CRETACEOUS ORGANIC FACIES AND OIL OCCURRENCE,
SCOTIAN SHELF

by

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ABSTRACT

A wide variety of organic-rich and organic-lean sediments (thirty cuttings and core samples from the Jurassic-Creteceous age) of five boreholes from the Scotian Basin (Cohasset D-42, Cohasset A-52, Evangeline H-98, Sable Island E-48, and Sable Island O-47) were examined by modern concepts of quantitative organic facies and source-rock potential. Organic facies acquired data from the maceral composition, organic input, oxidation criteria, vitrinite reflectance, and Rock-Eval pyrolysis. Four other samples from boreholes Mohican I-100 and Oneida O-25 were also analyzed by restricted petrographic method to determine source-rock potential. Five selected source-rocks were further analyzed by bitumen extraction and liquid chromatography. Stable carbon isotopes of saturate and aromatic fractions from the five selected source-rock extracts and six crude oils and condensates of Cohasset, Evangeline, and Sable Island boreholes, were analyzed to determine preliminary oil-source rock correlation.

Three major and three minor oil source-rocks (Type IIA-IIB and IIB) kerogens) were identified from Cohasset D-42, Cohasset A-52, Evangeline H-98, and Sable Island O-47 boreholes. High production indices and saturate/aromatic ratio of the shale extracts revealed possible major hydrocarbon generation and migration. Limestones (generally organic-lean sediments) contain abundant allochthonous bitumen. Contamination by lignite and pipe dope strongly influenced the Rock-Eval pyrolysis data. Most other sediments are either non-source rock or have possible gas-potential.

Crude oils and condensates from the Missisauga and Logan Canyon Formation of Cohasset D-42, Cohasset A-52, Sable Island E-48, Sable Island 5H-58E, are genetically related to Logan Canyon and Abenaki (Misaine) source-rock extracts of Cohasset D-42 and Cohasset A-52. Sable Island O-47 source rock extract and condensate of Missisauga Formation are genetically related according to isotope and extract data. However, the source-rock extract of deeper mature Shortland Shale of Evangeline H-98 (Type IIA-IIB kerogen) is not related to any of the Sable Island or Cohasset oils and thereby exclude the possibility of long distance migration.

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INTRODUCTION

Administrative Aspect

This research proposal was requested by Supply and Services of Canada, Nova Scotia at the initiation of the Atlantic Geoscience Centre, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Accordingly, I submitted the proposal on May 30, 1989. The proposal was accepted by SSC, Dartmouth, Nova Scotia on June 1, 1989. Research work was started from June 1, 1989.

According to the contract, COGLA, Halifax on my request, permitted me to collect thirty sediment samples (twenty-seven unwashed cuttings and three conventional cores) of five boreholes (Cohasset D-42, Cohasset A-52, Evangeline H-98, Sable Island E-48, and Sable Island O-47) of the Scotian Basin from the COGLA Repository at the Bedford Institute of Oceanography. Boreholes and samples were selected according to the advice of the scientific authority of this project (J. A. Wade and K. D. McAlpine). According to the contract, the petrographic work was carried out at the facility of the Atlantic Geosciences Centre of the Bedford Institute of Oceanography. The organic geochemical work (bitumen extract, liquid chromatography, and carbon isotopes of saturate and aromatic fractions) was subcontracted. In order to have a better evaluation of the data stipulated under this contract, several additional analytical works (vitrinite reflectance for all the thirty samples and organic facies analysis on four other samples) were done which were not charged in the contract.

Research Aspect

The Scotian Basin is a part of an accreted wedge of complex interconnected depocentres of Mesozoic and Cenozoic sediments, which is associated with the evolution of Mesozoic North Atlantic Basins (Grant et al., 1986; Wade and MacLean, in press). A number of crude oil, condensate, and gas discoveries were documented in the Scotian Basin mainly in the Sable Subbasin and surrounding areas. Although numerous publications were recorded on the various aspects of source-rock, crude oil, and condensate geochemistry (Barss et al., 1980; Bujak et al., 1977; Cassou et al., 1977; Rashid and McAlary, 1977; Powell and Snowdon, 1979; Powell, 1982, 1985; Purcell et al., 1979), however, the variability of organic facies related to source rock potential in different stratigraphic zones and possible oil-source rock correlation were not yet been properly defined. This is because these studies were done either by limited petrographic concepts or the chemical data was affected by contamination or maturation.

This research project is the second phase of the study of organic facies in the Scotian Basin and is an extension of the earlier work on the Sable Subbasin using modern concepts of organic petrography and source-rock evaluation (Mukhopadhyay et al., 1985; Dow et al., 1988; Mukhopadhyay, 1989; Mukhopadhyay and Birk, 1989; Mukhopadhyay and Wade,submitted). The objectives of the second phase of this research are:

1. To evaluate the organic facies and source potential of the sediments associated with the discovered oils and condensate in the Cohasset D-42, Cohasset A-52, Sable Istand E-48, and Sable Island 0-47 boreholes.

2. To evaluate the organic facies and source potential of Creteceous shales of distal Evangeline H-98 borehole for long distance migration of oil.

3. To evaluate a possible oil/condensate to source-rock correlation by bitumen extration, liquid chromatograohy, and carbon isotope of saturate and aromatic fractions of some limited samples of crude oil/condensate and source rock extracts.

LOCATION, SAMPLES, LITHOLOGY, AND STRATIGRAPHY

Boreholes Cohasset A-52, Cohasset D-42, Mohican I-100, Oneida 0-25 lie on the fringe of Sable Subbasin and within the Lahave Platform. Boreholes Sable Island E-48, Sable Island 0-47, and Evangeline H-98 occur within the Sable Subbasin. Figure 1 shows the location of these boreholes. Figure 2 depicts the generalized stratigraphy of the central Scotian Shelf as used for these samples. Table 1b indicates the lithology of each sample type from the various boreholes. Out of the thirty selected samples, eleven samples were chosen from Cohasset D-42 (Abenaki and Missisauga Formations), three core samples from the Cohasset A-52 (Logan Canyon Formation), thirteen from the Evangeline H-98 (Shortland Shale and Dawson Canyon Formations), two from the Sable Island E-48 (Logan Canyon Formation), and one sample from the Sable Island 0-47 (Missisauga Formation). Four additional samples (three from the borehole Mohican I-100 and one from the borehole Oneida 0-25: all of them belong to Abenaki Formation) were also analyzed microscopically (only from the kerogen smear slides supplied by AGC).

In the borehole Cohasset D-42, except two samples at the bottom part, all samples are shale mixed with either sandstone or limestone. However, samples between 13200 and 14230' are mainly limestone with various amount of shale. The upper five samples up to a depth of 10380' belongs to Missisauga

Formation and are deposited mainly in a very shallow to shallow marine or beach environment. The next three samples between 13200 to 13900' lie in the Baccaro Member of the Abenaki Formation, and mainly deposited in open shallow marine environment. The analyzed four samples below 14200' are derived from the Misaine Member of the Abenaki Formation and are deposited in a deep marine environment. All three core samples in the Cohasset A-52 are derived from the Cree Member of the Logan Canyon Formation and are deposited ina shallow marine environment. The depth of the samples of Cohasset A-52 are not true depth because the well is a deviated one. The true depths are also shown in Table 1b. All analyzed sediments from the borehole Evangeline H-98 are shale samples (gray to green color). The upper four samples (2335 to 3125m; mainly gray and green shale) of the borehole Evangeline H-98 belongs to Dawson Canyon Formation and are deposited in a deep marine open shelf or outer neritic to neritic environment. The lower nine samples of Evangeline H-98 are within Shortland Shale (equivalent to Logan Canyon) Formation and are deposited in a deep water open shelf, outer neritic to neritic environment. The two samples (dark gray shale) of the Sable Island E-48 lie within Naskapi Member of the Logan Canyon Formation and are deposited in open and restricted shallow marine environment. The only sample of Sable Island O-47 (gray shale) is from the Missisauga Formation and is deposited in a prodelta environment. The depositional environment of these samples are derived from the micropaleontological data.

All samples were washed using -200 mesh sieve with water, dried, hand-picked (discarding the probable contamination like pipe dope, lignite, paints etc.), and crushed to -20 to +40 mesh for whole rock preparation, -40 mesh for the kerogen isolation, and -60 mesh for Rock-Eval pyrolysis. However, in spite of proper cleaning and hand-picking most of the samples of the lower part of the Evangeline borehole contain still some fine grained contamination.

ANALYTICAL METHODS

Kerogen isolation was done by Atlantic Geoscience Centre according to the method of Barss and Williams (1973). Most of the isolated smear slides (18 samples) were already existed in slide bank of the palynology section of the AGC. Twelve samples were later subjected to kerogen isolation by the palynology section of the AGC after the samples were washed, dried, hand-picked, and crushed. For maceral point counting, three types of organic matter preparations (kerogen smear slide, whole rock polished pellet, and kerogen polished pellet) were taken using transmitted white light for the smear slides, incident white light for both types of polished plugs (whole rock and kerogen), and incident blue light (fluorescence) for all three preparations.

The maceral terminology used in this report are taken from Stach et al., (1982), Mukhopadhyay et al., (1985), and Mukhopadhyay (1989). Equivalent terms of various maceral types are taken from Teichmuller and Ottenjann (1977), van Gijzel (1981), Senftle et al., (1986), and Hutton (1987). Vitrinite reflectance was measured using whole rock polished plug and Zeiss Universal Microscope with MPM 01 photomultiplier and a computer program with IBM PC (developed by M. Avery at AGC).

Hand-picked crushed samples were sent for Rock-Eval pyrolysis to the Geochemistry Laboratory of ISPG (GSC), Calgary according to the contract. The Rock-Eval pyrolysis data used here are of ISPG (GSC), Calgary.

Six oil/condensate samples are collected by ISPG (GSC), Calgary. Out of these six samples, two crude oils are from Cohasset D-42 (Production Tests 3 and 7: one from Logan Canyon and one from Missisauga Formations), one crude oil is from Cohasset A-52 (D.S.T. # 1: Logan Canyon Formation), one condensate from Sable Island E-48 (D.S.T.# 3: Logan Canyon Formation), one crude oil is from Sable Island 3H-58 (D.S.T. #6: Logan Canyon), and one condensate from the Sable Island 5H-58 (Production Test #3 - Logan Canyon). The liquid chromatographic separation of saturate, aromatic fractions of the oils and condensates were done in the laboratory of ISPG, Calgary. The analytical methods used for liquid chromatography of crude oils are similar to the method described by Powell and Snowdon (1979). Five sediment samples (probable shale source rock) were selected from all five boreholes such as: Cohasset D-42 - 14520', Abenaki (Misaine) Formation; Cohasset A-52 - 2275m, Logan Canyon (Cree) Formation; Evangeline H-98 - 5020m, Shortland Shale; Sable Island E-48 - 8170', Logan Canyon; Sable Island O-47 - 12630', Missisauga Formation. A generalized stratigraphy of Scotian Shelf related to the analyzed samples is shown in Figure 2. Bitumen extrcation and liquid chromatography were done through a subcontract.

The stable carbon isotopic compositions of both aliphatic and aromatic hydrocarbon fractions of six oil/condensates and five probable source rock extracts were determined under a subcontract using a V. G. Micromass Mass Spectrometer. All values are reported relative to PDB (Pee Dee Belemnite) standard.

RESULTS AND DISCUSSION

Organic Petrography

a. Maceral Composition

The definition of various macerals as counted in Table 1a were incorporated in my earlier publication and report (Mukhopadhyay, 1989; Mukhopadhyay and Birk, 1989; Mukhopadhyay et al., 1985). Table 1a illustrates the maceral composition (in volume %), fluorescence characteristics of alginite and terrestrial exinite (sporinite and cutinite), and the stratigraphic units of all analyzed samples. The footnote in Table 1a illustrates the nature of each sample (especially whether it is organic lean or not and whether it is affected by contamination) and possible synonyms of various macerals and possible hydrocarbon potential.

