Cretaceous Oil Shale Potential

of the

Prairie Provinces, Canada

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by

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TABLE OF CONTENTS

FIGURES

CRETACEOUS OIL SHALE POTENTIAL OF THE PRAIRIE PROVINCES, CANADA

ABSTRACT

Four hundred forty-seven samples, obtained from cores and potash shafts penetrating the oil shale beds of the Upper Cretaceous Boyne and Favel Formations (1st and 2nd White Speckled shale zones respectively) at 29 locations across the Prairie Provinces, were analyzed for total organic carbon (TOC) and subjected to Rock-Eval pyrolysis. Of these, 382 samples from Saskatchewan and Manitoba were analyzed mineralogically by X-ray diffraction.

Both oil shale zones are thermally immature, and have not been petroleum source rocks across the Prairie Provinces, except for an area of low maturity in western Alberta. Samples over most of the area contain up to 4% organic carbon which is derived from Type III humic kerogen· above that, total organic carbon values ranging to 10% are provided by the addition of Type II sapropelic kerogen. Hydrocarbon yields on pyrolysis increase proportionately from 3.0 kg/t/1% TOC in the humic areas to 6.5 kg/t/1% TOC were sapropel predominates. Two areas of optimum hydrocarbon yield can be mapped, in the Pasquia Hills of eastern Saskatchewan, and, from limited data, along the outcrop edge of both units in western Saskatchewan. In both areas, average TOC values may range up to 10% with average hydrocarbon recoveries anticipated in excess of 40 to 50 kg/t (10 to 12.5 US g/t) from both the Boyne and Favel Formations.

Lithologically almost identical, both oil shale zones contain inversely related proportions of a quartz-clay-feldspar mode and a second mode dominated by calcite. Kerogen content increases to a maximum where the modes are essentially equal, or where calcite dominates slightly, but then decreases as pure limestone is approached. Numerous secondary minerals are present, including zeolites, non-hydrous silicates, sulfates, iron minerals and oxides, and include many mineral forms differentiated only by varying degrees of hydration. Oxidation minerals are common and are enigmatic to the preservation of the kerogen: whether such minerals were formed by alteration during deposition and lithification or are weathering products is not readily evident.

INTRODUCTION

Tyrrell (1892) first reported the presence of possible oil shales along the Manitoba Escarpment as he described the petroliferous odor emanating from the rocks when struck by a hammer. McInnes (1913) listed the first analysis of 7 Imperial gallons/ton (35 litres/tonne) with 22.5 lbs ammonium sulphate/ton (11.2 kilograms/tonne): the first significant geological comment came from S.C. Ells (1923), who stated "Oil shales of New Brunswick and Nova Scotia were deposited under different conditions from those of Manitoba and Saskatchewan." Although not stated specifically, Ells did understand that the depositional environment consisted of a marine "muddy sea" in the Manitoba-Saskatchewan area in contrast to the lacustrine environment of the New Brunswick oil shales. Ells also noted that the "oil" content of the Manitoba beds did not prevent weathering in contrast to the resistive nature of the Maritime shales.

Two oil shale zones are present along the Manitoba Escarpment, an upper Boyne Formation and a lower Favel Formation, separated by a non-oil shale, the Morden Formation. Both zones are characteristically similar, composed of white speckled shale with foraminiferal debris and coccoliths comprising the white specks. The units are traceable across the three Prairie Provinces, except for a central area of Saskatchewan where the medial Morden Formation is poorly defined to absent, resulting in an apparent single speckled shale unit (Fig. 1). Within the subsurface of Alberta, these zones are still informally defined as the First and Second White Speckled shale zones (Fig. 2).

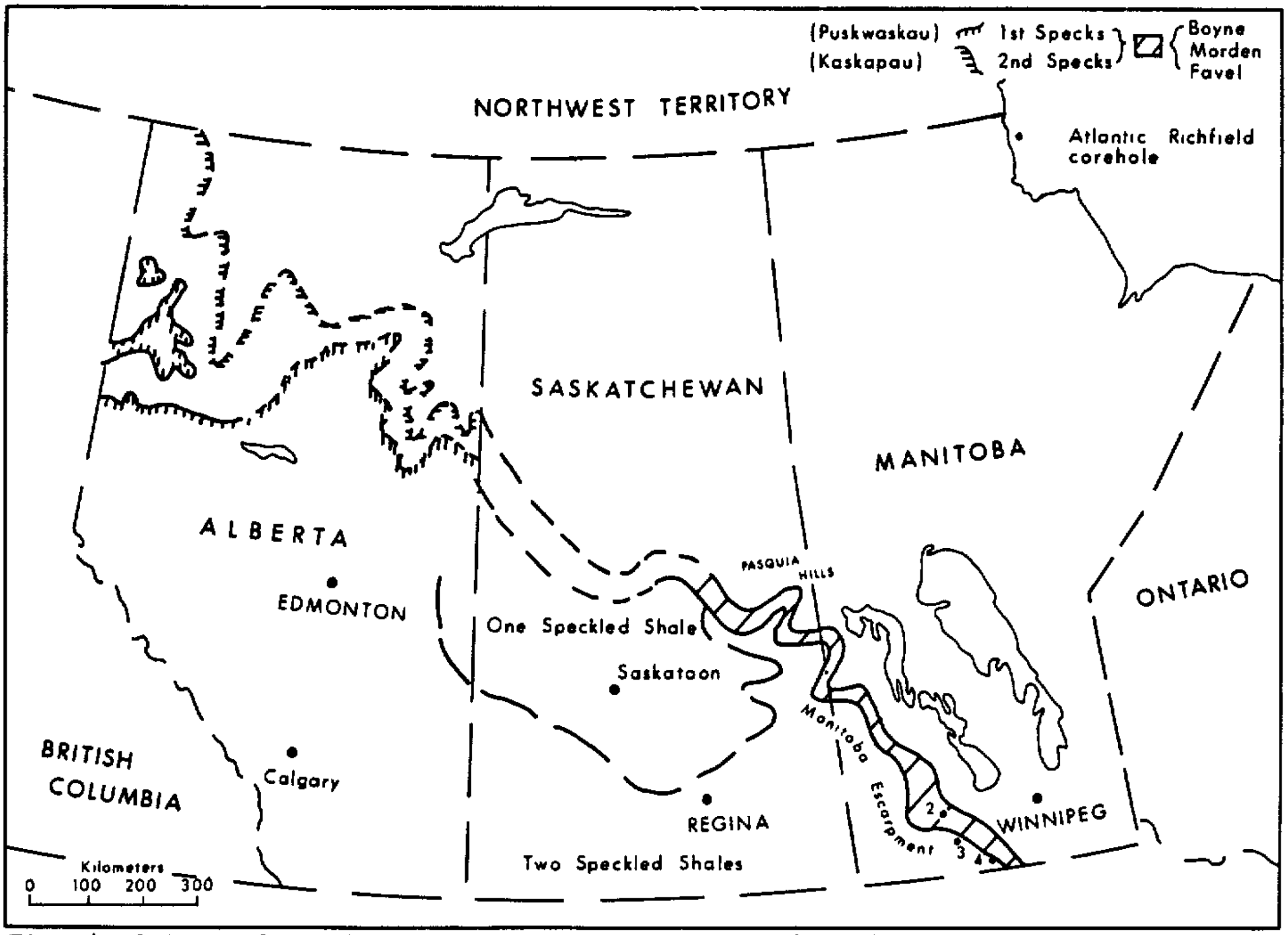


Fig. 1: Outcrop distribution of Upper Cretaceous oil shale zones, Prairie Provinces

Williams & Burk, 1964: NW Alberta	Williams & Burk, 1964: E Alta - W Sask			This Paper	Manitoba - Dept of Energy & Mines		McNeil & Caldwell, 1981 - Proposed	
PUSKWASKAU	BELLY RIVER			RIDING MOUNTAIN	RIDING MOUNTAIN		Pierre Shale	
PUSKWASKAU	MILK RIVER			PEMBINA	VERMILION RIVER	Pembina	Pierre Shale	
BAD HEART	Medicine Hat Ss	PARK	1st Specks	BOYNE	VERMILION RIVER	Boyne	NIOBRARA	
MUSKIKI		PARK	1st Specks	BOYNE	VERMILION RIVER	Boyne	NIOBRARA	
CARDIUM		PARK		MORDEN	VERMILION RIVER	Morden	MORDEN	
KASKAPAU		PARK		MORDEN	VERMILION RIVER	Morden	MORDEN	
KASKAPAU		LEA	2nd Specks	FAVEL	FAVEL	Assiniboine	FAVEL	Assiniboine
KASKAPAU		LEA	2nd Specks	FAVEL	FAVEL	Keld	FAVEL	Keld
DUNVEGAN				ASHVILLE	ASHVILLE		Belle Fourche Shale	

Fig. 2: Pertinent Upper Cretaceous stratigraphy
(FORMATIONS IN CAPITALS: Members and informal units in lower case)

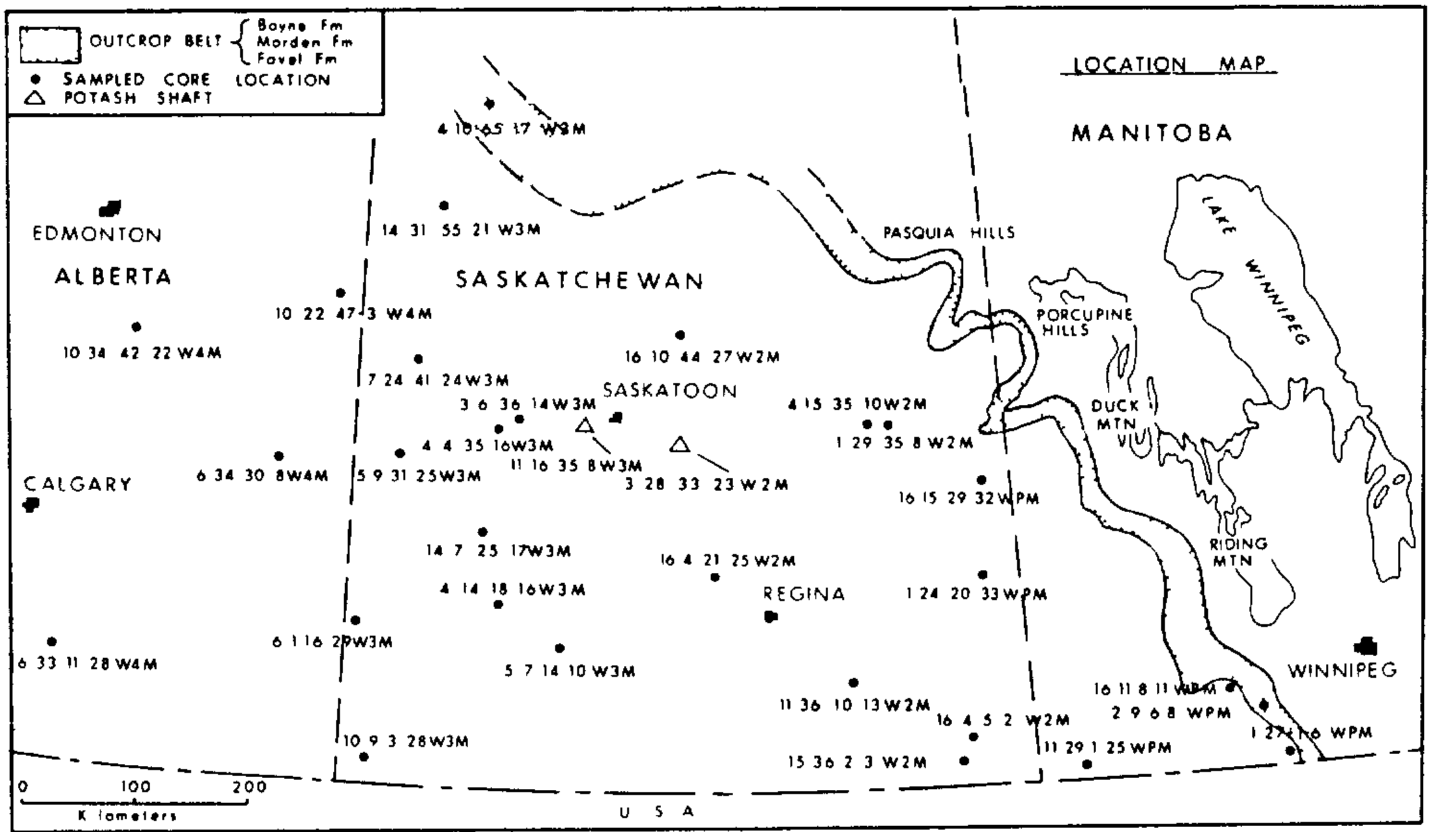


Fig. 3: Core and potash shaft sample localities

This report is concerned primarily with the organic geochemistry of the oil shales, as determined analytically, and based on samples collected from 4 coreholes in Manitoba, 20 subsurface cores and 2 potash shafts in Saskatchewan, and 4 subsurface cores in Alberta (Fig. 3). Data are also available from 40 Sun Oil coreholes (1966) located along the Manitoba Escarpment: these cores were subsequently lost or destroyed, but the analytical data can be compared with those of this study.

The analytical techniques utilized total organic carbon analysis and Rock-Eval pyrolysis for determination of organic content, and X-ray diffraction for mineral content. Fischer Assay data are available for the lost Sun Oil cores. Two brief reports by Hutton (1981 a,b) provide the background for the organic petrology comments.

Acknowledgements

Funding for the project was supplied entirely by the Department of Energy, Mines and Resources, Canada, through the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, Alberta.

The four Manitoba coreholes were sampled by L. Kovac, University of Manitoba, as part of his M.Sc. thesis (1984): these samples are common to his thesis and to this report. The co-operative efforts of the staff at the Saskatchewan Department of Energy and Mines were much appreciated, especially the provision of a computer list of cored intervals and assistance in core sampling. A computer search for pertinent Alberta cores, not available through Provincal Government agencies, was provided by Chevron Canada Resources Ltd. Sampling of the Alberta cores was carried out under the standard procedures and costs of the Alberta Energy Resources Conservation Board. The potash shaft intervals were analyzed from samples acquired by L.L. Price of the Geological Survey of Canada.

All analyses were conducted at the Institute of Sedimentary Petroleum Geology, Calgary, under the direction of Dr. L.R. Snowdon. Dr. A.E. Foscolos specifically supervised the X-ray diffraction analyses. M. Ferguson, R. Fanjoy and J. Wong provided the technical assistance.

L.R. Snowdon, F.D. Ball and D.F. Paterson read the manuscript and contributed significantly through their comments.

STRATIGRAPHY

Development of terminology for the Manitoba Escarpment, and subsequently for the subsurface of Manitoba and Saskatchewan, has been relatively straightforward, although several complications have arisen. Early oilfield terminology has been retained in the Alberta subsurface where the interval of the "White Specks" zones and adjacent lithologies are still not properly defined (Fig. 2).

Ells (1923) first used the term "Boyne" to refer to the white speckled shale zone which was faunally equated to the Niobrara Formation of United States sections at the south. Because of this stratigraphic equivalence, McNeil and Caldwell (1981) suggested use of Niobrara in preference to Boyne. Because Boyne has common past useage in Canadian publications, is almost universally used on correlation charts of Manitoba and eastern Saskatchewan, and has a geographic connotaton within a unit correlatable over a vast geographic area, the term "Boyne" is used preferentially herein, as was recommended previously by Macauley (1981).

Beds of the Favel Formation, in surface sections, can be subdivided into the Assiniboine and Keld Members (Wickendon, 1945) within which significant carbonate bands are recognized (Marco calcarenite and Laurier limestone; McNeil and Caldwell, 1981). Because organic carbon is present throughout the Favel Formation, no attempt has been made to define and map these sub-units over the large area, 625,000 km^2, (Fig. 3) of this regional geochemical evaluation.

In his unpublished thesis, Park (1965) illustrated the westerly thinning and eventual loss of the intervening Morden shale in Saskatchewan between the Boyne and Favel Formations: ultimately an area exists where only one shale unit is readily apparent (Fig.1). Within this area, thin beds of possible Morden strata can often be picked on geophysical logs and confirmed by geochemical analyses.

One of the problems for evaluating oil shale potential at the outcrop, either by surface samples or cores, lies in being able to differentiate between two lithologically similar sequences. The Boyne-Morden speckled shale-non-organic shale sequence is macroscopically identical to the Favel-Ashville sequence; however, the Boyne and Favel speckled shales can be differentiated by micropaleontology (Park, 1965; North and Caldwell, 1975; McNeil and Caldwell, 1981).

In the subsurface of Alberta and western Saskatchewan, the informal terms "First White Specks" and "Second White Specks," in descending (ie. drilling) order, have been used by the petroleum industry (Fig. 2): no need has been felt for formal nomenclature. Neither zone is readily defineable as an outcrop unit in northwestern Alberta where the upper zone (Boyne) is represented by part of the Puskwaskau Formation, and the lower (Favel), separated from the upper by a considerable section of sediments, equates to the lower part of the Kaskapau Formation (Figs. 1,2). No attempt has been made to investigate these zones in either the surface or subsurface north of Edmonton in Alberta.

Nomenclatural complexities occur above and below these two oil shale units at the east (McNeil and Caldwell, 1981) and units are incompletely defined at the west (Williams and Burke, 1964). On some of the illustrative logs, only Boyne and Favel, or White Specks zones, may be shown as these are the names pertinent to the study. Maps and discussion herein use Boyne and Favel only as these terms are appropriate and applicable to the equivalent "White Specks" units of Alberta and western Saskatchewan.

On the illustrative geochemical logs and interpretive data plots, data from overlying strata are generally shown as Pembina, the medial shale beds as Morden, and the underlying shale as Ashville. These are used for simplification in illustration of data from the non-organic zones bounding the potential oil shales, and do not imply their stratigraphic validity across the area.

LITHOLOGY

Both oil shale zones consist of identical lithologies, dark to medium grey to brownish-grey shale, with a variable degree of white speckling by coccolith and possible foraminiferal debris. The shales are finely laminated to fissile, but fissility decreases as carbonate content increases toward pure limestone beds. The calcareous shales grade to zones of lime marl where fossil debris becomes the dominant rock component. The lime marl beds, generally low in organic carbon content, may be measurable in metres and represent semi-regional units.

Bands of non-calcareous shale, barren of fossil debris, are present within the speckled intervals. Also, beds of non-calcareous shale, normally included within the overlying and underlying stratigraphic units, may contain significant organic carbon and are here included in the Boyne and Favel intervals; consequently, the markers defining these units may herein differ slightly from the general definitions based on calcareous distribution and/or geophysical log characteristics.

THICKNESS

The Boyne Formation ranges in thickness from 30 to 45m along the Manitoba Escarpment outcrop area, thins to approximately 15 to 18m in central Saskatchewan where deposited in continuity with the Favel beds, and thickens again westerly to a range of 35 to 60m in the Alberta subsurface.

Favel beds attain a general maximum thickness of 30 to 40m along the Escarpment, thin westerly to only a few metres in central Saskatchewan, and again thicken to 35 to 60m, similar to the Boyne, in the subsurface area of Alberta.

The intervening shale (Morden Formation) thins westerly from a maximum of 45m along the easterly outcrop belt to essentially zero in areas of central Saskatchewan and from there thickens westerly to greater than 100m of unnamed interval in the Alberta subsurface and 300m in the Alberta Foothills belt. Park (1965) illustrated these changes in regional correlation sections across Saskatchewan.

MINERALOGY

X-ray diffraction analyses are available for all Manitoba and Saskatchewan samples: the samples of the four Alberta cores were not analyzed. These XRD results are listed in Appendix A. Diagrammatic plots for the distribution of the main mineral components and of hydrocarbon potential ($S_1 + S_2$) from Rock-eval data were prepared for the four Manitoba coreholes, all of which were sampled in detail, and for five Saskatchewan locations where sampling penetrates both oil shale intervals. Some of these diagrams are presented within the text: the remainder are included at the end of Appendix A.

