturity, and source-rock potential of all analyzed samples from the three boreholes according to age and formation. According to organic facies distribution and oxidation level, no Type I or Type IIA source rocks (generating more than 80% oil) are encountered in any of these sediments. However, in S. Venture O-59, three oil-prone source rocks (Type IIa-IIB) (depths 4940m, 4980m, and 5420m) are encountered in Missisauga Formation and one in the Mic Mac Formation. The depositional environment for these oil-prone mature source rocks is partially anoxic prodelta shales (Oxfordian to Tithonian). There is only one typical oil-prone mature source rock in borehole Venture B-43 (depth:4959m, Tithonian). However, most of the Missisauga shales in Venture B-43 and Mic Mac shales (Oxfordian to Kimmeridgian) in S. Venture O-59 are condensate/ minor oil-prone source rocks (Type IIB). In the Louisbourg J-47 borehole, a vast majority of the analyzed samples from Missisauga and Mic Mac Formations, are gas prone mature Type IIB-III and III source-rock and derived either from the oxidized marine organic matter or terrestrial organic matter. Only one mature oil-prone Type IIA-IIB kerogen (depth 4830m; Oxfordian to Kimmeridgian) shale is observed in Louisbourg J-47, where more samples are analyzed. A typical anoxic facies derived from an upwelling region or mid-ocean anoxia due to high sedimentation rate and mixed organic matter, is absent in any of these sediments. Most of sediments are mildly oxidized and diluted with terrestrial organic matter.

CONCLUSIONS

1a. Petrographic analysis of fifty-two samples by transmitted and incident light microscopy, from three boreholes show wide variation of terrestrial (vitrinite, exinite, etc), mixed (liptodetrinite, etc.), and marine (particulate liptinite A, etc.) maceral types. Three types of amorphous liptinites are recognized from their morphologic characters and changes due to advanced maturity.

b. Fluorescence data suggest that all samples below 4000m are within oil and wet gas zone. However, vitrinite reflectance data show overmaturity below 5700m in boreholes S. Venture O-59 and Venture B-43. This suggests an extension of oil/wet gas floor due to overpressuring.

2. Cutting samples are found to be contaminated by lignite, pipe dope, asphalt, fibre, fresh wood, rubber, and paint, which mask chemical data.

3. Hydrocarbon potential of different source-rocks based on organic facies as defined by Jones (1987) can not characterize overmature and contaminated samples.

4. A new concept of organic facies (six types) using maceral association, oxidation level, and organic input identify four oil-prone source rocks in S. Venture O-59, one in Venture B-43, and one in Louisbourg J-47. S.Venture O-59

sediments contain more condensate-prone source rocks in the Oxfordian to Kimmeridgian age; both oil-prone and condensate-prone source rocks are mostly prodelta shales deposited in a partially sheltered basin. Louisbourg J-47 sediments are mainly deposited in open marine partially oxic basin and contain mainly gas-prone source rocks and non-source rocks.

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TABLE 1. Maceral Composition of shale samples from borehole S. Venture O-59, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
4010	44.5	2.2	16.0	2.5	2.2	0.9	8.4	14.8	1.6	4.7	2.2	yellow-orange
4130	38.6	1.1	52.5	0.0	1.1	0.0	2.0	0.9	1.3	1.8	0.7	orange
4940#	2.9	1.7	3.0	0.0	10.6	13.2	40.6	8.4	2.8	10.1	6.7	red
4980#	5.5	1.3	2.3	0.0	1.3	19.7	65.8	2.0	0.7	0.0	1.4	orange
5175#	25.2	2.9	16.8	0.7	1.9	1.2	31.8	14.0	1.9	2.4	1.2	orange
5255#	17.5	1.4	7.6	0.0	4.1	0.6	52.2	11.8	1.7	1.7	1.4	yellow-orange
5380#	18.7	1.5	5.4	0.2	2.5	3.8	27.2	36.6	1.4	1.6	1.1	orange
5420#	17.4	0.6	3.1	0.3	4.0	20.2	35.8	15.1	1.9	0.0	1.6	orange

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Minor O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole S. Venture O-59, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
5590-5595#	16.8	0.4	23.6	2.0	8.8	11.2	3.5	2.6	2.6	5.5	23.0	orange
5700#	16.1	3.0	18.6	0.2	7.7	0.0	15.8	28.0	1.7	5.9	3.0	red
5965#	19.6	2.2	6.1	0.3	2.5	2.5	52.8	9.6	0.0	0.9	3.5	red
6080#	7.5	1.4	7.9	1.3	2.7	4.9	55.4	17.6	0.0	0.3	1.0	dark brown
6115-6120#	4.3	1.3	4.6	0.0	0.0	41.4	23.2	9.9	1.0	5.0	9.3	dark brown
6170#	13.4	2.6	11.2	0.0	7.7	6.6	40.8	4.6	3.5	6.1	3.5	red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Low O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Venture B-43, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
4560	11.3	0.6	14.3	2.0	1.7	3.7	40.0	4.0	2.0	19.3	1.1	yellow-orange
4760#	17.9	2.3	15.2	0.0	0.6	1.3	44.8	2.0	3.3	11.9	0.7	orange
4959(c)	8.8	1.3	7.6	0.2	5.0	11.5	40.3	10.7	7.6	6.0	1.0	red
4962(c)	8.7	2.3	5.7	0.2	2.1	7.1	55.9	0.4	3.8	6.9	6.9	orange-red
5210#	29.6	5.7	8.0	0.7	2.0	4.3	35.0	5.0	5.0	3.0	1.7	orange-brown
5320#	27.0	2.0	7.0	0.3	0.3	2.0	40.7	7.0	1.0	11.7	1.0	orange-brown
5570#	47.0	4.3	17.0	1.3	0.7	2.3	22.0	1.7	0.0	3.0	0.7	orange-red
5620#	33.7	3.3	9.0	1.0	0.3	7.0	32.0	4.0	2.0	5.0	2.7	red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Minor O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Venture B-43, Scotian Shelf

SAMPLE					Part.	Amorphous Liptinite						Fluorescence
ID (m)	Vit.	Int.	Exin.	Res.	Lip.A	IIA	IIB	III	Alg.	Lpdet.	Bit.	of Exin/Alg
5770#	22.4	1.7	22.3	0.3	2.0	8.0	31.7	1.0	1.3	8.3	1.0	red-brown
5800#	40.0	1.3	25.7	1.7	0.7	3.3	11.6	8.0	0.7	5.0	2.0	red
5860#	38.7	1.7	26.0	1.0	0.0	0.7	10.6	7.0	2.0	9.3	3.0	red-brown
5871#	44.4	1.0	32.0	0.7	0.3	0.7	10.2	3.5	0.6	5.0	1.6	orange-red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Low O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Venture B-43, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
5770#	22.4	1.7	22.3	0.3	2.0	8.0	31.7	1.0	1.3	8.3	1.0	red-brown
5800#	40.0	1.3	25.7	1.7	0.7	3.3	11.6	8.0	0.7	5.0	2.0	red
5860#	38.7	1.7	26.0	1.0	0.0	0.7	10.6	7.0	2.0	9.3	3.0	red-brown
5871#	44.4	1.0	32.0	0.7	0.3	0.7	10.2	3.5	0.6	5.0	1.6	orange-red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Low O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Venture B-43, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
5770#	22.4	1.7	22.3	0.3	2.0	8.0	31.7	1.0	1.3	8.3	1.0	red-brown
5800#	40.0	1.3	25.7	1.7	0.7	3.3	11.6	8.0	0.7	5.0	2.0	red
5860#	38.7	1.7	26.0	1.0	0.0	0.7	10.6	7.0	2.0	9.3	3.0	red-brown
5871#	44.4	1.0	32.0	0.7	0.3	0.7	10.2	3.5	0.6	5.0	1.6	orange-red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Low O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE I. Maceral Composition of shale samples from borehole Louisbourg J-47, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
1030#	46.2	0.8	7.6	1.4	2.0	0.8	8.4	25.2	0.6	4.8	2.2	yellow-orange
1575#	41.4	1.6	11.8	1.3	4.3	11.8	21.4	1.6	2.0	1.2	1.6	yellow-orange
1905+#	45.7	0.3	11.7	1.3	2.3	4.3	16.8	10.4	2.3	0.3	4.6	red
2145#	41.7	1.3	35.0	1.6	0.6	1.0	10.2	0.7	1.3	5.0	1.6	yellow-orange
2695	22.0	2.0	18.8	1.3	0.7	1.6	34.2	13.9	0.6	0.3	4.6	yellow-orange
3105#	28.6	0.6	12.3	0.3	1.1	1.7	15.7	18.5	0.9	2.9	17.4	yellow-orange
3705#	28.9	2.0	31.9	0.0	3.9	2.6	21.4	4.6	0.7	1.0	3.0	orange
3825#	36.0	0.9	16.1	0.3	0.6	3.0	22.8	6.7	0.2	4.9	8.5	yellow-orange

