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ORGANIC GEOCHEMISTRY OF ALBERT FORMATION OIL SHALES IN THE DOVER-BOUDREAU AREA, NEW BRUNSWICK

G. Macauley and F.D. Bell

Geological Survey of Canada (Calgary)
3303 - 33 Street NW
Calgary, Alberta T2L 2A7

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ORGANIC GEOCHEMISTRY OF ALBERT FORMATION OIL SHALES IN THE DOVER-BOUDREAU AREA, NEW BRUNSWICK

ABSTRACT

Seventy-seven samples of Albert Formation oil shale from four coreholes in the Dover-Boudreau area were analyzed by Rock-Eval pyrolysis. These data were integrated with 184 Rock-Eval analyses from four other available sources to provide a comprehensive geochemical assessment of the area.

Oil shales in the Frederick Brook facies occur as high yield laminated marlstone, as poor quality clay marlstone and as intermediate yield dolomite marlstone. Oil shales are only sporadic in the coarse clastic dominated Hiram Brook facies, are present as low yield beds in the shale dominated Downing Creek facies and are absent from the Dawson Settlement facies of fine and coarse clastics and from the Round Hill conglomerates.

Kerogen appears to be dominantly Type I lamalginite, although either Type II matrix bituminite (amorphous kerogen) or Type I kerogen more thermally matured than the lamalginite can be interpreted to be present. Lamalginite in the Dover area is marginally mature whereas the matrix bituminite is at a low degree of thermal maturation within the oil generation window. Equivalent oil shale lithotypes at Boudreau are slightly less mature than at Dover. Mineral matrix effects in low organic content beds may cause thermal maturation at lower temperatures than for highly organic-rich lamalginites and generated bitumen may then obscure the interpretation of Rock-Eval parameters.

The best petroleum generation potential is in the Albert Mines Zone, approximately 15 m thick in the Dover area, where yields in excess of 100 kilograms/tonne are encountered.

INTRODUCTION

Oil shales of the Carboniferous Albert Formation in New Brunswick were first investigated by use of the Rock-Eval Pyrolysis technique by Macauley and Ball (1982) as part of an effort to determine the most effective cost-efficient procedure for the investigation of Canadian oil shale deposits. Rock-Eval analyses were found to be not only directly comparable in yield evaluation to the more common Fischer Assays, but also were found to provide considerably more information on the classification and maturation of the oil-generating kerogen. Only a few samples from the Dover-Boudreau area were analyzed in that study as the largest amount of core was available from the much better known and potentially more economically attractive Albert Mines area (Fig. 1). Those analyses were performed at Core Laboratories, Dallas, Texas.

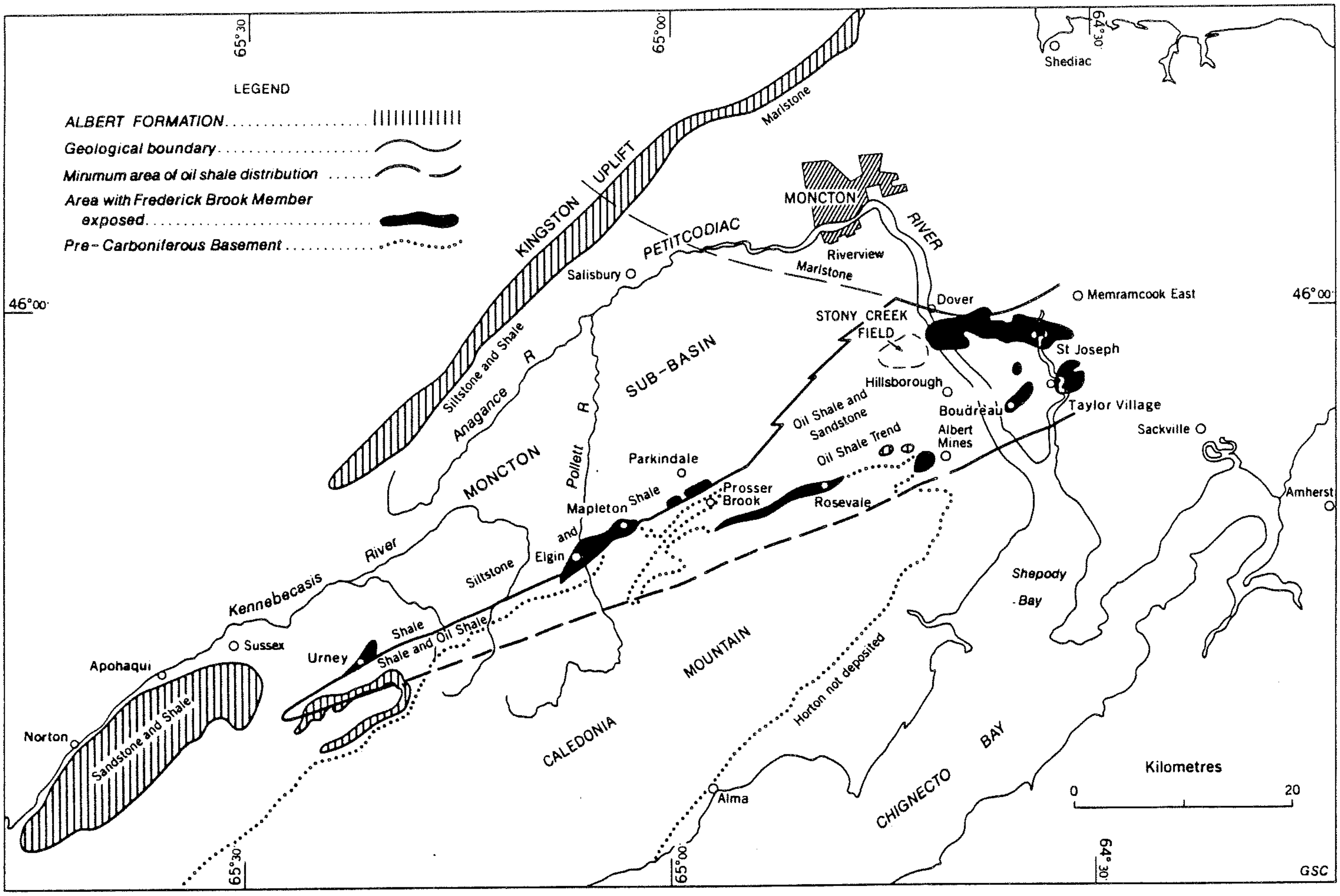
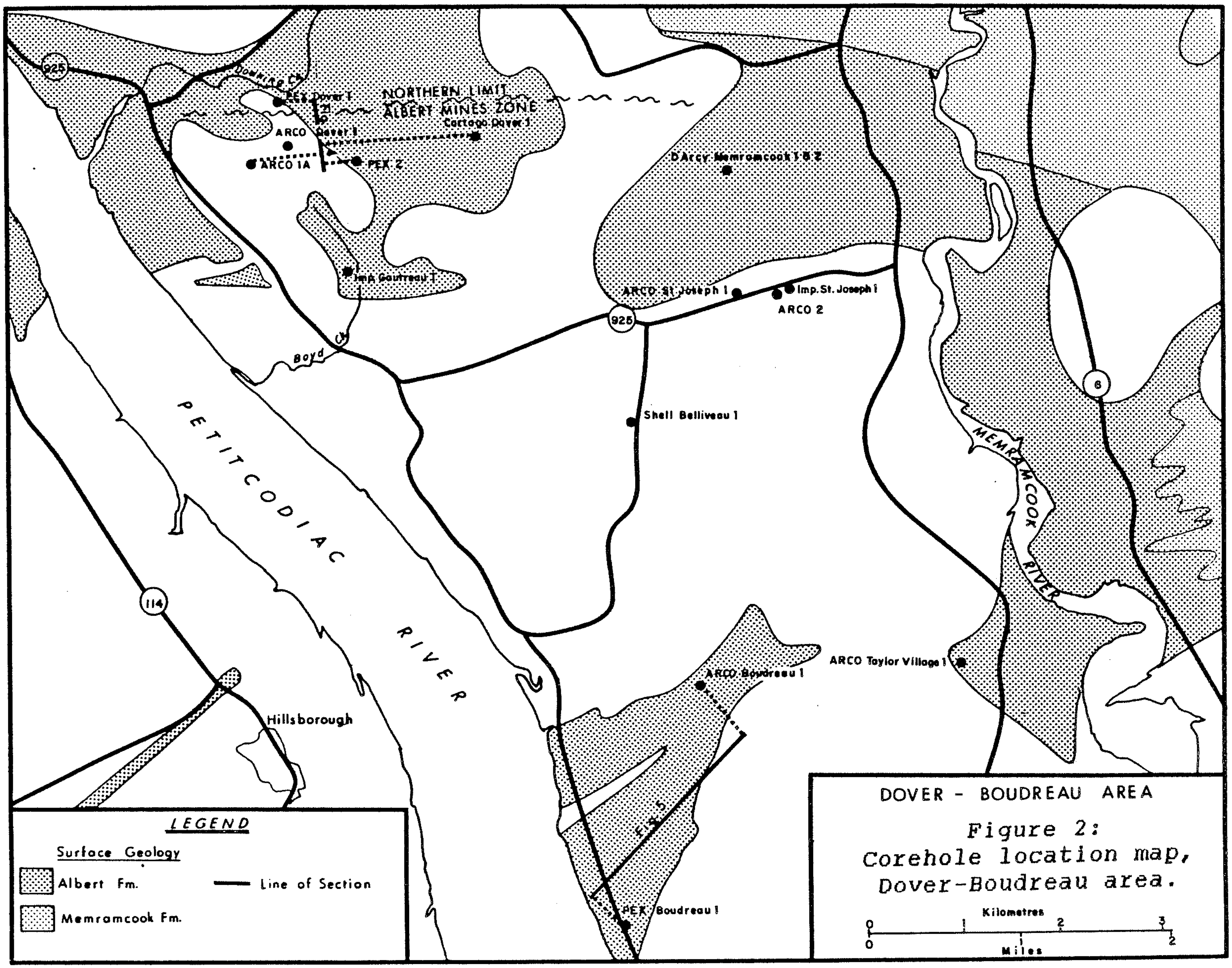


Figure 1: Outcrop areas of Albert Formation, New Brunswick, with interpreted lithologies of the Frederick Brook Member (after Macauley et al., 1985).

The few samples reported from Atlantic Richfield (Arco) Boudreau 1 and Arco Dover 1A (Fig. 2) revealed some difference in kerogen character from that at Albert Mines. The presence of humic detritus, recorded in core descriptions by Macauley and Ball (ibid.), was indicated by the Hydrogen and Oxygen indices and later confirmed by organic petrology investigations (Kalkreuth and Macauley, 1984). The interpretations of those Rock-Eval data were not entirely conclusive for the kerogen content nor for the maturation level, primarily because too few data were available. Also because of the limited data base, only tentative zonal correlations could be suggested from Dover-Boudreau to the Albert Mines area where Macauley and Ball (ibid.) had been able to establish a sub-division of the oil shale interval.

Three holes were cored by Petro-Canada Exploration (PEX), two at Dover and one at Boudreau (Fig. 2), in 1982. These were analyzed using both Fischer Assay and Rock-Eval Pyrolysis by Petro-Canada (Wright, 1982) with the Rock-Eval results from an analyzer at the company research laboratory in Calgary. Further



DOVER - BOUDREAU AREA

Figure 2:
Corehole location map,
Dover-Boudreau area.

Rock-Eval analyses of the PEX Dover 1 and 2 coreholes, carried out at the Institute of Sedimentary and Petroleum Geology (ISPG), Calgary, were included by Smith (1985) in his graduate study thesis. Although the above data are all in the public domain, none has as yet been published.

In the summer of 1986, Cartago Resources cored another hole at Dover (Fig. 2), for which samples have been analyzed by Rock-Eval Pyrolysis at both the Atlantic Coal Institute (ACI), Sydney, Nova Scotia and at ISPG, Calgary. They are included herein by permission of Cartago Resources. The writer further sampled the PEX coreholes to augment and enhance the data control at those locations, not only to assess better the economic potential, but with the hope of establishing better stratigraphic definition within the area.

This report brings together and analyzes all the Rock-Eval results from the six Dover-Boudreau holes for which the cores are currently available. Unfortunately seven prior cores, cut in 1942 near Taylor Village (Fig. 2) by the Canadian Department of Mines and Resources, have been discarded (Macauley, 1984). Cores have also been discarded for two Arco holes at St. Joseph and one at Taylor Village (Fig. 1).

STRATIGRAPHY

Regional stratigraphy of the Albert Formation, of lithofacies relationships within the Albert Formation, and of boundaries relative to both the overlying Moncton Group and underlying Memramcook Formation, have been discussed in considerable detail by several authors (Gussow, 1951; McLeod and Ruitenberg, 1978; McLeod, 1979; Howie, 1980; Macauley and Ball, 1982; Smith, 1985; Carter and Pickerill, 1986); consequently, no detailed discussion of stratigraphy will be included herein.

At Albert Mines, Macauley and Ball (1982) recognized three basic oil shale lithotypes: laminated marlstone, clay marlstone and dolomite marlstone, within the Frederick Brook Member, which is defined by oil shale content (Gussow, 1951) within the Albert Formation. On the basis of the dominance of a specific marlstone type, they sub-divided the Frederick Brook Member into four informal zones: an un-named upper unit with variable distribution of all three lithoypes and also non-organic shales, the Albert Mines zone dominated by high yield laminated marlstone, a zone of low yield clay marlstone, and a basal unit comprising mostly dolomite marlstone and dolostone beds. On plots of the oil and water yields from Arco Albert Mines 1A (Fig. 3), the high oil yields of the laminated marlstones and the high water content in the clays of the clay marlstones and shales clearly differentiate the zones. The laminated marlstones were structurally distorted and contorted into complex faults and folds because of slippage along kerogen-rich bedding planes in the laminated marlstones, whereas the clay marlstone beds were disturbed to a lesser degree and the dolomite marlstones exhibited bed competency during structural deformation.