One portion of powdered sample was pelletized on a cellulose substrate and X-rayed with Co$K\alpha$ radiation, iron filter, settings of 45Kv - 20ma, scanning speed of $1^{\circ}2\theta$/min/2cm, time constant 2 and range 2° to $40^{\circ}2\theta$. A second portion of the sample was sieved between 60 and 250 mesh sieves to obtain fine and very fine fractions. These fractions were pelletized on a cellulose substrate and X-rayed with Cukα radiation, Ni filter, setting of 40Kv - 20ma, scanning speed of $1^{\circ}2\Theta$/min/2cm, time constant of 2 and range 2° to $40^{\circ}2\Theta$.

Mineral percentage compositions obtained from diffraction peak heights are semi-quantitative only, varying with the degree of crystallinity, crystal size, and the amorphous material present, consequently, these data represent approximate relative concentrations and are not absolute values.

From the XRD results, several mineral suites are recognized, two of which represent the primary components, and the remainder constitute secondary, or trace, minerals.

Primary Mineral Modes

A quartz-clay-feldspar grouping defines the majority of the rock as a shale, in the sense of a fine grained laminated clay sediment. Quartz is the dominant member: clays are significant and present as mixed layer clays, illite and chlorite-kaolinite in order of decreasing percentages: feldspars are recorded only in minor amounts and are often absent (Figs. 4a, 4b).

Calcite, with only minor dolomite, is the second major mineral mode: the occurrence of calcite is in an apparent proportional inverse ratio to the quartz-clay-feldspar constituents (Figs. 4a, 4b). Dolomite is present only as a trace to a few percent, reaching to 20% in rare occurrences only. Where the dolomite concentration is high, the organic carbon content is minimal. In effect, most of the oil shale beds are calcareous shale grading to argillaceous limestone; however, non-calcareous shales may be organic, especially at the top of the Boyne (Fig. 4a). Kovac (1984), in a surface study, also notes significant kerogen content in some non-calcareous beds.

This inter-relationship of quartz-clay-feldspar and calcite may be economically significant. Figures 5a and 5b plot the hydrocarbon potential ($S_1 + S_2$) against the recorded percentage of calcite. The wide-spread distribution of points indicates that no direct correlation, on a single value basis, can be made for hydrocarbon potential and mineral content; however, an averaged value does indicate maximum yields at approximately 40% calcite in the Boyne Formation and 60% calcite in the Favel Formation based on XRD values. As calcite content increases, approaching pure limestone, the hydrocarbon potential decreases markedly

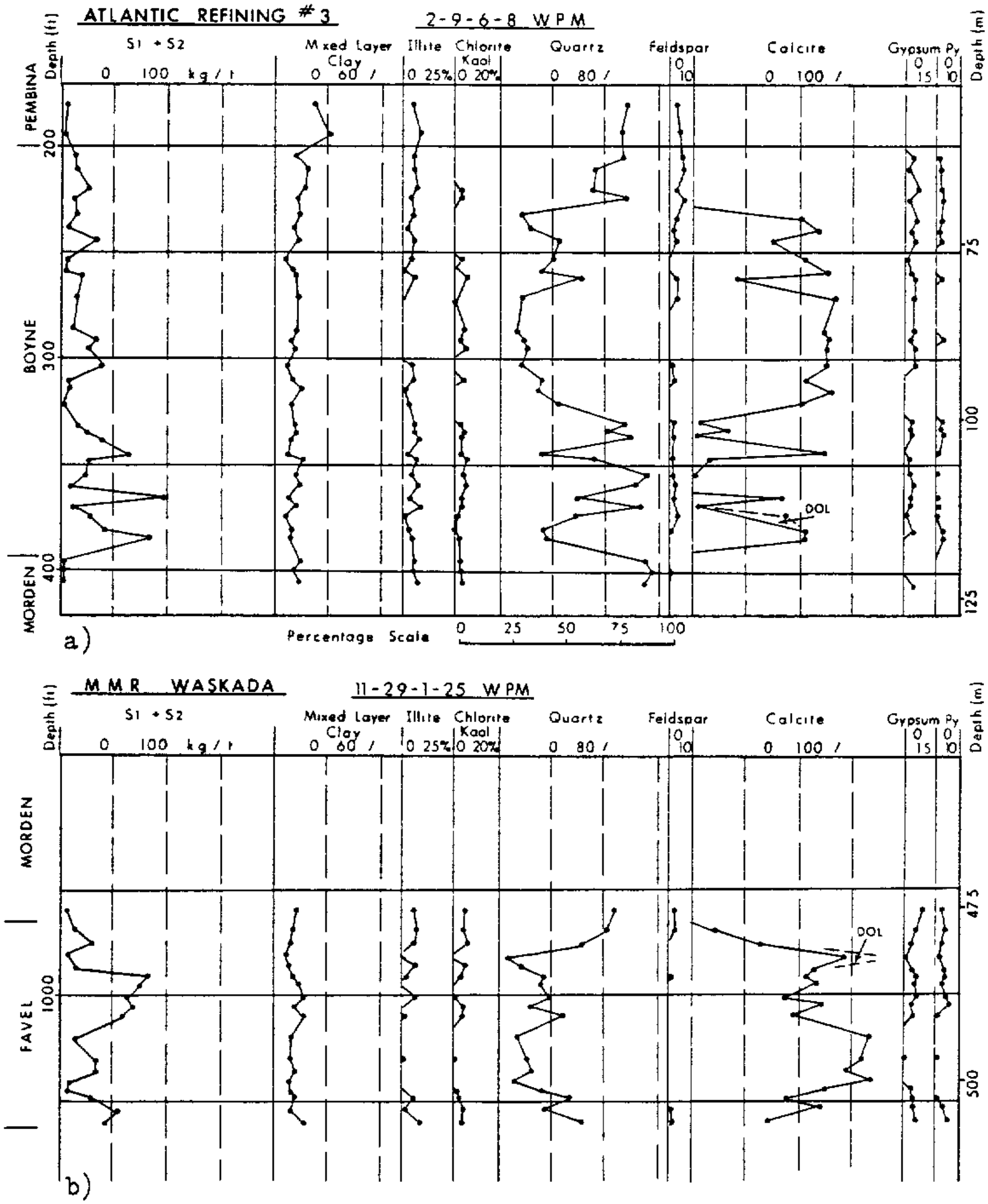


Fig. 4: Typical distribution plots of primary mineral components, a) Boyne Formation, b) Favel Formation

(Fig. 4b). The number of points plotted along the zero calcite line indicate the presence of a considerable amount of kerogen-bearing non-calcareous shale in the section, especially in the Boyne Formation (Fig. 5a).

Within the major clastic mineral mode, the ratio of quartz to clay ranges from approximately 3.1 in the shale to calcareous shales to 1.1 in the argillaceous limestone beds. Although mixed layer clays decrease as calcite increases, they are always present, whereas both illite and

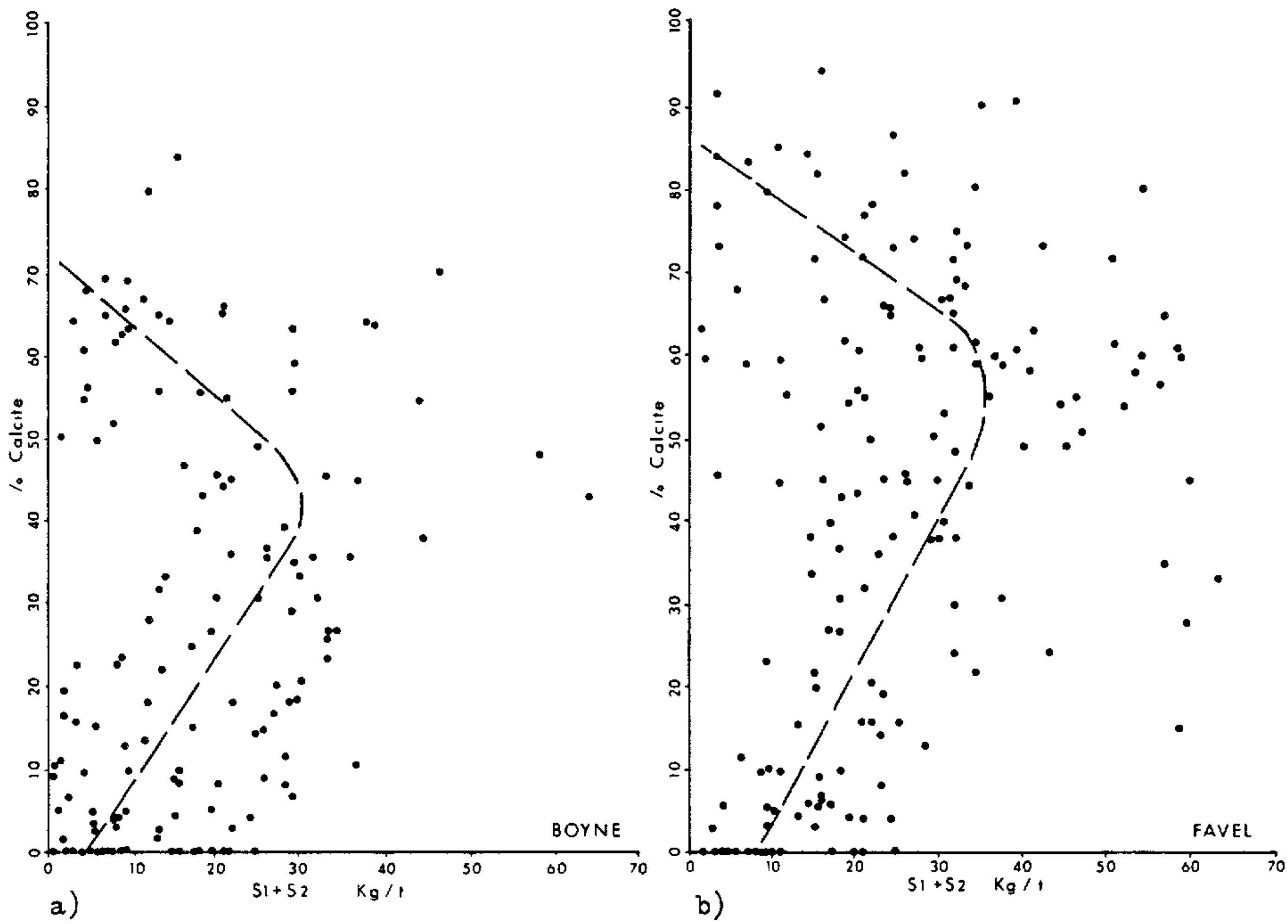


Fig. 5: Approximated calcite values from XRD plotted against hydrocarbon yield; a) Boyne Formation; b) Favel Formation

chlorite-kaolinite may be absent in these circumstances.

Pyrite, in small amounts, is almost ubiquitous, but does decrease, and is often absent in the most calcareous beds.

Secondary Mineral Modes

The secondary minerals can be arranged in seven distinct groups, with some of the minerals, especially those with significant Fe content, being reportable in two of the groups.

1) Zeolites: Numerous occurrences of specifically undetermined zeolites, hydrous silicates of Ca, Mg, Al, K, Na, and Fe are present in small amounts throughout the two oil shale zones, the intervening Morden and equivalent shale beds, and also in the uppermost of the underlying Ashville and equivalent shales (Appendix A). Specifically identified zeolites include clinoptilolite ($(CaKNa_2)O.Al_2O_3.10SiO_2.5H_2O$), analcime ($Na_2O.Al_2O_3.4SiO_2.2H_2O$), loughlinite ($Na_2Mg_3Si_6O_{16}.8H_2O$), heulandite ($(CaNa_2)O.Al_2O_3.9SiO_2.6H_2O$) and laumontite ($(CaNa_2)Al_2Si_4O_{12}.4H_2O$), and

also palygorskite ($(MgAl)_5.(SiAl)_8.O_2(OH)_2.8H_2O$). Many of the basic elements are common, especially Ca, Na, Si and Al, but occur in variable quantities and the degree of hydration also varies within the zeolite sequence. Because of the minimum feldspar content, the zeolites may represent the in situ destruction of the feldspars during sedimentation and lithification. Occasional large quantities of clinoptilolite (up to 20%) may result from the earliest breakdown of the feldspar. Fe is absent from the zeolites.

2): Non-hydrous silicates: In contrast to the zeolites, some non-hydrous silicates are present, including amphibole ($CaMg(Fe\ Mn)\ Si_4O_{11}$), biotite ($H_2K(Mg\ Fe)_3\ Al(SiO_4)_3$) and hydrobiotite, chlorite ($(HMg)Si_2O_9.(HMg)Al_2SiO_9$), and diopside ($CaMg(SiO_3)_2$). These may be in part detrital minerals or may be the altered products of detrital feldspar and mafic minerals.

3). Phosphates: Phosphate minerals are uncommon, but represent a sequence from complex (Millisite, $2CaO.Na_2O.6Al_2O_3.4P_2O_5.17H_2O$, and apatite, $(Ca(F,Cl))Ca_4(PO_4)_3$) to simpler (Strengite, $FePO_4.2H_2O$) structures, containing the same basic metallic elements as encountered in the zeolites, but including Fe, and with 2 of the 3 forms hydrated.

4). Sulfates: Nine sulfates are present, also with a wide range of elemental composition, and include jarosite ($K_2Fe_6(OH)_{12}(SO4)_4$), natrojarosite ($Na_2Fe_6(OH)_{12}(SO_4)_4$), alunite ($K_2Al_6(OH)_{12}(SO_4)_4$), bassanite ($CaSO_4$), gypsum ($CaSO_4.2H_2O$), baryte ($BaSO_4$), epsomite ($MgSO_4.7H_2O$), rozenite ($FeSO_4.4H_2O$)) and melanterite ($FeSO_4.7H_2O$). Analogous to the zeolites, Na,K,Ca,Mg and Al are the basic elements but with the addition of Fe. Also notable is the presence of minerals with identical compositions except for differing degrees of hydration.

Gypsum is the most prominent sulfate and appears to be distributed generally within the same zones in which pyrite is present. Free sulfur crystals were noted visually in association with gypsum crystals. The pyrite is a probable source of the sulfur required to form these sulfate minerals.

5). Carbonates: In addition to calcite and dolomite, ankerite ($CaCO_3.(Mg,Fe,Mn)CO_3$), dawsonite ($Na_3Al(CO_3)3.2AL(OH)_3$) and nesquehonite ($MgCO_3.3H_2O$) indicate possible alteration of some of the zeolite minerals to carbonates.

6). Fe Minerals: Pyrite is the most common iron mineral, but iron is also present with sulfur as greigite (Fe_3S_4), is present in a series of sulfates including jarosite ($K_2Fe_6(OH)_{12}(SO_4)_4$), natrojarosite ($Na_2Fe_6(OH)_{12}(SO_4)_4$), melanterite ($FeSO_4.7H_2O$) and rozenite ($FeSO_4.4H_2O$); as the oxides hematite (Fe_2O_3), goethite ($Fe_2O_3.H_2O$, including lepidocrocite), maghemite (Fe_2O_3) and magnetite ($FeO.Fe_2O_3$), and as the phosphate strengite ($FePO_4.2H_2O$). Many of the oxide and sulfate forms vary from each other only by degree of hydration, although differences in Fe valency are also significant.

Many of the iron minerals probably result by oxidation of the pyrite to produce the oxides and sulfates. The presence of K and Na in jarosite and natrojarosite could relate to alteration of zeolites and may indicate high salinities. Trace indications of halite (NaCl) and sylvite (KCl) could relate to such conditions. Independent of the mineral distribution, the Fe content of these strata is considerably higher than would be anticipated from general knowledge of Cretaceous shales.

7). Oxides: Several of the oxides were reported among the iron minerals (goethite, lepidocrocite, hematite, maghemite and magnetite). Tridymite (SiO_2) and cristobalite (SiO_2) are probable detrital minerals whereas gibbsite ($Al_2O_3.3H_2O$), bayerite ($Al_2O_3.3H_2O$) and diaspore ($Al_2O_3.H_2O$) may be oxidation products of the feldspars and zeolites. Anatase (TiO_2) occurs only once within the analyzed samples and may have little significance.

Interpretations

When were the seconday mineral suites, especially the sulfates and the oxides, generated? Are these the result of sedimentation and lithification processes or has exposure to the atmosphere resulted in oxidation of the core material? Most of the cores are in excess of 15 years old, but the Atlantic Refining cores in southwest Manitoba have been encased in plastic during that time. The organic material and the pyrite represent a reducing environment: how has the organic material been preserved during formation of the oxides and sulfates?

Zeolites, of inferior hardness (3.5-5.5), are unlikely detrital minerals, and are inferred to have formed in situ by chemical alteration, primarily hydration, of detrital feldspars. The zeolites contain Na,K,Ca,Mg,Al,Si, all of which are represented in virtually all the other secondary sequences. Zeolites are destroyed by acid: the generation of sulfuric or sulfurous acid on oxidation of the pyrite, inter-acting on the zeolites, would provide the basis for generation of many of the sulfates and some of the complex carbonates and phosphates. In all of the secondary mineral groups, the continuing breakdown to smaller molecular structures and the continuing introduction of Fe, S and O into the minerals is apparent.

Water of crystallization is common throughout all the secondary groups, in some cases defining several minerals with otherwise identical compositions. These rocks have probably not been subjected to depths of burial much in excess of the present or the heat and pressure would have eliminated much of this water.

Although no conclusion can be reached, the abundance of these secondary minerals, and the common sequential distributions of the cationic elements within them, may be indicative of depositional - lithification processes rather than weathering during the last few years under exposure to the atmosphere.

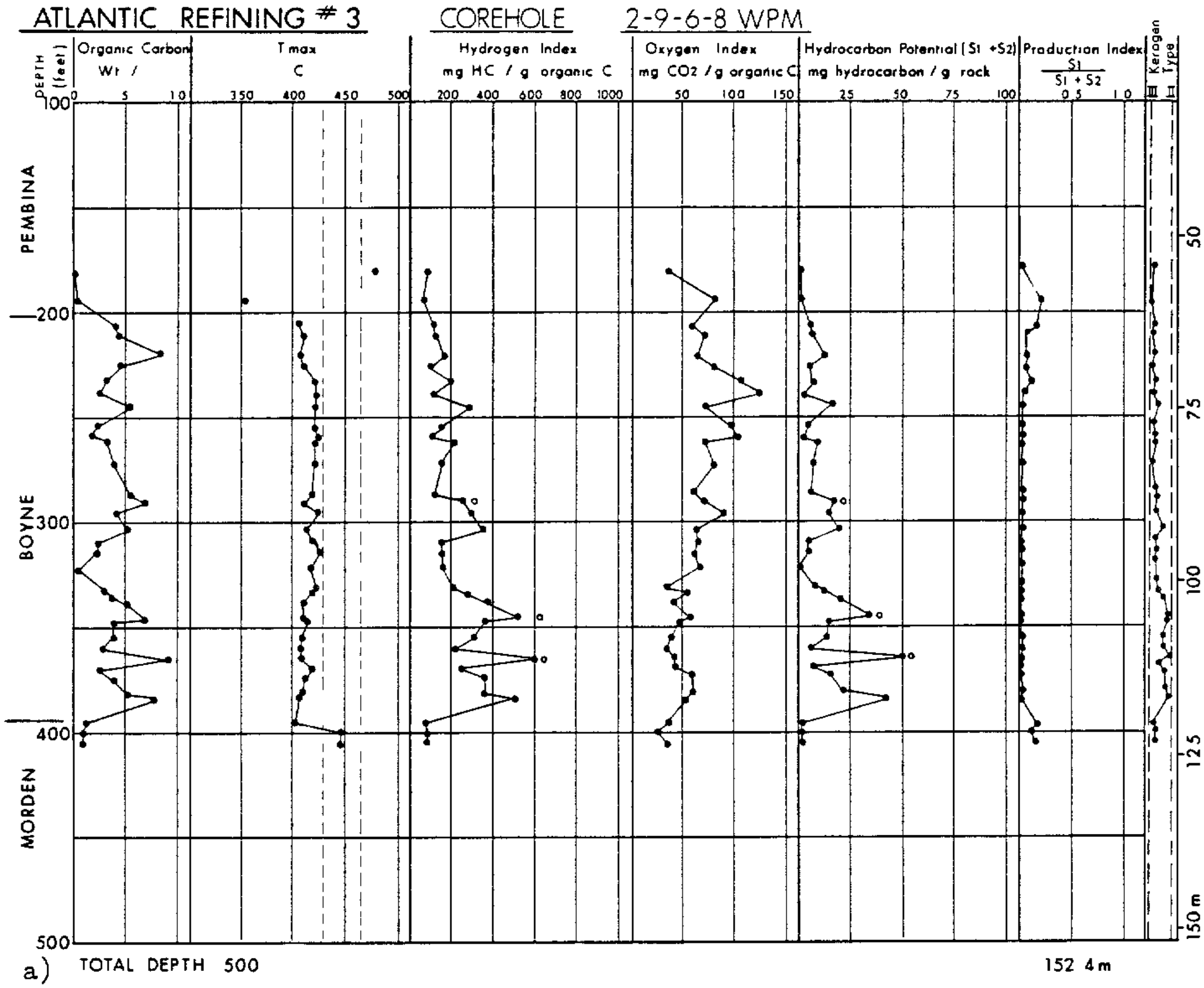
Ells (1923) noted the poorly resistive nature of these beds to weathering in contrast to other oil shales. The presence of many easily altered hydrous minerals can account for the low resistance to weathering. Ells also noted the dissimilarity to the New Brunswick oil shales, and Macauley (1981, p.viii) stated, "These Cretaceous deposits are analogous neither in lithology nor in depositional environment to the generally recognized oil shale types." The complex mineralogy is certainly supportive of that statement.