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Minor O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Louisbourg J-47, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
3995-4005#	27.4	0.3	38.0	0.3	0.6	1.0	12.9	5.3	0.0	1.6	12.6	orange
4035#	42.5	0.3	25.8	1.6	0	0.0	14.7	5.0	0.0	4.9	5.2	yellow-orange
4411(c)	33.1	2.7	15.2	1.1	1.1	2.8	24.5	9.8	2.5	5.6	1.6	yellow-orange
4420(c)	29.0	1.3	27.2	1.6	4.3	1.0	9.8	4.9	3.6	15.8	1.5	yellow-orange
4830#	4.8	9.6	3.3	0.0	1.9	30.5	24.3	18.0	3.3	0.5	3.8	orange
4845-4860#	38.7	2.0	25.3	0.0	1.0	0.0	15.2	6.7	1.0	2.2	7.9	orange
5175-5190#	21.4	35.3	9.8	0.3	2.1	0.0	9.8	9.3	0.0	0.0	12.0	orange
5437(c)	18.3	2.0	2.3	0.0	1.0	6.7	50.0	12.5	0.7	4.5	2.0	orange

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Phytoclasts, Zooclasts
Amorphous Liptinite I = Sapropelinite I
Amorphous Liptinite II = Sapropelinite II
Amorphous Liptinite III = Mixture of humic and liptinitic matrix (humosapropelinite)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Minor O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clasta = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Condensate + Gas

TABLE 1. Maceral Composition of shale samples from borehole Louisbourg J-47, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
5439(c)	32.3	1.0	11.2	1.3	2.1	0.6	25.6	20.0	1.3	3.6	1.0	red
5444(c)	32.9	2.3	14.0	1.0	0.7	1.0	33.2	9.3	0.7	4.6	0.3	red
5446(c)	41.8	1.6	16.1	0.7	1.3	1.0	24.3	2.6	1.3	8.0	1.3	orange
5453(c)	37.5	3.9	18.3	1.0	1.0	0.3	22.9	5.6	2.0	6.2	1.3	red
5455(c)	26.5	2.9	5.1	0.0	0.5	2.1	49.2	6.7	1.0	5.0	1.0	red
5580#	21.2	0.0	2.0	0.0	2.7	5.6	59.7	7.6	0.3	0.6	0.3	red
5655-5670#	12.5	0.6	2.5	0.0	3.1	8.9	49.1	6.7	0.3	0.6	15.7	yellow-orange
5730#	13.9	1.0	4.5	0.0	2.9	1.6	50.9	3.4	0.4	0.0	21.4	red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Minor O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

TABLE 1. Maceral Composition of shale samples from borehole Louisbourg J-47, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg
5925-5940#+	10.0	3.0	20.3	0.0	5.3	0.7	16.0	25.7	4.3	2.7	12.0	red
6000#+	15.0	4.7	14.8	0.0	1.6	3.5	18.2	30.9	1.1	1.9	8.3	red

Vit. = Vitrinite
Int. = Inertinite
Exin. = Exinite
Res. = Resinite

Part. Lip A = Lamalginite
Amorphous Liptinite IIA = Sapropelinite IIA
Amorphous Liptinite IIB = Sapropelinite IIB
Amorphous Liptinite III = Humosapropelinite (mixture of humic and liptinitic matrix)

Alg. = Alginite
Lpdet. = Liptodetrinite
Bit. = Bitumen

= Contamination; + = Low O.M; c = core

Sapropelinite = Bituminite = Amorphinite; Particulate Liptinite A = Acritarch, dinfl. clast = lamalginite

Amorphous Liptinite IIA = Oil; Amorphous Liptinite IIB = Condensate + Oil; Amorphous Liptinite III = Gas + Condensate

Table 2a. Elemental analysis of kerogens from borehole S. Venture O-59

DEPTH	NITROGEN WT %	CARBON WT %	HYDROGEN WT%	OXYGEN WT%	ATOMIC H/C	ATOMIC O/C
4010	1.07	64.83	4.25	8.13	0.79	0.09
4130	1.36	67.81	4.48	7.66	0.79	0.08
4980	0.92	42.27	3.83	22.43	1.09	0.40
5175	0.10	6.20	0.81	5.51	1.56	0.67
5380	0.73	32.74	2.99	18.85	1.10	0.43
5590	1.19	51.35	4.54	27.14	1.06	0.40
5965	1.25	49.71	4.51	26.88	1.09	0.41
6080	1.15	53.31	4.63	27.21	1.04	0.38
6115	1.09	46.79	3.85	28.44	0.99	0.46
6170	0.91	40.46	3.46	23.83	1.03	0.44

Table 2a. Elemental Analysis of kerogens from borehole Louisbourg J-47

DEPTH	NITROGEN WT %	CARBON WT %	HYDROGEN WT%	OXYGEN WT%	ATOMIC H/C	ATOMIC O/C
2695	1.15	52.79	4.63	13.29	1.05	0.19
4411	1.12	62.67	4.01	13.16	0.77	0.16
4420	1.30	73.63	4.41	6.99	0.72	0.07
5437	1.25	64.92	3.47	4.54	0.64	0.05
5439	1.25	64.65	3.40	4.68	0.63	0.05
5444	1.35	73.69	3.70	3.83	0.60	0.04
5446	1.08	67.36	3.32	3.65	0.59	0.04
5453	1.14	72.60	3.50	3.19	0.58	0.03
5455	0.73	43.47	3.07	9.47	0.85	0.16

Table 2b. Rock-Eval pyrolysis data

SAMPLE ID	S0 (mg/g)	S1 (mg/g)	S2 (mg/g)	T MAX	T.O.C.	O.P.I.	H.I.
	PRESENT HYDROCARBONS		POTENTIAL HYDROCARBONS	°C	WT %	S1/(S0+S1+S2)	100*S2/TOC
Louisbourg J-47 5439m	0.00	0.43	0.59	494	1.64	0.42	36
Louisbourg J-47 5455m	0.00	0.42	0.39	503	1.25	0.52	31
South Venture O-59 5380m	0.00	1.39	1.01	465	1.81	0.58	56
South Venture O-59 6115m	0.00	1.47	1.11	431	3.07	0.57	36
Venture B-43 4959m	0.00	0.74	0.86	457	2.02	0.46	43

Table 3. A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole S. Venture O-59

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. (%R_o) R_o	Std.D	(#) Organic Facies distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas Potential (**)
4010	Dark gray shale with minor sst	Missisauga	Barriasian-valanginian	Inner Neritic	0.74 (mature and oil zone)	0.08	2	3	14	19	60	2	mildly anoxic (shallow silled marine)	Terrest-rial	III	Gas
4130	Dark gray shale with minor Lst	Missisauga	same as above	Inner Neritic	0.76 (mature and oil zone)	0.07	1	1	4	53	40	1	mildly anoxic (shallow marine)	Terrest-rial	III	Gas
4940	Black shale	Missisauga	Late Kimm. to Tithonian	Inner Neritic - marginal marine	1.05 (mature and oil zone)	0.12	3	26	54	3	12	2	anoxic (partial) (silled shallow marine)	Mixed	IIA-IIB	Oil Cond.
4980	Black shale with minor sst	Missisauga	same as above	same as above	1.12 (mature and oil zone)	0.10	1	21	67	2	8	1	anoxic (partial) (same as above)	Mixed	IIA-IIB	Oil Cond.
5175	Dark gray shale with sst	Missisauga	same as above	same as above	1.22 (mature and oil zone)	0.10	2	3	35	18	39	3	mildly anoxic (shallow marine)	Terres-trial	IIB	Cond. Gas Oil
5255	Dark gray shale with sst	Missisauga	same as above	same as above	1.25 (mature and oil zone	0.08	2	5	54	8	30	1	mildly anoxic (shallow marine)	Terres-trial	IIB	Cond. Gas, oil