Due to advanced maturation of some sample (especially samples from the lower part of the borehole Cohasset D-42 and Evangeline H-98), most of the liptinite (reactive) macerals are transformed into some secondary inert or semi-inert macerals as defined earlier (Mukhopadhyay and Wade, in preparation; Mukhopadhyay et al., 1985). Original macerals were identified from the morphology of the secondary macerals mainly under incident white light.

All samples in borehole Cohasset D-42 (except sample at 13890') have dominant (more than 60-70%) terrestrial macerals like vitrinite, exinite (sporinite and cutinite), and amorphous liptinite IIB) (Fig. 3a, b, c, d). Amorphous liptinite IIB, in this case, are derived mainly from the biodegradation of terrestrial exinite. Samples 7600, 9300, 9910, and 10380' contain very well preserved yellow to red fluorescence cutinite and alginite; however, varigated fluorescence colors within single exinite and other morphological characteristics suggest partial oxidation of organic matter during deposition. Saprovitrinite is common in some of the upper samples (Fig. 4h). In spite of dominant terrestrial liptinite A (marine phytoclast such as dinoflagellate) are common in samples 9300' (orange fluorescence), 9910', and 10380'. Amorphous liptinite IIA (derived from the biodegradation of marine phytoplankton and zooplankton) are common in samples 9910', 13890', 14470', and 14520'. Samples 13200', 13800', 13890', 14230' are totally organic lean and possibly deposited in an open marine oxidizing environment; macerals are nonfluorescent and sometimes contain abundant inertinite (sample 13800) mainly as micrinite and inertodetrinite. A typical example is sample 13890'. This sample contains more than 40% marine amorphous organic matters which are completely micrinitized. Similar effect has been observed elsewhere when the marine organic matter settle down through oxidizing water column (Mukhopadhyay et al., 1983). Samples 10380', 14470', and 14520' mainly contain macerals of both marine and terrestrial origin and do not show much oxidation effect.

The three dark gray shales of the borehole Cohasset A-52 (Table 1a) also contain abundant terrestrial macerals like vitrinite, exinite, inertinite , and amorphous liptinite IIB (Fig. 3a, f, g, and h). However, these samples contain minor marine macerals like particulate liptinite A or alginite (Fig. 3f and h). Fluorescence data suggest marginal maturity and some oxidation.

In the borehole Evangeline H-98, organic matters mainly contain mixed marine and terrestrial macerals, although fine grained terrestrial macerals are dominant (Fig. 4a, b, c, d, and f). The upper samples (2335m, 2705m, and 3125m) contain an appreciable amount of particulate liptinite A (mainly acritarch and dinoflagellate; Fig. 4a, b). Fluorescence data of alginite and other morphologic character of the liptinitic macerals indicate that most of the terrestrial and marine liptinites have been subjected to partial oxidation during deposition and perhaps during transport (for terrestrial exinite and vitrinite). However, samples 4910m and 5020m contains an appreciable amount of amorphous liptinite (especially amorphous liptinite IIA) which are not oxidized (Fig. 4e).

All samples below 3830 m are mixed with abundant contamination from lignite, pipe dope, and paint, in spite of proper cleaning and hand picking. (Fig. 4c, d). The contaminated lignite grains were creating major problem in maceral analysis, especially when working with the smear slides. However, during point counting, the contaminations were excluded.

Petrographically, both samples from the Sable Island E-48 are similar in maceral composition having dominant terrestrial macerals like vitrinite, sporinite, and cutinite; however sample 8170' contains more particulate liptinite A (Fig. 4g) and sample 7930' contains more alginite. According to fluorescence characteristics, both samples are partially oxidized showing orange to red fluorescence for alginite, which is not normal comapred to vitrinite reflectance. The analyzed sample from Sable Island O-47 (12630') contains a major amount of mixed marine and terrestrial macerals. However, according to morphology the terrestrial liptinite macerals indicate partial oxidation possibly during transport.

All three samples from the borehole Mohican I-100 (10850',11030, and 11080') contains abundant terrestrial macerals like vitrinite and exinite. However, morphology determined from the limited analytical technique (worked only with smear slide) suggests partial oxidation of organic matter. Sample 11030' contains more marine organic matter than the other two samples. The single sample from borehole Oneida O-25 (12230') contains abundant terrestrial macerals like most of the anlyzed sediments from the other boreholes. However, it contains the highest exinite content (>50%), most of them show partial oxidation during deposition. The amorphous liptinite IIB of samples from Mohican I-100 and Oneida O-25 was derived mainly from the biodegradation of particulate liptinite A (marine) under mildly oxidizing condition as revealed by morphological characteristics. Therefore, the organic matter input for all four samples of these two wells are considered mixed, although they contain more than 70% terrestrial macerals.

b. Vitrinite reflectance

Table 1b illustrates the measured mean vitrinite reflectance and standard deviation of all samples from five boreholes. Sample 13800' in Cohasset D-42 do not contain any measureable vitrinite grains because the sample is organic-lean. Vitrinite reflectance of samples from the boreholes Mohican I-100 and Oneida O-25 could not be measured, because only smear slides were analyzed.

In borehole Cohasset D-42, all analyzed samples (between 7600' to 14520') are mature and within the oil zone (between 0.55 and 1.36% R_o). This corresponds with the fluorescence data. The three samples in Cohasset A-52 are either immature (0.44 to 0.49% R_o) or marginally mature (0.50% R_o). The lowest sample lie on top of the oil window. In the Evangeline H-98, a complete suite of immature to mature-overmature sediments (0.44 to 1.52% R_o) are observed, which are within the oil and wet gas zone. The abnormality in vitrinite reflectance of sample 4760 m implies possible contamination effect or suppression of vitrinite reflectance due to the presence of pipe dope or bitumen. The two samples from the Sable Island E-48 are marginally mature (0.51 to 0.56% R_o) for hydrocarbon generation. However, the sample of the Sable Island O-47 is mature and within the oil zone.

Rock-Eval Pyrolysis

All thirty samples from five boreholes (Cohasset D-42, Cohasset A-52, Evageline H-98, Sable Island E-48, and Sable Island O-47) were analyzed by Rock-Eval pyrolysis (Table 2). Except a few samples in Evangeline H-98 and Cohassset A-52 (2275) all samples show S_2 less than 2 mg HC/g Rock and hydrogen index less than 200 mg HC/g TOC, suggesting low potential. As an alternate explaination, source potential of some of the samples are lost because of hydrocarbon generation due to advanced maturation and hydrocarbon migration.

The samples in the Cohasset D-42 borehole, which is not affected much by contamination, T_{max} values increased proportionately from 435 to 465^{o}C between depths 7600' to 14520'. However, low organic

carbon content of samples between 13800 to 14390' affected the T_{max} values. All samples in the Cohasset D-42 contain high S_1 (migrated hydrocarbons or bitumens already generated due to advanced maturation) values, which eventually lead to higher production indices, possibly due to low S_2 values. The abnormally high S_1 in the organic-lean samples in Cohasset D-42 (samples 13200 to 14230'), suggest presence of migrated hydrocarbons in the pore structures of limestones. High production indices in the lower three samples (14390, 14470, and 14520') associated with advanced maturity and better kerogen quality suggest in situ generation and hydrocarbon migration.

The low S2 associated with high S_1 and production indices in three samples from Cohasset A-52, suggest either early generation of hydrocarbons in the source rock and possible migration or presence of migratory hydrocarbons or possible mal-function of the FID of the Rock-Eval instrument. Correlating microscopic data, it is suggested that sample 2275m has a better source rock quality and have possible significant early generation of hydrocarbons.

Most samples in the Evageline H-98 up to a depth of 3840m, have low S_2 and hydrogen index indicating low potential for liquid hydrocarbons. T_{max} data suggest marginally mature source rocks, which however, sometimes do not correspond to vitrinite reflectance data (0.87% R_0 for sample 3840m). All these samples have high S_1 and production index indicating either early generation of hydrocarbons or presence of migratory hydrocarbons. Considering elevated organic carbon content and apparent absence of carbonate, high S_3 and oxygen index in these samples suggest more oxidizing condition than the organic-rich samples of Cohasset D-42 or Cohasset A-52 wells. These data corroborate the S_3 value of deep sea sediments (Mukhopadhyay et al., 1983). Samples between 4420 and 4820m contain abundant lignite contamination, which possibly elevated the organic carbon content and hydrogen index values, and lowered T_{max}. Apparently, low production indices in samples 4780 and 4820m also corroborate the presence of immature sediments (contaminated lignite). The low amount of contamination in sample 5020m induced lowering of TOC, S_2, and hydrogen index, and increased production index.

All three samples from Sable Island E-48 and Sable Island O-47 are organic-rich, but lower in S_2 and hydrogen index. However, all three of them show elevated production indices compared to their maturity, which possibly implied early generation and migration of hydrocarbons.

Figures 5 and 6 illustrate the position of the various samples from the boreholes in a hydrogen index versus oxygen index (Fig. 5) and T_{max} versus hydrogen index diagram (Fig. 6). According to Fig. 5, four samples in the Cohasset D-42 (7600', 9300', 9900', and 10380'), all three samples from Cohasset

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A-52, five samples from Evangeline H-98 (4420m, 4780m, 4820m, 4910m, and 5020m), both samples from Sable Island E-48, and the sample from Sable Island O-47 (12630') lie within kerogen Type II and III maturation path suggesting potential source for liquid hydrocarbon generation. All other samples are within Type III and IV kerogen maturation and are not considered for potential genration of liquid hydrocarbons. In contrast to Figure 5, in Figure 6 (T_{max} versus hydrogen index diagram), all samples (except samples 4780m and 4820m) lie within kerogen Type III kerogen maturation path and are not considered for liquid hydrocarbon generation. The hydrocarbon potential for samples 4780m and 4820m are disregarded, because both samples are highly contaminated with lignite and pipe dope.

Figure 7 shows the relationship between vitrinite reflectance (% R_0) and hydrogen index and illustrates the maturation path of various kerogen types. Five selected source rocks from all five boreholes are plotted in this diagram. The plot suggests that samples from Cohasset D-42 (sample a) and Evangeline H-98 (sample c) are mature oil source rocks and are possibly derived from Type IIA-IIB kerogen. Other three samples (b, d, and e) from Cohasset A-52, Sable Island E-48, and Sable Island O-47, lie with Type III or IIB-III kerogen maturation path.

Organic Facies And Source-Rock Potential

The concept of organic facies related to various source rock potential and maturity, have been discussed earlier (Jones and Demaison, 1982; Jones, 1987;Mukhopadhyay and Birk, 1989; Mukhopadhyay and Wade, submitted). Table 1b illustrate the source-rock potential of various samples from the seven boreholes based on the proportion of six organic facies distribution and oxidation criteria. Accordingly, except one sample in borehole Cohasset D-42 (14470') and two samples from the borehole Evangeline H-98 (4910m and 5020m), no other sample can be considered as prolific oil source rock. However, few other samples such as 10380' and 14520' from Cohasset D-42, 2275m from Cohasset A-52, 4820m from Evangeline H-98, and 12630' from Sable Island O-47 are also considered as potential source rock for liquid hydrocarbons to a lesser degree. Samples 7600', 9300', and 9900' from Cohasset D-42 can be considered as potential source rock for condensate and gas. All other samples are either gas source rocks or non-source rock. Only a few samples like 7600', 9300', 9300', 14470', and 14520' from Cohasset D-42, 2275 from Cohasset A-52, 4910m and 5020m from Evangeline H-98 showed morphological features relevant to partially anoxic or restricted marine environment. None of these sediments, however, represent a total anoxia in the depositional regime. On the other hand, several samples in the Cohasset D-42 (between 13200 and 14200') indicate presence of severe oxidation in the depositional regime. The presence of abundant terrestrial organic matter in most of the sediments indicate possible destruction of marine phytoplanktons under oxidizing conditions due to their less protective cover.

Considering the organic facies and source-rock potential, only five samples (as seen in Figure 7) are selected for bitumen extraction, liquid chromatography, and possible oil-source rock correlation by carbon isotope of saturate and aromatic fractions.