Based on the fluid content, lithotype similarities and bed competency characteristics, Macauley and Ball (1982) tentatively recognized these units at both Arco Dover 1A and Arco Boudreau 1 (Fig. 2). Wright (1982) was even less inclined to recognize these units in the PEX coreholes. Smith (1985, Figs. 5, 6, 52) recognized the same four-fold unit at the PEX Dover holes, but reported much less dolomite marlstone in the basal unit. Ball (1986) has subsequently used the term "lower unit" in the Dover section to equate to the Dolomite Marlstone unit of the Albert Mines area. Ball (ibid.) has described the "lower unit" to comprise the same admixture of lithotypes recognized in the "upper unit." Dolomite marlstones are interbedded with conglomerates of the Round Hill Member at Arco Boudreau 1 (Macauley and Ball, 1982). Wright (1982) indicated typical dolomite marlstone at PEX Boudreau 1 in his text, but was unable to ascribe zones to the section penetrated and his brief core descriptions permit only generalized lithotype interpretations.

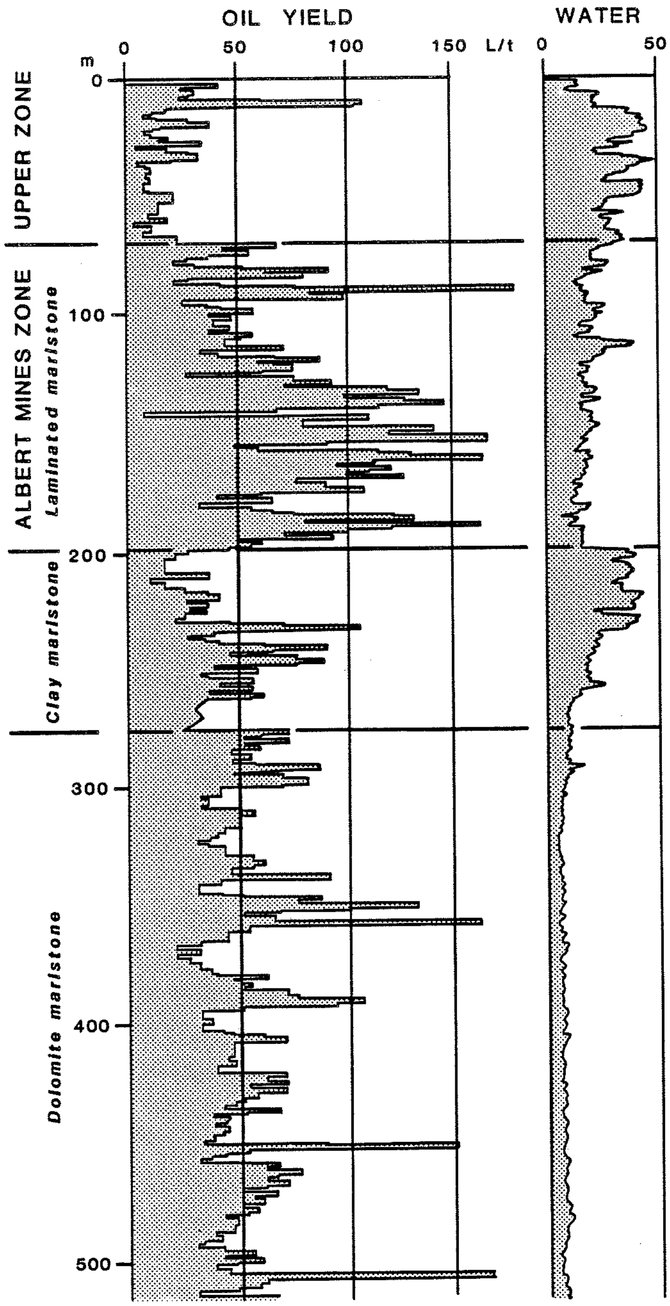


Figure 3: Shale oil and water yields, Atlantic Richfield Albert Mines 1A (after Macauley and, Ball, 1982).

Greiner (1962) divided the Albert Formation into three members, of which the uppermost Hiram Brook comprised siltstone, shale, calcareous sandstone and minor oil shale. The middle Frederick Brook Member contained oil shale, limestone, calcareous shale and siltstone, and the basal Dawson Settlement Member was characterized by sandstone, siltstone, shale and conglomerate. As noted by Macauley and Ball (1982), differentiation of the Dawson Settlement and Hiram Brook members would be most difficult if the medial Frederick Brook Member were not present. Conglomerates of the Round Hill Member (Carter and Pickerill, 1986) were recognized by Macauley and Ball (ibid.) to intertongue with the other three members of the Albert Formation.

The lateral and vertical relations of these units were such that Macauley and Ball (1982) treated them as facies. Wright (1982) concurred with this treatment and introduced the Downing Creek facies to encompass sections of shales, siltstones, sandstones and carbonates in which minor oil shales were present, in effect, Hiram Brook - Dawson Settlement facies containing oil shales in insufficient quantity to represent the Frederick Brook facies. Because of the complex inter-relationships of these units, all are treated as facies herein. This avoids the serious problem of inter-bedding members or having to include considerable non-representative lithology within many of the members. The Upper Shale zone of the Albert Mines area can be placed within the Downing Creek facies. The Albert Mines, Clay Marlstone and Dolomite Marlstone intervals are treated as zones within the Frederick Brook facies.

Based on the plotted lithologic logs and written descriptions of Macauley and Ball (1982), Wright (1982) and Ball (1986), diagrammatic cross-sections have been prepared for the Dover coreholes (Fig. 4) and for those at Boudreau (Fig. 5). Ball (ibid.) recognized a "lower zone" which he equated to the Dolomite Marlstone of the Albert Mines area. Most of his lower unit is here placed within the Downing Creek facies, but some intervals, particularly just below the Clay Marlstone, remain classified as Dolomite Marlstone. Ball (1986) had no difficulty recognizing the Albert Mines and Clay Marlstone zones in the Dover area.

The Downing Creek facies is defined from outcrop along Downing Creek immediately north of PEX Dover 1 (Fig. 1) and this facies is present in that corehole (Fig. 4). Wright (1982) also described Downing Creek facies along Boyd Creek to the south of the Dover coreholes.

The Albert Mines Zone is at the surface along an approximate east-west strike just north of PEX Dover 1 and Cartago Dover 1 (Ball, 1986, Plate 3). The zone continues beneath Enrage Formation cover to both the east and west, as seen at Arco Dover 1A. A high yield Albert Mines Zone is recognized in all coreholes except where eroded at PEX Dover 1. In addition to good petroleum recoveries, slickensided minor faulting and crenulations related to the kerogen laminae assist in the recognition of this unit across the Dover-Boudreau area.

Although dolomite marlstone lithology can be recognized as being the uppermost beds of a unit immediately below the Clay Marlstone interval at all locations except PEX Dover 1, the lithology in this area is thinner and more poorly developed than that encountered in the Albert Mines area. This "lower unit" is dominated variably by Downing Creek and Dawson Settlement facies

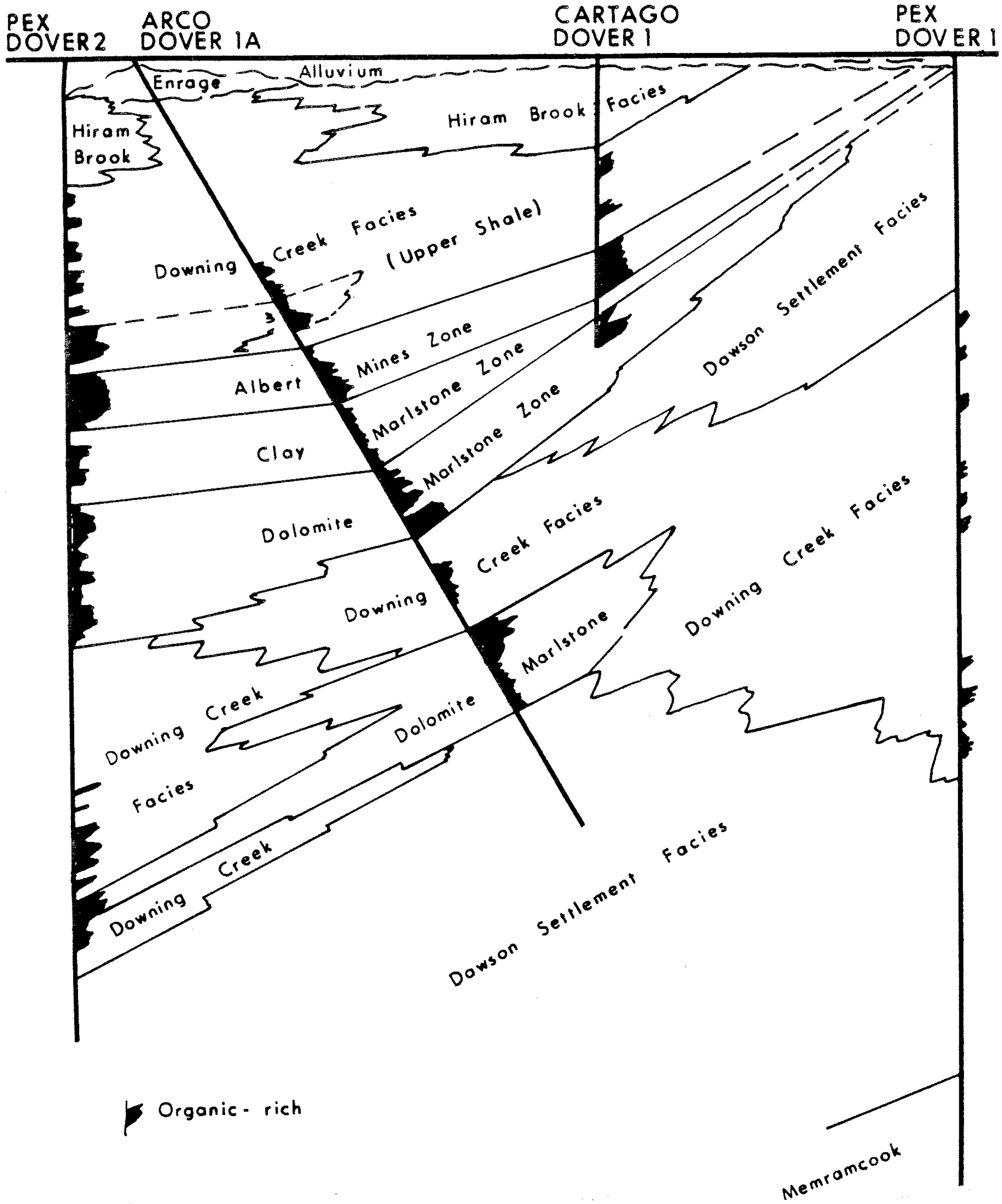


Figure 4: Diagrammatic facies correlation section, Dover area.

in the Dover area (Fig. 4), whereas Dolomite Marlstone of the Frederick Brook facies alternates with Round Hill facies at Boudreau (Fig. 5).

Clay marlstone beds are correlated on the basis of low yields and increased clay content, with minor evidence only of the increased water content so obvious in the Albert Mines area. Variable water content is less significant because of the increased clay component throughout the section below the Clay Marlstone Zone, as dolomite marlstones and dolostones are here only poorly developed.

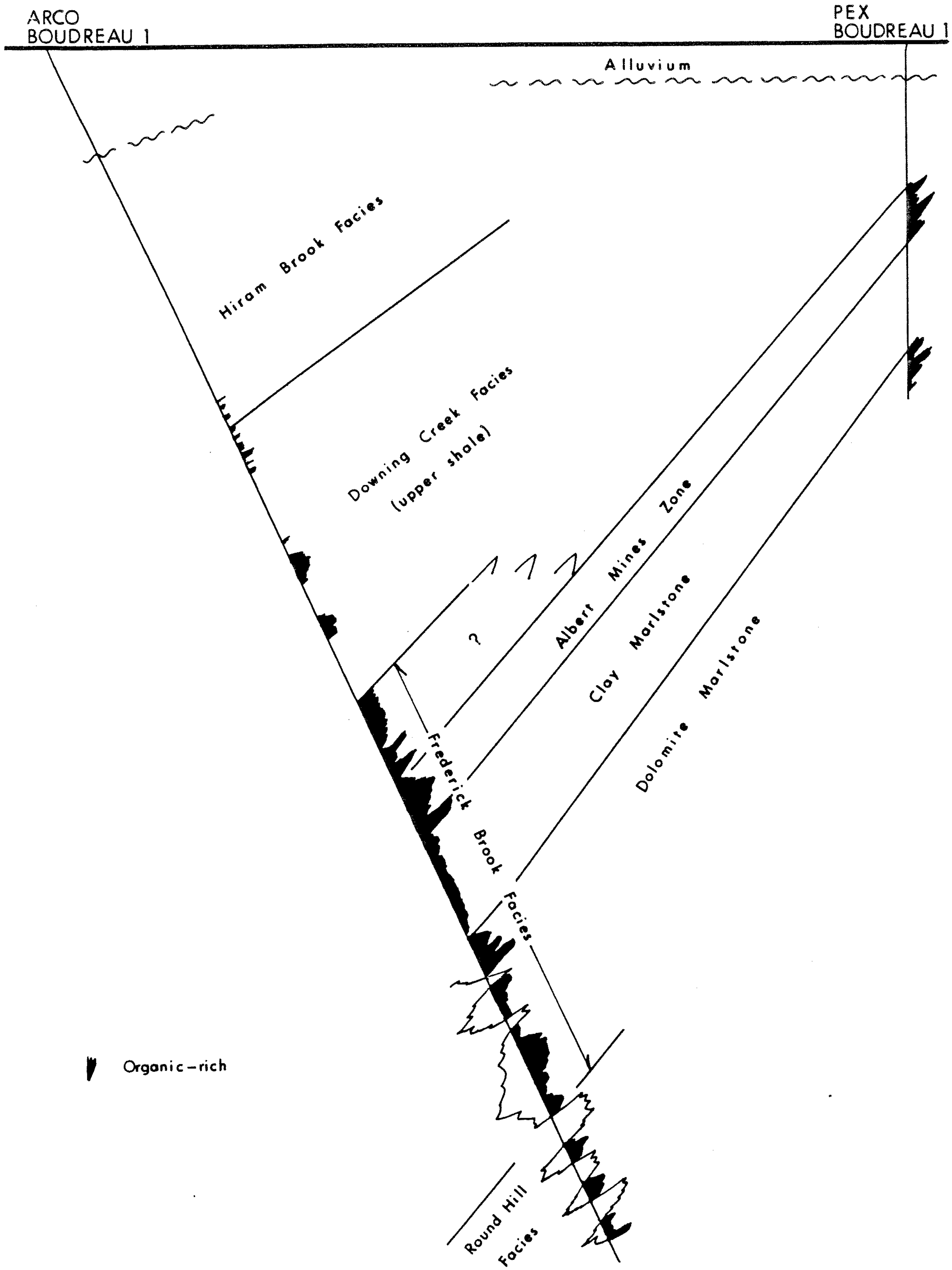


Figure 5: Diagrammatic facies correlation, Boudreau area.