* from micropaleontological data

** Kerogen Type and Oil/gas potential in immature or mature stage

\+ Environment determined from organic petrography

sst = sandstone; lst = limestone

ORGANIC FACIES

1 A - Alginite (Telalginite); B - Amorphous Liptinite I

2 A - Particulate Liptinite A (Lamalginite); B - Amorphous Liptinite IIA

3 A - Liptodetrinite; B - Amorphous Liptinite IIB

4 A - Exinite; B - Resinite+Fluorinite

5 A - Vitrinite; B - Amorphous Liptinite III

6 A - Inertinite(Autochthonous); B - Inertinite(Allochthonous)

(#) = Organic facies distribution calculated in bitumen-free basis

Table 3. A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Venture B-43

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. (%R_o) R_o	Std.Dv.	(#)Organic Facies distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/ Gas potential
4340	-	-	-	-	0.75	0.04	-	-	-	-	-	-	-	-	-	-
4560	Green marl + gray shale	Missisauga	Valangi-nian to Ber-riasian	Inner Neritic - marginal marine -continental)	-	-	2	5	60	17	15	1	mildly oxic (shallow marine; deltaic?)	Mixed	IIB	Cond. Gas
4610	-	Missisauga	-	-	0.82 (mature-oil zone)	0.03	-	-	-	-	-	-	-	-	-	-
4760	Calc. gray shale + green/gray shale	Missisauga	Titho-nian	Inner Neritic	-	-	3	2	58	15	20	2	Same as sample 4560m	Mixed	IIB	Cond. Gas
4959	Black shale	Missisauga	Tithon-ian	same as sample 4760	0.92 (mature - oil zone)	0.06	8	17	45	9	20	1	anoxic (partial) (sheltered shallow marine)	Mixed	IIA-IIB	Oil Cond.
4962	Dark gray shale	Missisauga	Titho-nian	same as sample 4760	-	-	4	10	67	6	11	2	mildly anoxic (shallow marine)	Mixed	IIB	Cond. Gas Oil
5000	-	Missisauga	-	-	1.04	0.03	-	-	-	-	-	-	-	-	-	-
5210	Gray shale + calc. green shale	Mic Mac	Kimmrid-gian	same as sample 4962	-	-	5	6	39	9	35	6	same as sample 4962	Mixed	IIB	Cond. Gas Oil

Table 3: A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole S. Venture O-59

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. (%R_o) R_o	Std.De.	Organic Facies distribution 1	2	3	4	5	6	Oxidation level (Environm+)	Organic input	Kerogen Type (**)	Oil/Gas Potential (**)
5380	Dark gray shale with sst	Missisauga	Oxford-Kimm	Inner neritic-outer neritic - marginal marine	1.42 (mature - cond/wet gas zone)	0.09	1	6	30	6	55	2	mildly anoxic (shallow marine)	Terrestrial	IIB-III	Gas Cond
5420	Dark gray shale with sst	Missisauga	Same as above	same as above	1.45 (mature - cond-wt gas zone	0.09	2	24	37	3	33	1	Anoxic (partial) (prodelta)	Mixed	IIA-IIB	Oil/ Cond
5590	Gray shale with sst	Missisauga	Same as above	same as above	1.78 (mature - wt gas zone	0.12	3	26	11	34	25	1	mildly oxic (prodelta)	Mixed	IIB	Gas/ Cond
5700	Dark gray shale with calc. silt -stone	Missisauga	Same as above	same as above	1.85 (mature - wt. gas zone	0.13	2	8	22	19	46	3	mildly oxic (shallow marine)	Mixed	IIB-III	Gas
5965	Calc. dark gray shale	Mic Mac	Same as above	Same as above	2.13 (overmature - gas zone)	0.11	-	6	54	7	31	2	mildly anoxic (prodelta)	Mixed	IIB	Cond Gas oil
6080	Calc. dark gray shale	Mic Mac	Same as above	same as above	2.20 (overmature - gas zone)	0.11	-	8	56	9	26	1	mildly anoxic (prodelta)	Mixed	IIB	Cond Gas Oil
6115	Dark gray shale	Mic Mac	Same as above	Same as above	2.25 (overmature - gas zone)	0.12	1	46	31	5	16	1	Anoxic (partial) (prodelta)	Mixed	IIA-IIB	Oil Cond
6170	Dark gray calc. shale	Mic Mac	Same as above	Same as above	2.42 (overmature - gas zone	0.18	4	15	48	11	19	3	mildly anoxic (prodelta)	mixed	IIB	Cond Gas Oil

Table 3. A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Venture B-43

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. (%R_o) R_o	Std.Dv.	(#)Organic Facies distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas potential
5225	-	Mic Mac	Kimmridgian	Inner Neritic	1.14 (mature - oil/wet gas zone)	0.03	-	-	-	-	-	-	-	-	-	-
5320	Gray shale + green calc shale	Mic Mac	Kimmri-dgian	Inner Neritic	1.26 (mature - oil/wet gas zone)	0.04	1	2	53	7	35	2	mildly anoxic (shallow marine)	Mixed	IIB	Cond. Gas Oil
5570	Gray shale +calc. sst.	Mic Mac	Oxford- Kimmri- dgian	Inner Neritic - margi. marine	1.91 (marginally overmature - wet/dry gas zone)	0.03	-	3	25	19	49	4	mildly oxic (shallow marine; deltaic)	Terres-trial	III	Gas
5620	Gray shale +marl	Mic Mac	Callo-vian	outer nertic	-	-	2	8	38	10	38	4	mildly oxic (deep marine)	Mixed	IIB-III	Gas Cond.
5770	Calc. gray shale	Mic mac	Callo-vian	Outer Neritic	-	-	1	10	40	23	24	2	mildly anoxic (shallow/deep marine)	Mixed	IIB	Cond. Gas Oil
5850	Calc gray shale	Mic Mac	Callo-vian	Outer Neritic	-	-	1	4	17	28	49	1	mildly oxic (deep marine)	Terres-trial	III	Gas
5820	-	Mic Mac	Callo-vian	-	2.08 (overmature-dry gas zone)	0.07	-	-	-	-	-	-	-	-	-	-

Table 3. A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Venture B-43

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. (%R_o) R_o	Vitrinite Refl. (%R_o) Std.Dv.	(#) Organic Facies distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas poten-tial
5860	Calc. gray shale	Mic Mac	Callo-vian	Outer Neritic	-	-	2	1	20	28	47	2	mildly oxic (deep marine)	Terres-trial	III	Gas
5871	Calc. gray shale	Mic Mac	Callo-vian	Outer Neritic	2.12 (overmature - dry gas zone)	0.03	1	1	15	34	48	1	mildly oxic (shallow-deep marine)	Terres-trial	III	Gas

Table . A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Louisbourg J-47

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. %R_o - R_o	Std. Dv.	Organic Facies Distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas potential
1030	Sst, dol. lst with minor shale	Banquereau	-	-	0.25 (immature)	0.03	1	3	14	9	72	1	mildly oxic (shallow marine)	Terrestrial	III	Gas (minor
1575	Gray shale with sst & lst	Dawson Canyon	Late Turonian	Outer Neritic	0.29 (immature)	0.03	2	16	23	13	44	2	mildly oxic (shallow marine)	Mixed	IIB-III	Gas
1905	Gray shale with sst & lst	Logan Canyon	E-Mid Cenom.	Inner Neritic	0.36 (immature)	0.06	2	7	18	14	58	1	mildly oxic (shallow marine)	Terrestrial	III	Gas (minor
2145	Gray shale & clay with sst	Logan Canyon	Albian	Inner Neritic	0.35 (immature)	0.04	1	2	16	37	43	1	mildly anoxic (shallow marine)	Terrestrial	IIB-III	Gas Cond.
2695	Gray shale & clay with lst & sst	Logan Canyon	Early Albian	Inner Neritic-Marginal marine	0.45 (immature)	0.05	1	3	36	21	37	2	mildly anoxic (shallow marine)	Terrestrial	IIB	Cond. Gas
3105	Gray sst with gray shale	Missisauga	L.Hauterivian - Barremian	same as above	0.52 (marginally mature)	0.05	1	3	22	16	57	1	mildly oxic (shallow marine)	Terrestrial	III	minor Gas
3635	-	-	-	-	0.66 (mature)	0.05	-	-	-	-	-	-	-	-	-	-
3705	Calc. shale & gray shale	Missisauga	Berriasian-Valang. - E.Hauteriv.	same as above +continental	-	-	1	6	22	33	36	2	mildly anoxic. (shallow marine & deltaic?	Terrestrial	IIB	Cond. Gas