Bitumen Extraction And Liquid Chromatography

Table 3 shows the bitumen extract (both in ppm and mg HC/g TOC) and liquid chromatographic data for five source rock extracts. Samples from Cohasset D-42 (14520') and Sable Island O-47 (12630') contain high NSO and asphaltene compared to the saturate fraction; sat/arom ratio and total bitumen extract are also low. Considering the maturity, the above data may indicate a possible depletion of hydrocarbons (especially saturate fractions), because of hydrocarbon migration. Considering the maturity, high bitumen extract, and high saturate/aromatic ratio, the sample from Evangeline H-98 (5020m) is a significant oil source rock. On the other hand, considering the low maturity and bitumen extract, samples from Cohasset A-52 (2275m) and Sable Island O-47 (12630') are considered as potential source for condensate and gas. However, sample from Sable Island O-47 (12630') indicates depletion of hydrocarbons possibly due to migration as seen from its maturity and saturate/aromatic ratio. Table 3 also includes some other liquid chromatography data (data with asterix) of samples from Cohasset D-42 (crude oil: 7376-7399', prod. test #3), Sable Island 3H-58 (oil: 5344-5348, D.S.T. #6), Sable Island 5H-58E (condensate: 5767-5775', prod. test. # 3), which are from Powell and Snowdon, (1979). These data indicate that these samples have a low saturate/aromatic ratio similar to the extracts from Cohasset D-42 (14520') and Sable Island E-48 (8170').

Genetic Correlation Of Crude Oil/Condensate And SR Extracts

The stable carbon isotopic compositions of $C_{15}+$ aliphatic and aromatic fractions are shown in Table 3, which are plotted in Fig. 8. Table 3 also contains some other isotope data (shown with an asterix), which are analyzed by Powell and Snowdon (1979) on samples from similar depths. The line, which separates the isotopic composition of terrestrial- and marine-derived liquid hydrocarbons in Fig. 8, is an arbitrary one, taken from Sofer et al, (1986).

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Except the condensate of Sable Island O-47 (12369-12775' - data from Powell and Snowdon, 1979), all other crude oil and condensate samples follow a narrow carbon isotope of aromatic fraction. All the three Cohasset oils (two from D-42 and one from A-52) are clustered together on the top left of Figure 8, showing more influence of terrestrial organic matter. Condensates from Sable Island E-48 (5630') and Sable island 5H-58 (5767') occur in close association with the two source rock extracts from Cohasset boreholes (a: 14520' of D-42; b: 2275m of A-52) which lie near the boundary of terrestrial and marine organic matter (Fig. 8). The source rock extract from Evangeline H-98 (sample c: 5020m) is totally different in isotopic composition from other source-rock extracts and crude oils or condensates. This data possibly exclude deeper matured Logan Canyon sediments as potential source for liquid hydrocarbons in Cohasset and Sable Island structures by long distance lateral migration. However, this interpretation should be taken with extreme care because of limited analytical data.

Two source-rock extracts from Sable Island (sample d: 8170') and O-47 (sample e: 12630') and the condensate from the Sable Island O-47 (12639' - data from Powell and Snowdon, 1979) are isotopically close to each other, but isotopically different from three Cohasset oils and source rock extracts. One oil from Sable Island 3H-58 is also different from the Cohasset oils.

Powell and Snowdon (1979) from the isotope composition, gasoline range hydrocarbons, gc-ms of aromatic hydrocarbons, classified three groups of oil and condensate families:

1. Oils from the Primrose samples of Wyandot Formation, which are not studied in the present report.

2. Oils and condensates from the Verrill Canyon, Missisauga, and MicMac Formations. One sample of Cohasset D-42 (Prod. Test. 3) belongs to this group. The condensate from Sable Island O-47 (data taken from Powell and Snowdon, 1979) also belongs to this group.

3. Oils and condensates from the Logan Canyon Formation. All other analyzed samples belong to this group.

The present limited analytical data, however, do not support the view of Powell and Snowdon (1979). Considering the isotopic composition and liquid chromatographic data, it is evident that Cohasset oils, condensates, and source rock extracts are genetically correlated. There is not much difference in maturity between Cohasset oils of Logan Canyon or Missisauga Formations or condensates from the Sable Island E-48 and 5H-58E. These data indicate that the isotopic composition of oil and condensate

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CONCLUSIONS

1. Quantitative maceral analysis of thirty four samples from seven boreholes (Cohasset D-42, Cohasset A-52, Evangeline H-98, Sable Island E-48, Sable Island O-47, Mohican I-100, Oneida O-25) revealed presence of dominant terrestrial macerals (vitrinite, sporinite, cutinite, inertinite) with varying proportions of mixed (liptodetrinite, amorphous liptinite IIB etc.), and marine (alginite, amorphous liptinite IIA etc.)organic matter. Three types of amorphous macerals are recognized based on their characteristics morphological features. The distinction between oxidized amorphous liptinite (oxidized during deposition) and matured amorphous liptinite is made from the identification of secondary macerals.

2. Vitrinite reflectance data indicate complete range of maturity in Cohasset D-42 (marginally mature to mature: 0.51 to 1.36% R_0) and Evangeline H-98 (immature to mature-overmature: 0.44 to 1.52 R_0) sediments. Two analyzed samples from the shallower depth of Sable Island E-48, are marginally mature (0.51 to 0.56% R_0) and one sample from the deeper part of borehole Sable Island O-47 is mature (0.85% R_0) for liquid hydrocarbon generation. Fluorescence data (orange to red fluorescence) of marginally mature sediments from the Cohasset A-52 and Sable Island E-48, indicate generation of liquid hydrocarbons in those samples.

3. Advanced concept of organic facies based on maceral association, oxidation level, and organic input recognized at least three major and three minor oil source rocks in mainly Cohasset D-42 and Evangeline H-98 boreholes. Most other analyzed sediments are either gas prone or non-source rock. None of the analyzed samples revealed totally anoxic environment; marine phytoplankton are partly destroyed by oxidation, because of their protective cover. High production indices in Rock-Eval pyrolysis for most of the non-contaminated samples indicate hydrocarbon generation and migration related to advanced maturation from these source rocks. The plot of vitrinite reflectance and hydrogen index corroborate microscopic data about the existance of oil source rock in the Cohasset and Evangeline boreholes.

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4. Samples below 4420m in Evangeline H-98 are severely affected by contamination from lignite and pipe dope. High hydrogen indices and T_{max} values in some samples in Evangeline H-98 was considered to be derived from the lignite contamination.

5. Bitumen extract, liquid chromatography, and stable carbon isotope of saturate and aromatic fraction of source rock extracts and crude oil and condensates indicate the following:

a. Cohasset source-rock extracts, Cohasset oils and some condensates from the Sable Island E-48 (5630') and Sable Island 5H-58 (5767') are possibly genetically related to each other. The variation of saturate/aromatic ratio in these samples are due to fractionation effect due to migration.

b. Evangeline source-rock, although considered as oil-source rock, is not genetically connected to Cohasset or Sable Island condensate or oils. This limited data possibly ruled out long distance horozontal migration from matured Logan Canyon source rock in the Shelf-break or slope.

c. Some of the oil and condensates from Sable Island boreholes are not genetically related to Cohasset oils and are possibly derived from deeper marine source rocks.

d. Families of oil and condensates are possibly not differentiated according to their Formation, but related to the nature of the source rocks in different Formations and short distance migration.

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Table 1a. Maceral Composition of shale samples from borehole Cohasset D-42, Scotian Shelf

SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
7600	24.0	2.6	33.4	0.8	3.4	5.0	20.2	0.4	2.6	6.2	1.4	yellow-orange	Missisauga
9300	21.8	2.2	27.0	0.2	3.6	3.0	33.8	1.0	1.6	4.2	1.6	yellow-red	Missisauga
9910	24.4	2.2	31.0	0.8	2.6	0.8	29.2	2.4	2.2	3.2	1.2	red	Missisauga
10380	11.0	3.6	29.4	0.4	12.8	10.2	17.6	0.4	3.6	4.4	6.6	yellow-red	Missisauga
13200+	32.1	7.7	28.3	0.0	9.0	1.0	3.0	0.3	1.3	3.3	14.0	nonfluorescent	Abenaki (Baccaro)
13800+	41.0	23.5	13.0	0.5	1.5	1.0	10.5	0.5	1.5	2.0	5.0	nonfluorescent	Abenaki (Baccaro)
13890+	19.4	8.8	12.8	0.0	5.0	30.8	18.4	0.6	0.2	1.6	2.4	red-nonfluores	Abenaki (Baccaro)
14230+	35.0	4.0	33.7	0.0	5.3	5.0	8.3	0.0	2.7	4.3	1.7	nonfluorescent	Abenaki (Misaine)

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

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SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
14390	30.8	5.8	38.0	0.5	7.3	1.5	8.0	1.0	1.5	3.5	2.1	red	Abenaki (Misaine)
14470	26.8	5.0	13.4	0.0	8.6	22.0	15.2	0.2	2.8	2.8	3.2	red	Abenaki (Misaine)
14520	22.8	5.4	17.8	0.0	6.8	19.4	18.8	0.0	2.4	3.6	3.0	red-nonfl.	Abenaki (Misaine)

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 1a. Maceral Composition of shale samples from borehole Evangeline H - 98 , Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
2335	30.2	7.6	33.0	1.2	9.4	2.6	5.8	0.8	1.6	4.4	3.4	orange-red	Dawson Canyon
2705	27.4	10.2	33.4	0.0	10.6	2.4	5.0	0.0	2.4	4.2	4.4	yellow-red	Dawson Canyon
3005	44.0	2.4	30.8	0.2	4.2	1.6	9.8	0.2	2.8	1.4	2.6	red	Dawson Canyon
3125	27.0	3.2	35.4	0.2	9.8	3.4	9.2	0.4	3.8	3.2	4.4	orange-red	Dawson Canyon
3590	54.8	6.2	15.0	0.2	3.0	2.0	10.2	3.8	1.6	0.6	2.6	red	Shortland Shale
3830	33.0	9.6	26.4	0.2	2.4	2.0	8.6	15.0	0.2	0.6	2.0	yellow-red	Shortland Shale
4420 #	30.8	3.0	14.6	0.0	4.4	9.0	17.6	3.2	5.4	6.4	5.6	red	Shortland Shale
4540 #	25.0	6.4	35.6	1.0	4.6	2.8	10.6	3.0	2.8	5.4	2.8	red	Shortland Shale

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 1a. Maceral Composition of shale samples from borehole Evangeline H-98, Scotian Shelf

SAMPLE ID (m)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
4640 #	30.0	3.6	29.2	0.0	7.2	3.6	11.2	0.4	2.4	10.6	1.8	red	Shortland Shale
4760 #	12.0	21.9	10.0	0.9	1.8	10.0	1.8	9.1	0.9	0.5	31.1	nonfluorescent	Shortland Shale
4820 #	20.8	22.6	18.4	0.2	3.0	4.4	15.6	5.4	2.8	2.2	4.6	red-nonfl.	Shortland Shale
4910 #	18.8	4.6	20.2	0.0	4.4	16.4	20.6	3.2	3.6	5.2	3.0	nonfluorescent	Shortland Shale
5020 #	26.8	5.8	10.6	0.0	6.0	20.8	23.6	2.0	3.6	0.8	0.0	nonfluorescent	Shortland Shale

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 1a. Maceral Composition of shale samples from borehole Sable Island E-48, Scotian Shelf

SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
7930	24.6	4.2	47.0	1.6	2.4	1.2	5.0	0.2	5.6	5.6	2.6	orange-red	Logan Canyon (Naskapi)
8170	27.2	4.4	39.0	0.2	5.2	3.2	13.4	0.0	2.0	1.8	3.6	orange	Logan Canyon (Naskapi)

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 1a. Maceral Composition of shale samples from borehole Sable Island O-47, Scotian Shelf

SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	Amorphous Liptinite IIB	Amorphous Liptinite III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
12630	23.0	3.0	29.4	1.4	3.6	6.2	28.6	0.2	1.2	1.8	1.6	red-nonfl.	Missisauga

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 1a. Maceral Composition of shale samples from borehole Mohican I-100, Scotian Shelf

SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
10850*	45.5	4.5	29.5	0.5	3.0	3.0	12.5	1.0	0.0	0.0	0.5		Abenaki (Baccaro)
11030*	28.9	6.0	33.8	0.4	3.1	8.0	15.4	1.0	0.5	0.0	3.0		Abenaki (Misaine)
11060*	31.0	8.0	35.5	0.0	5.0	3.5	12.0	0.5	1.5	0.5	2.5		Abenaki (Misaine)

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   * = Analyzed only by transmitted light

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 1a. Maceral Composition of shale samples from borehole Oneida O-25, Scotian Shelf

SAMPLE ID (ft)	Vit.	Int.	Exin.	Res.	Part. Lip.A	Amorphous Liptinite IIA	IIB	III	Alg.	Lpdet.	Bit.	Fluorescence of Exin/Alg	Formation (Member)
12230*	16.0	3.5	54.5	0.0	4.0	0.5	19.0	1.0	0.5	0.5	0.5		Abenaki (Misaine)

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 * = Analyzed only by transmitted light

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: 1b A COMPOSITE INTERPRETATION OF ORGANIC FACIES, MATURITY, AND SOURCE-ROCK POTENTIAL OF SEDIMENTS

	DEPTH (m)	LITHOLOGY	FORMATION	AGE	ENVIRONMENT (*)	VITRINITE REFL. (%Ro) Ro Std. D	(#) ORGANIC FACIES DISTRIBUTION						OXIDATION LEVEL (ENVIRONMENT)	ORGANIC INPUT	KEROGEN TYPE (**)	OIL/GAS POTENTIAL (**)
							1	2	3	4	5	6				
Cohasset A-52	1913 + 2138 + +	grey shale	Logan Canyon (Cree)	Albian	Shallow marine	0.45 0.04 (immature)	9.5	4.7	7.9	45.1	29.0	3.8	Partially oxidized	Terrestrial	IIB-III	Cond.-Gas
	1917 + 2142 + +	grey shale	Logan Canyon (cree)	Albian	Shallow marine	0.49 0.05 (immature)	5.3	4.5	4.1	34.0	45.6	6.5	Partially oxidized	Terrestrial	III	Gas
	2036 + 2275 + +	gray shale	Logan Canyon (Cree)	Aptian	Shallow marine	0.50 0.04 (marginally marine)	3.0	8.8	14.1	38.3	32.6	3.3	Partiallly anoxic	Mixed	IIB	Cond., Gas, Oil
Evangeline H-98	2335	gray shale	Dawson Canyon	-	Open shelf, outer neritic	0.44 0.04 (immature)	1.6	12.4	10.6	35.4	32.1	7.9	Partially oxidized	Mixed	III	Gas
	2705	gray and green shale	Dawson Canyon	-	Open shelf, outer neritic	0.45 0.08 (immature)	2.5	13.6	9.6	34.9	28.7	10.7	Partially oxidized	Mixed	III	Gas
	3005	gray and green shale	Dawson Canyon	-	Open shelf, outer neritic	0.66 0.08 (mature)	2.9	5.9	11.5	31.8	45.4	2.5	Partially oxidized	Terrestrial	III	Gas
	3125	grey-green shale	Dawson Canyon	-	Open shelf outer neritic, neritic	0.57 0.06 (marginally marine)	4.0	13.8	13.0	37.2	28.7	3.3	Partially oxidized	Mixed	III	Gas
	3590	gray shale	Shortland Shale	-	Deep water open shelf, outer neritic, neritic	0.76 0.03 (mature, oil zone)	1.6	5.1	11.1	15.6	60.2	6.4	Partially oxidized	Terrestrial	III	Gas
	3830	gray shale	Shortland Shale	-	Deep water open shelf, outer neritic, neritic	0.87 0.06 (mature, oil zone)	0.2	4.5	9.4	27.1	49.0	9.8	Oxidized	Terrestrial	III-IV	non-source
	4420	gray shale	Shortland Shale	-	Deep water open shelf, outer neritic, neritic	0.94 0.07 (mature, oil zone)	5.7	14.2	25.4	15.5	36.0	3.2	Oxidized	Mixed	III	Gas
	4540	gray shale	Shortland Shale	-	Deep water open shelf, outer neritic, neritic	0.93 0.12 (mature, oil zone)	2.9	7.6	16.5	37.6	28.8	6.6	Partially oxidized	Terrestrial Mixed	III	Gas
	4640	gray shale	Shortland Shale	-	Deep water open shelf, outer neritic, neritic	1.03 0.13 (mature, oil zone)	2.4	10.8	22.2	29.8	31.1	3.7	Partially oxidized	Mixed	III	Gas
	4760	grey shale	Shortland shale	-	Deep water, open shelf, outer neritic, neritic	0.88(?) 0.05 (mature, oil zone)	1.3	17.2	3.3	15.8	30.6	31.8	Oxidized	Marine-mixed	III	Gas
	4820	gray shale	Shortland shale	-	Deep water, open shelf, outer neritic, neritic	1.24 0.05 (mature, oil zone)	2.9	7.8	18.7	19.5	27.5	23.6	Partially oxidized	Marine-mixed	IIB	Cond., Gas, Oil
	4910	gray shale	Shortland shale	-	Deep water, open shelf, outer neritic, neritic	1.41 0.07 (mature, wet gas zone)	3.7	21.4	26.7	20.8	22.7	4.7	Partially anoxic	Mixed	IIA-IIB	Oil, Cond., Gas
	5020	gray shale	Shortland shale	-	Deep water, open shelf, outer neritic, neritic	1.52 0.03 (mature-overmature oil, wet gas zone)	3.6	26.8	24.4	10.6	28.8	5.8	Partially anoxic	Mixed	IIA-IIB	Oil, Cond., Gas

	FEET															
Sable Island E-48	7930	dark gray shale	Logan Canyon (Naskapi)	-	Open and restricted shallow marine	0.51 0.07 (marginally mature)	5.7	3.7	10.9	49.9	25.5	4.3	Partially oxidized	Terrestrial	III	Gas
	8170	gray shale & siltstone	Logan Canyon (Naskapi)	-	Open and restricted shallow marine	0.56 0.05 (marginally mature)	2.1	8.7	15.8	40.6	28.2	4.6	Partially oxidized	Mixed	III	Gas
Sable Island O-47	12630	gray shale	Missisauga	-	Prodelta	0.85 0.06 (mature, oil zone)	1.2	10.0	30.9	31.3	23.6	3.0	Partially oxidized	Mixed	IIB	Cond., Gas, Oil
Mohican I-100	10850	-	Abenaki (Baccaro)	-	Shallow marine	- -	-	6.0	12.5	30.2	46.8	4.5	Partially oxidized	Terrestrial	III	Gas
	11030	-	Abenaki (Misaine)	-	Deep marine	- -	0.5	11.4	15.9	35.2	30.8	6.2	Partially oxidized	Mixed	III	Gas
	11080	-	Abenaki (Misaine)	-	Deep marine	- -	1.5	8.7	12.8	36.4	32.4	8.2	Partially oxidized	Mixed	III	Gas
Oneida O-25	12230	-	Abenaki (Misaine)	-	Shallow marine		0.5	4.5	19.7	54.8	17.0	3.5	Partially oxidized	Terrestrial	III	Gas
Cohasset D-42	7600 7610	gray shale & sandstone	Missisauga	Barremian	Shallow marine, beach	0.55 0.05 (marginally mature)	2.6	8.5	26.8	34.8	24.7	2.6	Partially anoxic	Terrestrial	IIB-III	Gas-Cond.
	9300	gray shale & sandstone	Missisauga	Berriasian - Valanginian	Shallow marine, channel	0.51 0.08 (marginally mature)	1.6	6.7	38.6	27.7	23.2	2.2	Partially anoxic	Terrestrial	IIB-III	Gas-Cond.
	9910	gray shale & white sandstone	Missisauga	Portlandian - Berriasian	Shallow marine	0.61 0.06 (marginally mature)	2.2	3.4	32.8	32.2	27.2	2.2	Partially anoxic	Terrestrial	IIB-III	Gas-Cond.
	10380	gray shale & white clay	Missisauga	Kimmeridgian	Shallow marine	0.67 0.05 (mature)	3.8	24.6	23.6	32.0	12.2	3.8	Partially oxic	Mixed	IIB	Gas-Cond.-Oil
	13200	brown shale & limestone (oolitic)	Abenaki (Baccaro)	Callovian	Shallow marine	0.76 0.08 (mature, oil zone)	1.5	11.6	7.7	32.9	37.3	9.0	Partially oxidized	Mixed	III-IV	non-source
	13800	limestone and brown shale	Abenaki (Baccaro)	Callovian	Shallow open marine	- -	1.6	2.6	13.1	14.2	43.7	24.8	Oxidized	Mixed	IV	non-source
	13890	light gray shale & white limestone	Abenaki (Baccaro)	Bathonian	Shallow open marine	1.02 0.05 (mature, oil zone)	0.2	36.7	20.5	13.1	20.5	9.0	Totally oxidized	Mixed	IV	non-source

	14230	gray shale & minor limestone	Abenaki (Misaine)	Bathonian	Deep marine shelf	1.33 0.07 (mature, oil zone)	2.7	10.5	12.8	34.3	35.6	4.1	Partially oxidized	Mixed	III	Gas
	14390	gray shale & white limestone	Abenaki (Misaine)	Bathonian	Deep marine shelf	1.20 0.06 (mature, oil zone)	1.5	9.0	11.8	39.0	32.8	5.9	Partially oxidized	Mixed	III	Gas
	14470	gray shale	Abenaki (Misaine)	Bathonian	Deep marine shelf	1.31 0.06 (mature, oil zone)	2.9	31.6	18.6	13.8	27.9	5.2	Partially anoxic	Mixed	IIA-IIB	Oil, Cond., Gas
	14520	gray shale	Abenaki (Misaine)	Bathonian	Deep marine shelf	1.36 0.09 (mature, oil-gas zone)	2.5	27.0	23.0	18.4	23.5	5.6	Partially anoxic	Mixed	IIB	Cond., Gas, Oil

* From micropaleontological data
** Kerogen Type and Oil/Gas potential in immature or mature stages
\+ Environment determined from organic petrography
sst Sandstone
lst Limestone
\# Organic facies distribution calculated in bitumen-free basis
\+ True Depth; + + Driller's Depth

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 + Flourinite
5 A - Vitrinite
B - Amorphous Liptinite III
6 A - Inertinite (Autochthonous)
B - Inertinite (Allochthonous)