There are insufficient data to allow mapping of the various facies below the Albert Mines Zone. There is enough evidence to indicate that good oil shale zones, although probably of limited thickness, may be present in the lower part of the section and that further attempts to explore for such beds, especially in the Boudreau area, can be justified.

GEOCHEMISTRY

Rock-Eval analyses are generally carried out under a standard procedure. The S1 peak, representing light petroleum products, is collected at 300°C. The S2 peak, the petroleum product from the pyrolysis of kerogen and bitumen, is measured during heating at 25°C/min. and collected to a temperature of 600°C. Oxygen is determined by the S3 peak collected to a temperature of 390°C. For the more recent samples analyzed at ISPG and ACI, total organic carbon (TOC) was determined by burning all residual carbon in a separate oxidation oven built into the analyzer and operated at 600°C in air. At ISPG, all samples were ground to an approximate 150 micron particle size to ensure complete pyrolysis and burning of all residual carbon. For earlier ISPG and Core Laboratories analyses, TOC determinations were made in Leco WR12 analyzers after samples had been pulverized to 150 microns and treated in both cold and hot 6N hydrochloric acid to remove mineral carbon.

Where TOC content is low, or if the thermal maturation level is high to overmature, Tmax values can be questionable because of the inability of the computer to differentiate the true S2 peak from the "noise" of the flame ionization detector. The Oxygen Index is also a difficult parameter to measure accurately. Even though CO_2 is collected only below 390°C, excessively high Oxygen values are often indicated for low hydrocarbon recovery samples and attributed to the breakdown of carbonates in the samples. This should not occur until a temperature above 550°C is attained, nor is there an apparent reason that carbonate breakdown should occur only where TOC content is low.

Type I kerogens are chemically homogeneous and have Tmax values of 445 to 450°C, even at low levels of maturity, whereas low maturity Type II and III kerogens pyrolyze with a Tmax of 435°C (Espitalié et al., 1984). The effects of admixed kerogens on both Tmax and Hydrogen-Oxygen indices (HI-OI) has been described by Kalkreuth and Macauley (in press) for Type I-III torbanites in Nova Scotia.

From an initial perusal of the Rock-Eval data (Appendix A), wide ranges of Tmax and the Hydrogen-Oxygen indices were apparent, but no direct relationships were obvious. HI versus OI and yield (petroleum potential) versus TOC cross-plots have been standard interpretive procedures. In order to understand more completely the meaning of the various parameters, several additional cross-plots were prepared; HI/TOC, HI/Tmax and Tmax/TOC. Both those with apparent significant relationships and

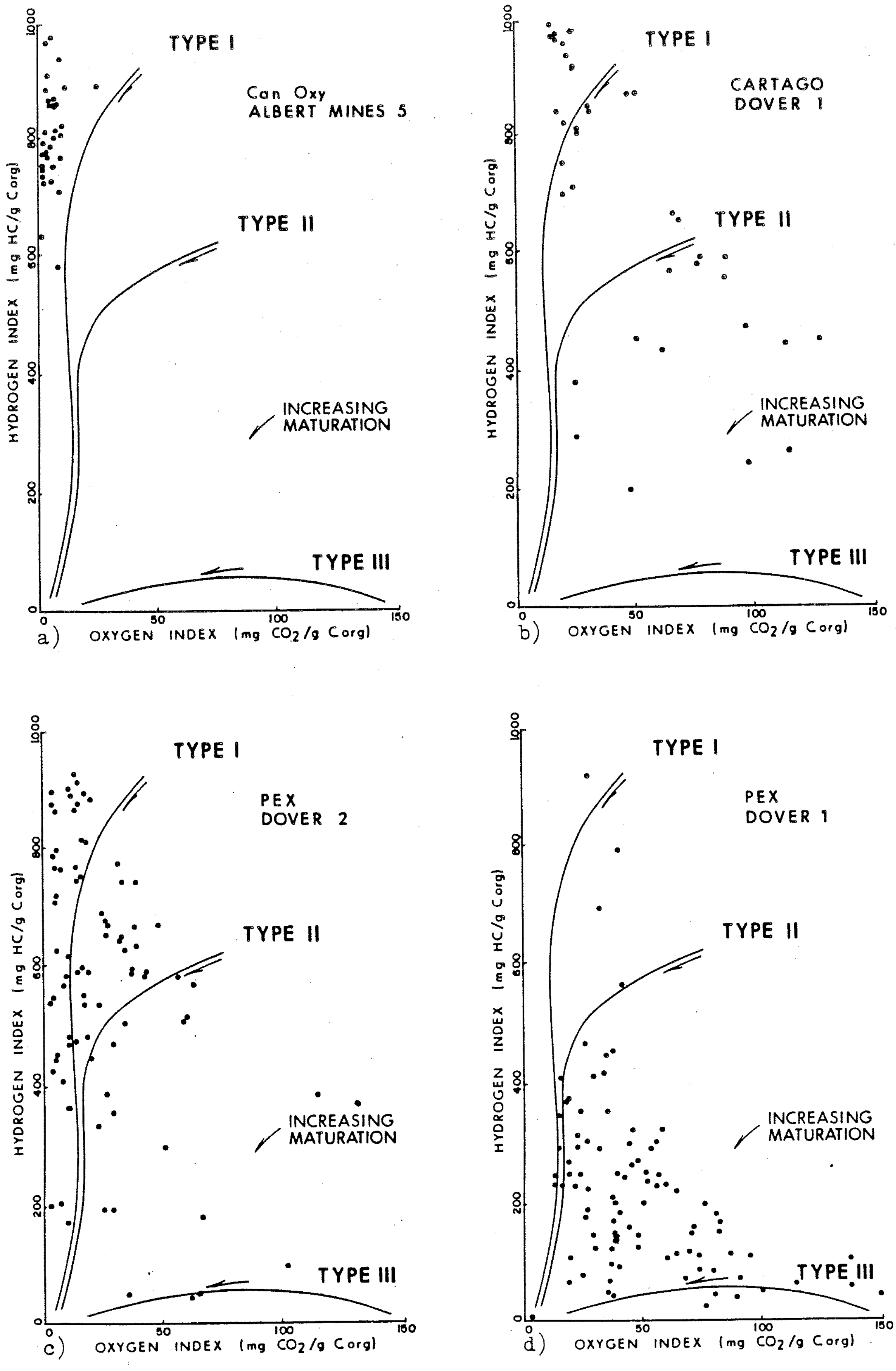


Figure 6: Hydrogen Index versus Oxygen Index.

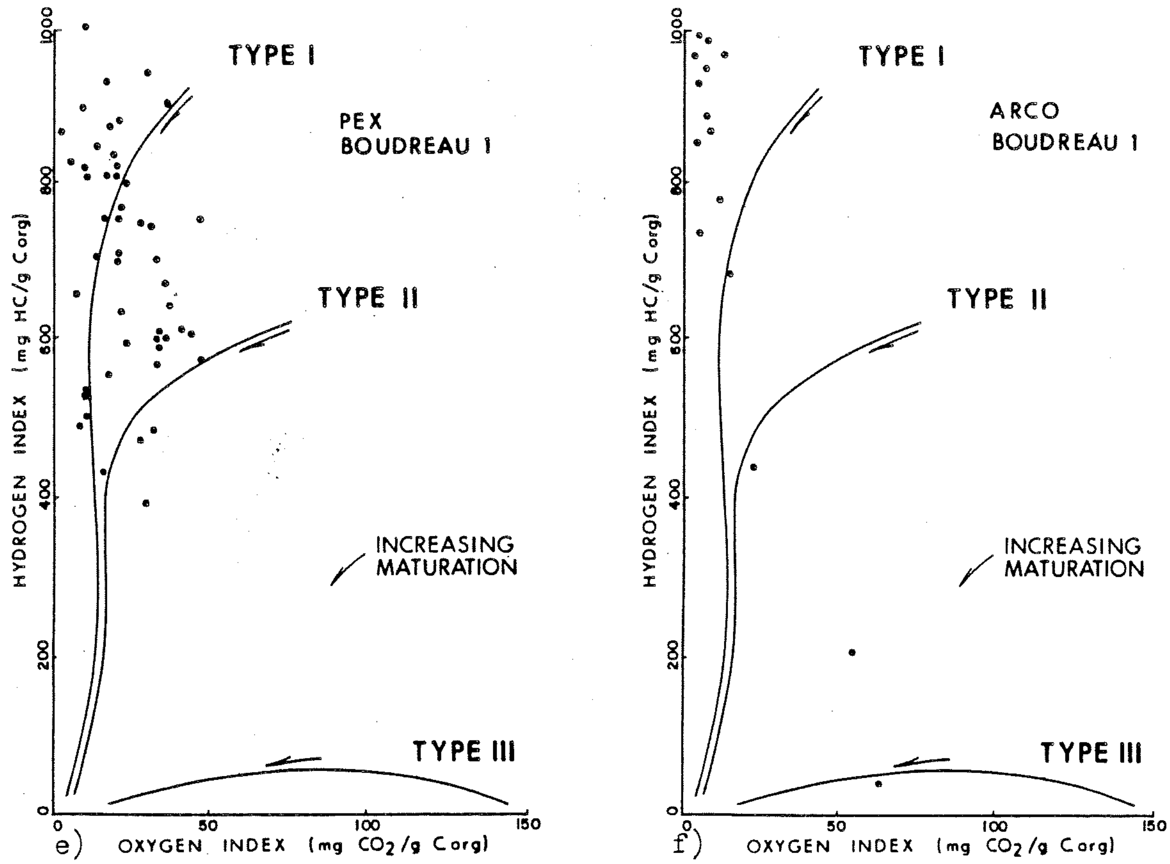


Figure 6: Hydrogen Index versus Oxygen Index (continued).

those definitely independent of each other are reproduced to illustrate the various plot characteristics encountered. A few analyses are available for Arco Dover 1 (Appendix A) but these were not plotted because the limited number, all from better yield beds, would not necessarily be indicative of the section at that location.

Hydrogen (HI) - Oxygen (OI) indices

At Albert Mines, the dominant kerogen, Type I lamalginite, is characterized by high Hydrogen Indices in the range 750 - 1000 with commensurately minimal, abnormally low Oxygen content (Fig. 6a) at a low maturation level in the oil generation window. Similar ranges of HI are encountered from Albert Mines laminated marlstones and from dolomite marlstone beds at both Cartago Dover 1 (Fig. 6b) and PEX Dover 2 (Fig. 6c), which generally contain slightly more Oxygen. Many samples, which exhibit relatively lower Hydrogen and higher Oxygen indices, are contained in the Hiram Brook and Downing Creek facies at these locations. Because these facies are inter-zoned, the HI differences cannot result from variable maturation levels attributable to differential burial. HI/OI data at PEX Dover 1 (Fig. 6d) are almost entirely indicative of the Downing Creek facies.

Similar HI/OI - facies relationships are evident in the Boudreau area analyses (Fig. 6e, f), although the HI values do not become so low as those encountered in the Dover area. Most of the Boudreau area samples are from the Albert Mines equivalent and from dolomite marlstone lithology.

Smith (1985) identified a maceral content gradation from dominant lamalginite in the high yield beds to liptodetrinite in the less prolific strata. These he assigned to Type I and Type II kerogens, respectively. His liptodetrinite seems to be very much like the amorphous sapropelic kerogen encountered in Type II marine deposits such as the Ordovician Collingwood oil shales of southern Ontario (Macauley et al., 1985), and also similar to the better yielding matrix bituminite in the dolomite marlstones and dolostones of the Albert Mines area. Whether the kerogen here is amorphous Type II or a similar form of Type I is difficult to determine either geochemically or petrologically. Certainly some degree of mineral matrix effect must be involved. Varying thermal maturation levels may be a significant factor within the wide range of TOC content as they reflect major differences in the maceral-mineral relationships. Varying maturation levels may cause both a range of onset temperatures for petroleum generation and a distortion of HI values within a short vertical section. Fluorescence microscopy will possibly be the best approach to determine small maturation differences within offsetting beds.

Possible Type III humic content must also be considered. Kalkreuth and Macauley (1984) established the presence of vitrinite in Hiram Brook facies at Arco Boudreau 1, and Smith (1985) recorded minor amounts of vitrinite and fusinite in the PEX coreholes. Kalkreuth and Macauley (in press) have illustrated the difficulties in Rock-Eval interpretation for torbanites in Nova Scotia where Type I and III kerogens are intimately admixed.

Utting (in press) described varying degrees of biodegradation of spores which he attributed to levels of bacterial activity sensitive to minor environmental differences. He also recognized the presence of other humic detritus in the Dover-Boudreau area. The changes in Oxygen Indices may well reflect differing levels of biodegradation varying with the quantity of kerogen and specific environmental conditions.