ORGANIC GEOCHEMISTRY

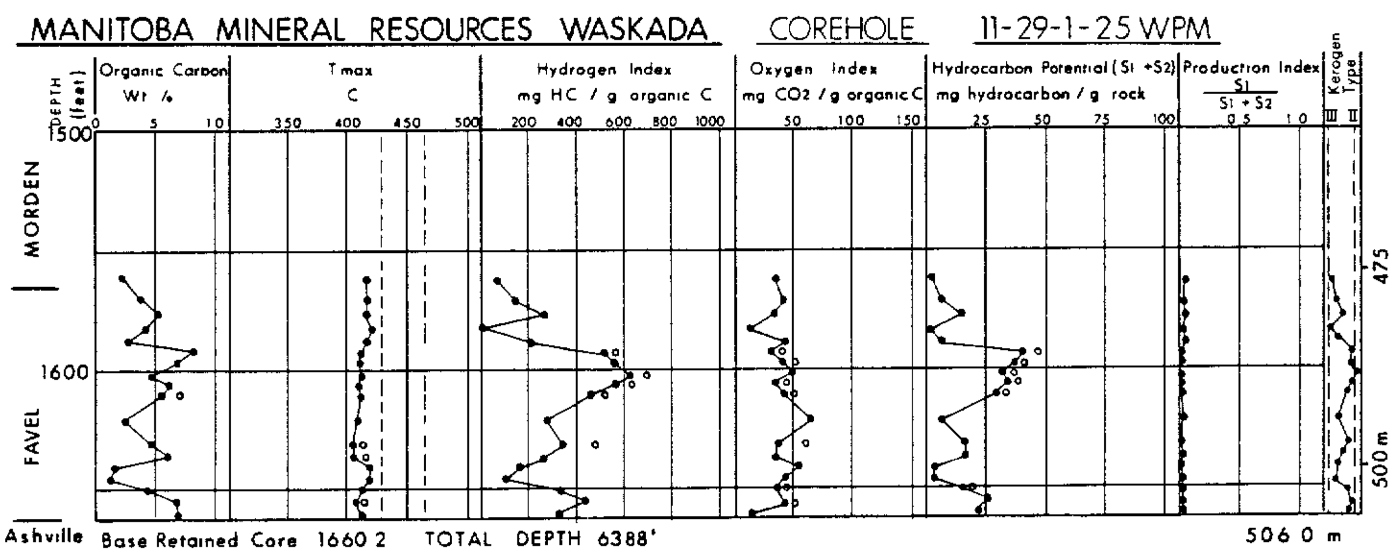
Appendix B lists all data from the analyses of total organic carbon and Rock-Eval pyrolyses. Core log plots were prepared for the 4 Manitoba coreholes and for those locations which sampled both oil shale units, of which 5 are located in Saskatchewan and one in Alberta. Those plots not utilized within the text are included in Appendix B following the numerical data. Plots of hydrogen index versus oxygen index, and of petroleum potential versus total organic carbon, are presented and utilized similar to the log plots of the Rock-Eval data.

Organic Maturation

Tmax values vary in the range 405 to 425° (Figs. 6a, 6b, and Appendix B), all below the oil generation window (435-465°C), indicating organic immaturity. An average Tmax was calculated for each location· results of the Favel analyses were plotted (Fig. 7). A general southwesterly



a)



b)

Fig 6: Typical plots of total organic carbon and Rock-Eval data; a) Boyne Formation, b) Favel Formation

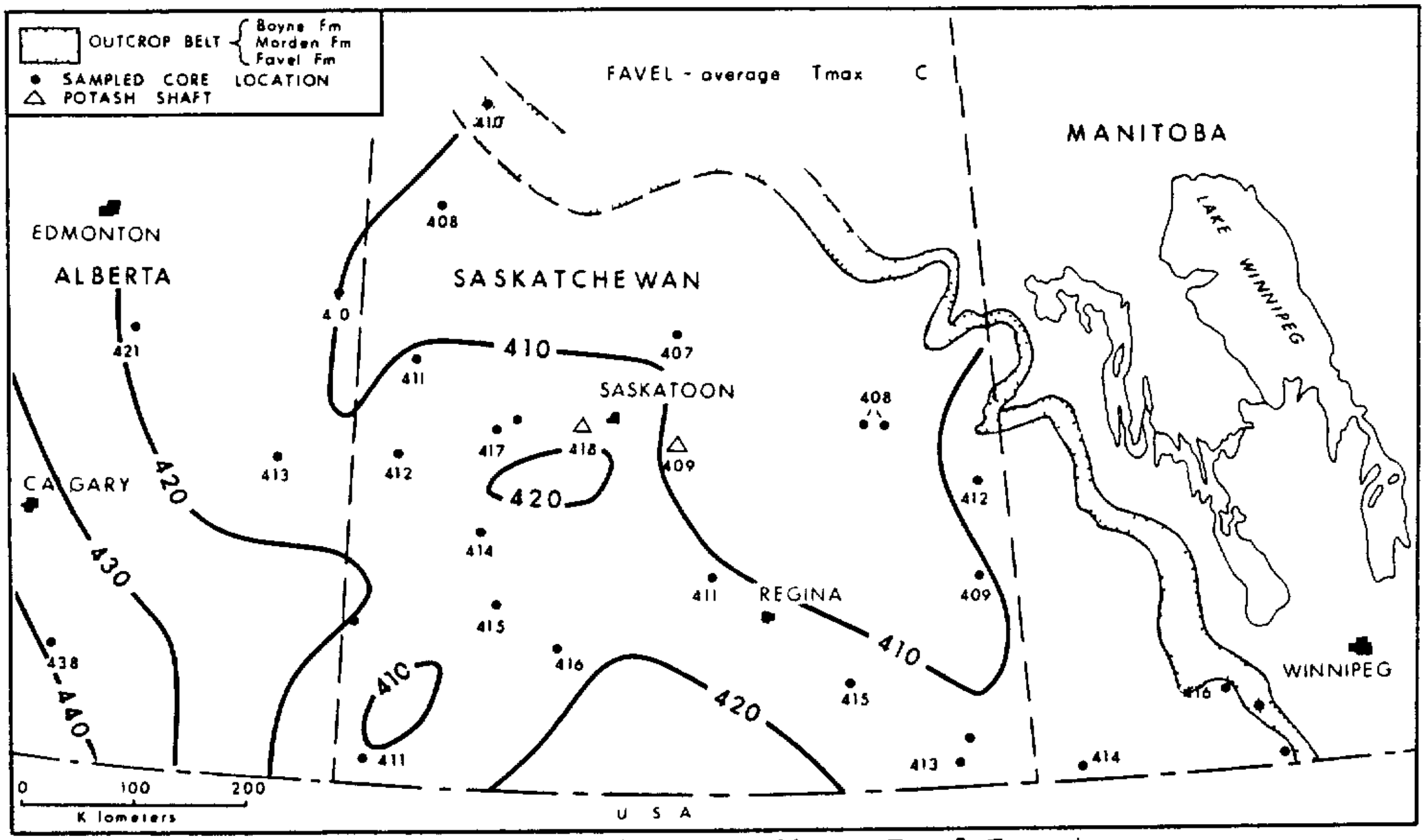


Fig. 7: Regional pattern of average Tmax variations, Favel Formation

increase of average Tmax is mappable, with indications of north-northeasterly cross trends of alternating higher and lower average values, differing by approximately 10°C between high and low. Low maturity (440°C) is encountered at the extreme soutwest in Alberta.

Immaturity is also indicated by the plots of hydrogen against oxygen indices (Figs. 8a, 8b). Although values vary considerably for the hydrogen indices, oxygen is not lost as hydrogen decreases; consequently the distribution of points reflects variable kerogen components rather than maturation changes.

Kerogen Type

An admixture of Type II and Type III kerogens can be interpreted from the hydrogen-oxygen distribution (Figs. 8a, 8b). Although interpretive techniques have been proposed to calculate the relative amounts of each kerogen type, the number of variables present, and the imprecise measurement of oxygen content by the Rock-Eval process, precluded use of these techniques. Herein, the relative position between the Type II and Type III vanKrevelen lines has been assumed to represent approximate relative amounts of each kerogen type. An interpretation of these values is presented with the log plot of Rock-Eval data (Figs. 6a, 6b). As anticipated by this technique,

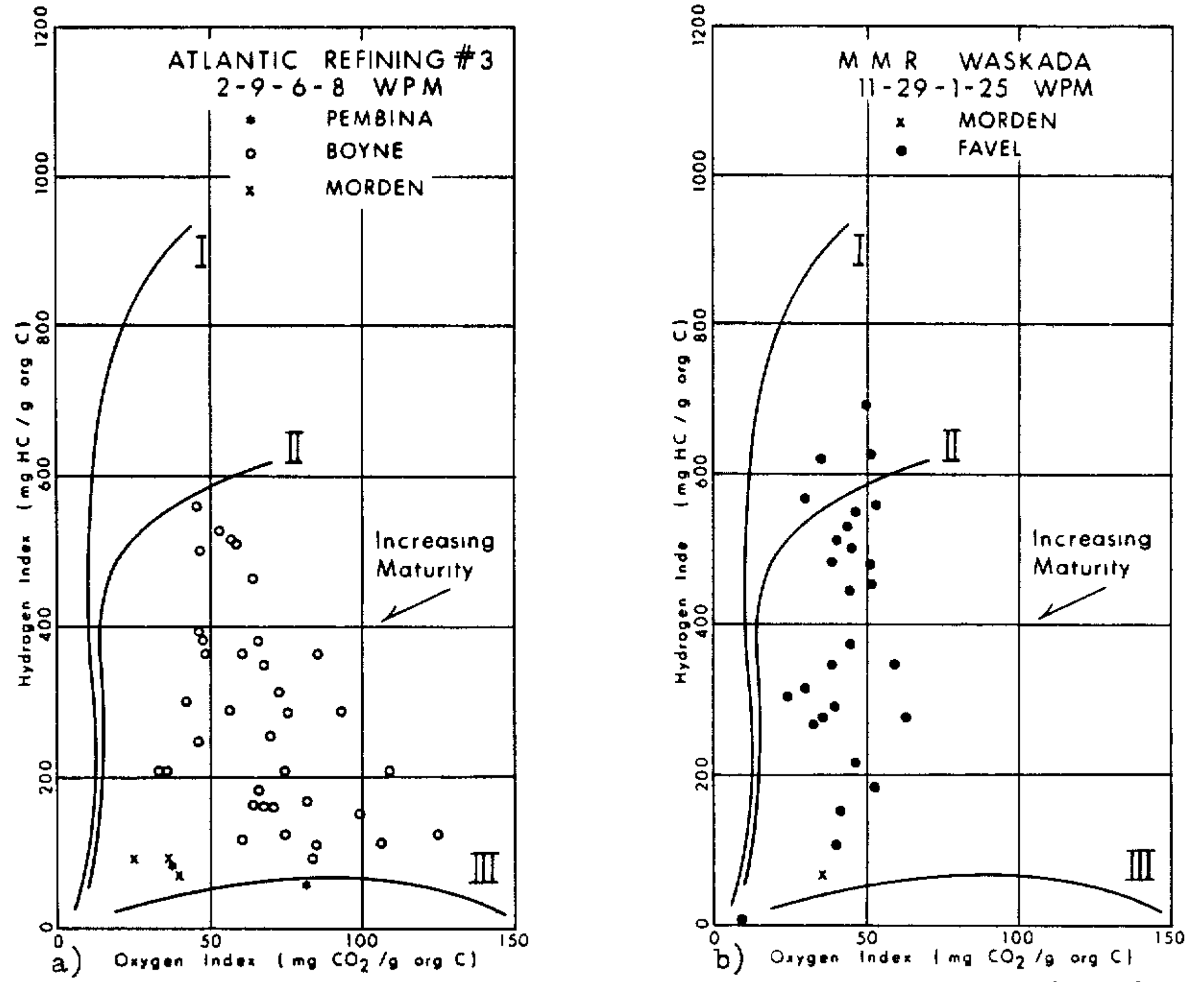


Fig. 8: Typical plots of hydrogen index, HI, against oxygen index, OI; a) Boyne Formation; b) Favel Formation

hydrogen indices increase with increasing Type II content: total organic carbon and hydrocarbon potential also increase commensurately. Specific low Tmax values reflect the higher Type II content with Tmax increasing as Type III kerogen increases. These relationships hold throughout the area (see other plotted data, Appendix B).

<u>Hydrocarbon Potential</u>

From the visual log plots, the hydrocarbon (petroleum) potential upon pyrolysis directly relates to the hydrogen index and total organic carbon values. The hydrocarbon yield/1% organic carbon is a significant figure for economic evaluation: the relationship is illustrated by plotting the petroleum potential ($S_1 + S_2$) against total organic carbon (Figs. 9a, 9b). This relationship is not 1st order linear as indicated by a curve of the average line. A close look at the Favel average line indicates one slops for those data below 3 to 4% organic carbon and a better yielding

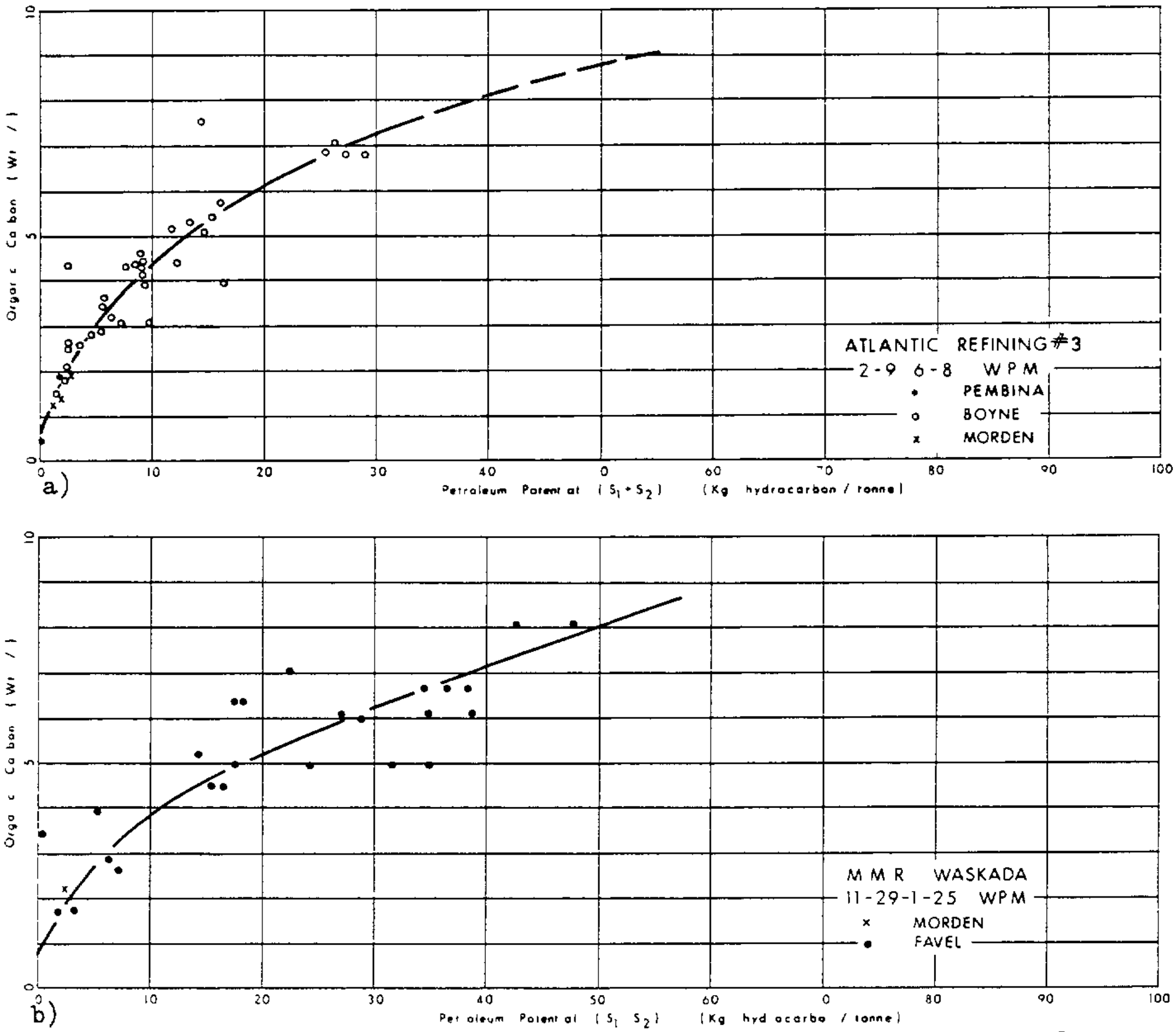


Fig 9: Typical plots of total organic carbon against hydrocarbon potential; a) Boyne Formation; b) Favel Formation

slope where carbon content increases beyond 4%. Along with the HI/OI plots and the Tmax variations, this is interpreted as a reflection of the varying distributions of Type II and Type III kerogens. All plots (Appendix B) show a similar change of slope to better yield ratios as the carbon content increases. The entire area is considered to contain an average 3 to 4% organic carbon derived from Type III humic kerogen within the organic beds zones with lesser organic carbon will contain almost entirely humic material· where organic carbon increases beyond 3 to 4%, the increase results from the addition of Type II sapropel, and increasing hydrocarbon recoveries reflect this change of kerogen.

Average yields per 1% organic carbon range 3.5 to 4.5 kg/t over the total interval of either oil shale unit, but increase within the units to beds yielding up to 6 kg/t where Type II kerogen predominates.

Because most of the cores utilized in this study have been exposed for a significant period of time, the effect of atmospheric weathering of the kerogen must be considered. Recent work by Kovac (1984) indicates the recent weathering has no appreciable effect on the kerogen and the hydrocarbon recovery potential of the Boyne and Favel oil shale strata.

Organic Petrology

Two short unpublished reports by Hutton (1981a, 1981b) describe the organic petrology of samples from the Boyne Formation at Atlantic Refining #3 and of samples from the Favel Formation at Atlantic Refining #2 in southwestern Manitoba (Fig. 3), and of 5 surface samples from the Pasquia Hills in Saskatchewan (Fig. 3).