Table 2. Rock-Eval pyrolysis data

Borehole	Depth (ft)	Sample No.	TOC	S_1	S_2	S_3	S_2/S_3	HI*	OI*	T_{max}	PI*
Cohasset	7600	559-30	2.66	0.20	1.23	0.56	2.21	46	21	435	0.14
D-42	9300	559-31	2.49	0.24	1.35	0.56	2.42	54	23	441	0.15
	9900	559-32	1.67	0.29	1.55	0.53	2.92	92	31	439	0.16
	10380	559-33	1.44	0.44	1.14	0.62	1.83	79	43	444	0.28
	13200	559-34	0.30	0.15	0.06	0.48	0.12	20	160	453/433	0.75
	13800	559-35	0.09	0.06	0.05	0.35	0.14	55	388	-	0.60
	13890	559-36	0.17	0.07	0.07	0.34	0.20	41	200	304	0.50
	14230	559-37	0.24	0.09	0.09	0.27	0.33	37	112	342	0.50
	14390	559-38	0.47	0.06	0.13	0.47	0.27	27	100	357	0.33
	14470	559-39	0.59	0.08	0.11	0.39	0.28	18	66	465	0.44
	14520	559-40	0.65	0.09	0.16	0.42	0.14	9	67	461	0.37
	Depth (m)										
Cohasset	2138	559-41	2.69	0.41	1.26	1.00	1.26	46	37	427/430	0.25
A-52	2143.5	559-42	1.98	0.22	0.82	0.71	1.15	41	35	426	0.21
	2275	559-43	4.60	1.37	2.80	1.19	2.35	60	25	430	0.33
Evangeline	2335	559-44	1.43	0.14	1.01	1.79	0.56	70	125	432	0.12
H-98	2705	559-45	1.39	0.13	0.83	1.36	0.61	59	97	430	0.14
	3005	559-46	1.43	0.17	0.81	2.07	0.39	56	144	423	0.17
	3125	559-47	1.28	0.17	0.69	1.79	0.38	53	139	430	0.20
	3590	559-48	1.11	0.32	0.58	2.32	0.25	52	209	429	0.36
	3830	559-49	1.04	0.16	0.47	2.46	0.19	45	236	433	0.26
	4420	559-50	4.60	0.77	3.24	3.33	0.97	70	72	434	0.19
	4540	559-51	7.72	0.99	5.00	8.95	0.55	64	115	439	0.17
	4640	559-52	5.21	1.05	3.29	5.99	0.54	63	114	436	0.24
	4780	559-53	13.34	2.33	25.75	6.49	3.96	193	48	405	0.08
	4820	559-54	1.84	0.32	3.64	2.64	1.37	197	143	400	0.08
	4910	559-55	6.24	0.78	6.58	2.60	2.05	105	41	402	0.11
	5020	559-56	2.06	0.63	1.05	1.43	0.73	50	69	415	0.37
	Depth (ft)										
Sable Island	7930	559-57	3.76	0.54	2.17	0.79	2.74	57	21	435	0.20
E-48	8170	559-58	2.81	1.85	1.00	0.54	0.23	35	19	438	0.23
Sable Island											
O-47	12630	559-59	2.02	0.43	1.02	0.83	1.22	50	41	448	0.30

*HI = Hydrogen Index (mg HC/g TOC); OI = Oxygen Index (mg CO_2/g TOC); PI = Production Index (S_1/S_1+S_2).

Table 3. Liquid chromatography and carbon isotope data

Borehole	Depth (ft or m)	Sample Type (Formation)	Bitumen Extract ppm	Bitumen Extract mg HC/g TOC	% Sat	% Arom	% NSO	% Asph	Sat/Arom	Del 13 C Saturate	Del 13 C Aromatics
	ft										
Cohasset D-42	14520	S.R. Extr. (Abeneki-Misaine)	91.3	14.0	23.5	14.7	50.0	11.8	1.6	-26.7	-25.0
	6107-6121 (Prod. Test 7)	Oil (Logan Canyon)	-	-	-	-	-	-		-27.3	-25.3
	7376-7399 (Prod. Test 3)	Oil (Missisauga)	-	-	73.2*	21.9*	0.4*	-	3.3	-27.2 (-26.85*)	-25.2 (-25.47*)
	meter										
Cohasset A-52	2275	S.R. Extr. (Logan Canyon)	1269.9	27.6	62.9	11.4	17.1	8.6	5.5	-26.8	-25.3
	2385-2388 (D.S.T # 1)	Oil (Logan Canyon)	-	-	-	-	-	-		-27.2	-25.0
Evangeline H-98	5020	S.R. Extr. (Shortland shale)	826.4	40.1	68.6	11.2	17.7	2.5	6.1	-27.9	-26.4
	ft										
Sable Island E-48	8170	S.R. Extr. (Logan Canyon)	376.8	13.4	30.8	20.5	35.9	12.8	1.5	-26.9	-25.7
	5630-5800 (D.S.T # 3)	Condensate (Logan Canyon)	-	-	-	-	-	-		-26.8	-25.2
O-47	12630	S.R. Extr. (Missisauga)	628.1	31.1	56.9	17.7	19.4	6.0	3.2	-26.9	-26.0
	12369-12775	Condensate (Missisauga)			48.1*	49.8*	1.0*	-	0.96	-27.28*	-25.67*
3H-58	5344-5348 (D.S.T. # 6)	Oil (Logan Canyon)	-	-	58.7*	37.5*	2.8*	-	1.56	-26.3 (-26.37*)	-25.2 (-25.68*)
5H-58	5767-5775 (Prod. Test 3)	Condensate (Logan Canyon)	-	-	63.8*	29.8*	1.9*	-	2.1	-27.0	-25.2

S.R. Extr. = Source Rock Bitumen Extract. (*) = Data taken from Powell and Snowdon (1979).

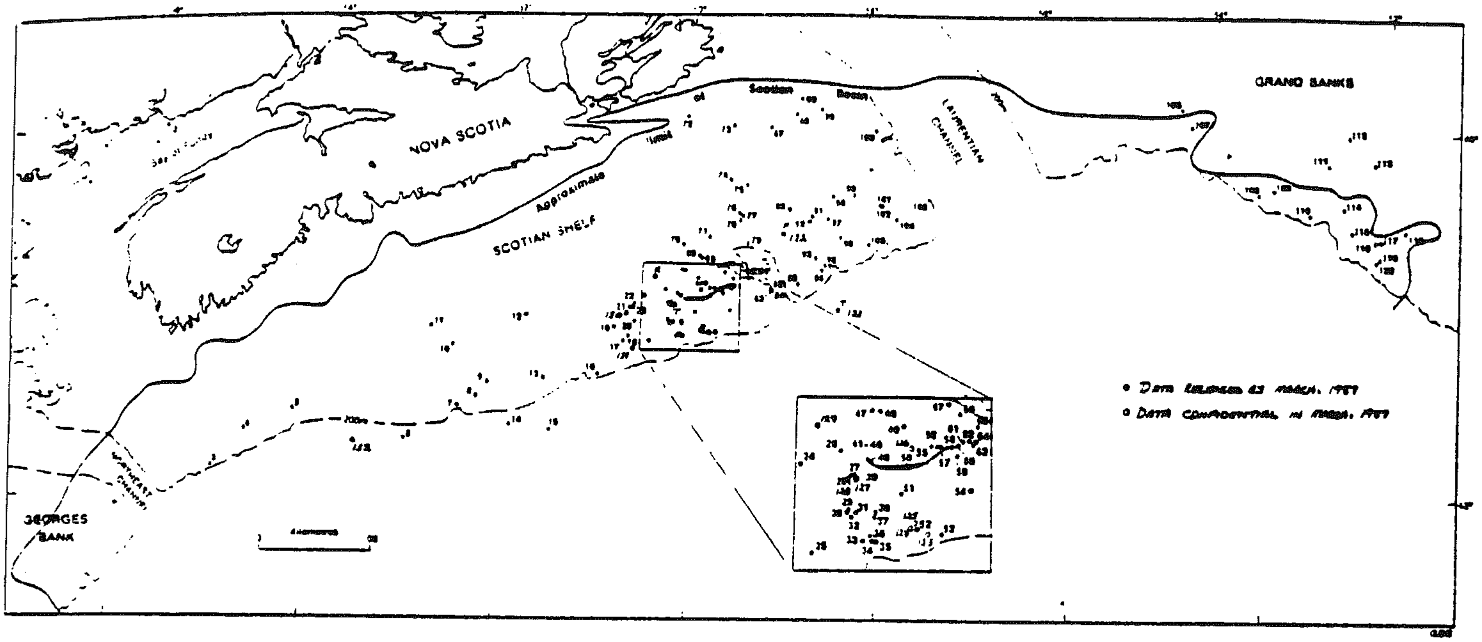


Table 5.2a

No.	Wells: Name	Status
1.	Chinampas N-37	P & A
2.	Cape Spencer No. 1	P & A
3.	Bonnet F-23	P & A
4.	Mohawk B-93	P & A
5.	Montagnais I-94	P & A
6.	Albatross B-13	P & A
7.	Mohican I-100	P & A
8.	Moheida P-15	P & A
9.	Glooscap C-63	P & A
10.	Naskapi N-30	P & A
11.	Sambro I-29	P & A
12.	Ojibwa C-07	P & A
13.	Oneida O-25	P & A
14.	Acadia K-62	P & A
15.	Shubenacadie H-100	P & A
16.	Evangeline H-98	P & A
17.	Alma K-85	Del. G
18.	Alma F-67	DISC. G
19.	Demascota G-32	P & A
20.	Cree C-35	P & A
21.	Cohasset A-52	Del. G
22.	Cohasset P-42	P & A
23.	Cohasset D-42	DISC. O
24.	Cohasset L-97	P & A
25.	Wenonah J-75	P & A
26.	Migrant N-20	P & A
27.	Thebaud P-84	DISC. G,C
28.	Thebaud I-94	Del. G,C
29.	Onondaga B-96	P & A
30.	Onondaga O-95	P & A
31.	Onondaga F-75	P & A
32.	Onondaga E-84	DISC. G
33.	Glenelg E-58 and E-58A	Del. G
34.	Glenelg J-48	DISC. G
35.	Glenelg H-38	P & A
36.	Glenelg N-49	Del. G
37.	Marmora C-34	P & A
38.	Marmora P-35	P & A
39.	Sable Island O-47	DISC. G
40.	Sable Island C-48	DISC. G,C,O
41.	Sable Island H-58	Del. G,C,O
42.	Sable Island 2H-58	Del. G,C,O
43.	Sable Island 3H-58	Del. G,O
44.	Sable Island 4H-58	Del. G,O
45.	Sable Island 5H-58	Del. G,C,O
46.	Sable Island 6H-58	P & A
47.	Penobscot B-41	P & A
48.	Penobscot L-30	P & A
49.	South Desbarres O-76	P & A
50.	Sable Island C-67	P & A
51.	Intrepid L-80	DISC. G
52.	Triumph P-50	P & A
53.	Chebucto G-90	DISC. G
54.	Eagle D-21	DISC. G
55.	Olympia A-12	DISC. G,C
56.	West Venture N-91	DISC. G
57.	West Venture B-92	P & A
58.	West Venture C-62	DISC. G,C
59.	South Venture O-59	DISC. G,C
60.	Venture B-52	Del. G,C
61.	Venture B-43	Del. G,C
62.	Venture D-23	DISC. G,C
63.	Venture H-22	Del. G,C
64.	Venture B-13	Del. G,C
65.	Arcadia J-16	DISC. G,C
66.	Citnalta I-59	DISC. G,C
67.	Uniacke G-72	DISC. G,C
68.	Abenaki J-56	P & A
69.	Abenaki L-57	P & A
70.	Dover A-43	P & A
71.	Iroquois J-17	P & A
72.	Eurydice P-36	P & A
73.	Fox I-22	P & A
74.	Erie D-26	P & A
75.	Wyandot E-53	P & A
76.	Mic Mac D-89	P & A
77.	Mic Mac J-77	P & A
78.	Mic Mac H-86	P & A
79.	Missisauga H-54	P & A
80.	Bluenose C-47	P & A
81.	Bluenose 2G-47	P & A
82.	Primrose F-41	P & A
83.	Primrose N-50	DISC. G,O
84.	Primrose A-41	P & A
85.	Southwest Banquereau F-34	P & A
86.	Tuscarora D-61	P & A
87.	Crow F-52	P & A
88.	Argo F-38	P & A
89.	Hercules G-15	P & A
90.	Jason C-20	P & A
91.	Chippewa G-67	P & A
92.	Chippewa L-75	P & A
93.	Sauk A-57	P & A
94.	Banquereau C-21	DISC. G
95.	North Banquereau I-13	P & A
96.	Louisbourg J-47	P & A
97.	Huron P-96	P & A
98.	West Esperanto B-78	P & A
99.	Esperanto K-78	P & A
100.	Adventure F-80	P & A
101.	Hesper P-52	P & A
102.	Hesper I-52	P & A
103.	South Griffin J-13	P & A
104.	Sachem D-76	P & A
105.	Dauntless D-35	P & A
106.	Hermine C-94	P & A
107.	Emerillon C-56	P & A
108.	Puffin B-90	P & A
109.	Kittiwake P-11	P & A
110.	Tern A-68	P & A
111.	Petrel A-62	P & A
112.	Gannet O-54	P & A
113.	Merganser I-60	P & A
114.	Shearwater J-20	P & A
115.	Brant P-87	P & A
116.	Gull F-72	P & A
117.	Tors Cove D-52	P & A
118.	Mallard M-45	P & A
119.	Heron H-73	P & A
120.	Heron J-72	P & A
121.	Tantallon M-41	P & A
122.	Peskowesk A-99	P & A
123.	West Chebucto K-20	Conf.
124.	North Triumph B-52	Del. G
125.	North Triumph G-43	DISC. G
126.	West Olympia O-51	Conf.
127.	Thebaud C-74	Del. G
128.	Thebaud I-93	Del. G
129.	Kegeshook G-67	P & A
130.	Panuke B-90	DISC. O
131.	Marigomish C-52	P & A
132.	Shelburne G-29	P & A