Hydrogen Indices - TOC

In the Albert Mines area, Hydrogen Indices in the range 700-1000, associated with the lamalginites, are independent of a wide range (2 to >20%)of TOC values (Fig. 7a). At both Cartago Dover 1 (Fig. 7b) and PEX Dover 2 (Fig. 7c), HI values above 700 increase with increasing TOC content, whereas a wide range of Hydrogen Indices are independent of a narrow range of TOC values less than 5%. For PEX Dover 2 (Fig. 7d), a full range of HI values are completely independent of TOC content below 5%. In essence, TOC content is independent of HI where HI exceeds 700, but HI is independent of TOC where TOC is less than 5%. This same

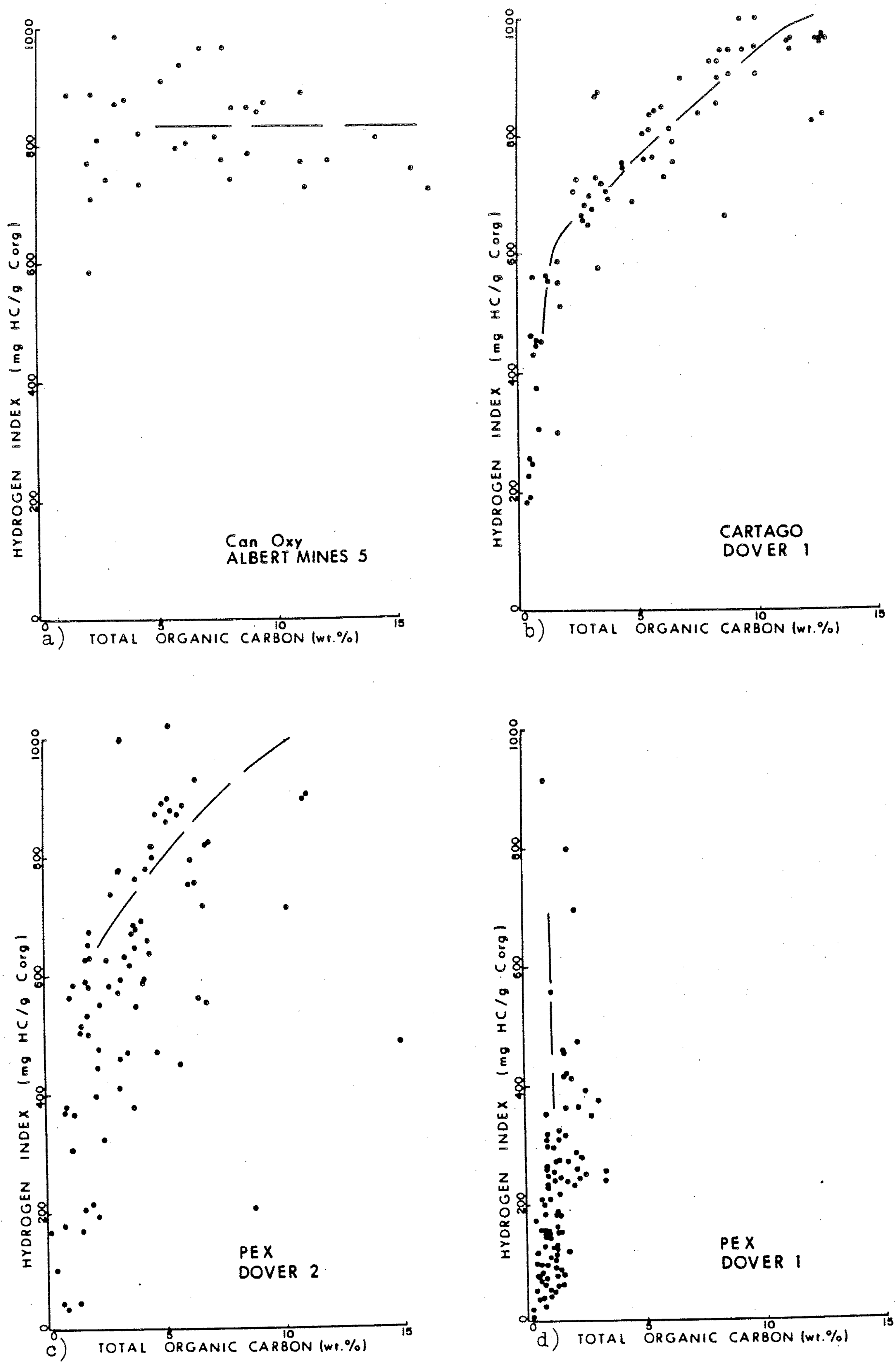


Figure 7: Hydrogen Index versus total organic carbon.

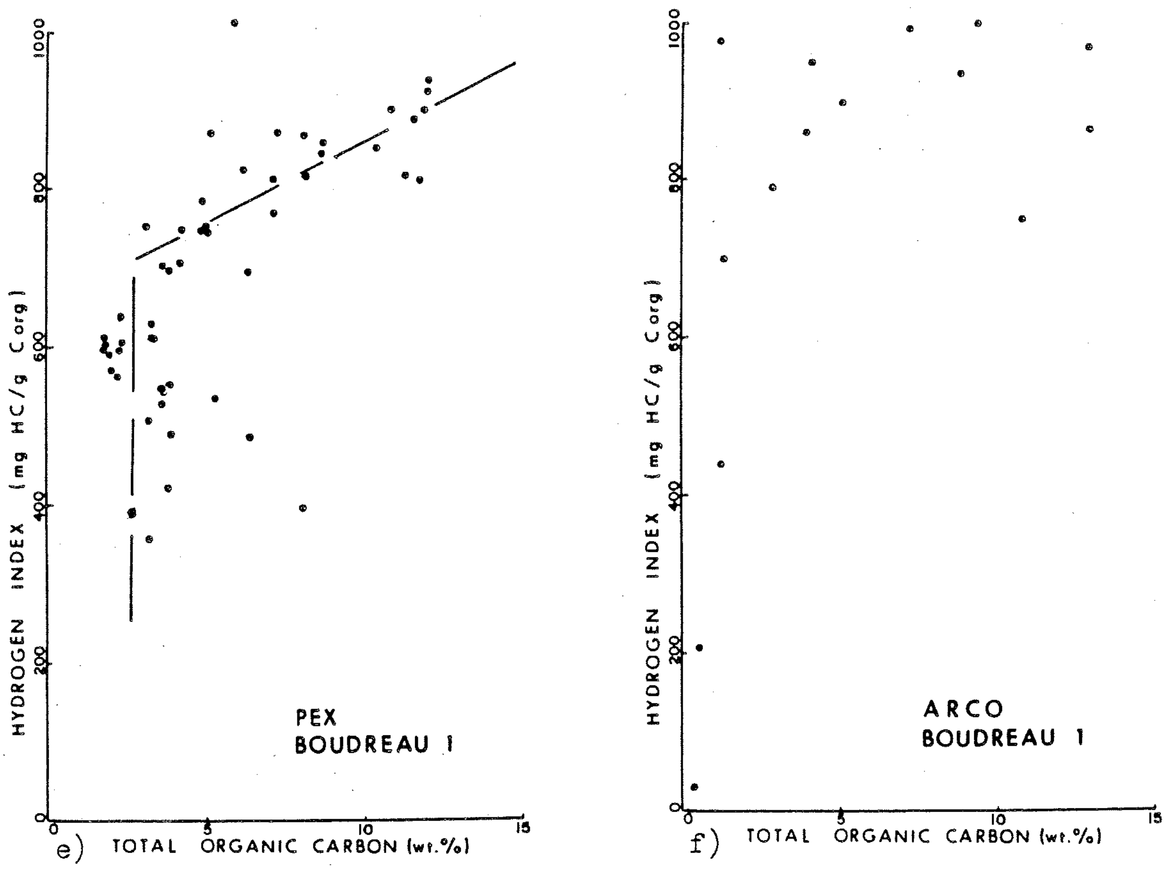


Figure 7: Hydrogen Index versus total organic carbon (continued).

relationship has been demonstrated by Macauley (1987) for Type I kerogens in the Carboniferous Rocky Brook Formation of western Newfoundland.

The same relationship is evident at the two Boudreau coreholes (Fig. 7e, f) but is more apparent at PEX Boudreau 1 (Fig. 7e) because of the greater number of data points.

Tmax

Tmax has been considered as a key parameter for the interpretation of thermal maturation. Tmax seems to an appropriate evaluation factor for Type II deposits, such as the Ordovician Collingwood beds of Ontario (Macauley, in press). For Type I deposits, the relationship of Tmax to maturation level is much less distinct. In theory, Type I kerogen does not mature below 445 to 450°C (Espitalié et al, 1984), but Tmax values in the range 432 to 455°C are common to the Frederick Brook oil shales at Albert Mines and in the Dover-Boudreau area (Figs. 8a-f). From organic petrographic studies (Kalkreuth and Macauley, 1984), Rock-Eval Production Indices (Macauley and Ball, 1982) and saturate fraction investigations (Altebaeumer, 1984), moderate thermal maturation has been established for this Tmax range at

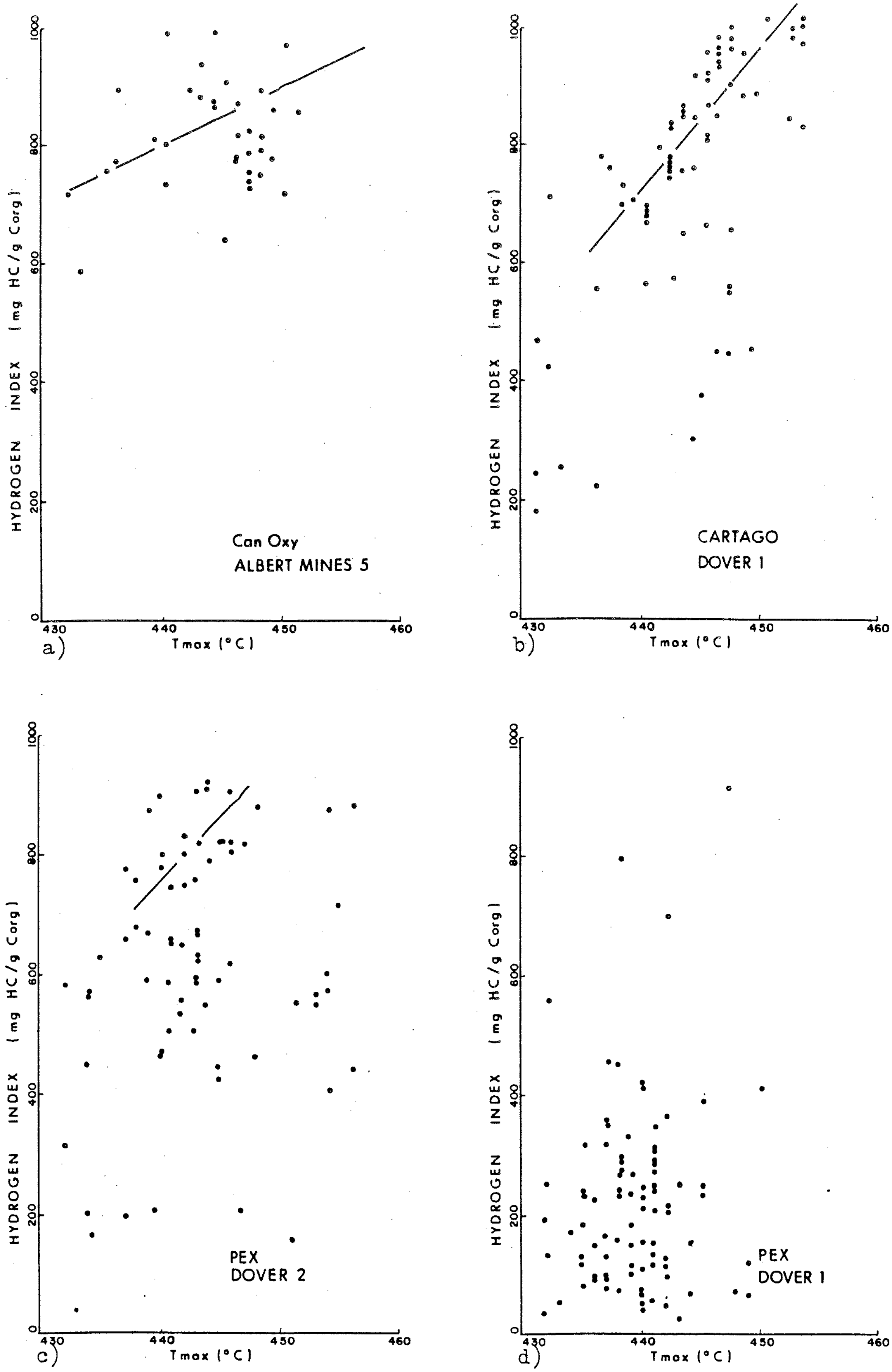


Figure 8: Hydrogen Index versus Tmax.

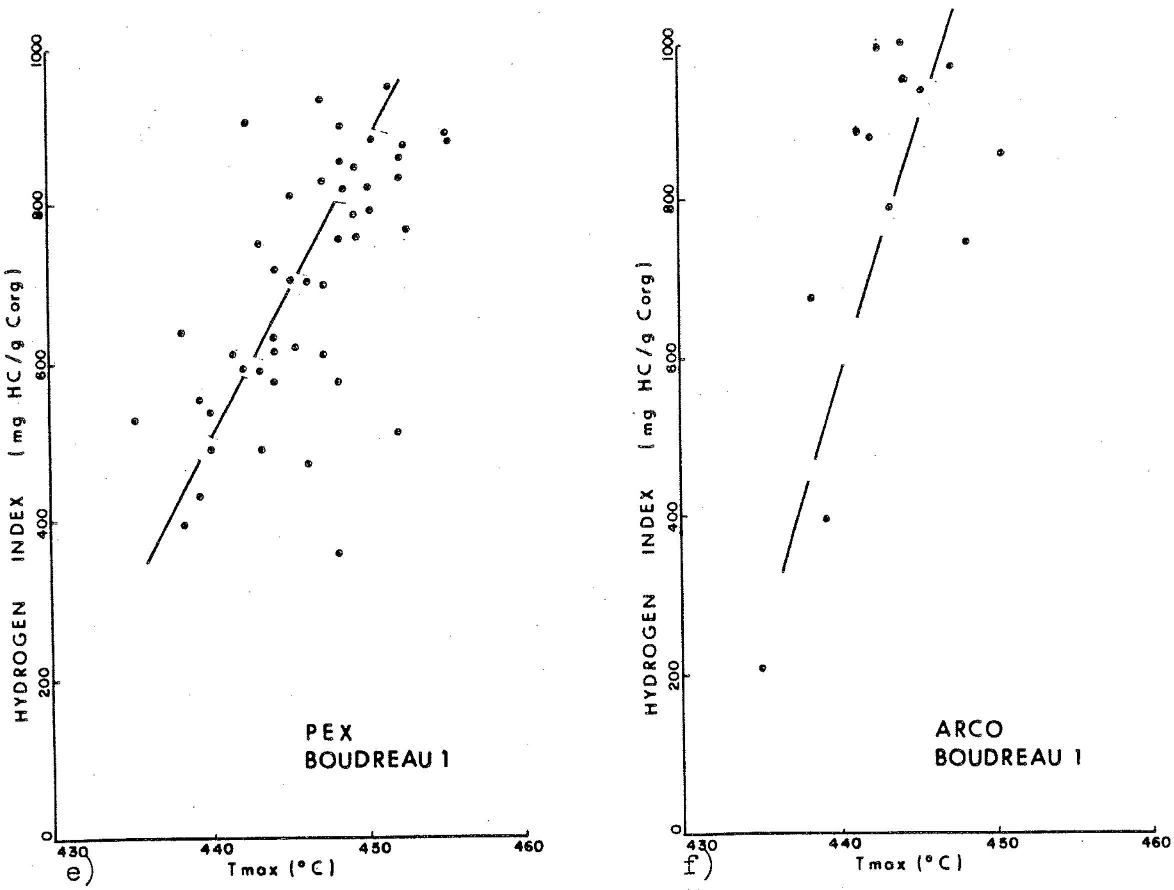


Figure 8: Hydrogen Index versus Tmax (continued).