Using both reflectance and flourescence observations, Hutton identified humic layers containing liptodetrinite and phytoplankton, intermixed with non-flourescing organic matter. Dinoflagellates and acritarchs are recognizable phytoplankton. Lesser quantities of exinite, alginite B, sporinite, vitrodetrinite and inertodetrinite, and bitumen are also reported.

The interpreted presence of both Type II phytoplanktonic kerogen and Type III humic kerogen is in accord with Hutton's observations.

Fischer Assay Data

Fischer Assay data are available for the three Atlantic Refining coreholes along the Manitoba Escarpment in southwest Manitoba.

At the #2 corehole (16-11-8-11WPM), the average yield by Fischer Assay of Favel beds was 4.7 U.S. g/t, which equates to 18.84 kg/t (at S.G. 0.962) compared the Rock-Eval average at 20.35 kg/t. Similarly, at #3 (2-9-6-8WPM), an average Fischer Assay of 3.55 U.S. g/t over Boyne beds equates to 14.18 kg/t (S.G. 0.958), almost identical to the Rock-Eval average of 13.79 kg/t. These results indicate the interchangeability of data from these two analytical techniques.

Boyne beds were analyzed at the #4 corehole (1-27-1-6WPM) Rock-Eval data averaged 10.74 kg/t, equivalent to 2.69 U.S. g/t (S.G. 0.954) for Boyne strata. Fischer assay data here averaged 1.41 U.S. g/t (5.6 kg/t), somewhat different from Rock-Eval on a percentage basis because of the low values, but not significantly different on absolute values.

ECONOMIC POTENTIAL

Any potential for economic oil shale development will depend on the distribution of total organic carbon and the ultimate hydrocarbon yields relative to the organic carbon content.

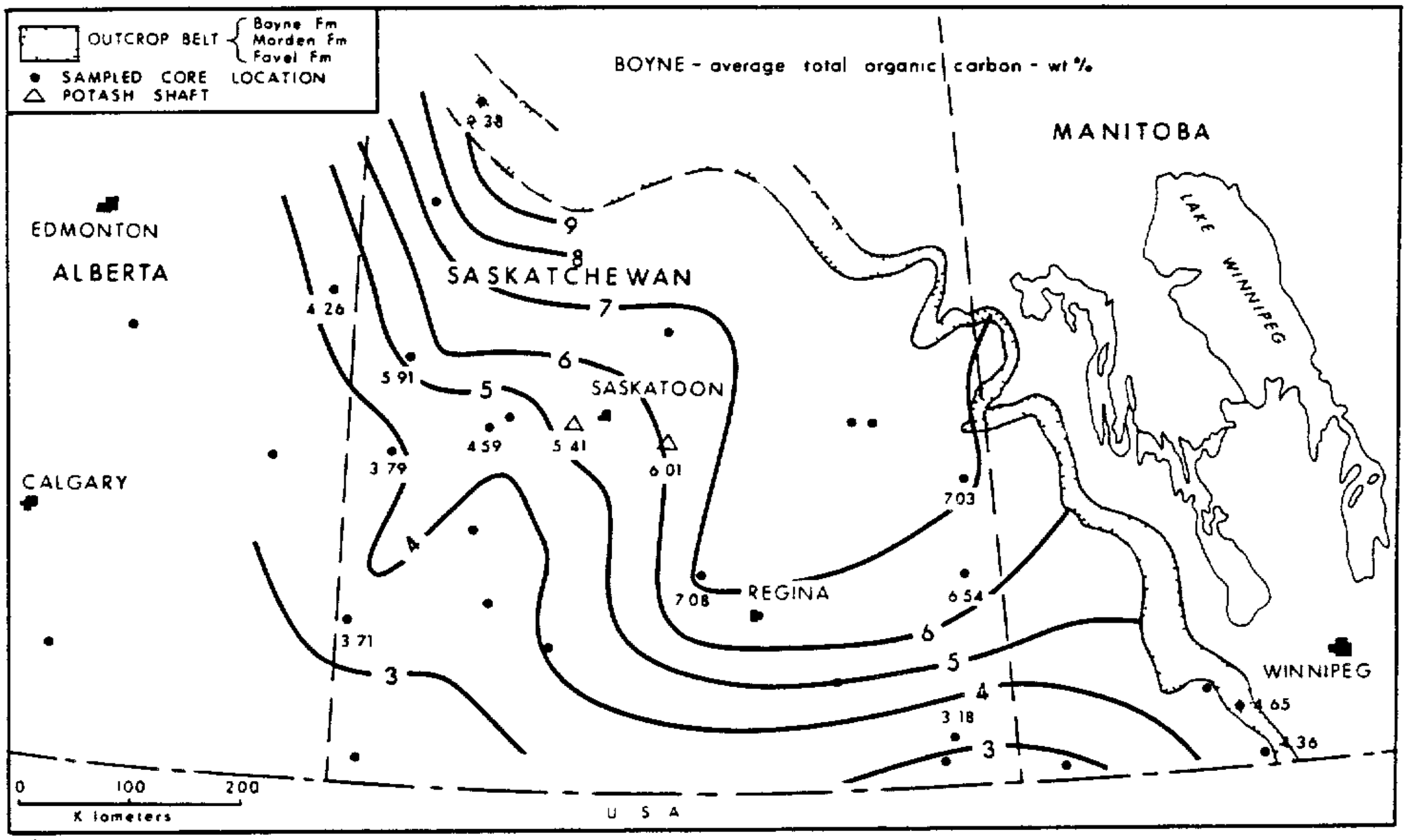
Data for each location were averaged for Boyne and Favel Formations for total organic carbon (Figs. 10a, 10b) and for average hydrocarbon yield ($S_1 + S_2$) (Figs. 11a, 11b). Fewer data points are available for the Boyne compared to the Favel, but similar geographic patterns of low carbon-poor yield and higher carbon-better yield areas are readily apparent, and compare directly with the geographic variations of average Tmax (Fig. 7).

Two areas of better potential are recognized, one trending northerly in the eastern part of Saskatchewan, and a second trending northeasterly along the Alberta-Saskatchewan border, separated by a less potential area trending north-northeasterly through Saskatoon.

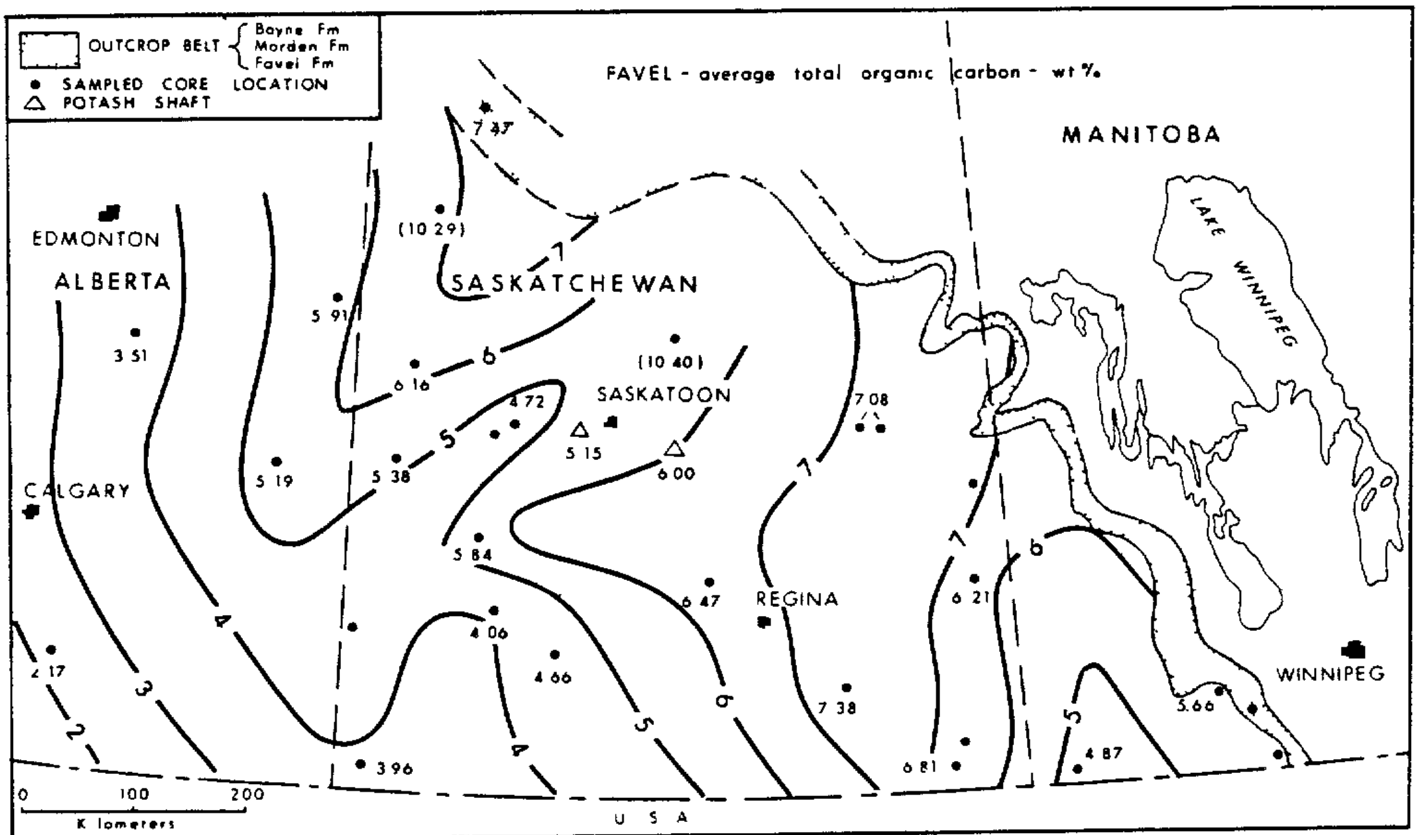
From these maps, the area at the northwest along the outcrop trend in Saskatchewan should be economically interesting, but some caution must be advised as the three key control points contain only a few analytical values which may have been selected inopportunely from higher yield beds. At 16-10-44-27W3M and 14-31-55-21-W3M (Figs. 10b, 11b; data shown in brackets), one and two samples respectively were analyzed. At the most northerly control point, 4-10-65-17W3M, two analyses provide the Boyne average, and three the Favel data. Nevertheless, the trend appears valid from other data, and the area must be considered "interesting."

The easterly trend is currently much more significant because considerable Fischer Assay data are available from the Sun Oil core program of 1964-1965 in the Pasquia Hills and Porcupine Hills (Figs. 3, 12). The Fischer Assay analyses of these, and of the three Atlantic Refining coreholes, are on file at, and can be obtained from, the Petroleum Branch, Department of Energy and Mines, Province of Manitoba, and the Geological Survey of Saskatchewan.

Morden beds are present and distinctively separate the Boyne and Favel along the Manitoba Escarpment (McNeil and Caldwell, 1980); however, no differentiation of the units was made by Sun Oil on the data sheets, and no interpretation of zones penetrated by these cores has been published. Elevations were calculated on the base of the oil shale unit, from the Sun Oil data, as defined by oil yields: most of the elevations appear regionally

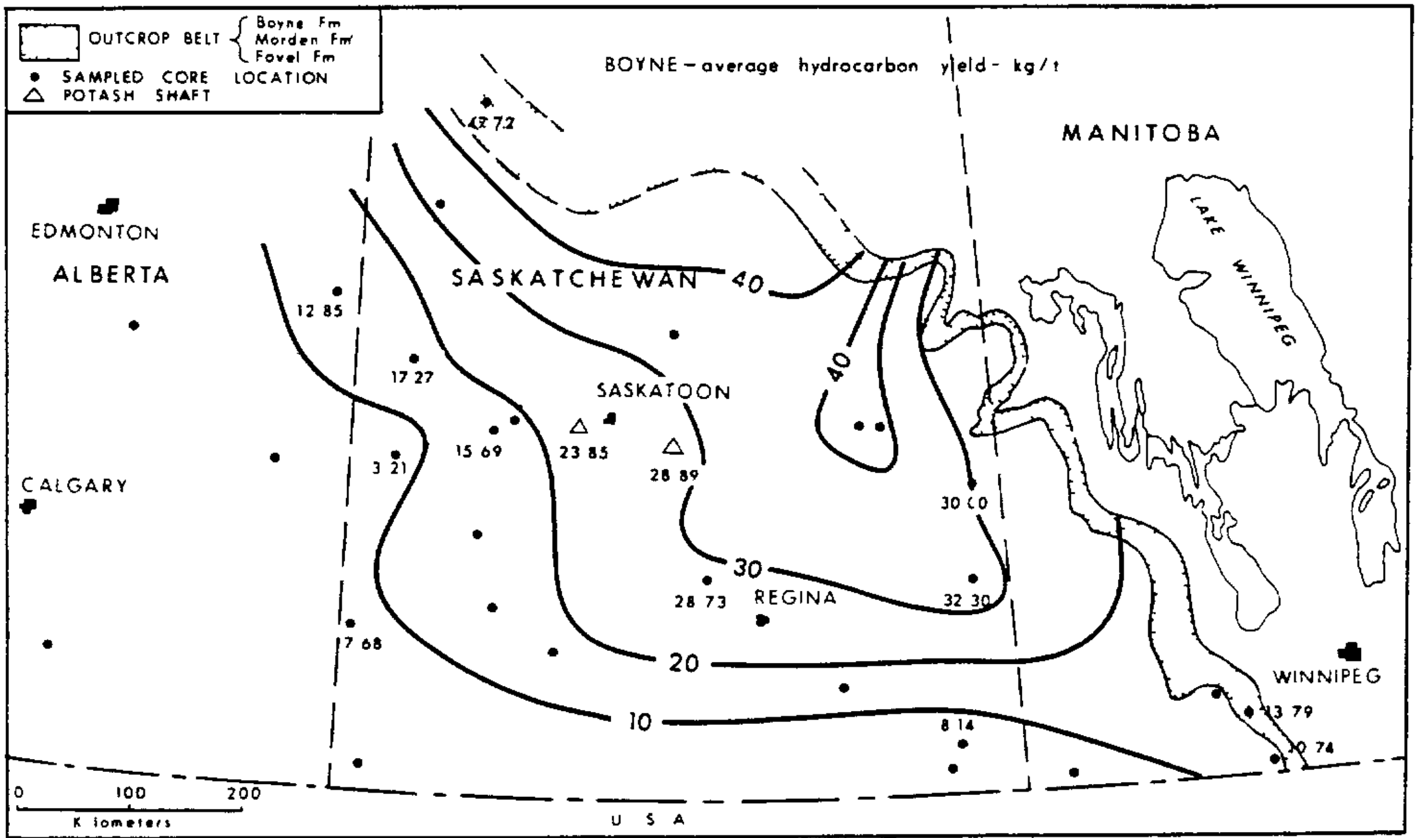


a)

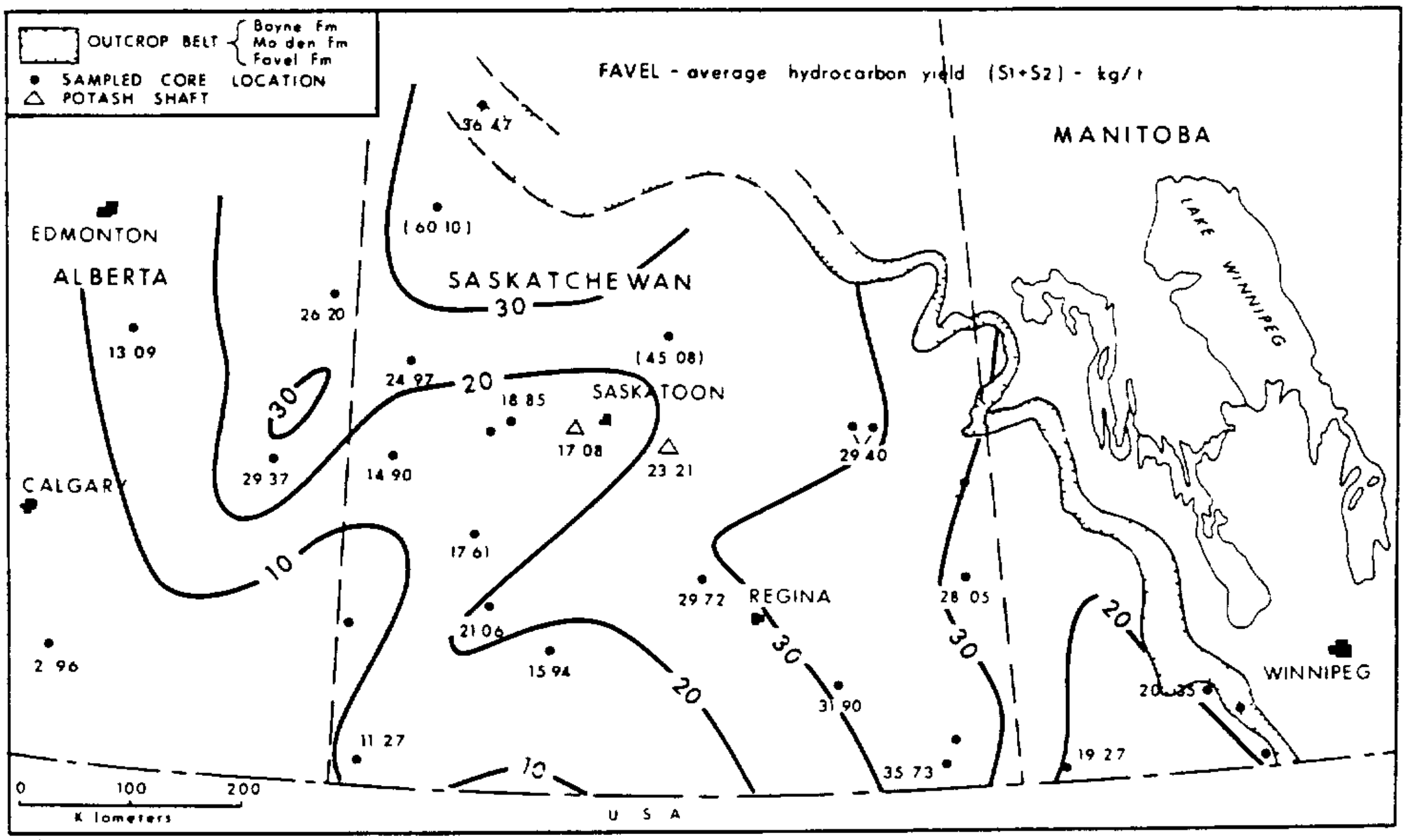


b)

Fig. 10: Regional distribution of averaged total organic carbon content; a) Boyne Formation; b) Favel Formation



a)



b)

Fig. 11. Regional distribution of averaged hydrocarbon yields;
a) Boyne Formation, b) Favel Formation