Confidential Wells (nos. 121–132)

P & A - plugged and abandoned
Del. - delineation well
DISC. - discovery well

G - gas
C - condensate
O - oil

Table 5.2b

No.	Wells: Name	
68.	Abenaki J-56	
69.	Abenaki L-57	
14.	Acadia K-62	
100.	Adventure F-80	
6.	Albatross B-13	
18.	Alma F-67	
17.	Alma K-85	
65.	Arcadia J-16	
88.	Argo F-38	
94.	Banquereau C-21	
80.	Bluenose C-47	
81.	Bluenose 2G-47	
3.	Bonnet F-23	
115.	Brant P-87	
2.	Cape Spencer No. 1	
53.	Chebucto G-90	
1.	Chinampas N-37	
91.	Chippewa G-67	
92.	Chippewa L-75	
21.	Cohasset A-52	*
23.	Cohasset D-42	*
24.	Cohasset L-97	
22.	Cohasset P-42	
20.	Cree C-35	
66.	Citnalta I-59	
87.	Crow F-52	
105.	Dauntless D-35	
19.	Demascota G-32	
70.	Dover A-43	
54.	Eagle D-21	
107.	Emerillon C-56	
74.	Erie D-26	
99.	Esperanto K-78	
72.	Eurydice P-36	
16.	Evangeline H-98	*
73.	Fox I-22	
112.	Gannet O-54	
33.	Glenelg E-58 and E-58A	
35.	Glenelg H-38	
34.	Glenelg J-48	
36.	Glenelg N-49	
9.	Glooscap C-63	
116.	Gull F-72	
89.	Hercules G-15	
106.	Hermine C-94	
119.	Heron H-73	
120.	Heron J-72	
102.	Hesper I-52	
101.	Hesper P-52	
97.	Huron P-96	
51.	Intrepid L-80	
71.	Iroquois J-17	
90.	Jason C-20	
129.	Kegeshook G-67	
109.	Kittiwake P-11	
96.	Louisbourg J-47	
118.	Mallard M-45	
37.	Marmora C-34	
38.	Marmora P-35	
113.	Merganser I-60	
131.	Marigomish C-52	
76.	Mic Mac D-89	
78.	Mic Mac H-86	
77.	Mic Mac J-77	
26.	Migrant N-20	
79.	Missisauga H-54	
4.	Mohawk B-93	
8.	Moheida P-15	*
7.	Mohican I-100	
5.	Montagnais I-94	
10.	Naskapi N-30	
95.	North Banquereau I-13	
124.	North Triumph B-52	
125.	North Triumph G-43	
12.	Ojibwa C-07	
55.	Olympia A-12	
13.	Oneida O-25	*
29.	Onondaga B-96	
32.	Onondaga E-84	
31.	Onondaga F-75	
30.	Onondaga O-95	
130.	Panuke B-90	
47.	Penobscot B-41	
48.	Penobscot L-30	
122.	Peskowesk A-99	
111.	Petrel A-62	
84.	Primrose A-41	
82.	Primrose F-41	
83.	Primrose N-50	
108.	Puffin B-90	
50.	Sable Island C-67	
40.	Sable Island C-48	*
41.	Sable Island H-58	
39.	Sable Island O-47	*
42.	Sable Island 2H-58	
43.	Sable Island 3H-58	*
44.	Sable Island 4H-58	*
45.	Sable Island 5H-58	
46.	Sable Island 6H-58	
104.	Sachem D-76	
11.	Sambro I-29	
93.	Sauk A-57	
114.	Shearwater J-20	
132.	Shelburne G-29	
15.	Shubenacadie H-100	
49.	South Desbarres O-76	
103.	South Griffin J-13	
59.	South Venture O-59	
85.	Southwest Banquereau F-34	
121.	Tantallon M-41	
110.	Tern A-68	
127.	Thebaud C-74	
128.	Thebaud I-93	
28.	Thebaud I-94	
27.	Thebaud P-84	
117.	Tors Cove D-52	
52.	Triumph P-50	
86.	Tuscarora D-61	
67.	Uniacke G-72	
64.	Venture B-13	
61.	Venture B-43	
60.	Venture B-52	
62.	Venture D-23	
63.	Venture H-22	
25.	Wenonah J-75	
123.	West Chebucto K-20	
98.	West Esperanto B-78	
126.	West Olympia O-51	
57.	West Venture B-92	
58.	West Venture C-62	
56.	West Venture N-91	
75.	Wyandot E-53	

* = Studied boreholes

Figure 1

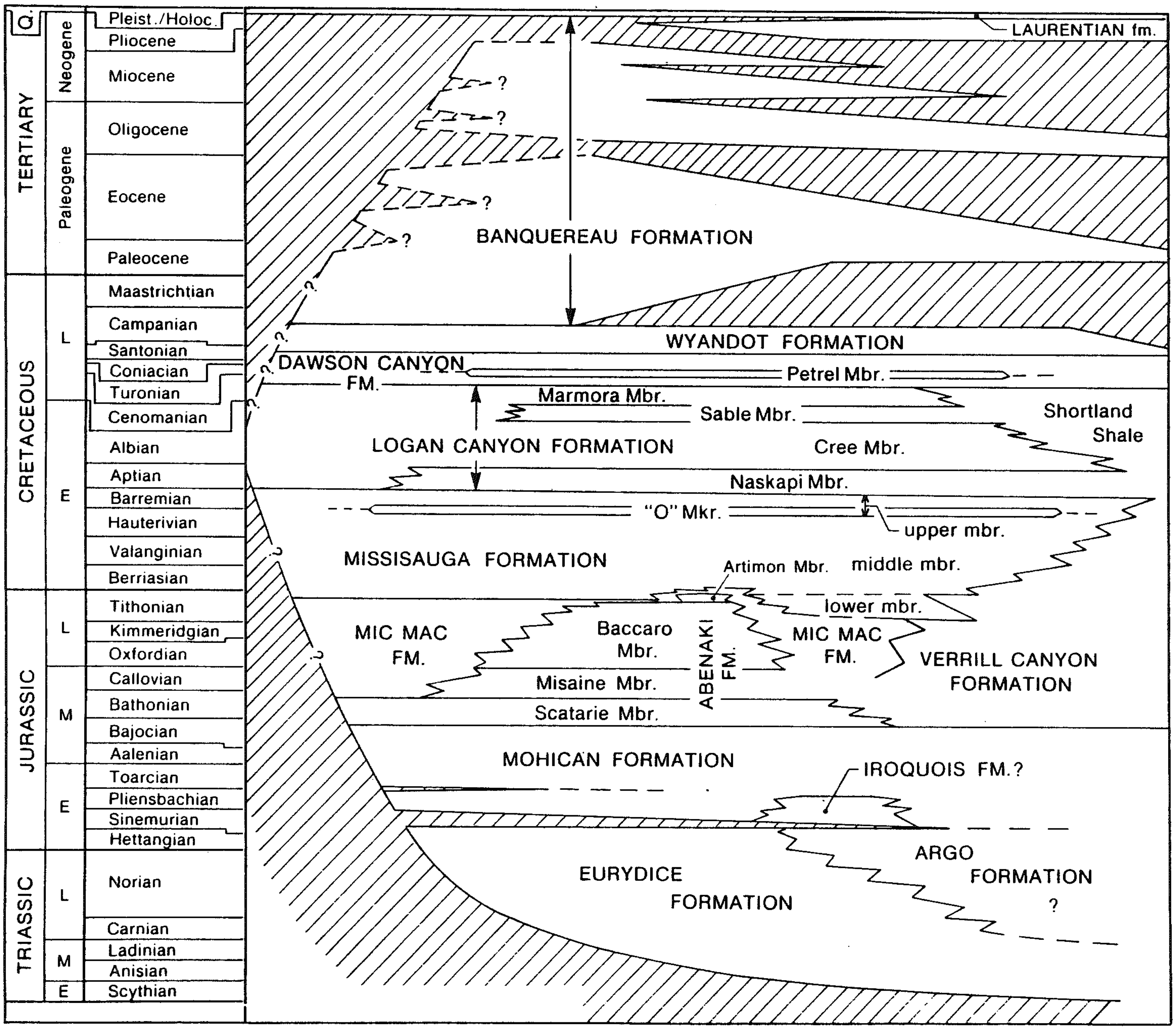

Q.
TERTIARY
Neogene
Paleogene
Pleist./Holoc.
Pliocene
Miocene
Oligocene
Eocene
Paleocene
CRETACEOUS
L
E
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
JURASSIC
L
M
E
Tithonian
Kimmeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Aalenian
Toarcian
Pliensbachian
Sinemurian
Hettangian
TRIASSIC
L
M
E
Norian
Carnian
Ladinian
Anisian
Scythian
LAURENTIAN fm.
BANQUEREAU FORMATION
WYANDOT FORMATION
DAWSON CANYON FM.
Petrel Mbr.
Marmora Mbr.
Sable Mbr.
Shortland Shale
LOGAN CANYON FORMATION
Cree Mbr.
Naskapi Mbr.
"O" Mkr.
upper mbr.
MISSISAUGA FORMATION
Artimon Mbr.
middle mbr.
lower mbr.
MIC MAC FM.
Baccaro Mbr.
ABENAKI FM.
MIC MAC FM.
VERRILL CANYON FORMATION
Misaine Mbr.
Scatarie Mbr.
MOHICAN FORMATION
IROQUOIS FM.?
ARGO FORMATION
EURYDICE FORMATION

Figure 2

3. Photomicrographs:

a. Inertodetrinite, rank-cutinite, rank-amorphous liptinite IIB, and macrinite. Cohasset D-42, 14390', kerogen concentrate, incident white light. X 500.

b. Inertinite, vitrinite, sporinite, cutinite, Cohasset D-42, 14390', kerogen concentrate, transmitted white light. X200.

c. Rank-amorphous liptinite IIA, particulate liptinite A, and vitrinite, Cohasset D-42, 14470', kerogen concentrate, transmitted white light. X200.

d. Rank-amorphous liptinite IIA, clay minerals, and bitumen with framboidal pyrite, Cohasset D-42, 14520', whole rock, incident white light.X500.

e. Inertodetrinite, macrinite, vitrinite, (both first and 2nd cycle), amorphous liptinite IIB (middle), oxidized sporinite, Cohasset A-52, 2138m, kerogen concentrate, incident white light. X500.

f. Vitrinite, sporinite, alginite, and oxidized framboidal pyrite, Cohasset A-52, 2138m, whole rock, incident white light. X500.

g. Gelocollinite (vitrinite), oxidized sporinite, and oxidized pyrite, Cohasset A-52, 2275m, whole rock, incident white light. X500.

h. Vitrinite, particulate liptinite A, amorphous liptinite IIB, and inertinite, Cohasset A-52, 2275m, kerogen concentrate, transmitted white light. X200.