Table . A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Louisbourg J-47

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. %R_o - R_o	Std. Dv.	Organic Facies Distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas poten-tial
3825	Gray sst + lst with coaly part.	Missisauga	Berria-sian - Valang. -E.Hau teriv.	Inner Neritic -Marginal marine-Continental	-	-	1	4	30	18	46	1	mildly anoxic (shallow marine & deltaic?	Terres-trial	IIB-III	Gas Cond.
3935	-	-	-	-	0.64 (mature)	0.06	-	-	-	-	-	-	-	-	-	-
3995	Calc. sst+ black shale	Missisauga	same as above	same as above	-	-	0	2	17	44	37	0	mildly anoxic (shallow marine)	Terres-trial	IIB-III	Gas Cond.
4035	Calc. sst + calc. gray shale	Missisauga	same as	same as above	-	-	0	0	20	29	50	1	mildly oxic (shallow marine)	Terres-trial	III	minor Gas
4411	Dark gray shale	Mic Mac	L.Oxfor -dian-Kimmrid.	Inner to Neritic to Outer Neritic	0.75 (mature & oil zone)	0.06	3	4	30	16	44	3	mildly anoxic (shallow marine)	Mixed	IIB	Cond. Oil Gas
4420	Dark gray shale	Mic Mac	same as above	same as above	-	-	4	5	26	29	35	1	same as above	Mixed	IIB	Cond. Oil Gas
4520	-	-	-	-	0.83	0.07	-	-	-	-	-	-	-	-	-	-
4830	Gray shale & lst	Mic Mac	same as above	same as above	-	-	4	34	25	4	23	10	Anoxic (partial)	Mixed	IIA-IIB	Oil Cond.
4845	Gray shale & lst	Mic Mac	same as above	same as above	-	-	1	1	20	27	49	2	mildly oxic (shallow marine)	Terres-trial	IIB-III	Gas Cond.

Table . A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Louisbourg J-47

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. %R_o R_o	Vitrinite Refl. %R_o Std. Dv.	Organic Facies Distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas potential
5175	Green marl with light gray shale	Mic Mac	L.Oxfordian - Kimm.	Inner to outer Neritic	1.22 (mature & oil zone)	0.16	-	2	12	11	35	40	Oxic (open marine)	Terrestrial	III-IV	non source
5437	Calc. dark gray shale	Mic Mac	Oxford.	same as above	1.35 (mature & oil/wet gas zone)	0.12	1	8	55	3	31	2	mildly anoxic (shallow - deep marine)	Mixed	IIB	Cond. Oil Gas
5439	Calc. dark shale	Mic Mac	Oxford.	same as above	-	-	1	3	29	13	53	1	mildly anoxic (shallow marine)	Terrestrial	IIB-III	Gas Cond.
5444	Calc. dark gray shale	Mic Mac	Oxford.	same as above	-	-	1	2	38	15	42	2	mildly anoxic (shallow marine)	Terrestrial	IIB-III	Gas Cond.
5446	same as above	Mic Mac	same as above	same as above	-	-	1	2	32	18	45	2	same as above	same as above	same as above	same as above
5453	same as above	Mic Mac	same as above	same as above	-	-	2	1	30	19	44	4	same as above	same as above	same as above	same as above
5455	Gray shale	Mic Mac	same as above	same as above	-	-	1	3	55	5	33	3	same as above	Mixed	IIB	Cond. Oil Gas

Table . A composite interpretation on organic facies, maturity, and source-rock potential of sediments from borehole Louisbourg J-47

Depth (m)	Lithology	Formation	Age	Environment (*)	Vitrinite Refl. %Ro- R_o	Std. Dv.	Organic Facies Distribution 1	2	3	4	5	6	Oxidation level (environm+)	Organic input	Kerogen Type (**)	Oil/Gas poten-tial
5580	Mixture: green 1st + gray shale	Mic Mac	Oxford.	Inner to outer Neritic	-	-	0	9	60	2	29	-	mildly anoxic (shallow marine)	Terres-trial	IIB	Gas Cond.
5655	Gray shale with minor green 1st	Mic Mac	same as above	same as above	1.81 (mature & wet-gas zone)	0.15	0	14	59	3	23	1	same as above	Mixed	IIB	Cond. Gas
5730	same as above	Mic Mac	same as above	same as above	-	-	0	6	65	6	22	1	same as above	Mixed	IIB	Cond. Gas
5780	-	-	-	-	1.64	0.14	-	-	-	-	-	-	-	-	-	-
5925	Calc. gray shale with 1st	Mic Mac	Callov. - Oxfor -dian	Inner Neritic - Marginal marine	-	-	5	7	21	23	41	3	mildly oxic (partly open marine)	mixed	III	gas
6000	Mixture: gray shale & green 1st	Mic Mac	same as above	same as above	-	-	1	6	22	16	50	5	same as above	same as above	III	Gas

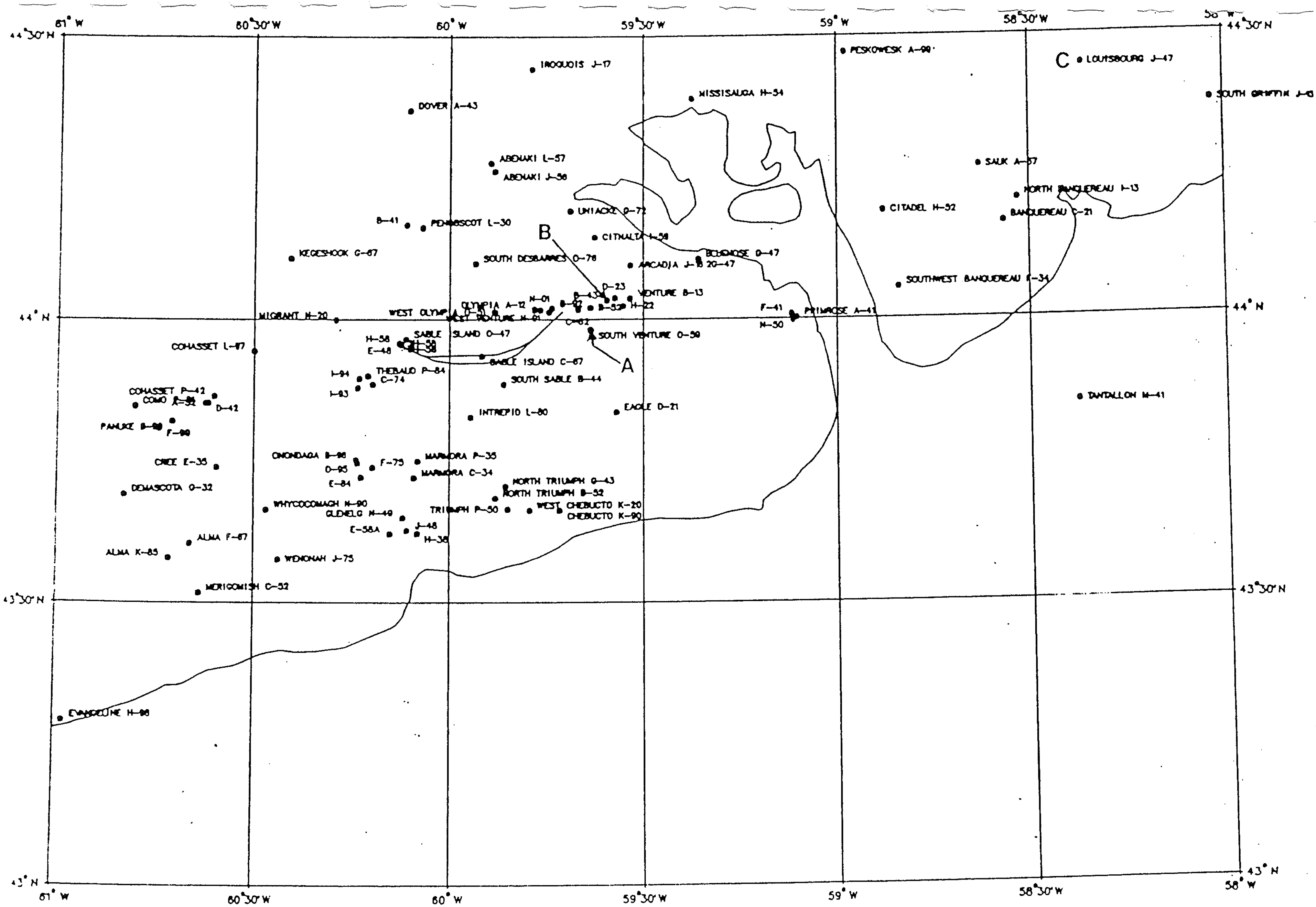

Fig. 1. Location map of the boreholes from Scotian Shelf
Analyzed boreholes: A - South Venture O-59; B - Venture B-43; C - Louisbourg J-47