Albert Mines, even though many values are much below the minimum projected 445°C for petroleum generation.

At CanOxy Albert Mines 5, Tmax ranges from 432 to 452 C°from dominantly lamalginite kerogen with HI values above 700 (Fig. 8a). A possible increase of Tmax with increasing HI can be interpreted although the points are widely distributed. This diverse high range of HI has been attributed to movement of both light petroleum and bitumen within the oil shale beds by both Macauley and Ball (1982) and Altebaeumer (1985).

Particularly at Cartago Dover 1 (Fig. 8b), but also at PEX Dover 2 (Fig. 8c), mutually increasing HI-Tmax values are apparent where HI exceeds 700: for lower HI values, there is no apparent inter-dependency of these two parameters, a conclusion substantiated by HI/Tmax cross-plot for the PEX Dover 1 data (Fig. 8d). These lower HI values may represent matrix bituminite (amorphous) kerogen. If the apparent differences in kerogen character are reflected in different initial maturation temperatures, then varying maturation levels may be indicated by the Tmax range. Alternatively, generated bitumen may have a very different Rock-Eval Tmax than associated kerogen and thus create a wide range of Tmax values within a deposit with a fairly uniform maturity level.

Tmax appears to increase in proportion to HI values in the Boudreau area (Fig. 8e, f), even for HI values below 700, although a wider Tmax range is evident for HI <700 at PEX Boudreau 1 (Fig. 8e). Insufficient very low potential beds have been sampled at the Boudreau locations to confirm completely the observations of the Dover area.

Tmax - TOC

At CanOxy Albert Mines 5, Tmax in the range 440 - 450°C is essentially independent of TOC if TOC is exceeds 5%. Below 5% TOC, Tmax is lower in the range 430 - 440 °C (Fig. 9a). At Cartago Dover 1, Tmax and TOC are independent below 5% TOC; however, above 5% TOC, Tmax rises with increasing TOC (Fig. 9b). A wide range of Tmax values is evident for the lower TOC range samples. No relationship is evident at PEX Dover 2 (Fig. 9c). The low kerogen beds of PEX Dover 1 (Fig. 9d) exhibit a full range of Tmax values where the two parameters are independent.

In the Boudreau area, lower Tmax relate to lower TOC content and higher Tmax to higher TOC, with the same 5% dividing value. Although this grouping can be recognized, there is no inter-dependency of the parameters within each specific group as evidenced at PEX Boudreau 1 (Fig. 9e). Possible inter-dependency is indicated at Arco Boudreau 1 (Fig. 9f), although this may be in part the result of a limited data base.

Petroleum Potential

Although the Petroleum Potential (S1+S2), the total pyrolyzable hydrocarbon product, is significant to the economic potential of an oil shale deposit, the yield ratio (Petroleum Potential/TOC) is a more effective parameter in assisting determination of kerogen type and maturation level. Macauley et al. (1986) noted that yield ratios for Type I oil shales generally exceeded 8 kg/t/%TOC; those for Type II marine sapropelic deposits ranged from 6 to 7.5 kg/t/%TOC, and the Type II mixed marinites yielded in a lower range generally below 4.5 kg/t/%TOC.

Yield ratios for the lamalginites at CanOxy Albert Mines 5 are in the range 9 to 10 kg/t/%TOC, for which all data ({S1+S2}/TOC) plot on a virtually straight line (Fig. 10a) trending through the origin. The indicated lack of inert kerogen may result from the relatively low content of inert carbon compared to the high yield material. The deflection to lower yield ratios in the highest recovery beds may reflect expulsion of hydrocarbons. The movement of hydrocarbons within beds has been proposed by both Macauley and Ball (1982) and Altebaeumer (1985).

In the Dover-Boudreau area, except for the anomalous PEX Dover 1 location which cored only Downing Creek facies, the yield ratio plots (Fig. 10b-c, e-f) are similar. All indicate an inert carbon in the range 1 to 1.5% and have similar slopes which indicate a reducing yield ratio from as high as 10 kg/t/%TOC to

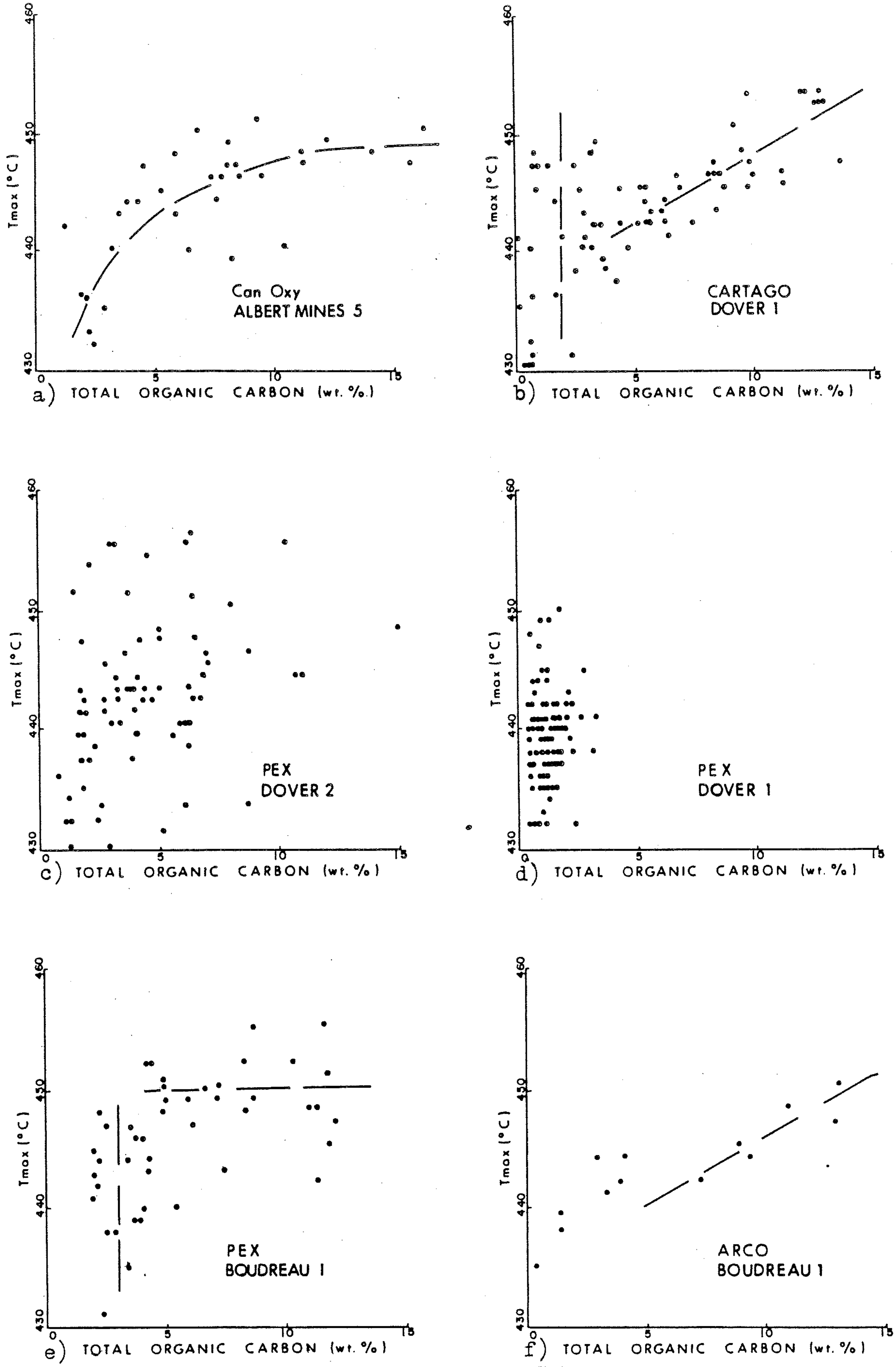


Figure 9: Tmax versus total organic carbon.

lower values near 7 kg/t/%TOC at 3 to 4% TOC. PEX Dover 2 (Fig. 10c) reflects a break with significantly reducing yield ratio in the lowest TOC samples, recognizable because of the number of data points, and which reflects the much lower yield ratio similar to that of the matrix bituminite (amorphous) kerogen of the Downing Creek facies at PEX Dover 1 (Fig. 10d).

The varying yield ratios were compared with the Hydrogen Indices and TOC content (Appendix A). There is little doubt that the Petroleum Potential varies directly with the TOC content and is influenced by the character of the kerogen. Whether the kerogen itself varies in Hydrogen content or whether similar initial kerogen has been differentially matured cannot be determined from recovery data.

Transformation Ratios

Transformation Ratios (TR) (previously called Production Indices, PI), were noted (Appendix A) to span a wide value range, with a distinct impression that the range would relate to lithotype variations. Average TR values were then calculated by lithofacies and as an average for each corehole (Table I).

Corehole	Transformation Ratio Averages						
	Hiram Brook	Upper Zone	Albert Mines	Clay Marl	Dolomite Marl	Downing facies	Avge
CanOxy 5	--	.13	.11	.14	.23*	--	.17
PEX Dover 1	--	--	--	--	--	.14	.14
PEX Dover 2	--	.14	.07^	.12	.19*	--	.14
C Dover 1	.24*	.16	.06^	.18	.10^	--	.13
PEX Boudreau	--	--	.09^	13	.08^	--	.09^
Arco Boudreau	.51*	.08	.06^	--	.06^	--	.08^

Table I: *Averaged Transformation Ratio Data*; * high; ^ low.

At CanOxy Albert Mines 5 (Macauley and Ball, 1982), specific Production Indices (PI) range 0.10 to 0.30, indicative of a moderate thermal maturation level within the oil generation window. From the indices, beds of the Dolomite Marlstone Zone, which contain matrix bituminite, are the most thermally matured (Table I), a conclusion confirmed by organic petrography (Kalkreuth and Macauley, 1984), whereas the laminated marlstones of the Albert Mines zone are the least matured.

The same zonal maturation relationship is also evident in the Dover area where laminated marlstones are the least mature, as defined from Production Indices, although the Dover area is comparatively somewhat less mature than Albert Mines. Samples from the Boudreau area have the lowest PI values of the three areas and may either be less mature than Dover (not indicated by other parameters) or the limited sample coverage may be biased toward lamalginite kerogen content. The latter is suspected.

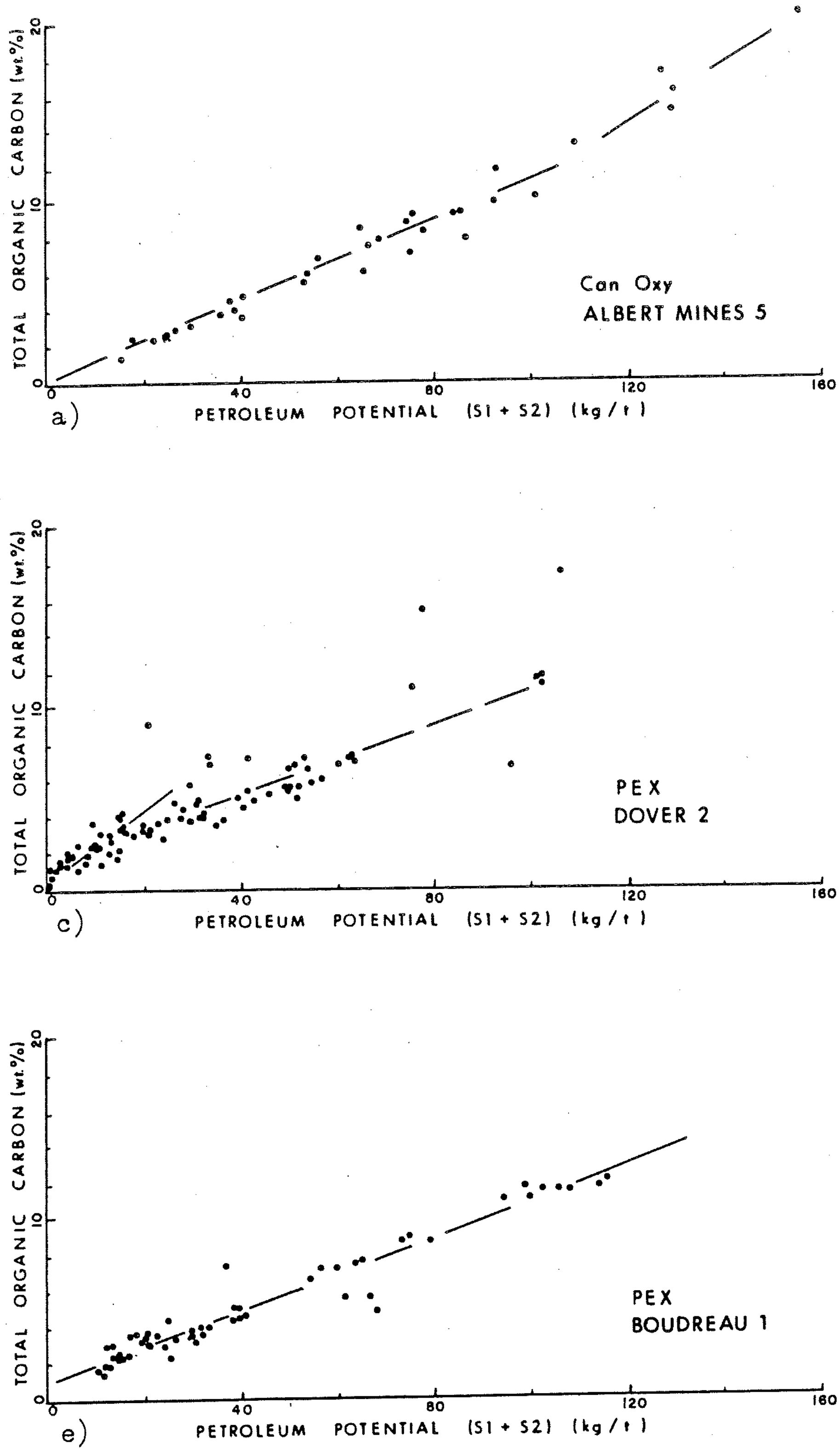


Figure 10: Total organic carbon versus petroleum potential.