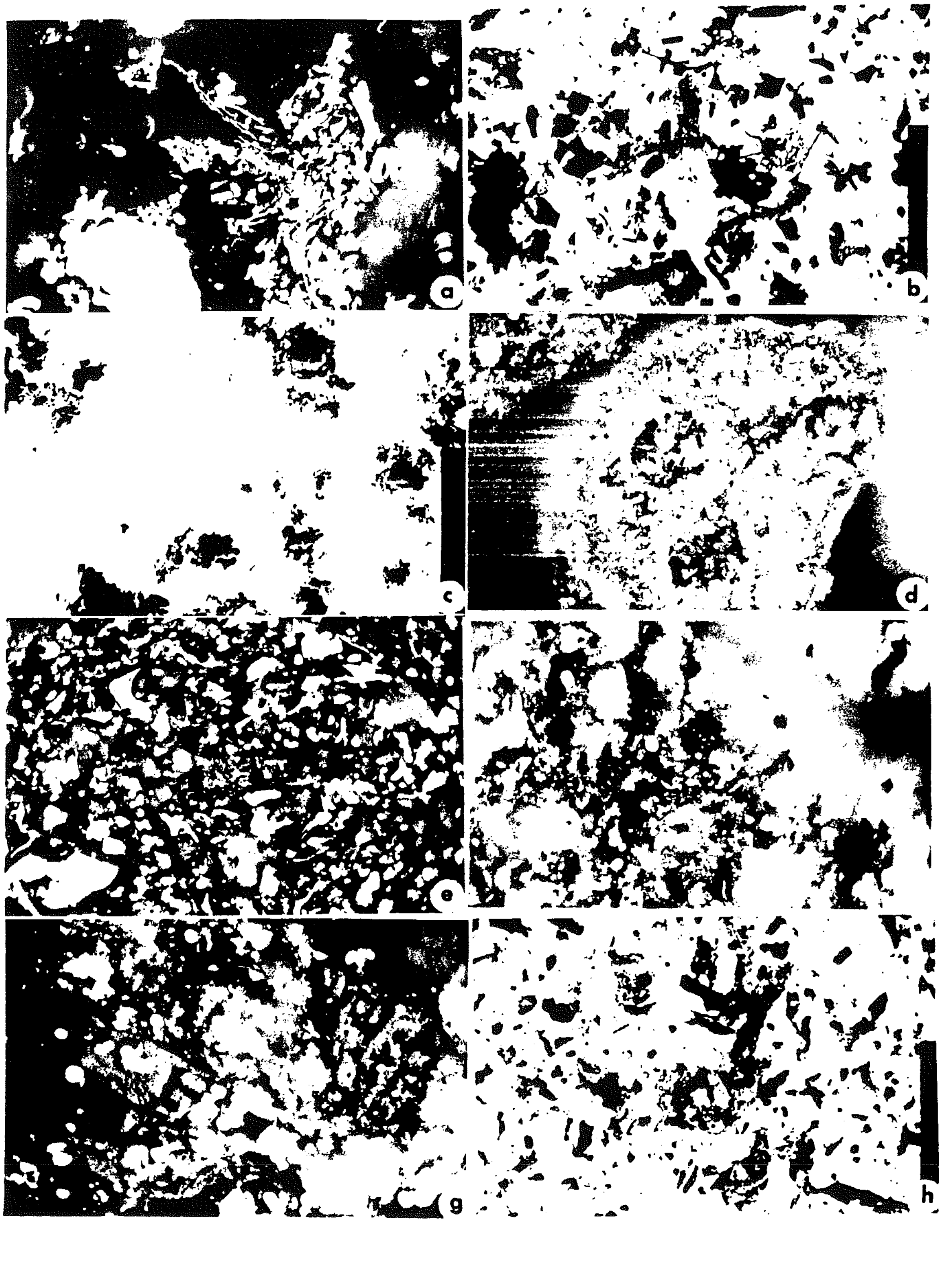


Figure 3

Fig. 4. Photomicrographs

a. Sporinite, partially biodegraded particulate liptinite A (dinoflagellate), vitrinite, and amorphous liptinite IIA. Evangeline H-98, 2335m, kerogen concentrate, transmitted white light. X200.

b. Particulate liptinite A (acritarch etc.), vitrinite, and amorphous liptinite IIB. Evangeline H-98, 2335m, kerogen concentrate, transmitted white light. X200.

c. Vitrinite, lignite contamination (large dark grain), and liptodetrinite. Evangeline H-98, 4760m, kerogen concentrate, traansmitted white light. X200.

d. vitrinite, lignite contamination (trimacerite grain), clay minerals, and oxidized pyrite. Evangeline H-98, 4780m, whole rock, incident white light. X500.

e. Amorphous liptinite IIA mixed with mineral groundmass and partially oxidized framboidal pyrite. Evangeline H-98, 4910m, whole rock, incident white light. X500.

f. Vitrinite, sporinite, amorphous IIB, and inertinite. Evangeline H-98, 5020m, kerogen concentrate, transmitted white light. X200.

g. Vitrinite, amorphous liptinite IIB, partially biodegraded particulate liptinite A (dinoflagellate). Sable Island E-48, 8170m, kerogen concentrate, transmitted white light. X200.

h. Sapropvitrinite and partially oxidized framboidal pyrite. Cohasset D-42, 7610', whole rock, reflected white light. X500.

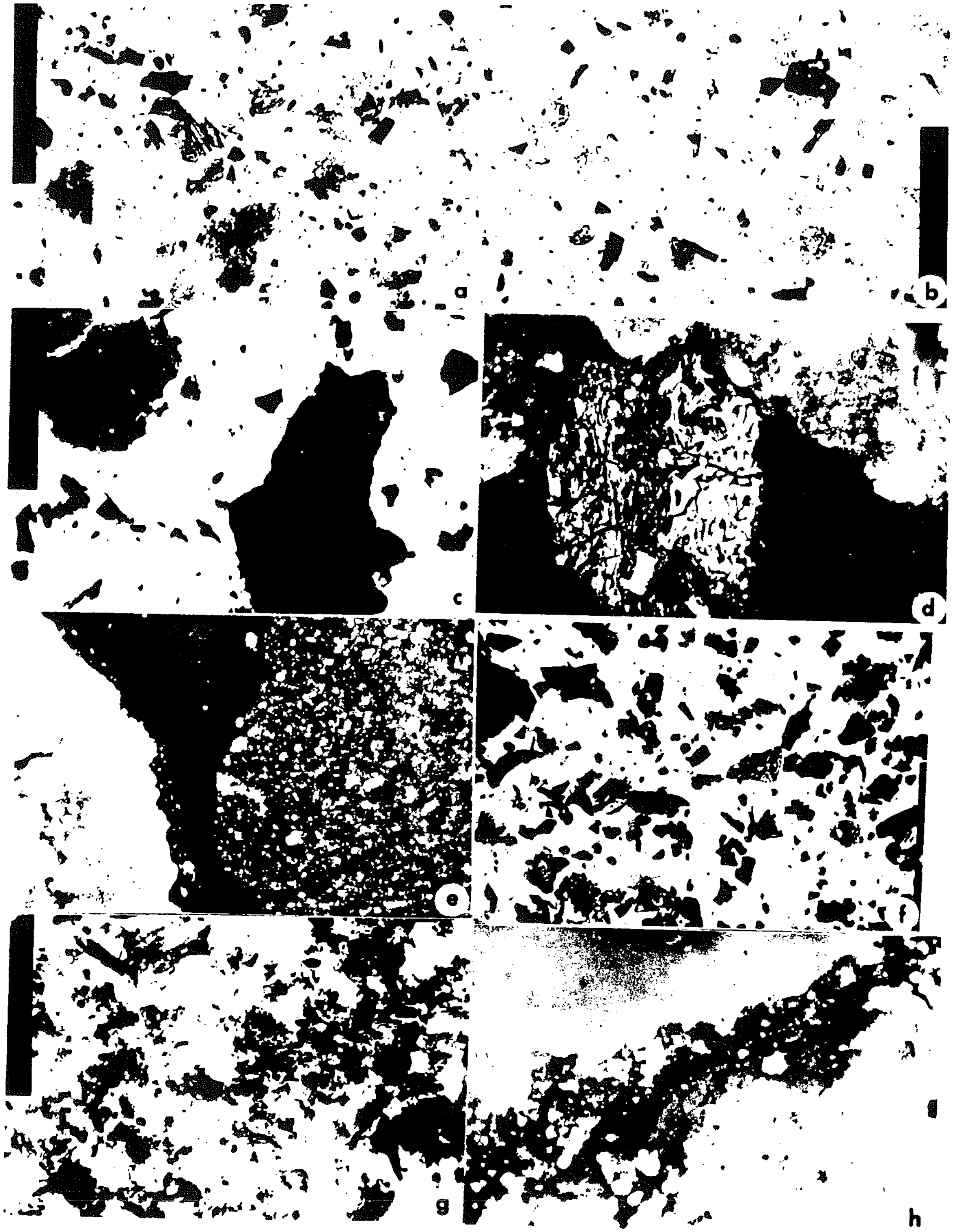
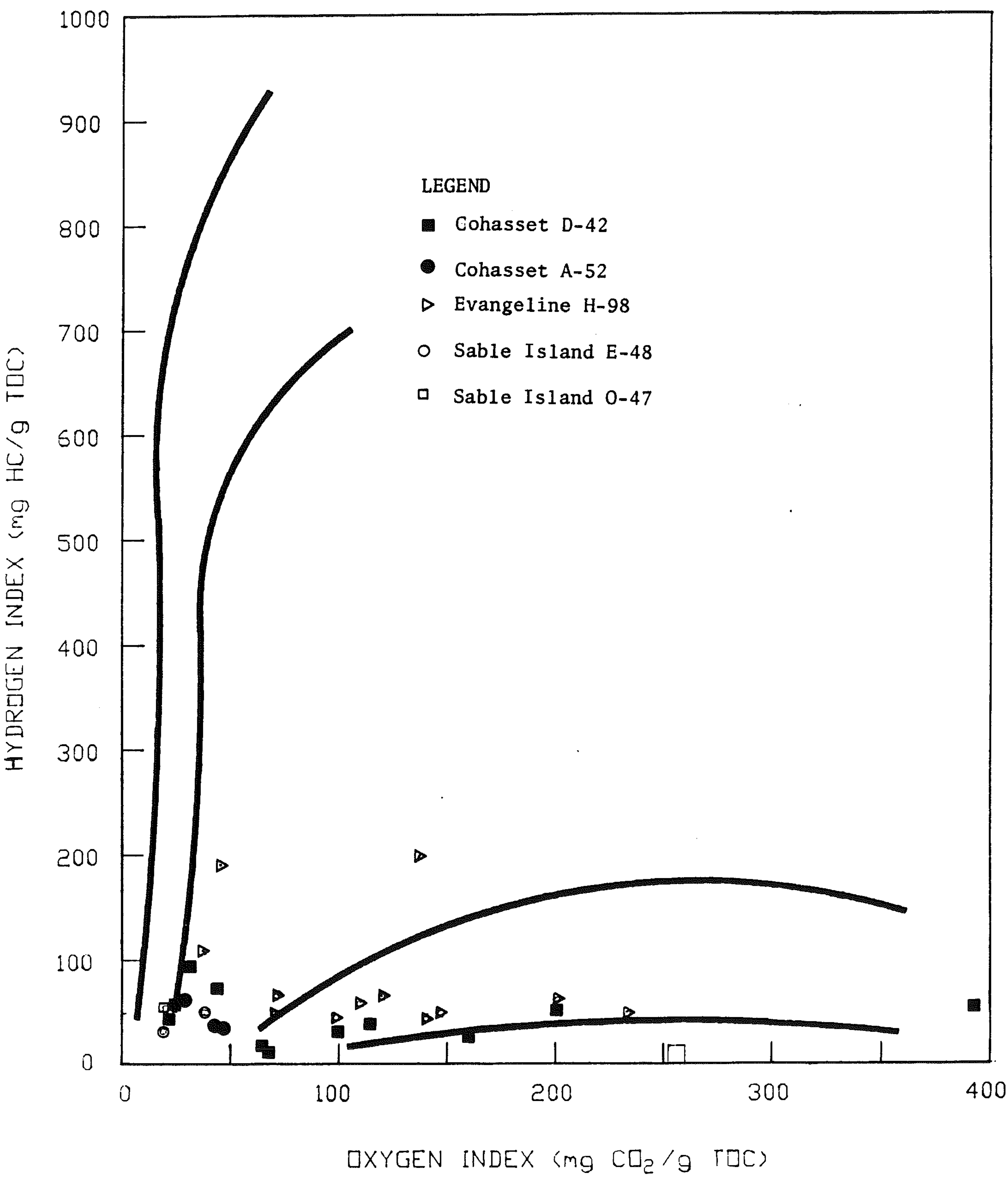