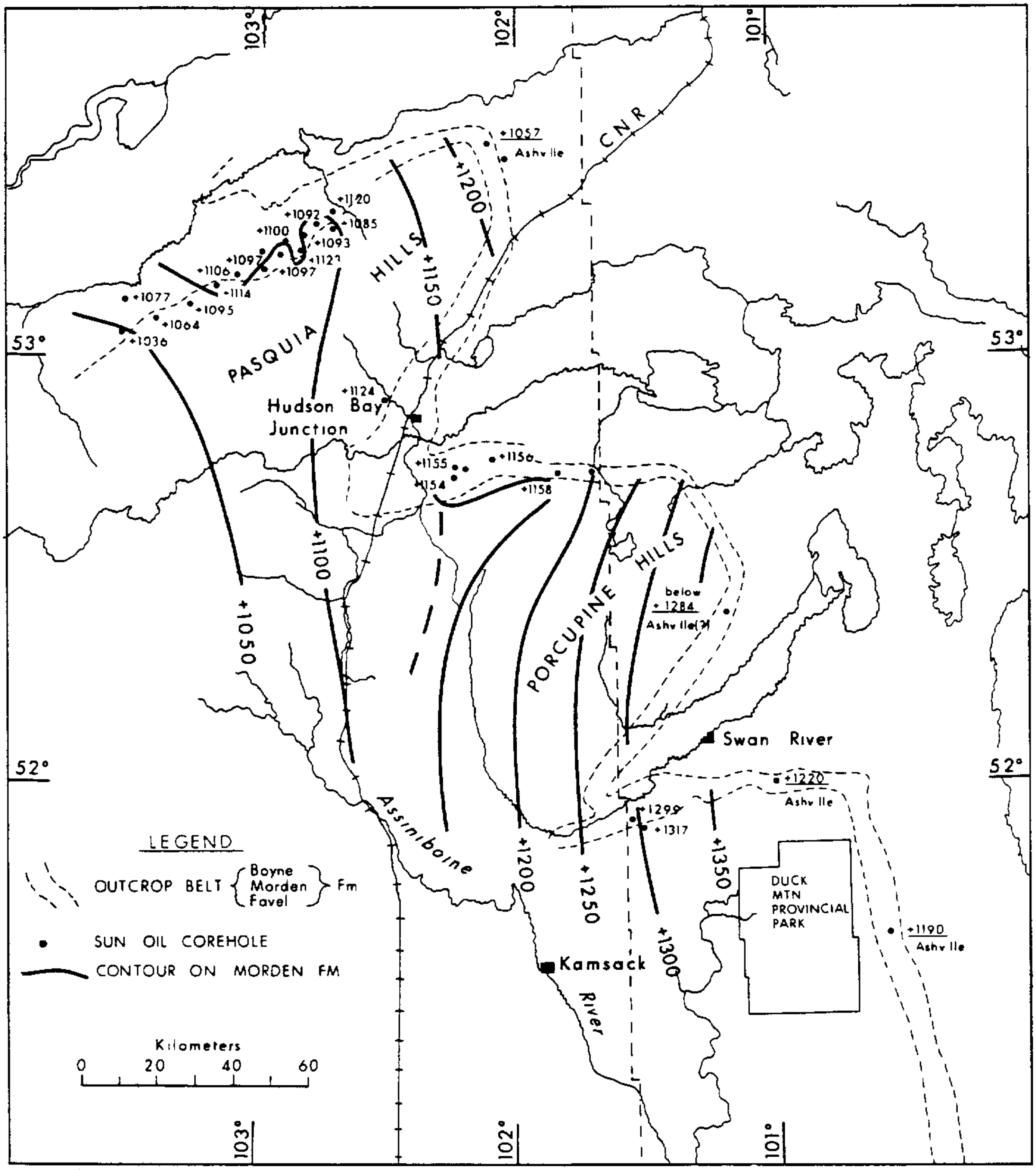


Fig. 12. Contours on Morden Formation from Sun Oil Company corehole data, Pasquia Hills - Porcupine Hills - Duck Mountain area

compatable and are mapped herein as contours on the Morden Formation (Fig. 12). Four values, two located on the north and east flank of Duck Mountain, one at the east end of the Porcupine Hills, and one at the eastern extremity of the Pasquia Hills, are approximately 100 to 150 feet low to the Morden contours; consequently, these cores are interpreted to penetrate the Favel Formation. Irregularities of the contours on the north flanks of the Pasquia and Porcupine Hills reflect distribution of organic material downward in the section. Based on organic content, the Boyne-Morden contact is in part a lateral facies relationship.

Because oil gravities (generally 0.965 in this area) are available, Fischer Assay yields have been converted to kg/t and are shown on Fig. 13. An area of optimum yield, in the range 40 to 50 kg/t from the Boyne Formation, is mapped on the north flank of Pasquia Hills, with recoveries decreasing both easterly and westerly of the optimum area. These detailed trend lines and data have been incorporated into the more regional hydrocarbon yield maps of both the Boyne (Fig. 11a) and Favel (Fig. 11b) Formations. From these interpretations, the north slope of the Pasquia Hills, as also concluded by Beck (1974), is the most attractive area for oil shale development along the Manitoba Escarpment. This attempted differentiation of Boyne and Favel data changes the distributional trend to north-south from northeasterly as shown by Macauley (1981) when combining all data, independent of zone.

The quality of oil recovered is in the poorer range of shale oil types, with specific gravities averaging 0.952 at the southerly end of the Manitoba Escarpment, and becoming heavier northerly to 0.965 to 0.970 in the Porcupine and Pasquia Hills. Because Rock-Eval data are not available to compare to the Fischer Assays in the northern area, no reason is readily evident for the northerly increased specific gravity.

Also of possible economic significance is the large amount of water recovered on the Fischer Assays. Almost all assays yielded a minimum 40 kg/t (10 US g/t) with many ranging to 80 kg/t (20 US g/t) and some as high as 120 kg/t (30 US g/t). These yields reflect the water of clay minerals and also the many hydrous forms of the zeolites, sulfates and oxides.

Source Rock Potential

Thermal maturation, as interpreted from the values of Tmax and of the hydrogen and oxygen indices, indicate that oil has not been generated

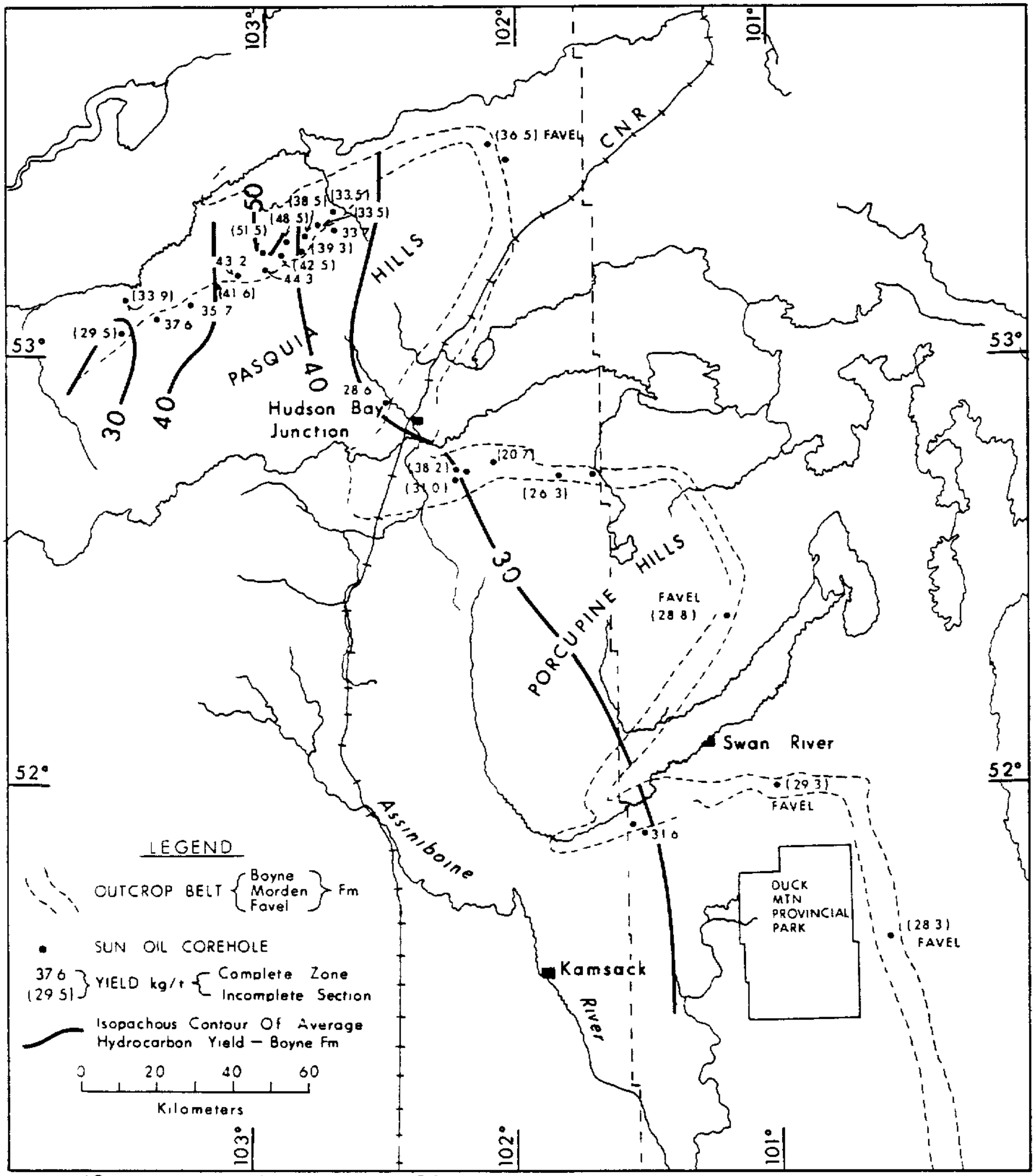


Fig. 13: Average hydrocarbon yield from the Boyne Formation, Sun Oil Company corehole data, Pasquia Hills - Porcupine Hills - Duck Mountain area

from these two zones over almost the entire study area. Data at 6-33-11-28W4M, in southern Alberta, approaches low maturity. Although average carbon values are low, there is sufficient organic content for oil generation. The low maturity is verified by the production index, the ratio of S_1 volatile oil content to the total hydrocarbon recovery(S_1 + S_2), which varies from 0.25 to 0.31. Elsewhere, the production indices range from 0.02 to 0.06, only occasionally as high as 0.10 (Figs. 6a, 6b) in the oil shale zones. From the indicated Tmax distribution (Fig. 7), these zones are probable oil source rocks in western Alberta only.

At 6-34-30-8W4M, production indices average 0.31, ranging as high as 0.55. Other data, especially Tmax (average 415°C), indicate the kerogen to be thermally immature. The petroleum (S_1) content and apparent excellent hydrocarbon yield (Fig. 11b) could indicate migration into the zone, but are more likely the result of contamination by an oil-base drilling fluid.

Dry gas is prevalent in the Milk River and Medicine Hat Formations of southeastern Alberta and southwestern Saskatchewan where sandstone units pinch out updip into the two White Specks (Boyne and Favel) units. An early biogenic origin from the kerogen of these deposits has been proposed for the origin of this gas (Fuex, 1977). Gas reported near Kamsack, Saskatchewan (Fig. 13) (Wickenden, 1945), although of limited economic significance (Macauley, 1981), is of interest because of probable similar biogenic origin.

SUMMARY

Potential oil shales of the Boyne and Favel Formations (First and Second White Speckled shales) are thermally immature across the Prairie Provinces, except for possible low maturity in western Alberta. Type III humic material provides some organic carbon content everywhere, with additional Type II sapropel increasing the organic carbon along two north-south trends, one in western and one in eastern Saskatchewan. These areas of maximum organic content are developed as cross trends to a regional northeasterly increase of kerogen content. Yields per 1% organic carbon increase as the Type II content increases, from lows of 3 to 3.5 to highs of 6 to 6.5 kg/t/1% organic carbon. The best yields average better than 40 kg/t for both zones along the north slope of the Pasquia Hills in

eastern Saskatchewan and toward the outcrop at the west of the Province, although control data are sparse in this latter area.

Kerogen content increases to an averaged maximum where calcite approximates 40% in the Boyne and 60% in the Favel and decreases significantly in relatively pure limestone beds. Calcite concentrations are inversely proportional to the quartz-clay-feldspar component.

Secondary mineral suites, including zeolites, sulfates, oxides, and considerable iron minerals, all containing varying amounts of water of crystallization, indicate continuing mineral alteration during deposition and lithification, but a lithic immaturity as the sediments have not been buried to any depth much greater than presently encountered.

Except for western Alberta, these zones have not been the source of any hydrocarbons from thermal maturation, but have probably contributed significantly to eastern Alberta and western Saskatchewan gas reserves by early biogenic degradation processes.

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APPPENDIX A

X-RAY DIFFRACTION RESULTS

Semi-quantitative results of whole rock were obtained from diffraction peak heights which may vary with degrees of crystallinity, crystal size, and with any amorphous material present. These data represent relative approximate concentrations and are not absolute values.

ABBREVIATIONS

Minerals:

Al: alunite
Amph: amphibole
An: analcime
Ana: anatase
Anh: anhydrite
Ank: ankerite
Ap: apatite
Bar: baryte
Bas: bassanite
Bay: bayerite
Bt: biotite
Cal: calcite
Ch: chlorite
Cli: clinoptilolite
Cri: cristobalite
Daw dawsonite
Dia: diaspore
Dio: diopside
Dol: dolomite
Ep: epsomite
F: feldspars
Gib: Gibbsite
Goe: goethite
Gr greigite
Gyp: gypsum
Hal: halite
Hem: hematite
Heu: heulandite
Hyb: hydrobiotite
Ill: illite
Jar: jarosite
K: kaolinite
Lau: Laumontite
Lep: lepidocrocite
Lou: loughlinite
Mag: magnetite
Mel: melanterite
Mgh: maghemite
Mil: millisite
MLC: mixed layer clays
Mon: monohydrocalcite
Nat: natrojarosite
Nes: nesquehonite
Pal. palygorskite
Py: pyrite
Qtz: quartz
Roz: rozenite
Sid: siderite
sp: spinel
Str: strengite
Syl. sylvite
Tri: tridymite
Wur: wurtzite
Z: zeolite

Zones:

P: Pembina and equivalent strata overlying the Boyne-First Specks
B: Boyne and First Speckled shale
M: Morden and shale beds separating the Speckled shales
F: Favel and Second Speckled shale
A: Ashville and equivalent strata underlying the Favel-Second Specks

Note: The Potash shafts were average sampled over 5 foot intervals: the indicated depth is the top of the sampled section.

Depth (ft)	Depth (m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
Atlantic Refining #4			1-27-1-6WPM								
165	50.3	P	19	10	--	57	5	5	--	--	Dol 4, Sid tr
183	55.8	P	25	--	--	66	6	--	--	3	
193	58.9	B	20	--	--	49	8	-	7	5	Lou? 11, Sid tr
198	60.4	B	12	--	--	14	4	67	--	3	
215	65.5	B	13	--	--	15	3	66	--	--	Bas tr, Dol tr, Sp 3
220	67.1	B	16	tr	5	16	tr	63	tr	--	
224	68.3	B	tr	--	--	10	--	84	6	--	
229	69.8	B	tr	--	--	24	2	69	5	-	
230	70.1	B	10	--	--	12	3	63	9	tr	Bar tr, Dio 3
234	71.3	B	16	--	tr	29	tr	47	--	3	Tri 6
238	72.5	B	12	--	--	22	tr	63	--	--	Ana 3, Bar tr
249	75.9	B	11	tr	5	22	--	62	tr	--	Bar tr
255	77.7	B	14	--	tr	18	tr	57	5	tr	Tri 2, Dol 3
260	79.2	B	7	tr	tr	43	--	50	tr	--	
265	80.8	B	12	tr	7	17	--	64	--	--	Dol tr, Hem tr
274	83.5	B	12	--	--	8	--	80	--	--	
279	85.0	B	17	11	7	45	tr	20	--	--	
283	86.3	B	14	10	5	57	tr	tr	8	6	Amph tr
291	88.7	B	15	11	6	68	tr	--	tr	--	
297	90.5	B	13	9	4	63	6	--	5	--	Dol tr
303	92.4	B	12	10	5	62	3	--	6	2	Dol tr
307	93.6	B	11	11	4	63	3	5	--	3	Jar tr
312	95.1	B	14	10	5	58	8	--	5	--	Mgh tr
317	96.6	B	11	8	5	56	5	--	tr	5	Syl 5, Dol tr, Tri tr
323	98.5	B	12	5	--	19	tr	23	--	--	Dol 41
330	100.6	B	14	8	tr	54	3	17	--	4	
335	102.1	B	12	8	5	56	2	9	5	3	Goe tr
345	105.2	B	8	5	4	23	2	23	5	tr	Dol 30 Sid tr
352	107.3	B	10	9	6	46	tr	15	6	2	Nes? 6
364	111.0	B	13	9	6	65	tr	--	--	--	Bas tr, Jar 4, Mgh 3
368	112.2	B	9	7	5	57	--	12	7	3	
374	114.0	M	11	7	5	61	3	6	5	2	Dol tr
379	115.5	M	12	7	5	68	3	--	5	--	
384	117.0	M	11	7	tr	75	4	--	--	3	Jar tr
389	118.6	M	12	8	5	71	tr	--	--	--	Jar 4, Sid tr
393	119.8	M	9	6	3	70	3	--	5	--	Jar 4, Dol tr, Sid tr
399	121.6	M	11	8	tr	73	3	--	5	--	
MMR Waskada		11-29-1-25WPM									
1560	475.5	M	12	6	7	57	3	--	9	3	Sid tr, Amph tr, Gr tr
1570	478.5	F	9	7	4	51	3	12	6	4	Dol 4
1577	480.7	F	8	6	5	40	--	33	4	4	Dol tr
1578	481.0	F	8	5	5	46	--	19	5	3	Dol 3, Pal? 6, Sid tr
1583	482.5	F	5	--	--	5	--	73	tr	2	Dol 15
1588	484.0	F	7	5	5	12	--	58	4	4	Bar 2, Ap 3

Depth (ft)	Depth (m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
1593	485.6	F	9	tr	4	20	tr	54	6	4	Dol 3
1598	487.1	F	11	--	--	20	--	58	6	3	Dol 2, Gr tr
1603	488.6	F	14	6	tr	24	tr	44	7	5	
1606	489.5	F	9	--	4	16	--	60	4	7	
1611	491.0	F	13	tr	4	31	--	48	4	tr	
1616	492.6	F	11	4	4	30	--	41	4	3	Dol 2
1621	494.1	F	8	--	--	9	--	83	--	--	
1626	495.6	F	8	--	--	15	--	77	tr	--	Ank tr
1631	497.1	F	8	tr	tr	13	--	79	tr	tr	
1636	498.7	F	9	--	--	13	--	74	--	--	Ep? tr
1641	500.2	F	8	--	--	8	--	84	--	--	
1646	501.7	F	9	tr	3	21	--	63	--	--	Gr tr, Dol 4
1651	503.2	F	11	5	4	35	--	45	tr	tr	Dol tr
1656	504.7	F	9	tr	4	23	tr	61	--	3	
1660	506.0	F	14	9	5	29	tr	36	tr	5	Bar tr, Al 4, Sid tr
Atlantic Refining #3				2-9-6-8WPM							
182	55.5	P	19	7	--	62	5	--	--	--	Cri tr
195	56.4	P	26	9	--	59	6	--	--	--	
206	62.8	B	10	5	--	58	7	--	5	2	Jar 7, Bas 4 Mgh 2
211	64.3	B	17	7	--	47	7	--	4	3	Z 9, Jar 6
220	67.1	B	15	8	6	45	6	--	8	3	Dol 4, Jar 5
225	68.6	B	11	5	3	61	8	--	3	5	Jar 4
234	71.3	B	12	5	--	11	3	52	7	4	Goe 3, Dol 3
239	72.8	B	9	3	--	15	2	61	5	3	Dol 2
245	74.5	B	12	7	--	29	4	39	6	3	Ank tr
254	77.4	B	5	4	3	26	tr	55	3	--	Bas 2, Goe 2
258	78.6	B	10	tr	tr	21	tr	64	5	tr	Ap tr
262	79.9	B	11	6	6	21	tr	23	7	3	
271	82.6	B	11	tr	tr	11	3	69	tr	--	
287	87.5	B	12	tr	5	9	--	65	6	--	Amph tr, Bay 3
290	88.4	B	8	tr	4	12	tr	66	5	3	
296	90.2	B	10	--	5	14	--	65	6	--	
304	92.7	B	6	5	--	11	2	65	5	1	Amph 5
310	94.5	B	10	6	5	20	3	56	--	--	
315	96.0	B	13	tr	--	19	--	68	--	--	Sid tr
323	98.5	B	8	5	--	29	--	51	--	--	An 3, Ank 4
328	100.0	B	9	5	4	27	tr	46	--	2	Ank 7, Ap tr
333	101.5	B	11	7	5	61	4	4	5	4	
336	102.4	B	11	7	5	52	tr	18	4	3	Goe tr, Ank tr
339	103.3	B	8	8	4	63	3	3	4	3	Sid 2, Ank 2 Amph tr
346	105.5	B	6	3	3	21	1	64	tr	2	Bas tr
347	105.8	B	13	7	4	47	3	9	5	--	Dol 12
355	108.2	B	10	5	4	70	3	3	4	1	Sid 1
360	109.7	B	12	8	5	65	4	--	6	--	
365	111.3	B	6	3	3	37	2	43	4	2	Dol tr
370	112.8	B	10	10	5	67	tr	4	4	tr	Amph tr, Dol tr
375	114.3	B	5	2	3	37	5	25	2	1	Dol 20
382	116.4	B	9	4	--	20	1	55	6	3	Anh 2
384	117.0	B	8	6	4	21	2	55	--	4	

Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
395	120.4	M	12	6	5	69	--	--	tr	2	Jar 6, Ap tr
400	121.9	M	9	5	4	73	3	--	--	--	Jar 4, An 2 Bay tr
405	123.4	M	12	7	5	69	2	--	5	--	Jar tr
Atlantic Refining #2				16-11-8-11WPM							
177	53.9	M	12	5	4	66	3	--	2	--	Jar 4, Syl 4
187	57.0	M	14	5	5	73	--	--	--	1	Jar 2
197	60.0	F	7	3	3	69	3	--	2	2	Tri 4, Jar 5, Sid tr, Mgh 2
219	66.8	F	10	7	5	65	5	--	tr	2	Jar 6, Sid tr
224	68.3	F	9	5	5	72	3	--	--	3	Jar 3
232	70.7	F	10	5	6	54	--	10	8	5	Gib 2, Ank tr
236	71.9	F	6	4	4	47	--	23	7	4	Ank 5
241	73.5	F	13	tr	5	40	--	32	5	5	Ank tr
244	74.4	F	10	6	5	37	tr	27	8	3	Ank 4
247	75.3	F	13	9	6	40	--	14	13	5	
253	77.1	F	6	5	tr	14	--	71	3	1	
256	78.0	F	10	8	7	22	--	38	9	6	
258	78.6	F	7	3	3	14	1	66	4	1	Dia? 1
260	79.2	F	7	4	--	17	--	61	6	2	Bas 3
264	80.5	F	6	3	2	14	2	67	4	2	
269	82.0	F	11	tr	--	12	--	72	5	--	
273	83.2	F	8	6	5	19	3	50	6	3	Jar tr
278	84.7	F	tr	--	--	10	--	6	79	--	Tri? 5
283	86.3	F	10	--	--	5	--	80	5	--	
287	87.5	F	6	3	3	14	--	72	tr	2	
293	89.3	F	tr	--	--	4	--	92	--	--	Sid 2, Bar 2 Z tr
298	90.8	F	7	tr	--	13	--	78	--	--	Bar 2
302	92.0	F	tr	--	--	9	tr	91	--	--	
307	93.6	F	6	3	--	15	1	69	3	2	Bar 1
312	95.1	F	12	--	--	23	--	65	--	--	
321	97.8	F	8	5	--	14	--	64	6	--	Dol 3
326	99.4	F	tr	--	--	14	--	60	11	10	Dol 5
331	100.9	F	9	6	5	19	--	56	5	--	
336	102.4	F	6	3	3	28	2	49	4	2	Daw 1, Mon 2
341	103.9	F	10	7	4	21	tr	56	tr	--	
345	105.2	F	16	tr	5	24	--	46	6	3	Sid tr
350	106.7	F	13	tr	4	24	--	45	6	3	Ank 5
356	108.5	F	12	7	5	63	4	--	4	--	Z 5
360	109.7	F	10	5	5	61	--	4	4	6	Dol 2, Mgh 2
365	111.3	F	7	9	10	57	--	4	7	6	
365	111.3	F	6	3	3	37	2	43	4	2	Dol tr
370	112.8	F	10	10	5	67	tr	4	4	tr	Amph tr, Dol tr
International Yarbo				1-24-20-33WPM							
662	201.8	P	25	16	6	44	4	--	5	--	
669	203.9	B	13	9	4	16	3	48	3	4	
671	204.5	B	18	7	3	9	--	59	--	4	
679	207.0	B	14	11	5	33	--	35	--	--	Dol 2
684	208.5	B	10	12	6	40	3	23	2	4	

Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
694	211.5	B	18	16	9	50	tr	--	3	4	
703	214.3	B	11	12	8	56	tr	4	tr	4	Dol 2
712	217.0	B	15	16	8	51	tr	7	--	3	
721	219.8	B	24	18	6	32	--	17	--	3	Bas tr
728	221.9	B	12	9	6	33	--	38	--	2	
737	224.6	B	20	16	7	57	--	--	--	--	
750	228.6	B	20	11	9	53	3	--	--	4	
756	230.4	B	16	9	7	41	3	16	4	2	Ank 2
764	232.9	B	16	8	7	37	tr	11	11	5	Dol 2, Mgh 2
768	234.1	M	20	10	6	40	--	--	4	3	Hyb 7, Jar 6, Gib 4, Tri tr
783	238.7	M	12	8	4	38	--	--	3	5	Z 4, Mag 3, Roz 9, Gib 5, Bar 5, Tri 4
798	243.2	M	11	8	3	23	--	--	3	8	Z 5, Tri 4, Roz 12, Bar 5, Anh 5, Bas 3, Gib 5
807	246.0	F	15	7	4	20	--	45	3	4	Dol 2
813	247.8	F	17	10	6	30	3	27	4	3	An tr
820	250.0	F	9	5	3	14	tr	63	3	4	
825	251.5	F	16	5	tr	14	3	55	4	4	Sid tr
830	253.0	F	7	4	--	8	--	72	--	3	Dol tr, Cli 6, Amph tr, Bas tr
835	254.5	F	10	7	--	13	--	45	5	4	Cli 13, Sid 3
840	256.0	F	12	5	--	10	4	51	3	3	Cli 10, Sid 2
846	257.9	F	tr	4	--	7	--	82	--	tr	Z 7
853	260.0	F	4	3	--	8	--	78	--	2	Z 5
858	261.5	F	tr	2	--	6	tr	84	--	2	Z 6
866	264.0	F	9	4	--	6	tr	75	--	2	Z 4
871	265.5	F	7	4	tr	12	2	72	--	2	
879	267.9	F	6	4	2	11	--	73	2	2	Dol tr
895	272.8	F	16	13	6	45	4	4	4	6	Dol 2
Western Petroleum #1 16-15-29-32WPM											
250	76.2	B	25	17	8	43	tr	--	7	tr	Ap tr
260	79.2	B	17	17	7	30	tr	17	6	6	
271	82.6	B	6	6	2	15	2	64	2	3	Sid tr
275	83.8	B	7	4	tr	15	2	70	--	2	
278	84.7	B	11	6	4	9	--	63	4	3	Dol tr
Imperial Oxbow 15-36-2-3W2M											
2698	822.4	F	12	5	4	38	3	28	3	5	Mil? 2
2703	823.9	F	9	4	4	14	2	57	4	4	Str? 2
2710	826.0	F	tr	5	--	26	--	66	--	tr	Dol 3
2718	828.4	F	tr	3	2	19	--	74	--	tr	Dol 2
2723	830.0	F	9	5	6	15	--	59	--	2	Z 4, Dol tr
2728	831.5	F	tr	tr	6	17	--	73	--	4	Bar tr, Dol tr
2733	833.0	F	7	3	4	15	tr	67	--	2	Dol 2
2740	835.2	F	5	4	--	16	tr	73	--	tr	Dol 2
2743	836.1	F	tr	tr	--	18	--	82	--	tr	Dol tr
2750	838.2	F	8	3	3	23	tr	61	tr	tr	Dol 2

Depth (ft)	Depth (m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
2757	840.3	F	18	7	4	28	2	33	tr	4	Dol 4, Amph tr
2764	842.5	F	12	9	4	37	2	22	4	4	Dol 5, Tri tr
2770	844.3	F	8	6	4	36	2	37	1	4	Dol 2
2780	847.3	F	19	12	7	41	5	8	3	5	Sid tr
Bobjo Alameda #1			16-4-5-2W2M								
2103	641.0	B	17	10	9	51	2	9	--	2	Dol tr
2126	648.0	B	15	13	9	48	3	10	tr	2	
2135	650.8	B	15	10	11	48	3	5	tr	3	Ank 5
Dome Talmage		11-36-10-13W2M									
2257	687.9	F	18	6	3	25	--	38	5	5	
2262	689.5	F	13	5	3	26	4	41	--	3	Dol 3
2267	691.0	F	7	3	3	30	tr	42	3	2	Sp? 7, Dol 3
2272	692.5	F	9	tr	12	8	--	67	--	2	Dol 2
2280	694.9	F	5	--	tr	9	--	86	tr	--	
2283	695.9	F	18	tr	13	6	2	61	--	tr	
Imperial Findlater			16-4-21-25W2M								
1533	467.3	P	18	12	8	52	3	--	3	2	Dol 2
1541	469.7	P	13	10	6	63	3	--	--	2	Dol 3
1549	472.1	B	9	5	5	19	3	56	tr	3	
1554	473.7	B	7	7	4	19	--	56	4	3	Dol tr
1560	475.5	B	14	13	6	33	5	26	tr	3	
1566	477.3	B	11	13	11	57	--	--	3	5	
1573	479.5	B	20	15	7	47	3	3	--	2	Bar 3
1583	482.5	B	9	6	5	21	2	45	3	9	
1590	484.6	B	24	7	8	31	--	8	14	6	Ank 2
1601	488.0	M	12	tr	tr	5	tr	77	--	2	Bar 2, Sid 2
1602	488.3	F	19	6	2	31	tr	35	3	4	
1607	489.8	F	10	3	tr	16	tr	65	3	3	
1611	491.0	F	tr	tr	--	6	--	94	tr	tr	
1619	493.5	F	30	6	1	6	--	55	--	2	
1622	494.4	F	11	4	tr	17	2	60	4	2	Gr tr
1628	496.2	F	12	9	6	51	5	6	tr	9	Dol 2
1633	497.7	F	8	7	4	36	2	31	3	5	Bar 2, Dol 2
1638	499.3	F	7	4	3	15	--	65	3	3	
1644	501.1	F	7	3	3	15	--	67	3	2	
1648	502.3	F	11	6	4	19	tr	54	3	3	Mgh tr
1654	504.1	F	54	6	4	56	--	3	3	3	
1659	505.7	F	44	14	1	23	2	10	--	6	Z tr
Alwinsal Potash Shaft				3-28-33-23W2M							
950	289.6	P	19	13	5	51	5	--	4	3	
955	291.1	P	16	13	6	58	5	--	2	--	
960	292.6	P	17	10	4	63	4	--	tr	2	
965	294.1	P	24	15	5	50	5	--	--	1	
970	295.7	P	16	10	5	59	4	--	2	2	Dol 2
975	297.2	P	26	12	7	48	5	--	--	2	
980	298.7	P	16	10	7	61	4	--	--	2	
985	300.2	P	15	11	7	61	4	--	--	2	
990	301.8	B	15	15	7	52	3	--	3	3	Dol 2

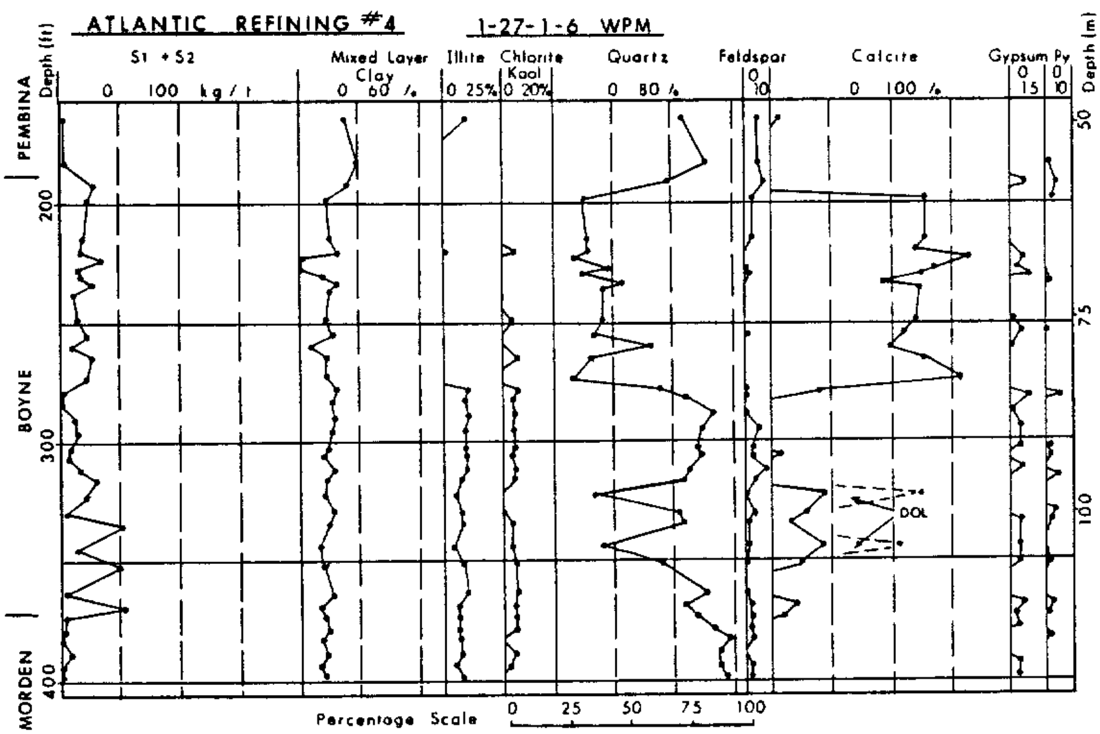
Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
995	303.3	B	17	14	7	50	--	tr	4	3	Dol 2, Bar 2, Sid tr
1000	304.8	B	11	8	5	45	2	18	5	3	Dol 3
1005	306.3	B	10	7	4	29	--	36	6	4	Gr 2, Dol 2
1010	307.8	B	6	5	5	27	--	47	5	3	Dol 2
1015	309.4	B	12	8	5	23	tr	46	4	2	
1020	310.9	B	10	6	4	36	--	36	4	2	Dol 2
1025	312.4	B	16	8	5	33	2	26	5	3	Dol 2, Sid tr
1030	313.9	B	8	5	4	31	--	45	3	2	Dol 2
1035	315.5	B	16	11	6	32	3	27	3	2	Dol tr
1040	317.0	B	16	7	4	31	--	36	4	2	
1045	318.5	B	13	18	8	35	5	13	3	3	Dol 2
1050	320.0	B	7	7	4	40	2	31	3	4	Dol 2
1055	321.6	B	11	9	4	21	tr	49	4	2	
1060	323.1	B	7	11	5	35	--	37	2	3	
1065	324.6	B	15	15	6	50	3	8	--	2	Sid 1
1070	326.1	B	18	13	tr	33	--	27	--	3	Ana 4
1075	327.7	B	21	17	3	32	tr	21	2	3	Dol 1
1080	329.2	B	27	--	--	24	4	18	--	3	Bt 24
1085	330.7	M	38	--	2	20	8	--	1	2	Sid 1, Bt 28
1090	332.2	F	8	--	tr	7	--	85	tr	--	
1095	333.8	F	7	4	3	18	--	61	4	3	Sid tr
1100	335.3	F	18	9	4	35	--	24	5	5	
1105	336.8	F	23	16	5	34	6	5	5	4	Sid tr
1113	339.2	F	21	13	6	48	4	--	4	4	
1115	339.9										
Imperial Okla #1			1-29-35-8W2M								
1057	322.2	F	9	4	3	8	--	68	3	2	Z 3
1063	324.0	F	12	tr	3	14	--	58	6	3	Tri 2, Bar 2
1068	325.5	F	7	5	4	15	tr	63	3	3	Dol tr
1072	326.7	F	8	5	4	17	tr	58	4	4	Z tr
1078	328.6	F	9	10	11	13	2	50	tr	3	Bar 2
1085	330.7	F	14	10	6	39	4	15	5	4	Bar 3
1098	334.7	F	12	9	7	61	tr	--	8	3	
Sohio Allenbee Lintlaw				4-15-35-10W2M							
1230	374.9	F	15	7	--	55	--	--	4	tr	Roz 7, Cli 6, Gib 3, Tri 3, Dol tr
1235	376.4	F	14	8	4	39	tr	--	--	tr	Roz 10, Anh 4, Jar 4, Gib 4, Tri 3, Lep? 3, Hem 2
1240	378.0	F	12	5	--	47	3	--	3	tr	Cli 7, Roz 5, Anh 4, Gib 3, Jar 3
1247	380.1	F	18	7	3	35	4	--	6	tr	Z 7, Roz 7, Gib 4, Tri 3, Anh 3, Dol 3
1251	381.3	F	17	9	6	50	3	--	3	4	Jar 5, Dol tr
1256	382.8	F	19	10	6	36	tr	--	8	3	Lau? 12, Jar 6, Bas tr

Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
1260	384.0	F	19	6	2	34	3	24	3	6	Ank 3
1263	385.0	F	12	6	2	18	--	54	4	4	Dol tr
1270	387.1	F	tr	--	--	10	--	90	tr	tr	
1275	388.6	F	tr	--	--	12	--	86	--	2	Jar tr
1279	389.8	F	6	tr	--	11	--	80	--	3	Hem tr
Grey Oil Syndicate #1	16-10-44-27W2M										
1182	360.3	F	6	3	--	25	tr	49	tr	5	Cli 10, Sid 2, Tri tr
1190	362.7	A	21	11	2	38	--	--	3	3	Cli 22
1195	364.2	A	23	14	7	40	4	--	tr	4	Jar 4, Mel tr, Sid tr
Amoco Senate	10-9-3-28W3M										
2666	812.6	F	14	6	4	40	tr	29	--	3	Ank 4, Anh tr
2670	813.8	F	36	4	15	27	2	10	tr	3	Dol 3
2674	815.0	F	48	8	12	16	--	10	2	2	Ank 2
2679	816.6	F	10	8	3	54	3	15	tr	2	Dol 5
2684	818.1	F	13	9	4	46	4	10	5	4	Dol 5, Sid tr
2690	819.9	F	12	8	4	55	3	6	2	4	Dol 4, Hem 2
2700	823.0	F	15	10	6	59	3	--	4	3	
2710	826.0	F	13	9	6	62	3	--	3	4	
Braddock Crown #1	5-7-14-10W3M										
2621	798.9	F	19	13	5	57	--	--	3	3	
2629	801.3	F	30	10	tr	8	--	50	tr	2	
2637	803.8	F	28	10	3	41	--	60	2	3	
2646	806.5	F	7	7	--	32	--	53	--	2	Dol 2
2654	808.9	F	11	7	3	24	2	46	3	2	Dol 2, Sid tr
2660	810.8	F	19	10	3	45	7	10	2	4	
2667	812.9	F	29	12	4	46	3	--	3	3	
2673	814.7	F	26	11	4	47	3	--	3	2	Dia 4
NCO Horsham	6-1-16-29W3M										
1666	507.8	B	15	13	8	49	3	3	5	2	Dol 2
1668	508.4	B	13	13	8	51	--	5	4	2	Dol 4
1671	509.3	B	16	11	8	55	tr	10	6	2	Dol 2
1676	510.8	B	13	9	6	57	2	3	5	3	Dol 2, Sid tr
1681	512.4	B	14	10	5	48	--	13	6	2	Dol 2, Sid tr
1686	513.9	B	10	7	4	59	3	5	2	3	Dol 7
1691	515.4	B	8	6	4	59	3	11	4	tr	Dol 5
1696	516.9	B	13	10	8	47	3	7	3	3	Dol 6
1701	518.5	B	11	9	5	57	3	2	2	2	Dol 9
1706	520.0	B	12	9	5	55	--	11	3	2	Dol 3
Norcanols Pennant #1	4-14-18-16W3M										
2414	735.8	F	9	4	7	18	tr	60	2	tr	
2418	737.0	F	9	4	10	14	--	59	tr	2	
2423	738.5	F	6	3	3	21	--	62	2	1	Dol 3, Gib tr
2427	739.8	F	5	7	5	32	--	41	5	2	Dol 2
2457	748.9	A	76	10	tr	5	11	--	--	2	Dol 2
2462	750.4	A	23	14	17	41	3	--	tr	2	