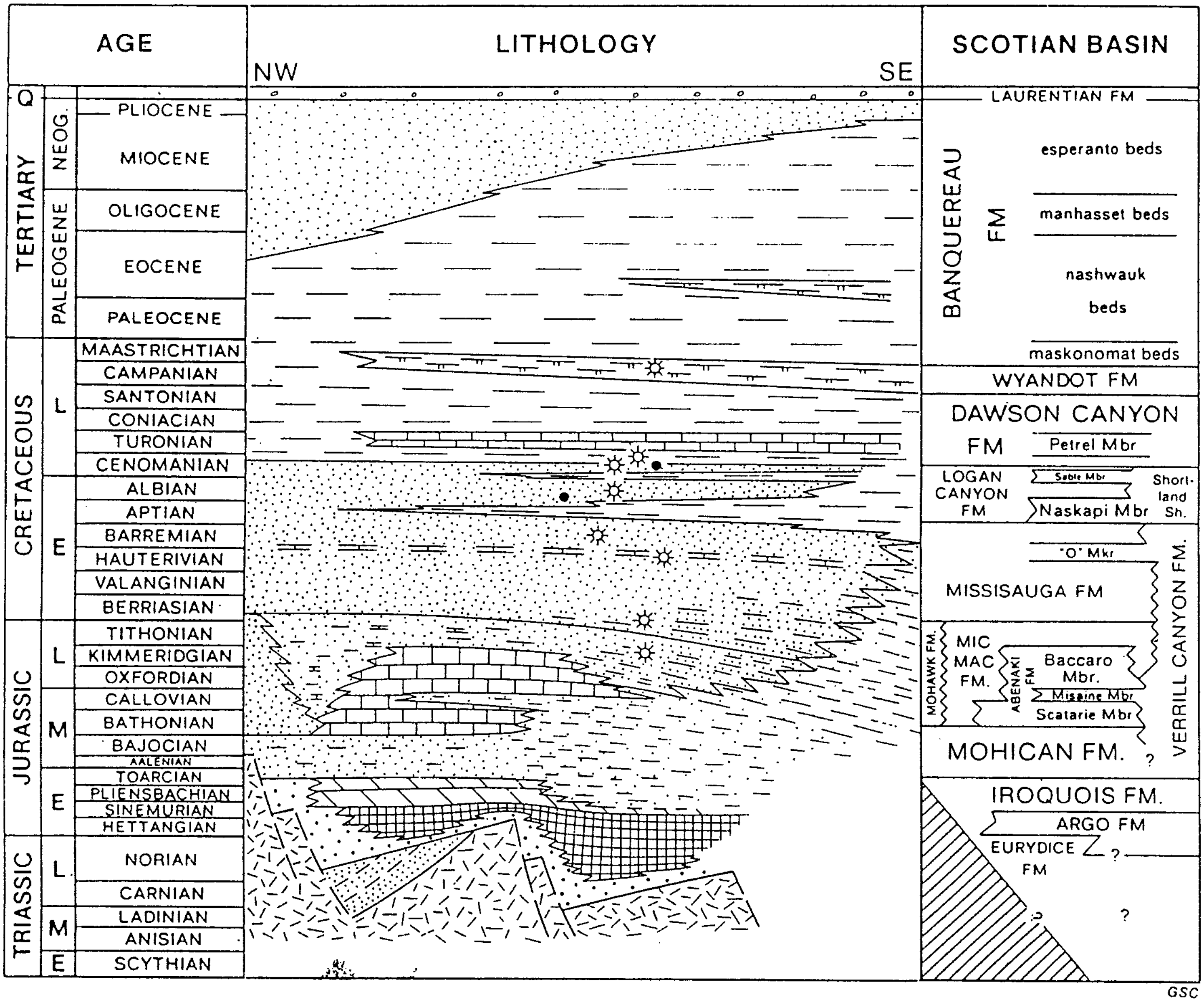

Fig. 2. Generalized stratigraphy of the Scotian Shelf (after Grant et al., 1986)

Figure 3.

Photomicrographs:

Photos C, D, and F are taken in transmitted white light. All other photos are taken in incident white light.

Magnification: 500X for incident light; 200X for transmitted light.

A. Sporinite, cutinite, liptodetrinite, vitrinite, and framboidal pyrite. Louisbourg J-47, 4411m, whole rock.

B. Sporinite, vitrinite, inertodetrinite, amorphous liptinite IIB, and framboidal pyrite. Louisbourg J-47, 4411m, Kerogen concentrate.

C. Amorphous liptinite IIA and IIB, vitrinite, liptodetrinite, and pyrite. Louisbourg J-47, 5455m, kerogen concentrate.

D. Amorphous liptinite IIB, contamination (fiber?), and vitrinite. Louisbourg J-47, 5655m, kerogen concentrate.

E. Sporinite, vitrinite, liptodetrinite, and oxidized pyrite. Louisbourg J-47, 6000m, whole rock.

F. Contamination (fresh wood?), vitrinite, amorphous liptinite III. Louisbourg J-47, 6000m, kerogen concentrate.

G. Vitrinite (autochthonous and allochthonous), cutinite, macrinite, and framboidal pyrite. S. Venture O-59, 4130m, kerogen concentrate.

H. Vitrinite (autochthonous), and partially oxidized pyrite. S. Venture O-59, 4130m, whole rock.

I. Vitrinite (autochnous mainly), fusinite, inertodetrinite, sporinite, and framboidal pyrite, S. Venture O-59, 4010m, kerogen concentrate.

J. Vitrinite (autochthonous and allochthonous), sporinite, amorphous liptinite III, and framboidal pyrite. S. Venture O-59, 4010m, kerogen concentrate.