Figure 4



1000
900
800
700
600
500
400
300
200
100
0
HYDROGEN INDEX (mg HC/g TOC)
LEGEND
Cohasset D-42
Cohasset A-52
Evangeline H-98
Sable Island E-48
Sable Island O-47
0
100
200
300
400
OXYGEN INDEX (mg CO_2/g TOC)

Figure 5

HYDROGEN INDEX-Tmax DIAGRAM

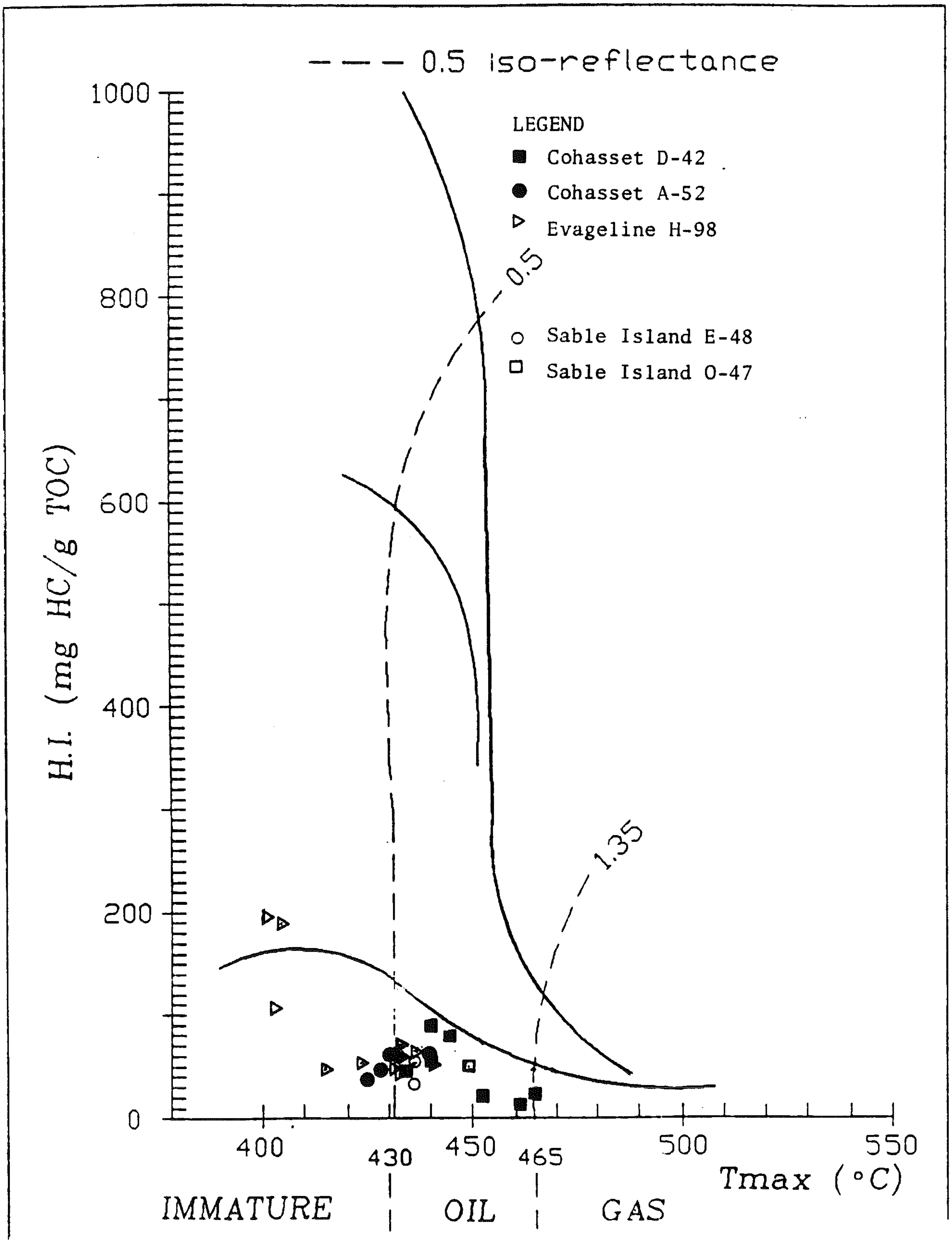
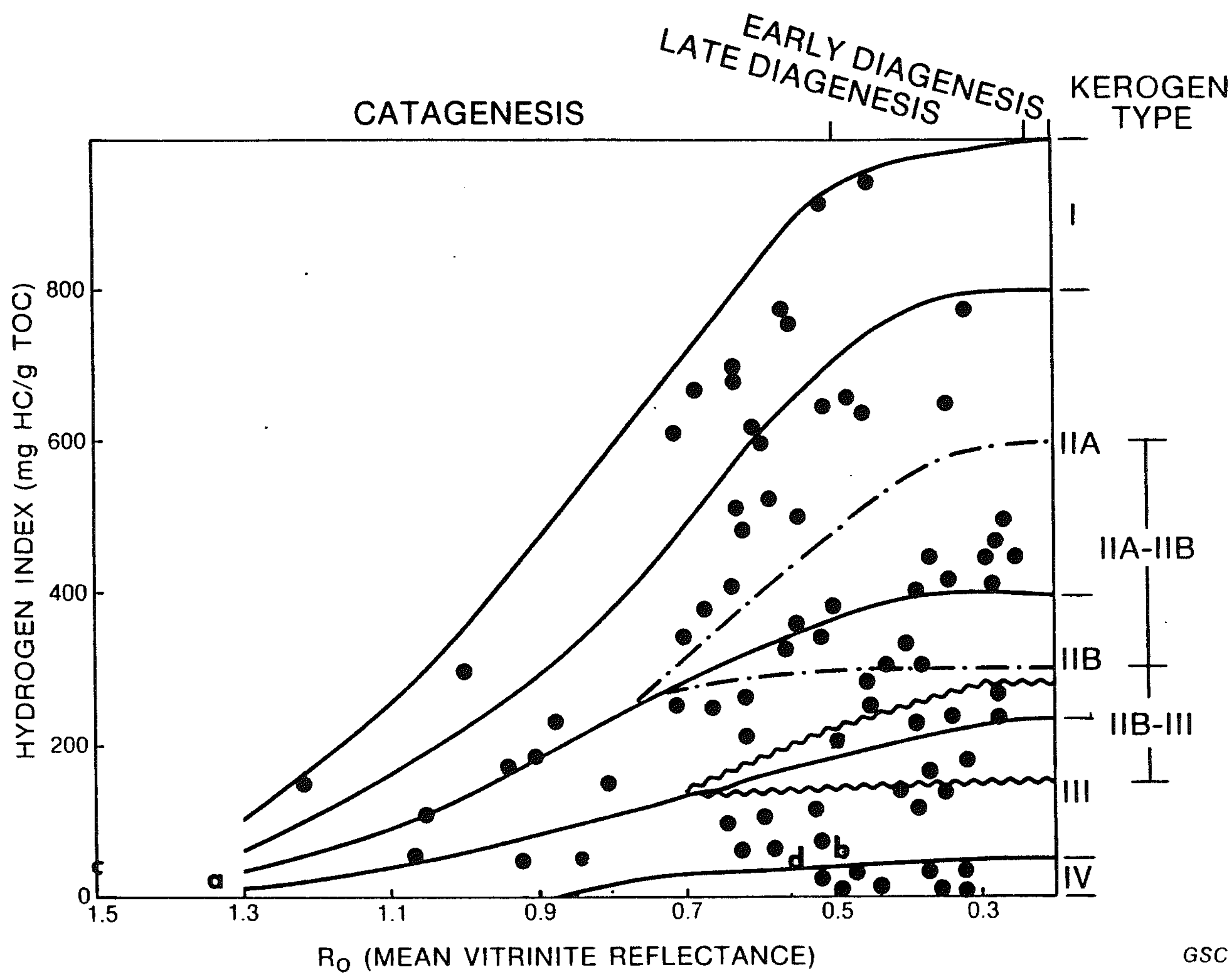


Figure 6



a: Cohasset D-42, 14520'; b: Cohasset A-52, 2275m c: Evangeline H-98, 5020m
d: Sable Island E-48, 8170'; e: Sable Island O-47, 12630'.

Figure 7

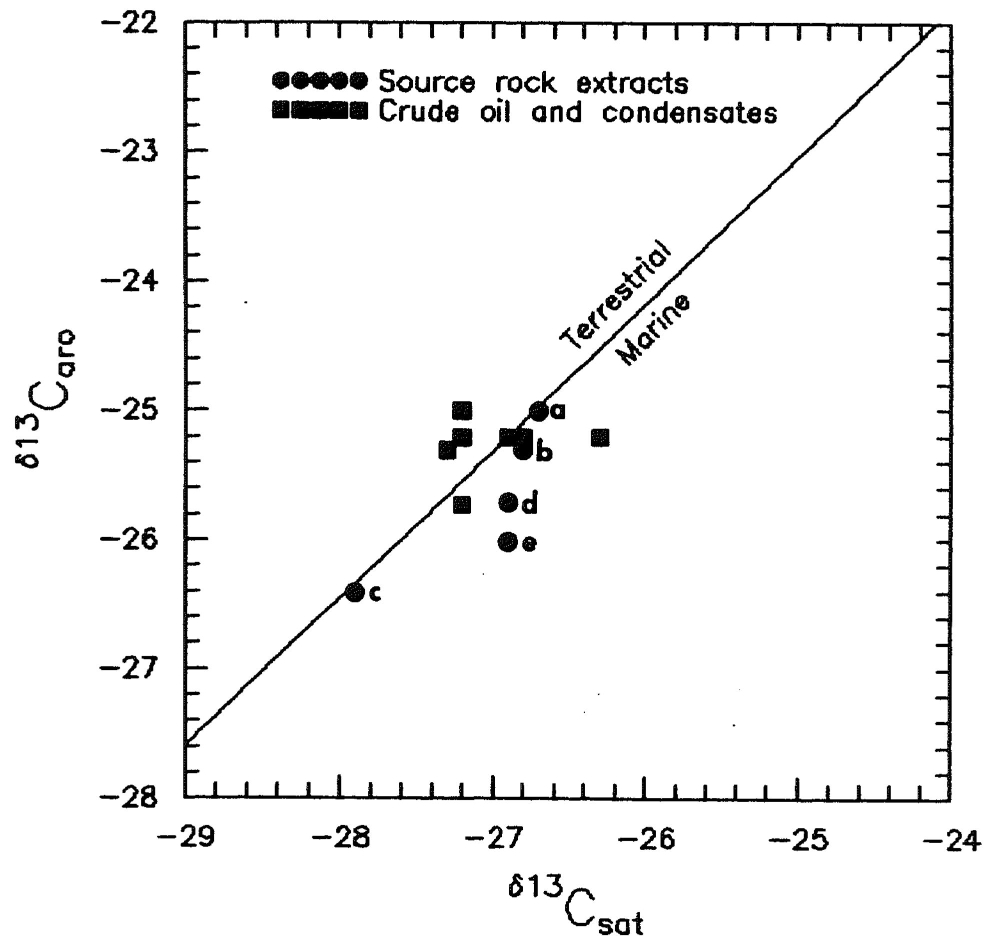

Source rock extracts
Crude oil and condensates
Terrestrial
Marine
a
b
c
d
e
−22
−23
−24
−25
−26
−27
−28
−29
−28
−27
−26
−25
−24
δ13C_{aro}
δ13C_{sat}

Figure 8