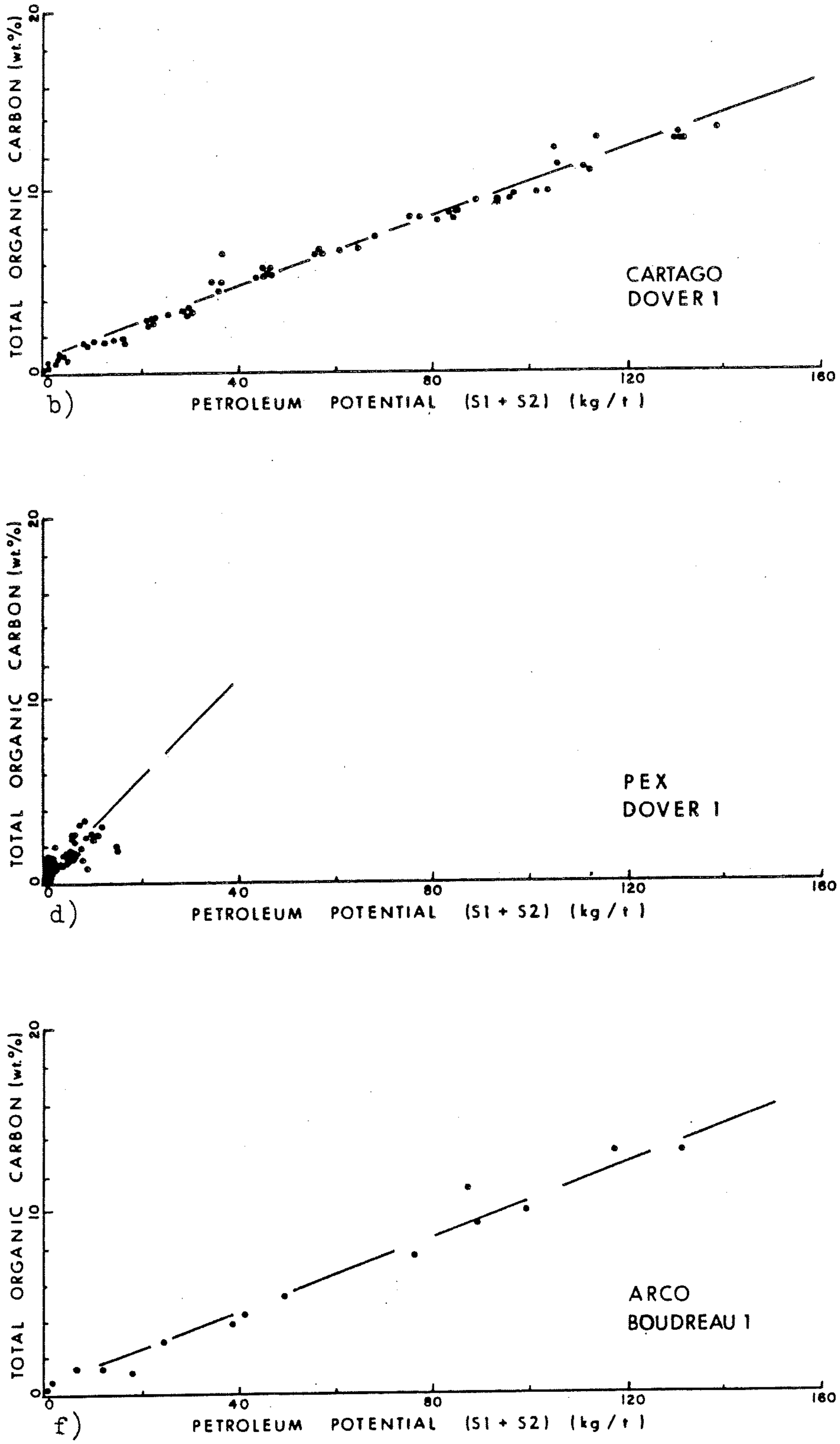


Figure 10: Total organic carbon versus petroleum potential (continued).

CLASSIFICATION AND MATURATION

Kerogen of the better quality oil shale beds, in which TOC exceeds 5%, has been confirmed as Type I lamalginite typical of continental lacustrine deposits by several sources (Macauley and Ball, 1982; Kalkreuth and Macauley, 1984; Altebaeumer, 1985; and Smith, 1985). During initial study of the Albert Formation oil shales, the writers concluded that the kerogen type was uniform throughout the deposits, and that bedding characteristics were related to quantity rather than type of kerogen. A stronger petroliferous odor on breaking core of the dolostone beds was considered to indicate greater maturation in these beds, primarily resulting from their occurrence toward the base of the oil shale section.

The three key lithotypes, laminated marlstone, clay marlstone and dolomite marlstone, were found to be interlaminated, interbedded and intergradational. Smith (1985) confirmed the intergradation of all lithologies with related increasing and/or decreasing kerogen content. In this aspect, one is forced to wonder if both Type I and Type II kerogens exist (Smith, ibid.), or if a mineral-matrix effect has been responsible for an apparent range of thermal maturation, whereby bitumen/kerogen ratios pyrolyze with significantly different Rock-Eval parameters.

Tmax seems to indicate either a wide range of maturation from values above 435°C, or only marginal maturation if the initial maturation temperature of 445-450°C is considered valid for the deposit. Reviewing all parameters, marginal maturity is here interpreted for the Albert Mines laminated marlstones and the better grade dolomite marlstones of the Dover-Boudreau area. The lower quality beds of the Hiram Brook and Downing Creek (including upper shale) facies are in the range of low maturity. The equivalent intervals at the Albert Mines deposit are slightly more mature, ranging from low to moderate thermal maturity. This confirms the relative maturation levels suspected by Macauley and Ball (1982).

EXPLOITATION

Two zones, the Albert Mines Zone and an uppermost Dolomite Marlstone unit immediately below the Clay Marlstone equivalent, are of economic interest in the Dover-Boudreau area. Further intervals in the Lower Shale Unit, as equated to the Albert Mines area Dolomite Marlstones, may be present and significant, but control is currently too sparse to evaluate properly this part of the section. A much greater knowledge of the distribution of the Downing Creek facies, especially as encountered on Boyd Creek (Fig. 1), and of the Round Hill conglomerate facies in the Boudreau area, will be necessary to map this lower part of the oil shale interval.

A limit of Albert Mines Zone occurrence is recognized where removed at the PEX Dover 1 corehole. A northerly limit can be projected paralleling the Memramcook-Albert contact (Fig. 1). Whether the Dolomite Marlstone penetrated at the base of the Cartago Dover 1 location is not present due to facies change or has been removed by erosion at PEX Dover 1 (Fig. 4) is indeterminate, but erosion is the preferred interpretation because of the presence of Dawson Settlement facies at the top of the PEX corehole. Facies changes are rapid, but there is every indication that this particular dolomite marlstone lithology was areally widespread.

There are insufficient control points to attempt any regional economic evaluation. Table II summarizes the pertinent economic factors for the above two zones of interest. Although the dolomite marlstones have much less than excellent petroleum potential, they warrant continued investigation because of their proximity in the section to the Albert Mines Zone and the consequent ability to be cored at minimum expense. These beds may be richer in dolomite content and thus of possible lesser interest for potential co-combustion with high sulfur coal, a process which currently appears to be more successful with calcite than with dolomite.

Corehole	Albert Mines Zone			Dolomite Marlstone		
	Thickness m	TOC Wt%	Yield kg/t	Thickness m	TOC Wt%	Yield kg/t
PEX Dover 1	0	-	-	0	-	-
PEX Dover 2	15.5	13.92	100.9	51	3.48	22.5
Cartago Dover 1	16.0	10.18	97.8	>12.8	5.01	42.2
Arco Dover 1A	25	-	-	30	4.62	53.4
PEX Boudreau 1	15.3	5.38	47.6	20	5.34	42.0
Arco Boudreau 1	26	8.67	80.6	25	11.18	113.6

Table II: *Pertinent Economic Parameters, Dover-Boudreau Area*

From Table II, the Albert Mines Zone is economically more potential at Dover than at Boudreau. The indicated excellent Dolomite Marlstone zone at Arco Boudreau 1 is possibly misleading because of a limited data base.

SUMMARY

The stratigraphy of the Albert Formation in the Dover-Boudreau area is a complex facies relationship, which includes:

Hiram Brook: an uppermost facies of sandstone, siltstone and shale with occasional oil shale bed

Frederick Brook: a medial facies dominated by oil shale beds with associated carbonates, shales and minor siltstones and sandstones

Dawson Settlement: a basal facies similar in character to the Hiram Brook but without oil shale beds

Downing Creek: dominantly shale with lesser sandstone and oil shale beds; developed lateral to and overlying and underlying the Frederick Brook facies

Round Hill: conglomerates lateral to and interbedded with all other Albert Formation facies.

Oil shales of the Frederick Brook facies occur in three dominant lithotypes: high grade laminated marlstones characterized by lamalginite; medium grade dolomite marlstones in part with lamalginite but grading to poorer quality marlstone and dolostone with a matrix bituminite kerogen; low grade clay marlstones with organic shale interbeds. Three zones can be differentiated on the basis of the lithotypes: the Albert Mines Zone which is recognized across the entire area but is lost by erosion to the north of the Dover coreholes; a Clay Marlstone Zone of poor quality oil shale and shale; and Dolomite Marlstone immediately below the Clay Marlstone, of limited development and grading downward and laterally to Downing Creek facies.

Type I lamalginite is the dominant kerogen of the laminate beds which are thermally marginally mature. As kerogen content decreases, the lamalginite decreases at the expense of increasing matrix bituminite (liptodetrinite ?), considered to be Type I kerogen of low thermal maturity. The increased maturation level of the low kerogen intervals may be a mineral matrix effect. Type II kerogen has also been proposed to explain differences in the behavior of high versus low kerogen content.

Rock-Eval parameters react differently to kerogen content above versus below 5%, coincident with the change in dominance of either lamalginite or matrix bituminite. HI, TOC and Tmax exhibit various inter-dependencies and independencies for each of the above kerogen content ranges.

The maturation level is slightly less at Boudreau than in the Dover area. Both areas are less mature than the low to moderate maturation level of the prolific Albert Mines deposit.

The Albert Mines Zone of laminated marlstones is sufficiently thick (15 m) and has the indicated Petroleum Potential (100 kg/t) necessary to be of economic interest. A zone of Dolomite Marlstone, although much less attractive, is worthy of continued investigation during the course of determining the Albert Mines potential.

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Dover #1 corehole are included by permission of Cartago Resources, Vancouver.

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APPENDIX A

ROCK-EVAL ANALYTICAL DATA

ALBERT FORMATION

DOVER-BOUDREAU AREA

New Brunswick

Published data incorporated herein (some apparently erroneous data selectively deleted)

^ Ball, 1986
# Macauley and Ball, 1982
* Smith, 1985
x Wright, 1982

N.B. in depth column, m indicates median value for analyzed interval as reported by the authors

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX DOVER #1										
Downing Creek facies										
98.3	0.93	440	0.23	1.94	0.35	208	37	2.17	.10	2.33
	0.93	438	0.24	2.28	0.53	245	56	2.52	.10	2.70
99.8	0.35	439	0.04	0.42	0.70	119	200	0.46	.09	1.31
	0.37	442	0.02	0.37	0.51	100	137	0.39	.05	1.05
*101.65	0.43	436	0.08	0.42	0.41	98	95	0.50	.16	1.16
x102.09m	0.84	447	0.70	7.57	0.22	901	26	8.27	.09	9.84
102.7	0.96	439	0.49	3.11	0.53	323	55	3.60	.14	3.75
	0.92	437	0.47	3.24	0.39	352	42	3.71	.13	4.03
*102.77	1.51	441	0.65	4.66	0.38	309	25	5.21	.12	3.45
*102.99	1.83	438	1.40	14.34	0.69	784	38	15.74	.08	8.60
104.2	1.50	440	0.56	6.27	0.51	418	34	6.83	.08	4.55
x104.18m	1.72	450	0.66	6.99	0.29	406	17	7.65	.09	4.44
104.6	1.52	440	0.52	6.27	0.45	412	29	6.79	.08	4.46
106.2	1.61	437	0.63	7.26	0.61	450	37	7.89	.08	4.90
	1.62	438	0.61	7.21	0.58	445	35	7.82	.08	4.82
*106.37	2.01	442	1.03	13.82	0.61	688	30	14.85	.06	7.38
*108.00	0.99	433	0.11	0.46	0.38	46	38	0.57	.19	0.57
*108.33	0.63	428	0.39	0.86	0.66	66	137	1.15	.33	1.82
x109.00m	0.62	444	0.29	0.95	0.24	153	39	1.24	.23	2.00
109.8	0.50	435	0.10	0.40	0.45	80	90	0.50	.20	1.00
	0.44	432	0.09	0.15	0.66	34	150	0.24	.38	0.54
*109.53	0.20	468	0.01	0.11	0.16	55	80	0.12	.08	0.60
*109.66	1.10	432	3.18	6.10	0.51	555	46	9.28	.34	8.43
x110.87m	1.28	435	0.31	1.59	0.47	124	37	1.90	.16	1.48
*111.19	1.30	440	0.28	2.02	0.49	155	38	2.30	.12	1.76
111.3	1.05	437	0.18	1.32	0.73	125	69	1.50	.12	1.42
	1.09	436	0.20	1.54	0.47	141	43	1.74	.11	1.59
*111.66	1.65	435	0.91	3.93	0.41	238	25	4.84	.18	2.93
*115.34	2.15	442	0.84	7.73	0.69	360	32	8.57	.09	3.98
*115.75	1.11	445	0.23	2.83	0.60	235	54	3.06	.07	2.75
*118.82	2.53	441	0.82	8.77	0.36	347	14	9.59	.08	3.79
*120.56	0.50	448	0.05	0.36	0.38	72	76	0.41	.12	0.82
x123.95m	1.44	435	0.35	4.51	0.80	313	56	4.86	.08	3.44
124.7	1.15	441	0.25	3.10	0.53	269	46	3.35	.07	2.91
	1.11	441	0.23	3.24	0.34	291	30	3.47	.07	3.12
x125.25m	1.13	445	0.25	2.76	0.46	244	41	3.01	.08	2.66
*125.66	2.53	445	0.70	9.72	0.40	384	16	10.42	.06	4.11
*128.38	1.18	441	0.28	1.87	0.56	56	158	0.47	.13	1.82
128.8	0.63	441	0.13	1.29	0.47	204	74	1.42	.09	2.25
	0.82	438	0.25	2.43	0.42	296	51	2.68	.09	3.26
	0.79	441	0.28	2.43	0.33	307	41	2.71	.10	3.43
	0.64	442	0.12	1.29	0.31	201	48	1.41	.09	2.20
*131.69	0.65	443	0.01	0.13	0.49	26	75	0.14	.07	0.21
144.5	1.15	435	0.33	2.87	0.44	180	25	2.40	.14	2.08
	1.16	439	0.31	2.12	0.29	182	38	2.43	.13	2.11
x147.10m	0.60	432	0.20	1.14	0.57	190	78	1.34	.15	5.15
x154.25m	1.18	439	0.26	1.75	0.56	148	47	2.01	.13	1.70
*158.87	0.82	441	0.17	1.13	0.09	138	11	1.20	.14	1.46
163.4	1.20	438	0.06	0.86	0.44	71	36	0.92	.07	0.76
	1.29	437	0.07	1.04	0.33	80	25	1.11	.06	0.86