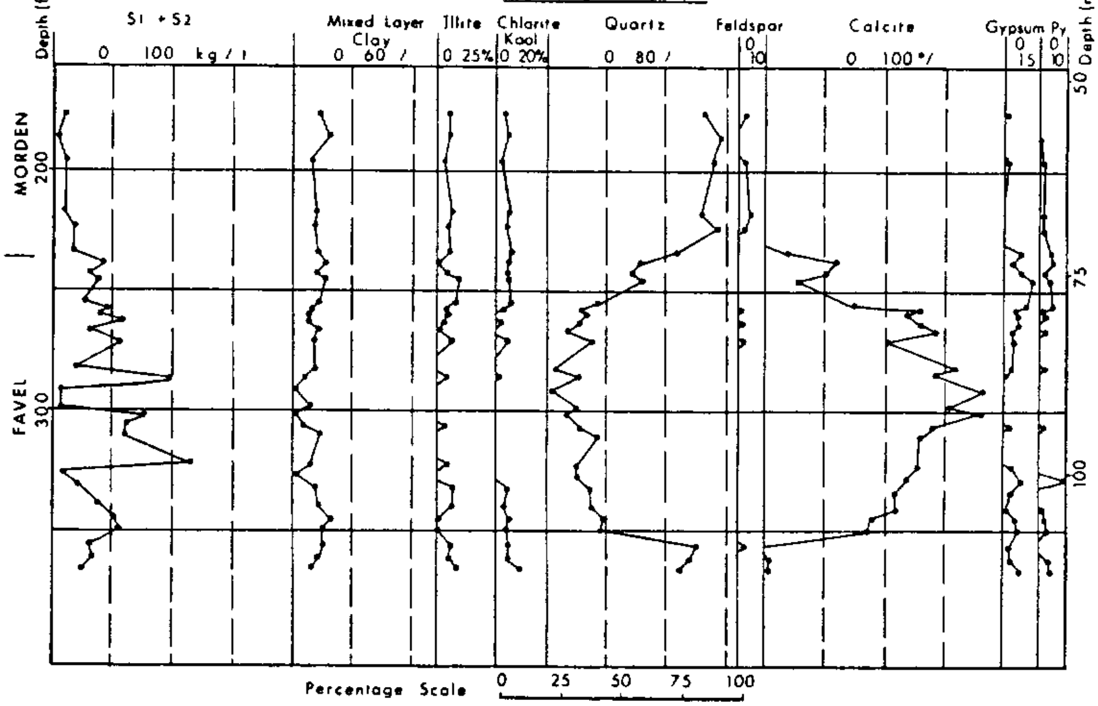
Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
Marvel Kamalta Plato 14-7-25-17W3M											
1723	525.2	F	16	7	3	27	--	38	4	3	Dol 2
1726	526.1	F	11	7	--	25	tr	45	4	6	Dol 2, Bas tr, Sid tr
1730	527.3	F	9	6	5	32	--	38	4	3	Dol 3
1732	527.9	F	8	8	3	25	2	43	5	4	Dol 2
1737	529.4	F	9	6	4	31	--	40	4	4	Dol 2
1742	531.0	F	14	12	7	51	3	3	3	2	Dol 4, Sid 1, Bas tr
1747	532.5	F	5	3	2	12	--	73	3	2	
1752	534.0	F	16	10	6	27	tr	31	5	5	
1758	535.8	F	14	7	7	40	3	16	7	6	
Imperial Smiley 5-9-31-25W3M											
1813	552.6	B	12	8	3	50	tr	15	3	5	Dol 4
1827	556.9	B	17	9	4	60	4	--	3	3	
1840	560.8	B	11	8	5	71	3	--	--	2	
1850	563.9	B	12	10	6	68	4	--	--	--	
1860	566.9	B	13	11	6	65	3	--	--	2	
1880	573.0	B	12	10	5	68	3	tr	--	2	
1900	579.1	F	20	15	3	45	tr	3	5	2	Nat? 4, Anh 3, Dol tr
1910	582.2	F	18	7	--	40	tr	16	8	2	Nat 6, Dol 3, Sid tr
1925	586.7	F	13	7	3	23	3	40	4	4	Dol 3
1951	594.7	F	12	8	7	43	2	19	--	7	Dol 2
1955	595.9	F	8	7	5	19	2	52	3	4	Sid tr
1960	597.4	F	5	4	3	15	--	68	--	3	Dol 2
Cominco Vanscoy Potash Shaft 11-16-35-8W3M											
1170	356.6	P	15	16	6	53	3	--	5	2	
1175	358.1	P	16	12	7	53	3	3	--	2	Dol 2, Sid 2
1180	359.7	P	17	16	8	47	3	--	4	3	Bas tr
1185	361.2	P	17	15	7	55	4	2	--	2	
1190	362.7	P	15	14	8	51	3	--	4	2	Dol 3
1195	364.2	P	16	13	7	58	3	--	--	3	
1200	365.8	P	13	13	6	60	3	--	2	3	
1205	367.3										
1215	370.3	B	15	9	5	24	tr	36	5	4	Dol 2, Bas tr
1220	371.9	B	13	9	4	30	2	32	5	3	Dol 2
1225	373.4	B	14	10	5	30	2	27	3	4	Sid 3, Dol 2
1230	374.9	B	11	9	5	34	2	31	4	2	Dol 2, Bas tr
1235	376.4	B	12	12	6	29	--	33	4	2	Dol 2
1240	378.0	B	9	7	5	27	--	44	4	2	Dol 2
1245	379.5	B	10	9	4	28	2	39	4	2	Dol 2
1250	381.0	B	8	13	5	35	tr	32	3	2	Dol 2
1255	382.5	B	7	11	6	28	tr	43	3	2	
1260	384.0	B	10	13	6	46	2	20	--	3	
1265	385.6	B	17	15	7	48	3	8	--	2	Dol tr
1270	387.1	B	13	20	7	33	tr	22	--	3	Dol 2
1275	388.6	F	15	16	7	46	4	9	--	3	
1280	390.1	F	21	17	9	39	4	7	--	3	

Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
1285	391.7	F	16	11	7	45	3	10	5	3	
1290	393.2	F	14	14	7	49	4	6	--	4	Dol 2
1295	394.7	F	15	15	7	50	4	4	3	4	
1300	396.2	F	15	19	7	45	4	7	--	3	
1305	397.8	F	17	17	7	52	3	6	--	2	
1310	399.3										
Duperow Crown #1	4-9-35-16W3M										
1862	567.5	F	15	15	7	51	3	6	--	--	
1869	569.7	F	11	13	3	47	2	20	--	--	Mgh 2
1882	573.6	F	10	7	4	58	2	13	3	--	
1889	575.8	F	14	10	5	45	3	21	--	--	
Eagle Hill #2	3-6-36-14W3M										
1701	518.5	P	18	14	7	51	4	--	3	--	Dol 3
1709	520.9	P	16	9	6	62	2	--	--	2	Dol 3
1719	524.0	B	12	7	5	34	--	33	3	3	Dol 3
1726	526.1	B	10	12	4	41	2	28	--	3	
1737	529.3	B	14	14	5	44	4	15	tr	4	
1744	532.8	B	19	13	5	40	3	18	--	2	
1749	533.1	B	13	10	5	49	3	14	3	3	
1755	534.9	B	21	14	7	31	--	10	--	4	Dol 3
1761	536.8	B	10	--	7	42	2	3	--	3	Bt 33
1772	540.1	B	17	14	6	52	4	4	--	3	
1780	542.5	B	15	12	7	58	4	2	--	3	Bas tr
Verbata #2	7-24-41-24W3M										
1220	371.9	B	16	11	5	35	tr	27	3	3	
1227	374.0	B	13	9	5	40	--	29	--	4	Dol tr
1235	376.4	B	9	7	5	34	--	39	3	3	
1242	378.6	B	20	13	6	54	3	--	--	4	
1248	380.4	B	13	14	7	53	3	6	tr	4	
1255	382.5	B	14	12	5	43	3	16	3	4	
1262	384.7	B	15	13	6	55	2	6	--	3	
1268	386.5	B	15	10	5	48	3	11	--	3	Bas 3, Dol 2
1275	388.6	B	14	12	6	59	3	2	tr	4	
1281	390.4	B	16	10	6	50	3	8	3	4	Dol tr
1300	396.2	M	14	10	5	49	tr	12	3	4	Hal? 3
1306	398.1	F	15	10	4	49	3	16	--	3	
1311	399.6	F	26	10	--	46	3	--	4	4	Jar 7, Sid tr
1322	403.0	F	7	4	tr	39	tr	45	--	3	Dol 2
1326	404.2	F	11	6	--	39	tr	38	--	2	Dol 4
1331	405.7	F	26	4	--	25	--	40	tr	3	Dol 2
1342	409.0	F	9	6	2	35	tr	30	2	4	Cli 5, Mgh 4, Dol 3
1352	412.1	F	23	13	8	52	--	--	--	4	
St. Walburg #1	14-31-55-21W3M										
982	299.3	F	17	5	tr	21	--	23	3	6	Wur? 12, Cli 10, Sid 3
987	300.8	F	6	5	--	16	--	49	3	5	Cli 13, Sid 3

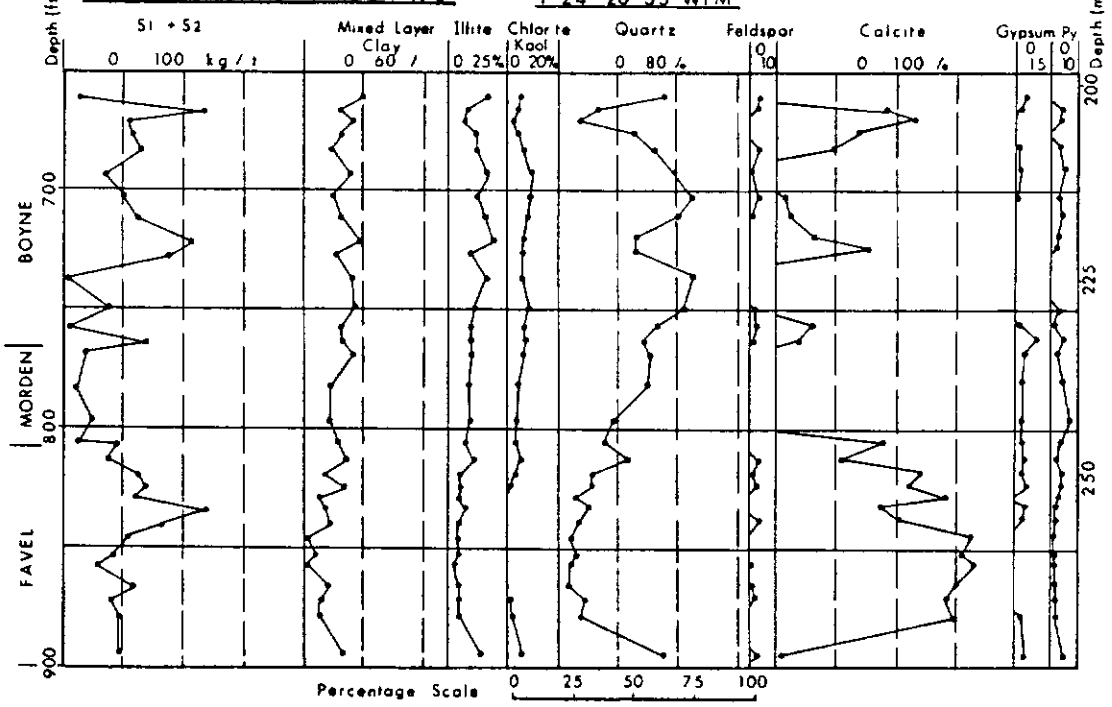
Depth (ft)	(m)	Zone	MLC %	Ill %	Ch/K %	Qtz %	F %	Cal %	Gyp %	Py %	Others %
Flotten Lake #2			4-10-65-17W3M								
275	83.8	B	14	11	4	30	4	16	3	6	Cli 9, Sid 3
308	93.9	B	11	7	--	28	--	27	--	5	Cli 18, Sid 4
315	96.0	M	24	13	--	48	10	--	3	tr	Sid 2
323	98.5	M	20	14	3	44	4	--	--	2	Cli 11, Sid 2
333	101.5	F	tr	--	--	6	--	81	3	3	Z 7, ..mph tr
340	103.6	F	9	5	--	10	3	62	3	5	Sid 3
344	104.9	F	4	3	--	8	3	38	2	4	Heu 35, Sid 4
352	107.3	A	38	9	3	36	4	--	2	--	Cli 5, Jar 3