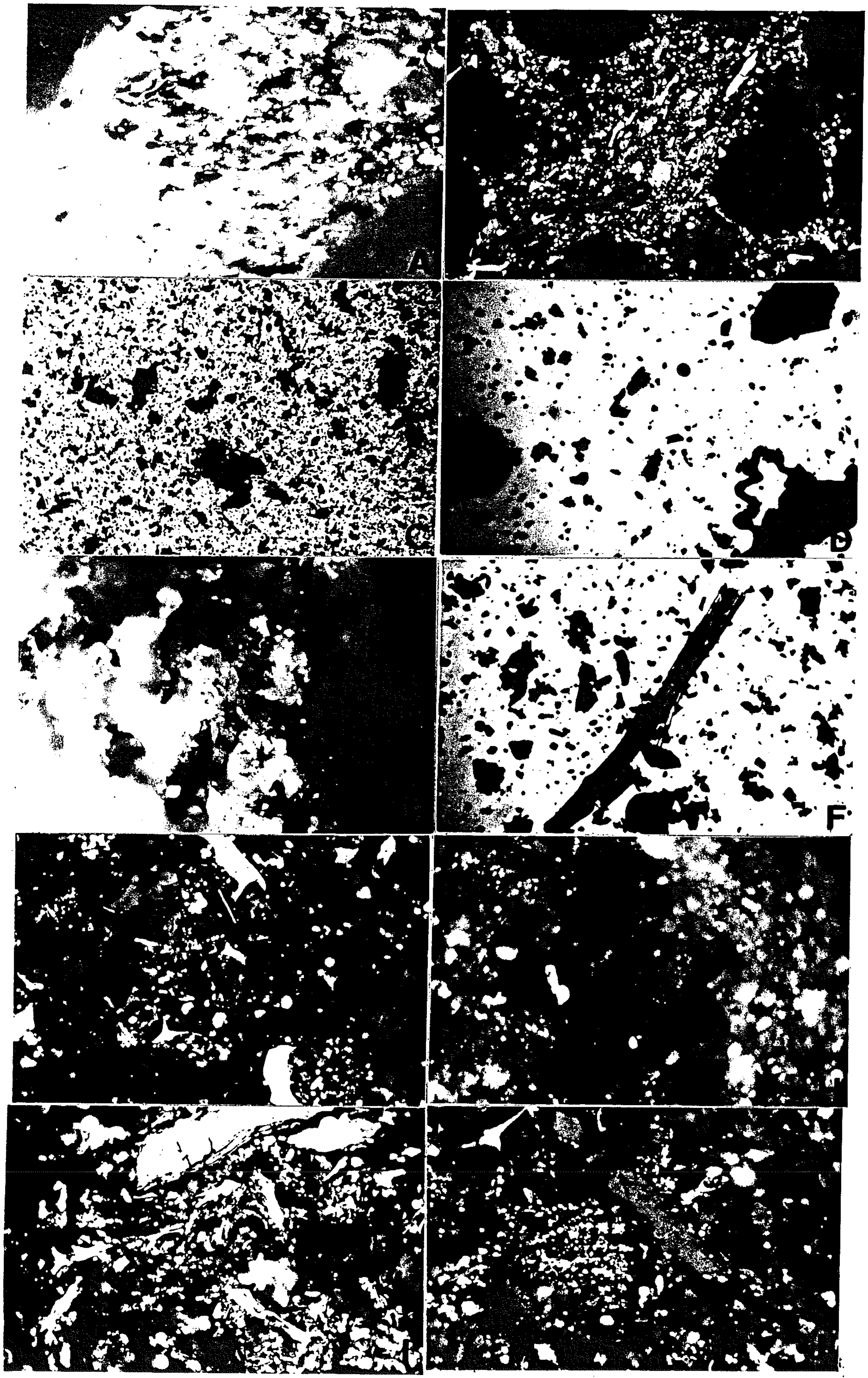

Fig. 3

Figure 4

Photomicrographs:

All photos are taken in incident white light.

Magnification: 500X

A. Amorphous liptinite IIB, liptodetrinite, and pyrite. S. Venture O-59, 5420m, kerogen concentrate.

B. Amorphous liptinite IIA and pyrite. S. Venture O-59, 5420m, kerogen concentrate.

C. Vitrinite, sporinite, and oxidized framboidal pyrite. S. Venture O-59. 5700m, whole rock.

D. Lignite contamination (Ro = 0.40%) showing ulminite, semifusinite, cutinite, and sclerotinite with clay minerals. S. Venture O-59, 5700m, whole rock.

E. Amorphous liptinite IIB, vitrinite, sporinite, and framboidal pyrite (partially oxidized). S. Venture O-59, 5965m, kerogen concentrate.

F. Amorphous liptinite IIA and III (one grain), and framboidal pyrite. S. Venture O-59, 6115m, whole rock.

G. Amorphous liptinite IIB, vitrinite, and rank-sporinite with framboidal pyrite. S. Venture O-59, 6115m, kerogen concentrate.

H. Lignite (gelinite; Ro = 0.40%) and pipe dope contamination. S. Venture O-59. 6115m, kerogen concentrate.

I. Amorphous liptinite IIB, vitrinite, rank-sporinite, rank-liptodetrinite, and framboidal pyrite. S. Venture O-59, 6170m, kerogen concentrate.

J. Micrinite generated from amorphous liptinite IIA, and framboidal pyrite. S. Venture O-59, 6170m, kerogen conc.

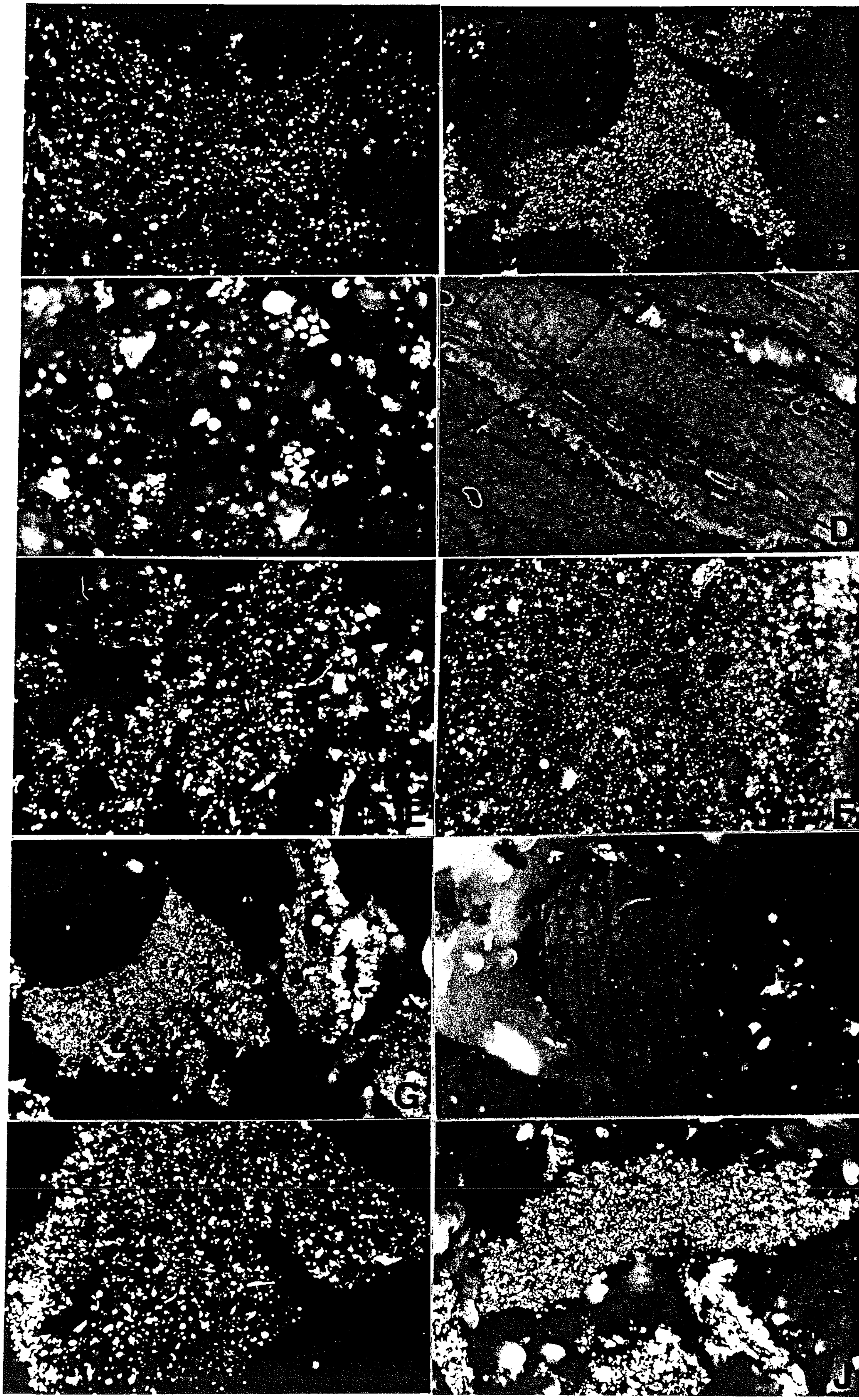

Fig. 4

Some generalized geochemical and microscopic characteristics of Organic Facies A-D. The H/C values at %R_o .5 are the cornerstone of the definitions of the organic facies. The HI and OI values for the different organic facies are approximations at best and may vary slightly above/below the indicated values.

Organic Facies	H/C at %R_o = 0.5	Pyrolysis Yield[a] HI	OI	Dominant Organic Matter
A	≥ 1.45	> 850	10 - 30	Algal; Amorphous
AB	1.35 - 1.45	650 - 850	20 - 50	Amorphous; Minor Terrestrial
B	1.15 - 1.35	400 - 650	30 - 80	Amorphous; Common Terrestrial
BC	.95 - 1.15	250 - 400	40 - 80	Mixed; Some Oxidation
C	.75 - .95	125 - 250	50 - 150	Terrestrial; Some Oxidation
CD	.60 - .75	50 - 125	40 - 150+	Oxidized; Reworked
D	≤ .6	< 50	20 - 200+	Highly Oxidized; Reworked