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX DOVER #1 (continued)										
x164.55m	0.51	432	0.21	1.15	0.43	126	47	1.36	.15	2.66
x166.05m	1.34	429	0.29	2.44	0.36	182	27	2.83	.11	2.11
*168.98	0.55	440	0.05	0.22	0.26	40	47	0.27	.18	0.49
x171.55m	0.41	401	0.80	0.71	0.15	173	37	0.86	.53	2.09
*171.92	0.23		0.01	0.01	0.01	4	4	0.02	.50	0.08
x173.05m	0.75	412	0.93	1.09	0.21	145	28	1.30	.46	1.73
x174.55	0.95	439	0.15	0.94	0.35	99	37	1.29	.13	1.35
*175.10	1.04	442	0.21	1.01	0.31	47	31	1.22	.17	1.17
x176.05m	1.40	449	0.14	0.87	0.26	62	19	1.13	.14	0.80
*176.29	1.62	442	0.36	1.97	0.49	122	30	2.33	.15	1.43
176.8	1.07	437	0.11	1.02	0.55	95	38	1.13	.10	1.05
	1.14	436	0.13	1.10	0.61	96	73	1.23	.11	1.07
	1.10	449	0.12	1.30	0.42	118	64	1.42	.08	1.29
179.4	0.84	441	0.18	0.97	0.62	115	73	1.15	.16	1.36
	0.81	435	0.18	0.93	0.52	114	64	1.11	.16	1.37
195.6	0.80	440	0.12	0.72	0.72	46	90	0.84	.14	1.05
	0.74	437	0.11	0.70	0.70	94	81	0.81	.14	1.09
214.7	0.47	440	0.05	0.33	0.54	70	114	0.40	.17	0.85
	0.47	440	0.07	0.31	0.47	65	100	0.36	.14	0.76
x222.07m	0.91	442	0.23	1.08	0.29	119	87	1.87	.18	2.05
x223.57m	3.23	438	0.86	7.48	0.56	232	17	8.04	.10	2.48
x225.47m	1.19	434	0.25	2.00	0.95	168	80	2.95	.11	2.47
*228.02	3.21	441	0.76	7.79	0.43	243	13	8.55	.08	2.66
228.5	1.31	441	0.36	3.15	0.68	240	51	3.51	.10	2.96
	1.27	438	0.37	3.39	0.38	266	29	3.76	.10	2.67
*229.87	0.60	441	0.12	0.92	0.49	153	82	1.04	.11	1.73
x231.62m	1.37	442	0.37	2.97	0.51	217	37	3.48	.11	2.54
232.0	0.16		0.02	0.03	0.63	18	393	0.05	.40	0.31
	0.16		0.01	0.00	0.56		349	0.01	1.00	
x233.12m	2.07	443	0.60	5.22	0.39	252	19	5.61	.10	2.71
x235.56m	0.72	444	0.01	0.50	0.49	69	68	0.99	.02	1.37
247.6	0.89	440	0.22	2.21	0.45	248	50	2.43	.09	2.73
	0.86	439	0.23	2.27	0.39	263	45	2.50	.09	2.90
251.5	0.79	436	0.22	1.76	0.50	222	63	1.98	.11	2.50
	0.78	435	0.24	1.81	0.47	232	60	2.05	.12	2.62
253.3	0.57	437	0.15	0.92	0.41	161	71	1.07	.14	1.87
	0.57	438	0.15	0.90	0.40	157	70	1.05	.14	1.84
*253.70	1.66	437	0.78	5.84	0.38	352	23	6.62	.11	3.98
x253.75m	2.23	438	0.01	5.95	0.41	267	18	6.36	.15	2.85
*254.85	1.84	440	0.59	4.12	0.39	224	21	4.71	.12	2.55
x255.25m	2.07	429	1.32	9.65	0.53	466	26	10.18	.12	4.91
*256.88	2.00	440	0.38	2.11	0.39	106	20	2.49	.15	1.24
x261.35m	2.95	425	1.07	11.00	0.45	373	15	11.45	.09	3.88
x262.95m	2.30	432	0.52	5.68	0.76	247	33	6.44	.08	2.80
264.0	1.46	437	0.60	4.65	0.33	318	22	5.25	.11	3.59
	1.52	438	0.59	4.48	0.32	294	21	5.07	.12	3.33
*266.51	2.00	441	1.10	5.65	0.29	283	15	6.75	.16	3.37
*275.17	2.12	439	0.62	5.05	0.30	237	14	5.67	.10	2.67

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX DOVER #2										
Frederick Brook upper zone										
x 49.25m	1.41	430	0.62	7.24	0.48	513	34	7.86	.08	5.57
x 50.75m	1.22	433	0.12	0.53	0.44	43	36	0.56	.19	0.45
x 52.47m	1.87	439	0.38	3.97	0.06	212	3	4.35	.09	2.32
x 59.32m	2.25	453	1.03	12.45	0,08	553	4	13.48	.08	5.99
x 61.07m	5.13	455	4.59	45.08	0.16	879	3	49.67	.09	9.68
* 72.43	3.46	440	3.33	16.26	1.00	470	29	19.59	.16	5.66
* 75.79	2.05	430	2.91	8.02	0.54	391	26	10.93	.26	5.33
82.7	4.35	440	6.29	33.80	0.55	777	12	40.09	.15	9.21
	4.41	443	6.11	35.95	0.74	815	16	42.06	.16	9.53
85.3	5.60	439	5.55	48.65	0.72	868	12	54.20	.10	9.67
	5.33	448	5.20	46.67	0.78	875	14	51.87	.10	9.73
x 85.65m	4.68	454	5.02	40.53	0.21	866	4	45.55	.11	9.73
x 87.15m	1.51	451	0.29	2.61	0.13	171	9	2.90	.10	1.92
x 88.65m	3.77	451	4.15	20.98	0.13	557	3	25.13	.17	6.66
x 90.15m	3.05	455	3.57	12.49	0.17	410	6	16.06	.22	5.26
90.5	3.87	443	4.28	25.97	0.98	671	25	30.25	.14	7.81
	3.95	443	4.28	26.83	1.00	679	25	31.11	.14	7.87
x 91.86m	6.70	468	4.57	47.80	0.17	713	3	52.37	.09	7.81
x 97.32m	6.40	456	5.72	28.54	0.18	446	3	34.26	.17	5.35
x 98.80m	5.79	469	3.47	26.08	0.18	450	3	29.55	.12	5.10
x100.12m	3.01	455	3.05	17.39	0.21	578	7	20.44	.18	6.79
x101.44m	8.09	450	9.57		0.60		7			
x102.94m	6.33	451	8.69		0.93		15			
x104.42m	3.21	444	3.30	25.62	0.97	779	30	28.92	.12	9.00
x106.92m	1.84	435	1.51	11.63	0.68	632	37	13.14	.12	7.14
114.9	3.89	441	3.16	25.15	1.14	646	30	28.31	.11	7.27
	3.89	441	3.11	25.28	1.20	649	30	28.39	.11	7.29
Albert Mines zone										
116.8	6.91	446	5.46	56.26	0.98	814	14	61.72	.09	8.93
	6.95	445	5.41	56.84	1.05	817	15	62.25	.09	8.95
*117.41	14.91	448	5.82	72.03	1.39	483	9	77.85	.07	5.22
*119.74	17.15	454	3.81	100.70	1.85	587	11	104.51	.03	6.09
124.7	10.82	444	5.57	96.90	1.21	895	11	102.47	.05	9.69
	10.95	444	5.43	98.84	1.25	902	11	104.27	.05	9.52
*125.53	27.40	453	7.91	209.73	1.51	765	6	217.64	.03	7.94
*127.32	31.25	446	18.32	133.15	1.26	426	4	151.47	.12	4.84
130.1	6.42	442	3.99	59.62	0.85	928	13	63.61	.06	9.80
	6.43	447	3.92	59.09	0.96	918	14	63.01	.06	9.79
Clay Marlstone zone										
132.0	2.69	441	2.07	19.98	1.00	742	37	22.05	.09	8.18
	2.71	442	2.04	20.13	1.13	742	41	22.17	.09	8.19
138.5	1.84	437	2.21	11.94	0.78	648	42	14.15	.16	7.69
	1.89	438	2.19	12.81	0.97	677	51	15.00	.15	7.93
Lower zone										
x159.53m	2.14	437	1.84	4.31	0.59	201	28	6.15	.30	2.87
x162.00m	2.46	432	3.35	7.87	0.52	320	21	11.22	.30	4.56
x163.50m	2.66	429	6.27	10.06	0.28	378	11	16.33	.38	6.13
164.0	1.17	432	2.82	6.86	0.66	586	56	9.68	.29	8.27
	1.20	434	2.73	6.86	0.76	568	63	9.55	.29	7.95
x165.00m	3.06	440	2.69	14.32	0.38	468	12	17.01	.16	5.55

Depth m	TOC Wt%	Tmax °C	S1	S2 mg/g	S3	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX DOVER #2 (continued)										
165.5	5.02	443	3.33	44.77	0.83	891	16	48.10	.07	9.58
	4.89	446	3.31	43.12	0.95	881	19	48.63	.07	9.49
x166.48m	4.18	446	2.87	24.13	0.58	592	14	27.00	.10	6.45
*170.01	0.75	435	0.30	1.33	1.23	177	164	1.63	.18	2.17
*182.14	6.76	445	1.85	31.28	0.75	463	11	33.13	.05	4.90
183.5	6.22	438	3.98	47.12	0.87	754	13	51.10	.08	8.21
	6.05	443	3.70	45.66	0.89	757	14	49.36	.07	8.15
187.0	0.93	425	1.35	3.56	1.07	382	115	4.91	.27	5.27
	0.90	427	1.27	3.37	1.18	374	131	4.64	.27	5.15
*193.02	2.09	434	2.61	9.42	0.43	451	21	12.03	.21	5.75
*206.50	6.59	442	2.56	36.77	1.10	558	17	39.33	.06	5.96
x231.49m	8.63	434	3.43	18.12	0.69	212	8	21.55	.16	2.49
239.0	3.24	442	3.93	20.20	1.07	623	33	24.13	.16	7.44
	3.36	443	3.76	20.07	1.21	597	36	23.83	.16	7.09
240.0	4.10	439	3.58	28.16	1.03	686	24	31.24	.11	7.74
	4.32	442	3.51	28.01	1.13	648	26	31.52	.11	7.29
x241.37m	6.07	434	8.50	86.37	0.58		10	94.87	.10	
242.3	1.91	441	3.54	11.08	0.65	588	34	14.62	.24	7.65
	1.95	441	3.64	11.42	0.86	588	44	15.06	.24	7.77
245.0	1.75	441	1.13	8.79	1.05	502	60	9.92	.11	5.73
	1.76	443	1.21	8.88	1.06	504	60	10.09	.12	5.66
*249.32	6.89	444	3.56	38.05	1.00	552	15	41.61	.08	6.03
x251.47m	3.41	443	3.61	21.4	0.2	628	6	25.0	.15	7.33
x255.67m	3.88	437	2.64	29.8	0.3	768	8	32.5	.09	8.37
x259.70m	6,08	440	4.91	48.3	0.3	794	5	53.2	.09	8.75
x266.41m	5.22	432	9.34	79.32	0.81		11		.11	
x300.25m	1.81	439	1.35	10.6	0.3	586	17	8.64	.11	
x303.25m	5.96	440	3.08	53.1	0.4	891	5	56.2	.06	6.62
*303.66	2.76	445	1.49	16.04	1.19	581	43	17.53	.08	6.35
*305.07	3.54	446	2.01	34.24	0.63	618	11	36.25	.05	10.24
x306.25m	4.61	442	2.28	36.8	0.5	798	7	39.1	.06	8.48
*307.78	10.04	455	3.06	71.75	0.56	715	6	74.81	.04	7.45
x309.25m	4.62	425	3.43	47.7	0.4	1033	9	51.5	.09	11.14
*309.81	4.12	444	1.80	23.99	0.78	582	19	25.79	.06	6.25
x310.75m	3.28	422	3.09	32.4	0.5	988	15	35.5	.09	10.82
x312.36m	1.17	421	1.05	3.7	0.6	316	51	4.8	.22	4.10
x313.79m	0.92	422	0.42	1.7	0.6	185	65	2.1	.20	2.28
x315.32m	0.49	419	0.33	0.5	0.6	102	102	0.8	.40	1.63
x316.85m	0.63	413	0.17	0.3	0.4	48	64	0.5	.36	0.79
x318.79m	0.66	411	0.25	0.3	0.4	46	61	0.6	.46	0.90
x319.87m	1.09	412	2.98	4.0	0.3	367	28	7.0	.43	0.64
x321.44m	2.38	419	2.03	11.4	0.4	479	17	13.4	.15	5.63
x322.97m	1.82	442	1.34	9.8	0.4	539	22	12.1	.12	6.64
x324.45m	1.63	447	0.92	3.5	0.4	215	25	4.4	.21	1.28
PEX BOUDREAU #1										
Frederick Brook Upper Shale (Downing Creek)										
61.2	1.98	443	1.02	11.73	0.65	592	32	12.75	.08	6.43
Albert Mines Zone										
x 62.93m	5.10	430	5.82	62.8	0.5		10	68.6	.09	
63.3	3.59	447	2.37	25.21	0.96	702	32	27.58	.09	7.68