[a]Derived from Rock-Eval pyrolysis data where

HI = hydrogen index = mg hydrocarbons generated/g TOC

OI = oxygen index = mg CO_2 generated/g TOC

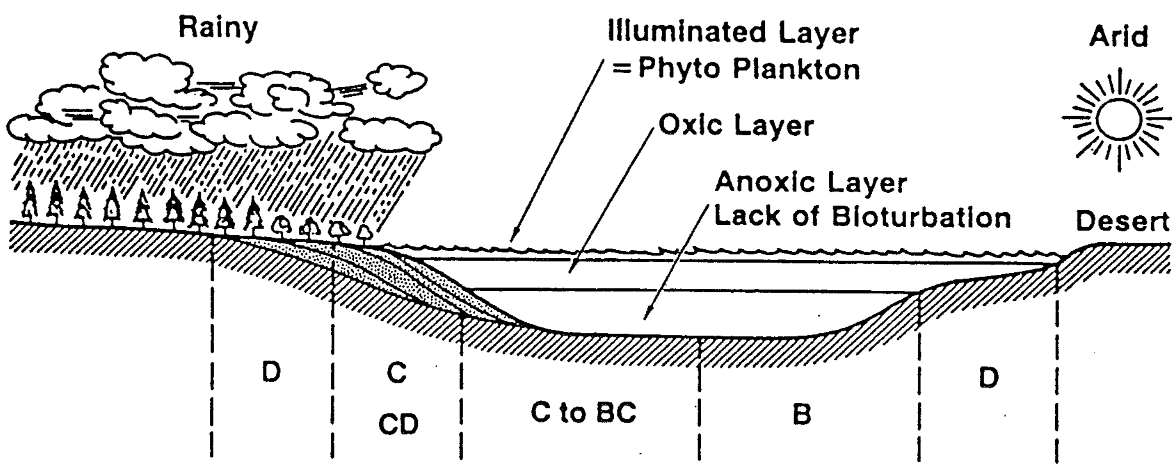

Fig. 5a. Very schematic illustration of different depositional environments in which different organic facies might form. (after Jones, 1987)

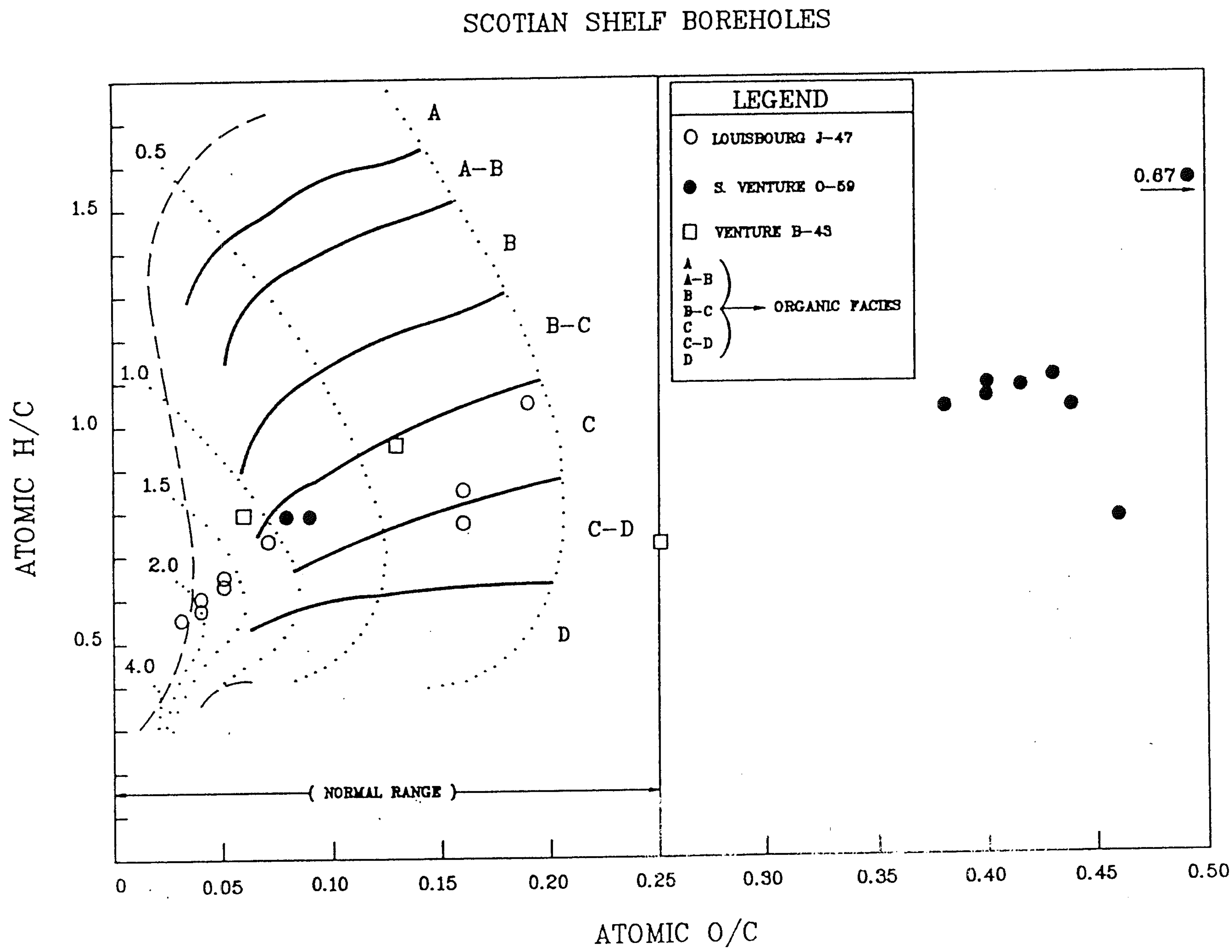

Fig. 5b. Maturation path of different organic facies (after Jones, 1987)

Appendix A.

Amorphous liptinite or sapropelinite:

These are amorphous organic matter which are mainly derived from the biodegradation of phytoplankton, exinite etc. These are mainly fluffy and granular in transmitted light, dark gray to light gray in reflected white light, and yellow fluorescent to non-fluorescent in blue-light excitation. Different types of amorphous liptinites are recognized from their relict structure, morphology, and fluorescent colors (in low maturation). Equivalent terms are Bituminite (Teichmuller and Ottenjann, 1977) and Amorphinite (van Gijzel, 1981; Senftle et al., 1986).

a. Amorphous liptinite I: This maceral is derived from the biodegradation of either Botryococcus and Tasmanites algae. This maceral has yellow fluorescence under low maturation and preserve the outer structure of those algae. For details description, see Mukhopadhyay et al., (1985)

b. Amorphous liptinite IIA: This maceral is derived from the biodegradation of dinoflagellates, acritarch, coccolith, diatoms, and foraminiferal soft parts. This is granular, extremely fluffy in transmitted light and yellowish brown in blue-light excitation (in low maturation). For detailed description, see Mukhopadhyay et al., (1985).

c. Amorphous liptinite IIB: This maceral is a biodegradation product mixture of organic matter such as phytoplankton and terrestrial exinite (sporinite, cutinite, and suberinite). This is flaky and clustered in transmitted light and dark brown in blue-light excitation.

d. Amorphous liptinite III or humosapropelinite: This maceral is a biodegradation product of humic organic matter with minor amount of terrestrial exinite. This is similar to amorphous liptinite IIB, however, this maceral shows other characteristics of a vitrinite maceral.

Particulate liptinite A:

This group includes morphologically preserved dinoflagellates, acritarchs, coccolith, and other small unicellular algae along with foraminiferal remains. Equivalent term is lamalginite (Hutton, 1987).

For the descriptions of alginite, exinite (sporinite, cutinite), inertinite, and vitrinite, bitumen (exsudatinite), we refer Stach et al., (1982).

Organic Facies:

According to Jones and Demaison (1982), organic facies is a mappable subdivision of a designated stratigraphic unit, distinguished from the adjacent subdivisions on the basis of the character of its organic constituents, without regard to the inorganic aspects of the sediment.

APPENDIX B: Amorphous organic matter related to kerogen types and hydrocarbon potential

Kerogen Type	ORGANIC FACIES				
	Amorphous maceral type (fluorescence)	Associated major macerals	Environment of deposition	Range of Hydrogen Index (mg HC/g TOC)	Pyrolysis-GC Pattern
I	Sapro I* (golden yellow)	Alginite	Lakes or Algal Mat (shallow marine or fresh water)	Greater than 800	Mainly n-alkanes between C_{10}-C_{30}
IIA	Sapro IIA* (yellow brown)	Alginite Sapro I, Part. Liptinite A&B, Liptodetrinite	Lagoon or Lakes (marine or fresh) Upwelling area (shallow or deep marine)	550-800	Dominant Cyclo- and normal alkanes between C_8-C_{27}
IIA-IIB	Sapro IIA* + Sapro IIB* (brown or orange)	Part. Liptinite A&B, Liptodetri-nite	Upwelling region, Prodelta, Delta Lakes, Deep marine anoxia	300-600	Mixed cyclo and normal alkanes + aromatics between C_6 - C_{20}
IIB	Sapro IIB* (brown)	Part. Liptinite B&A, Cutinite, Resinite, Sapro IIA	Deltaic marsh, lagoon, back-barrier, deep-marine anoxia	225-400	Mixed aromatics and cycloalkanes
III	Humosapro* (nonfluorescent to dark brown)	Part. Liptinite B, Desmo- + Telo-collinite	Delta swamp, Partial Oxy. shallow or deep marine basins	50-225	Mainly aromatics
IV	Micrinite (nonfluorescent)	Fusinite, Macrinite	Oxidized swamp or deep-marine basins, tidal flat	Less than 50	Minor hydrocarbon

Sapro I*, IIA*, IIB*, and Humosapro* - Sapropelinite I, IIA, and IIB and Humosapropelinite
Part. Liptinite - Particulate Liptinite A&B

(after Mukhopadhyay, 1989)

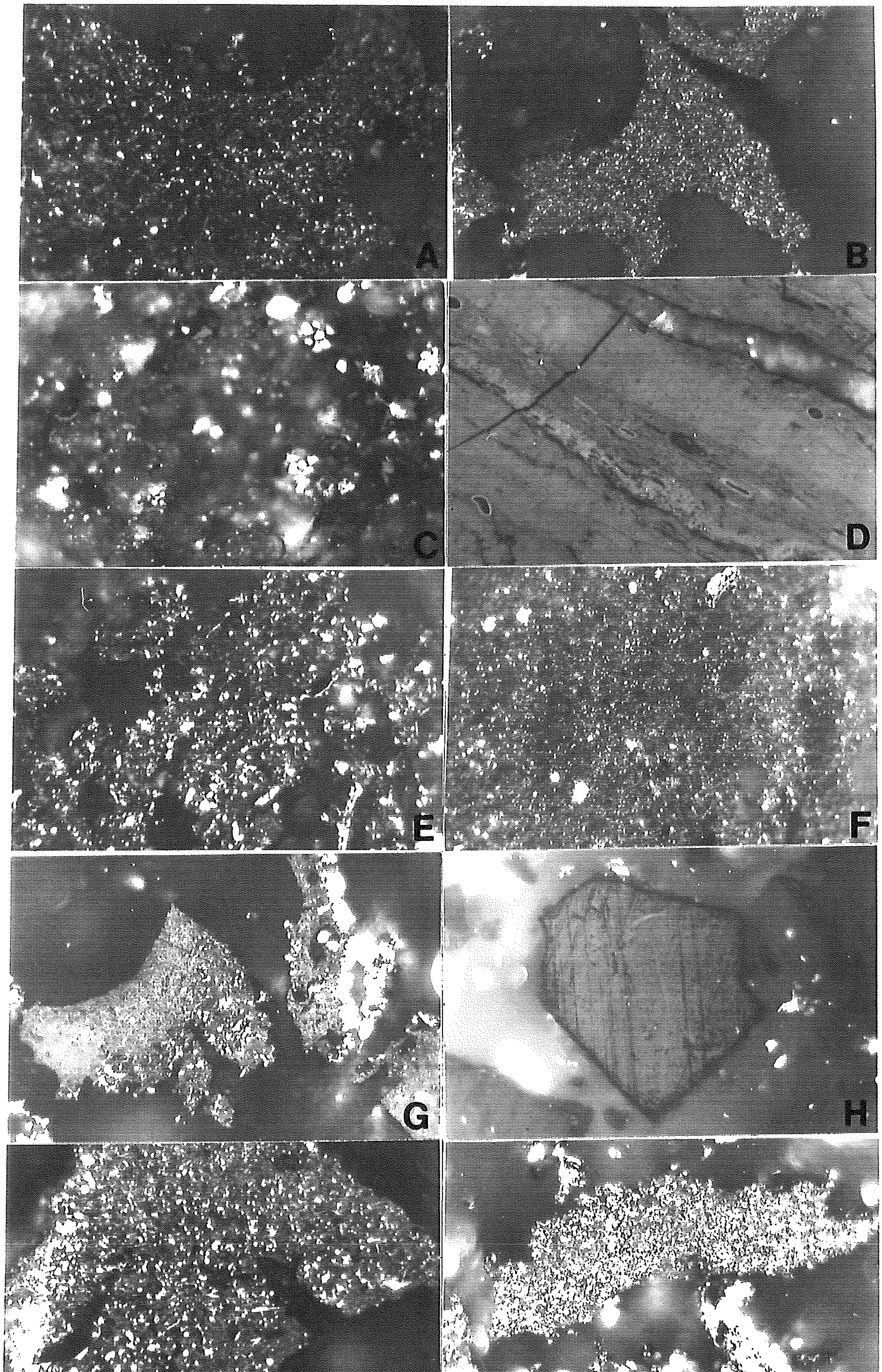

Fig. 4

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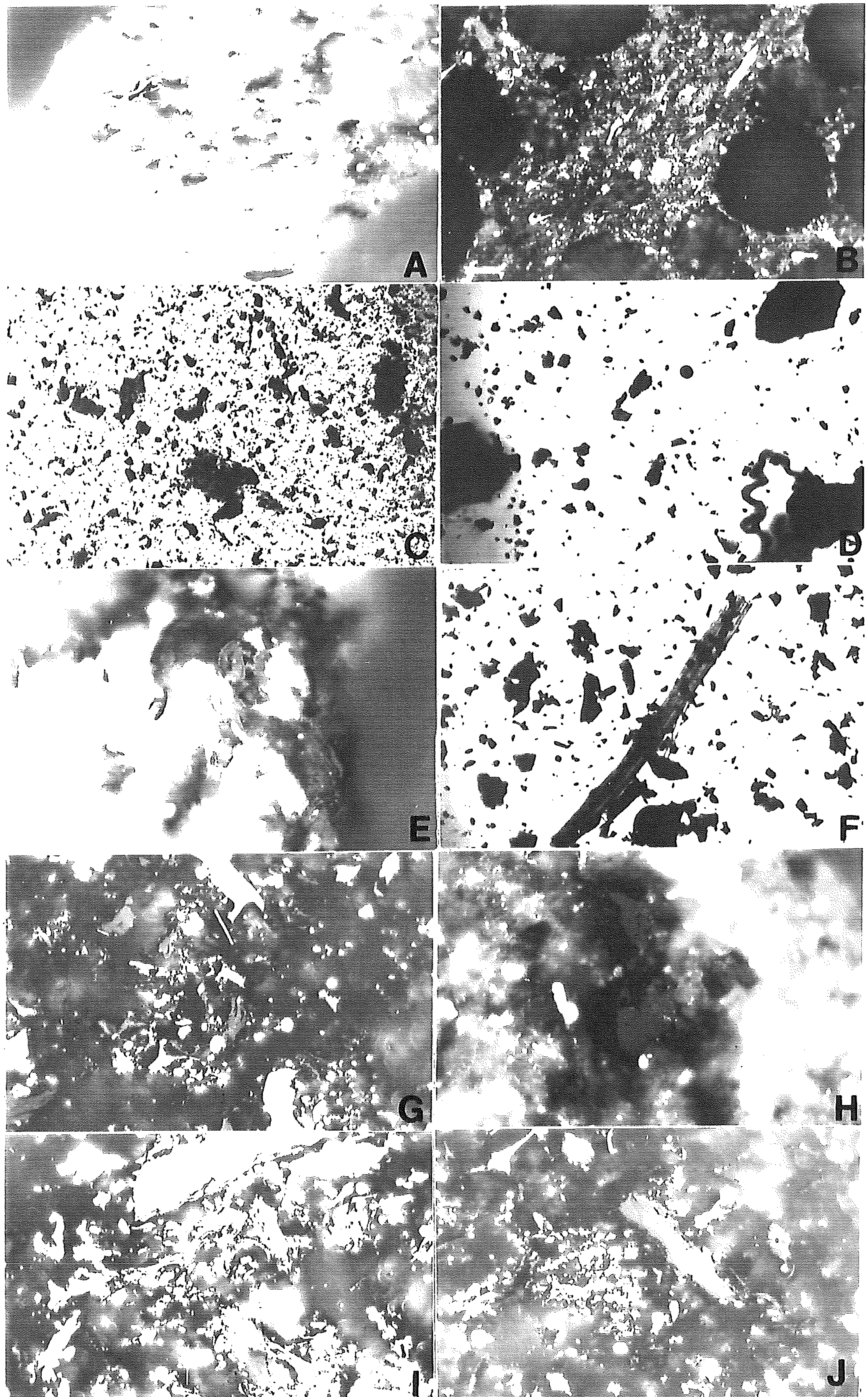

Fig. 3

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