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX BOUDREAU #1 (continued)										
x 64.50m	5.90	449	4.98	61.9	0.5		9	66.9	.07	11.33
64.8	11.38	442	6.34	102.08	1.09	897	9	108.42	.06	9.52
	11.80	451	4.04	111.11	3.33	941	29	115.15	.04	9.75
65.3	1.98	441	2.43	12.05	0.86	608	43	14.48	.17	7.31
	1.93	445	2.34	11.83	0.78	612	40	14.17	.17	7.34
x 65.99m	2.27	431	3.67	23.5	0.5		22	27.2	.14	
x 67.45m	5.85	424	6.12	59.6	0.6	1018	10	61.7	.09	10.54
x 68.95m	4.62	452	3.06	36.5	0.1	862	2	39.6	.08	9.38
69.0	11.34	448	6.19	92.36	1.19	814	10	98.58	.06	8.69
	10.93	448	3.88	92.57	4.36	892	37	101.45	.04	9.28
x 70.45m	1.77	420	1.52	10.6	0.4	594	23	12.1	.13	6.83
x 71.95m	3.52	435	2.81	18.8	0.4	534	11	21.6	.13	6.13
x 73.45m	5.29	440	2.92	28.4	0.6	537	11	31.3	.09	5.91
73.5	4.07	443	2.32	30.55	1.93	750	47	32.87	.07	8.02
	3.89	446	2.59	27.26	0.77	700	19	29.85	.09	7.67
	4.23	444	2.66	30.20	0.86	713	20	32.86	.08	7.76
x 74.95m	3.85	439	2.58	21.4	0.6	556	16	24.0	.11	6.23
76.1	2.44	438	2.78	15.64	0.92	640	37	18.42	.15	7.54
		445	2.22	13.35	1.78			15.57	.14	
x 76.66m	7.33	443	2.97	35.8	0.6	488	8	38.8	.08	5.29
79.9	8.29	448	3.99	71.16	0.82	858	9	75.15	.05	9.06
	7.24	450	2.42	63.33	2.72	874	37	65.75	.04	9.08
Clay Marlstone zone										
82.5	2.33	447	1.90	14.06	0.82	603	35	15.96	.12	6.84
	2.11	448	1.74	11.96	0.70	566	33	13.70	.13	6.49
x 82.51m	2.87	438	1.63	11.1	0.8	395	29	12.7	.13	4.51
Lower zone										
113.8		446	4.13	101.34	3.26			105.47	.04	
	11.76	445	6.74	95.16	1.20	809	10	101.90	.07	8.66
	11.95	447	4.57	110.85	2.00	927	16	115.42	.04	9.65
126.0	3.97	440	1.93	19.24	1.28	484	32	21.17	.09	5.33
	3.71	446	1.68	17.35	1.02	467	27	19.03	.09	5.12
128.0	2.11	444	2.88	12.08	0.98	572	46	14.96	.19	7.09
	2.14	442	3.07	12.79	0.69	597	32	15.86	.19	7.41
x128.13m	3.85	439	1.84	16.5	0.6	429	16	18.1	.10	4.70
x129.96m	3.55	421	2.33	24.8	0.5	699	14	27.2	.09	7.68
131.0	3.27	444	1.58	19.96	1.09	610	33	21.54	.07	6.58
	3.31	444	1.67	21.01	0.75	634	22	22.68	.07	6.85
x131.46m	3.12	424	2.12	23.6	0.5	756	16	25.9	.08	8.30
x132.94m	3.22	448	1.08	11.5	0.5	357	16	13.6	.09	4.22
x134.39m	3.99	427	3.16	32.1	0.7	805	18	33.2	.09	8.37
135.00	4.84	448	2.68	36.15	1.26	746	26	38.83	.07	8.02
	4.95	450	2.65	38.76	0.95	783	19	41.41	.06	8.36
x135.84m	6.20	447	3.99	51.3	0.3	827	5	54.5	.07	8.79
x137.40m	4.22	452	3.09	22.4	0.5	507	11	25.5	.12	5.76
138.6	7.06	449	3.13	53.94	1.39	764	19	57.07	.05	8.08
	7.20	452	3.00	58.20	1.14	808	15	61.20	.05	8.50
141.6	10.44	452	6.37	88.33	1.35	846	12	94.70	.07	9.07
	11.59	455	5.74	101.95	1.89	879	16	107.69	.05	9.29
144.6	7.60	450	4.97	61.48	1.48	808	19	66.45	.07	8.74
	8.49	455	4.93	74.56	1.40	878	16	79.49	.06	9.36

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
PEX BOUDREAU 1 (continued)										
146.0	8.56	449	4.99	71.74	1.45	838	17	76.73	.07	8.96
		453	4.64	81.49	1.55			86.13	.05	
153.8	4.97	449	2.91	36.90	1.45	742	29	39.81	.07	8.01
	4.94	451	2.79	37.10	0.94	751	19	39.89	.07	8.07
CARTAGO DOVER #1										
Hiram Brook										
7.01	0.53	436	0.06	1.30	0.51	245	96	1.36	.04	2.56
	0.53	433	0.07	1.40	0.60	264	113	1.47	.05	2.77
9.44	0.04		0.00	0.01	0.27			0.01		
	0.04		0.01	0.00	0.17			0.01	1.00	
11.27	2.44	438	5.64	17.88	0.56	732	22	23.52	.24	9.63
	2.37	432	6.01	16.88	0.57	712	24	22.89	.26	9.65
12.95	0.06	441	0.02	0.03	0.32			0.40	.40	0.83
	0.06	435	0.03	0.03	0.17			0.50	.50	1.00
17.06	0.53	440	0.75	2.98	0.37	562	69	3.73	.20	7.03
		439	0.76	2.92	0.26			3.68	.21	
Frederick Brook upper zone										
35.96	3.64	439	5.14	25.70	0.90	706	24	30.84	.17	8.47
	3.68	438	5.30	25.62	0.74	696	20	30.92	.17	8.40
^ 38.86m	5.69	442	3.78	43.31		761		47.09	.08	8.27
^ 39.62m	4.42	442	3.85	33.44		757		37.29	.10	8.43
40.08	0.59	432	0.49	2.54	0.36	430	61	3.03	.16	5.13
	0.55	431	0.49	2.58	0.53	469	96	3.07	.16	5.58
40.61	0.34	431	0.13	0.66	0.17	194	50	0.78	.15	2.29
	0.29	431	0.12	0.69	0.47	237	162	0.82	.16	2.82
42.29	1.77	444	0.44	5.50	0.44	310	24	5.94	.07	3.35
	4.17	437	6.28	31.15	0.83	747	19	37.43	.17	8.97
^ 44.95m	1.62	429	5.37	8.35		515		13.72	.39	8.46
45.11	1.68	436	7.49	9.80	1.45	583	86	17.29	.43	10.29
	1.71	436	7.53	9.50	1.38	555	86	17.03	.44	9.95
49.07	0.80	445	0.99	3.03	0.19	378	23	4.02	.25	5.02
	0.79	448	0.96	3.57	0.40	451	50	4.53	.21	5.73
52.12	9.14	450	4.94	90.90	1.27	994	13	95.84	.05	10.48
	9.91	453	5.19	98.68	1.28	995	12	103.87	.05	10.48
^ 59.05m	8.27	446	6.18	76.81		929		82.99	.07	10.03
59.43	3.35	449	2.21	29.17	1.78	870	53	31.38	.07	9.36
	3.25	448	2.14	28.22	1.64	868	50	30.36	.07	9.34
^ 59.78m	2.77	440	4.39	18.39		664		22.78	.19	8.22
63.55	0.90	447	0.33	4.03	1.18	447	117	4.36	.08	4.84
	0.86	446	0.30	3.88	1.01	451	131	4.18	.07	4.86
Albert Mines zone										
^ 69.79m	8.50	446	4.12	80.77		950		84.99	.05	9.98
70.56	12.76	452	6.52	123.79	1.89	970	14	130.31	.05	10.21
	12.96	453	6.45	123.60	1.77	953	13	130.05	.05	10.03
^ 70.71m	8.17	446	4.46	75.47		924		79.93	.06	9.78
^ 71.62m	8.76	445	5.52	78.83		900		84.35	.07	9.62
^ 72.54m	6.66	445	3.76	57.16		858		60.92	.06	9.14
^ 73.45m	13.55	447	6.33	131.60		971		137.93	.05	10.17
^ 74.37m	8.27	447	4.11	73.72		891		77.83	.05	9.41
^ 75.28m	11.22	446	6.25	108.22		965		114.42	.05	9.64

Depth	TOC	Tmax	S1	S2	S3	HI	OI	S1+S2	TR	Ratio
m	Wt%	°C	mg/g					kg/t		kg/t /%TOC
CARTAGO DOVER #1 (continued)										
^ 76.20m	9.67	446	5.83	91.34		945		97.17	.06	10.04
76.20	12.81	452	6.44	122.79	2.02	958	15	129.23	.05	10.08
	12.39	453	6.10	119.18	1.93	961	15	125.28	.05	10.11
^ 77.11m	6.87	445	3.83	62.13		904		65.96	.06	9.60
^ 78.02m	9.96	446	4.78	90.37		907		95.15	.05	9.55
^ 78.94m	11.35	447	4.87	110.00		969		114.87	.04	10.12
79.32	12.21	453	4.21	100.20	2.40	820	19	104.41	.04	8.55
	12.89	452	4.58	108.15	2.16	839	16	112.23	.04	8.80
^ 79.85m	9.43	448	4.37	89.07		945		93.44	.05	9.90
^ 80.77m	11.23	445	6.21	106.28		946		112.49	.06	10.01
^ 81.68m	9.94	447	5.80	94.62		952		100.42	.06	10.10
^ 82.60m	6.19	442	5.27	50.68		819		55.95	.09	9.03
^ 83.51m	6.20	444	3.98	52.97		854		56.95	.07	9.18
Clay Marlstone zone										
^ 84.42m	2.93	443	4.34	19.07		651		23.41	.19	7.98
84.58	2.48	447	4.48	16.29	1.83	656	73	20.74	.21	8.36
	2.52	445	4.56	16.87	1.81	669	71	21.43	.21	8.50
87.17	1.34	447	0.93	7.54	1.09	562	81	8.47	.11	6.32
	1.36	447	0.90	7.53	1.10	553	80	8.43	.11	6.19
Lower zone										
^ 94.94m	8.24	443	4.49	69.73		846		74.22	.06	9.00
95.70	5.43	445	3.69	43.92	1.38	808	25	46.87	.08	8.76
	5.34	445	3.53	43.34	1.39	804	25	47.61	.08	8.69
^ 95.74m	6.12	443	3.81	44.59		729		38.40	.08	6.27
^ 97.07m	3.49	442	2.82	25.08		719		27.90	.10	7.99
^ 97.99m	4.53	440	4.02	31.18		688		35.20	.11	7.77
^ 98.90m	3.39	442	4.09	19.43		573		23.52	.17	6.93
^ 99.82m	5.50	442	4.95	41.47		754		46.34	.11	8.42
^100.73m	7.40	442	6.51	61.84		836		68.35	.10	9.23
^101.65m	6.43	441	6.27	50.45		785		56.72	.11	8.82
^102.56m	5.17	442	5.38	39.15		757		44.53	.12	8.61
103.32	5.56	443	4.67	46.79	1.63	841	29	51.46	.09	9.25
	5.49	444	4.56	46.14	1.61	840	29	50.70	.09	9.23
^103.47m	3.15	440	3.10	23.03		731		26.13	.12	8.29
^104.39m	2.91	441	2.16	20.20		694		22.36	.10	7.68
^105.30m	2.00	441	1.46	13.49		675		14.95	.10	7.47
ATLANTICRICHFIELD BOUDREAU #1										
Hiram Brook										
#132.9	0.44	428	0.77	0.28	0.18	41	64	0.95	.81	2.15
#147.8	1.35	426	5.47	13.02	0.16	964	12	18.49	.30	13.69
Frederick Brook upper zone										
#191.5	1.46	439	0.54	6.43	0.35	440	24	6.97	.08	4.77
#261.5	2.96	444	0.93	23.12	0.31	781	11	24.05	.04	8.12
#289.0	0.61	435	0.28	1.29	0.36	212	59	1.57	.18	2.57
#302.8	5.24	441	2.25	46.49	0.39	887	7	48.74	.05	9.30
#315.2	4.03	444	2.44	38.20	0.28	948	7	40.64	.06	10.08
Albert Mines zone										
#371.9	8.97	445	4.33	83.51	0.34	931	4	87.84	.05	9.79
#375.8	3.95	442	3.61	34.42	0.37	871	9	38.03	.09	9.62
#379.2	13.04	450	4.73	111.28	0.38	853	3	116.01	.04	8.89

Depth m	TOC Wt%	Tmax °C	S1 mg/g	S2 mg/g	S3 mg/g	HI	OI	S1+S2 kg/t	TR	Ratio kg/t /%TOC
ATLANTICRICHFIELD BOUDREAU 1 (continued)										
Lower zone										
#433.1	9.42	444	4.35	93.95	0.47	997	5	98.30	.04	10.43
#443.2	12.94	447	4.31	124.60	0.42	963	3	128.91	.03	9.96
#476.5	1.41	438	1.80	9.70	0.21	688	15	11.50	.16	8.15
#481.3	7.23	442	3.52	71.23	0.41	985	6	74.75	.05	10.33
#551.4	10.97	448	4.84	81.14	0.55	740	5	85.98	.06	7.83
ATLANTIC RICHFIELD DOVER #1A										
Frederick Brook upper zone										
# 34.1	6.89	443	3.43	68.34	0.38	992	6	71.77	.05	10.41
# 40.9	3.09	436	1.46	15.76	0.60	510	19	17.22	.08	5.57
Lower zone										
#191.1	4.71	443	2.61	42.48	0.36	909	8	45.44	.06	9.64
#198.7	2.00	440	1.23	11.94	0.40	597	20	13.17	.09	6.58
#202.7	9.16	445	6.03	85.80	0.42	933	5	91.53	.07	9.99