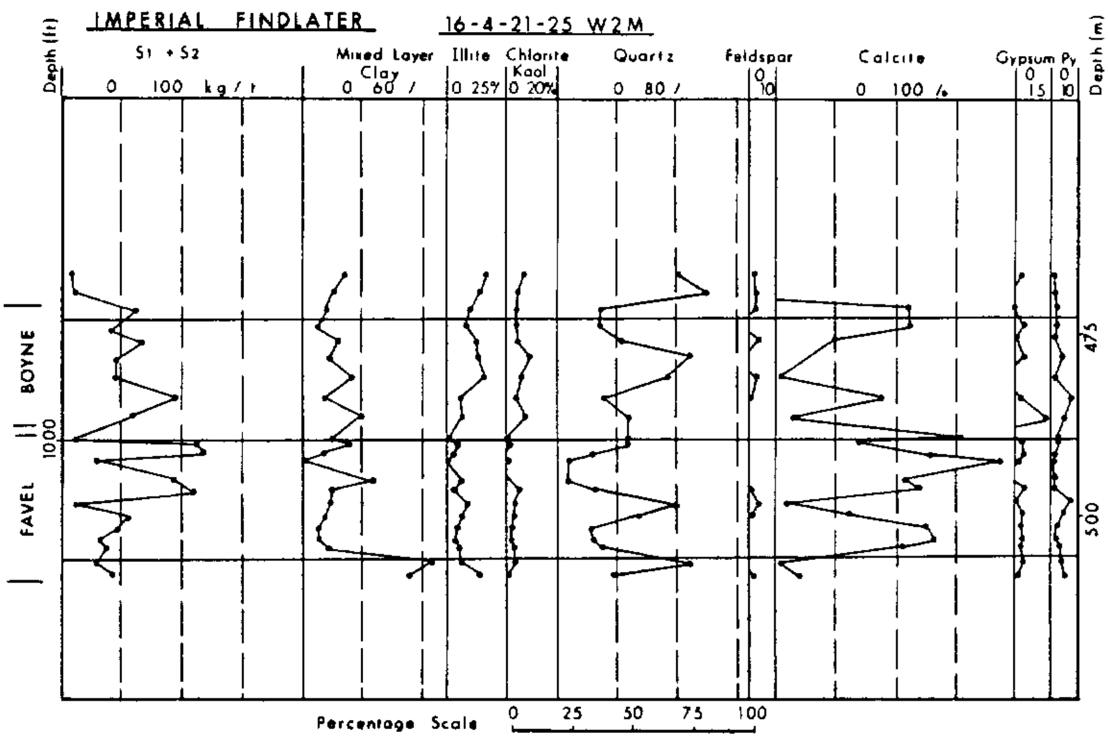


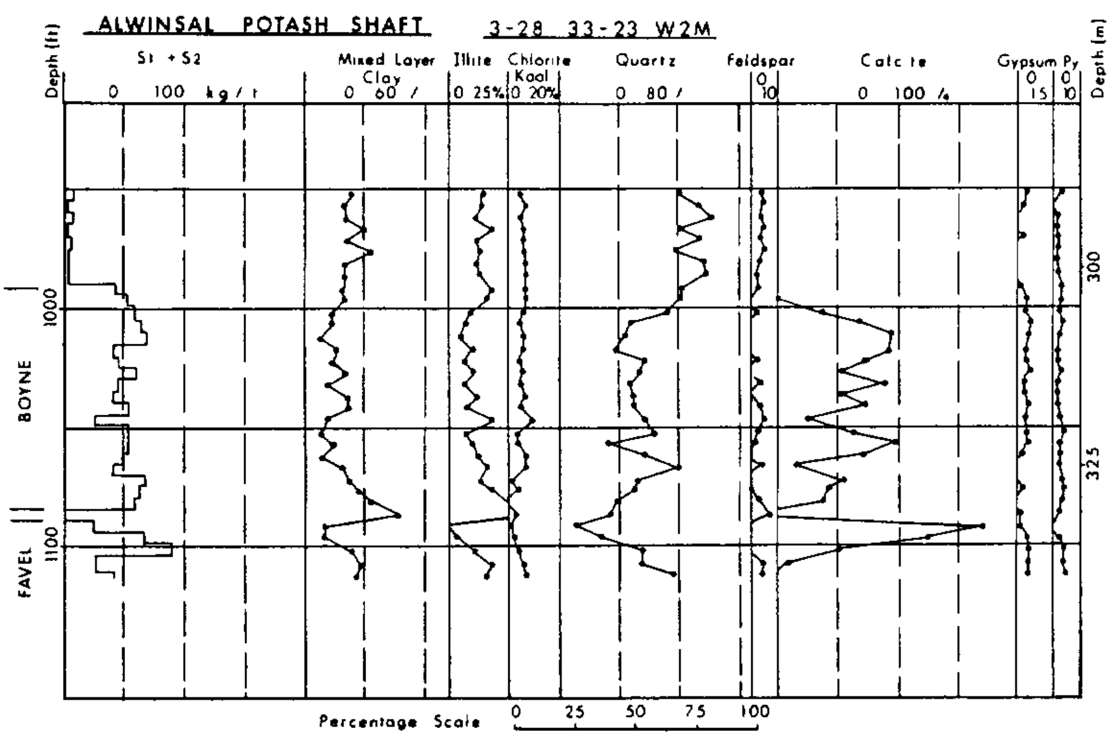
ATLANTIC REFINING #2 16-11-8-11 WPM

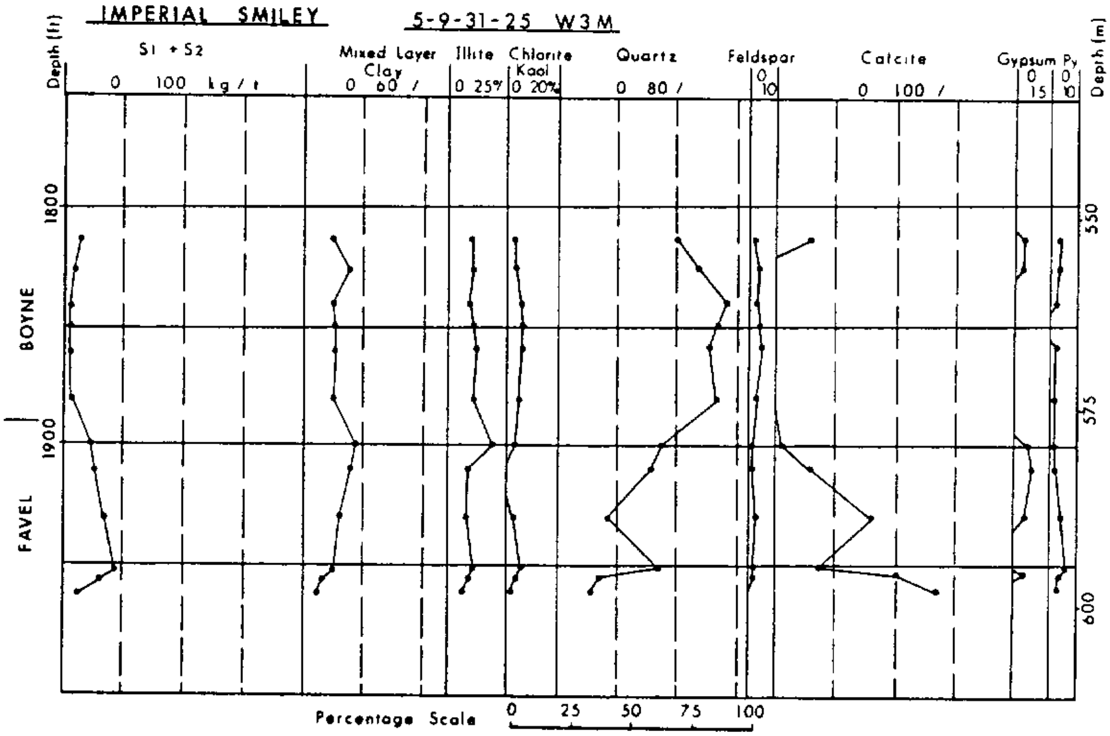


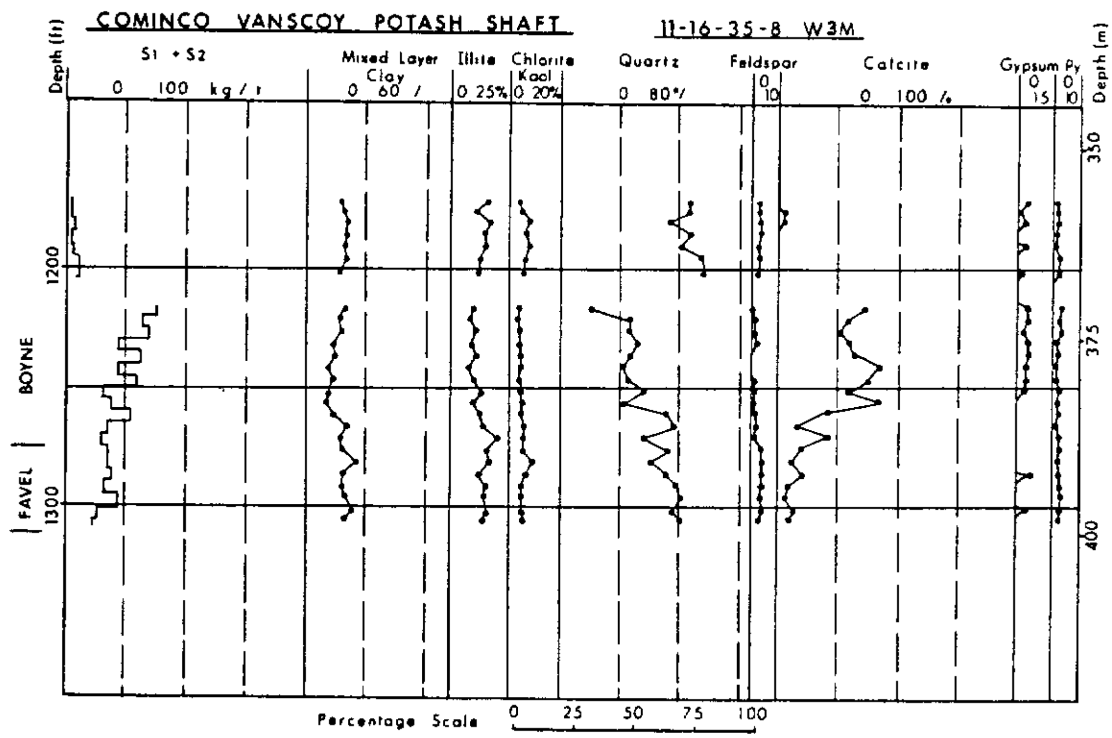
INTERNATIONAL YARBO 17S 1-24-20-33 WPM




IMPERIAL FINDLATER
16-4-21-25 W2M
Depth (ft)
S1 + S2
0 100 kg/t
Mixed Layer Clay
0 60 /
Illite
0 25%
Chlorite Kaol
0 20%
Quartz
0 80 /
Feldspar
0 10
Calcite
0 100 %
Gypsum
0 15
Py
0 10
Depth (m)
BOYNE
FAVEL
1000
475
500
Percentage Scale
0 25 50 75 100


ALWINSAL POTASH SHAFT
3-28 33-23 W2M
Depth (ft)
S1 + S2
0 100 kg/t
Mixed Layer Clay
0 60 /
Illite
0 25%
Chlorite Kaol
0 20%
Quartz
0 80 /
Feldspar
0 10
Calcite
0 100 %
Gypsum
0 15
Py
0 10
Depth (m)
1000
BOYNE
1100
FAVEL
300
325
Percentage Scale
0 25 50 75 100


IMPERIAL SMILEY
5-9-31-25 W3M
Depth (ft)
S1 + S2
0 100 kg/t
Mixed Layer Clay
0 60 /
Illite
0 25%
Chlorite Kaol
0 20%
Quartz
0 80 /
Feldspar
0 10
Calcite
0 100 /
Gypsum
0 15
Py
0 10
Depth (m)
1800
1900
550
575
600
BOYNE
FAVEL
Percentage Scale
0 25 50 75 100


COMINCO VANSCOY POTASH SHAFT
11-16-35-8 W3M
Depth (ft)
S1 + S2
0 100 kg/t
Mixed Layer Clay
0 60 /
Illite
0 25%
Chlorite Kaol
0 20%
Quartz
0 80%
Feldspar
0 10
Calcite
0 100 %
Gypsum
0 15
Py
0 10
Depth (m)
1200
1300
350
375
400
BOYNE
FAVEL
Percentage Scale
0 25 50 75 100

APPENDIX B

TOTAL ORGANIC CARBON & ROCK-EVAL DATA

ABBREVIATIONS

Depth

ft:	feet
m:	metres

Zones

P:	Pembina and equivalent strata overlying Boyne-First White Specks
B:	Boyne and First White Speckled shale
M:	Morden and shale beds separating the speckled shales
F:	Favel and Second White Speckled shale
A:	Ashville and equivalent strata underlying the Favel-Second White Specks

TOC:	Total organic carbon measured by weight present
Tmax:	Maximum temperature of pyrolysis
S_1:	Yield of free hydrocarbons, in milligrams/gram of rock
S_2:	Yield of hydrocarbons from pyrolysis of kerogen and bitumen, in milligrams/gram of rock
S_3	CO_2 produced by pyrolysis of organic matter, in milligrams /gram of rock
HI:	Hydrogen Index, the ratio of pyrolyzed hydrocarbon recovery (S_2) to percentage organic carbon content
OI.	Oxygen Index, the ratio of pyrolyzed CO_2 (S_3) to percentage organic carbon content
Pet Pot.	Petroleum Potential, total recovered hydrocarbons (S_1+S_2), in milligrams/gram, which equates to kilograms/tonne (kg/t)
PI.	Production Index, the ratio of free hydrocarbon to total recovered hydrocarbon ($S_1/(S_1+S_2)$)
Note	The Potash shafts were averaged samples over 5 foot intervals· the indicated depth is the top of the sampled section.

Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1 (mg/g)	S_2 (mg/g)	S_3 (mg/g)	HI	OI	Pet Pot kg/t	PI
Atlantic Refining #4			1-27-1-6WPM								
165	50.3	P	0.44	392	.00	.05	.49	11	111	.05	.00
183	55.8	P	1.86	415	.06	1.58	.51	84	27	1.64	.03
193	58.9	B	7.55	407	1.03	13.44	3.07	178	40	14.47	.07
198	60.4	B	5.20	423	.32	11.62	3.89	223	74	11.94	.02
215	65.5	B	4.57	424	.19	8.73	2.75	191	60	8.92	.02
220	67.1	B	4.10	425	.22	9.19	2.82	224	68	9.41	.02
224	68.3	B	5.42	415	.40	15.14	3.80	279	70	15.54	.02
229	69.8	B	3.93	423	.24	9.34	3.02	237	76	9.58	.02
230	70.1	B	4.26	418	.24	9.01	3.28	211	76	9.25	.02
234	71.3	B	5.75	419	.38	15.87	3.47	276	60	16.25	.02
238	72.5	B	3.72	424	.17	5.68	2.68	152	72	5.85	.02
249	75.9	B	4.30	421	.21	7.63	3.77	177	74	7.84	.02
255	77.7	B	5.32	420	.38	13.03	3.74	244	70	13.41	.02
260	79.2	B	3.46	421	.16	5.44	1.82	157	52	5.60	.02
265	80.8	B	5.03	423	.36	14.60	3.04	290	60	14.96	.02
274	83.5	B	4.37	414	.39	11.90	3.57	272	81	12.29	.03
279	85.0	B	1.85	421	.06	1.53	.98	82	52	1.59	.03
283	86.3	B	4.45	408	.12	2.50	1.07	56	24	2.62	.04
291	88.7	B	3.29	422	.22	6.09	1.34	185	40	6.31	.03
297	90.5	B	4.38	410	.76	8.75	1.50	99	34	9.51	.07
303	92.4	B	2.76	413	.32	4.05	1.11	146	40	4.37	.07
307	93.6	B	2.77	423	.16	5.10	1.20	184	43	5.26	.03
312	95.1	B	4.43	408	.84	7.85	2.01	177	45	8.69	.08
317	96.6	B	4.92	419	.62	16.06	2.32	326	47	16.68	.02
323	98.5	B	3.06	414	.38	9.49	2.00	310	65	9.87	.03
330	100.6	B	1.51	413	.06	1.29	.97	85	64	1.35	.04
335	102.1	B	6.76	414	.97	25.05	3.24	370	47	26.01	.03
345	105.2	B	3.01	415	.33	6.73	1.81	223	60	7.06	.04
352	107.3	B	7.05	416	.94	25.01	3.52	355	49	25.94	.03
364	111.0	B	2.57	407	.40	2.07	1.06	80	41	2.47	.16
368	112.2	B	6.82	415	1.00	27.43	3.79	401	55	28.43	.03
374	114.0	M	2.64	415	.17	3.45	1.64	131	62	3.62	.04
379	115.5	M	1.99	411	.20	2.06	.81	103	40	2.26	.08
384	117.0	M	2.03	419	.09	2.27	.66	111	32	2.36	.03
389	118.6	M	2.65	411	.46	2.11	.77	79	29	2.57	.17
393	119.8	M	1.45	422	.30	1.23	.54	84	37	1.53	.19
399	121.6	M	1.31	433	.28	1.02	.64	77	48	1.30	.21
MMR Waskada		11-29-1-25WPM									
1560	475.5	M	2.22	418	.07	1.57	.83	70	37	1.63	.03
1570	478.5	F	3.82	418	.16	5.90	1.58	154	41	6.06	.02
1577	480.7	F	5.17	419	.32	14.03	1.72	271	33	14.35	.02
1583	482.5	F	4.30	423	.00	.10	.44	2	10	.10	.00
1588	484.0	F	2.80	417	.39	5.95	1.34	212	47	6.34	.06
1593	485.6	F	8.11	412	1.00	43.80	2.89	540	36	44.80	.02
1598	487.1	F	6.73	412	.78	36.81	3.34	546	48	37.59	.02
1603	488.6	F	4.97	412	.77	32.70	2.54	657	51	33.46	.02
1606	489.5	F	6.11	409	.84	35.97	2.58	588	41	36.80	.02
1611	491.0	F	6.31	411	.72	30.82	3.10	487	49	31.53	.02
1621	494.1	F	2.55	409	.17	6.96	1.67	272	65	7.13	.02
1631	497.1	F	4.90	410	.44	20.57	2.48	414	50	21.03	.02

Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1636	498.7	F	6.31	412	.33	17.57	2.31	277	36	17.82	.02
1641	500.2	F	1.63	422	.03	2.99	.89	183	54	3.02	.01
1646	501.7	F	1.50	420	.03	1.56	.62	104	41	1.59	.01
1651	503.2	F	4.43	412	.35	15.96	1.87	360	42	16 29	.02
1656	504.7	F	6.02	413	.54	26.77	2.86	445	47	27.30	.02
1660	506.0	F	7.06	413	.43	22.11	1.90	313	27	22.54	.02
Atlantic Refining #3				2-9-6-8WPM							
182	55.5	P	.35	479	.00	.30	.13	85	37	.30	.00
195	56.4	P	.31	353	.06	.19	.25	61	80	.25	.24
206	62.8	B	4.43	407	1.12	5.61	2.70	126	60	6.73	.16
211	64.3	B	4.90	412	.55	6.48	3.58	132	73	7.03	.07
220	67.1	B	8.75	408	1.32	15.93	5.69	182	65	17.25	.07
225	68.6	B	4.60	411	.60	4.42	3.82	96	83	5.02	.11
234	71.3	B	3.46	423	.34	7.26	3.75	209	108	7.60	.04
239	72.8	B	2.95	426	.10	3.75	3.69	127	125	3.85	.02
245	74.5	B	5.84	422	.39	17.25	4.43	295	75	17.64	.02
254	77.4	B	2.71	421	.13	4.09	2.68	150	98	4.22	.03
258	78.6	B	2.19	427	.06	2.56	2.30	116	105	2.62	.02
262	79.9	B	3.82	422	.22	7.92	2.78	207	72	8.14	.02
271	82.6	B	4.10	421	.17	6.94	3.40	169	82	7.11	.02
287	87.5	B	5.63	418	.19	6.39	3.57	113	63	6.58	.02
290	88.4	B	7.08	411	.54	20.48	5.06	289	71	21.01	.02
296	90.2	B	4.49	425	.36	12.80	4.26	285	94	13.16	.02
304	92.7	B	5.41	413	.57	20.47	3.59	378	66	21.04	.02
310	94.5	B	2.77	423	.12	4.71	1.89	170	68	4.83	.02
315	96.0	B	2.72	427	.10	4.72	1.78	173	65	4.82	.02
323	98.5	B	.95	418	.03	1.59	.67	167	70	1.68	.01
333	101.5	B	3.47	423	.33	7.55	1.22	217	35	7.88	.04
336	102.4	B	4.02	421	.33	11.75	2.25	292	55	12.08	.02
339	103.3	B	5.34	412	.71	20.94	2.50	392	47	21.65	.03
346	105.5	B	7.41	416	1.36	36.38	4.56	491	61	37.73	.03
347	105.8	B	4.10	416	.48	14.91	2.01	363	49	15.39	.03
355	108.2	B	4.18	414	.50	12.91	1.79	308	42	13.41	.03
360	109.7	B	3.19	409	.36	6.82	1.10	213	34	7.18	.05
365	111.3	B	9.86	409	2.04	52.70	4.59	536	46	54.72	.03
370	112.8	B	2.96	423	.25	7.42	1.38	250	46	7.67	.03
375	114.3	B	4.39	415	.59	16.33	2.73	371	62	16.92	.03
382	116.4	B	5.72	412	.66	21.09	3.89	368	68	21.74	.03
384	117.0	B	8.20	410	1.77	42.75	2.61	521	56	44.51	.04
395	120.4	M	1.69	404	.31	1.35	.69	79	40	1.66	.18
400	121.9	M	1.38	448	.19	1.30	.35	94	25	1.49	.12
405	123.4	M	1.30	449	.23	1.22	.47	93	36	1.45	.15
Atlantic Refining #2				16-11-8-11WPM							
177	53.9	M	2.92	413	.95	4.28	.95	146	32	5.23	.18
187	57.0	M	1.72	413	.22	1.36	.45	88	29	1.59	.13
197	60.0	F	3.80	413	1.19	6.07	1.36	159	35	7.26	.16
219	66.8	F	3.24	413	.96	4.74	1.20	146	37	5.70	.16
224	68.3	F	3.93	413	1.13	8.06	1.43	205	36	9.19	.12
236	71.9	F	3.78	419	.27	8.86	2.50	234	66	9.13	.02
241	73.5	F	5.31	416	.58	19.93	2.75	375	51	20.51	.02

Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
244	74.4	F	4.17	415	.64	16.06	3.08	368	70	16.70	.03
247	75.3	F	7.07	416	.87	21.92	3.31	307	46	22.79	.03
256	78.0	F	5.36	419	.50	14.31	2.40	266	44	14.81	.03
258	78.6	F	5.58	415	.73	22.87	3.46	410	62	23.59	.03
260	79.2	F	5.21	419	.58	19.51	3.34	370	63	20.09	.02
264	80.5	F	7.63	413	.99	29.21	4.46	376	57	30.19	.03
269	82.0	F	5.02	411	.48	14.43	3.55	289	71	14.91	.03
273	83.2	F	6.72	416	.92	28.05	3.84	417	57	28.96	.03
283	86.3	F	2.86	408	.26	8.59	1.69	299	58	8.85	.02
287	87.5	F	9.73	411	1.71	48.85	4.87	512	50	51.60	.03
293	89.3	F	1.63	423	.09	2.81	1.24	172	76	2.90	.03
298	90.8	F	1.98	428	.09	3.01	1.27	157	64	3.10	.02
302	92.0	F	8.16	413	1.13	38.23	4.18	468	51	39.35	.02
307	93.6	F	7.53	409	.79	31.72	4.64	420	61	32.49	.02
312	95.1	F	8.39	418	.72	30.82	4.16	367	49	31.54	.02
321	97.8	F	8.00	408	1.94	55.89	4.90	698	61	57.88	.03
326	99.4	F	10.76	420	.09	2.28	1.46	21	13	2.37	.03
331	100.9	F	2.10	421	.37	11.51	2.86	548	136	11.88	.03
341	103.9	F	4.69	417	.55	19.44	3.55	414	75	19.99	.02
345	105.2	F	5.74	416	.76	25.46	3.72	430	65	26.21	.02
350	106.7	F	6.50	428	.65	28.73	3.98	442	61	29.32	.02
356	108.5	F	6.82	413	1.18	16.00	1.96	234	28	17.18	.06
360	109.7	F	6.18	418	.68	18.49	3.90	299	63	19.17	.03
365	111.3	F	5.59	423	.82	19.43	2.27	347	40	20.25	.04
365	111.3	F	6.59	419	.59	12.30	1.80	186	27	12.89	.04
International Yarbo				1-24-20-33WPM							
662	201.8	P	3.59	414	.47	6.06	1.54	168	42	6.53	.07
669	203.9	B	11.28	412	2.27	56.12	6.25	497	55	58.39	.03
671	204.5	B	6.65	416	.94	28.44	4.09	427	61	29.38	.03
679	207.0	B	6.38	415	.81	28.79	3.59	451	56	39.60	.02
684	208.5	B	7.33	414	.98	32.03	3.59	436	48	33.01	.02
694	211.5	B	4.98	422	.46	17.46	2.17	350	43	17.92	.02
703	214.3	B	7.01	415	.71	23.35	3.76	333	53	24.06	.02
712	217.0	B	6.60	417	.80	28.56	3.11	432	47	29.36	.02
721	219.8	B	9.19	414	1.72	52.79	3.76	574	40	54.51	.03
728	221.9	B	7.27	412	1.45	42.70	3.91	587	53	44.15	.03
737	224.6	B	1.12	414	.03	.94	.70	83	62	.97	.03
750	228.6	B	5.55	412	1.05	18.90	2.05	340	36	19.95	.05
756	230.4	B	2.24	421	.26	3.55	1.88	158	84	3.81	.06
764	232.9	B	9.54	409	1.59	34.69	5.60	363	58	36.28	.04
768	234.1	M	6.23	401	1.01	7.96	3.01	127	48	8.97	.11
783	238.7	M	5.47	406	.69	5.44	2.52	99	46	6.13	.11
798	243.2	M	6.63	404	.86	11.25	3.38	170	50	12.11	.07
807	243.2	M	5.44	417	.37	8.35	3.43	153	63	8.72	.03
807	246.0	F	5.44	413	.90	21.74	5.03	399	92	22.64	.03
813	247.8	F	5.97	411	.85	17.50	3.82	293	63	18.35	.04
820	250.0	F	7.53	410	1.22	33.03	5.35	438	71	34.25	.03
825	251.5	F	7.45	410	1.15	35.19	4.93	472	66	36.34	.03
830	253.0	F	6.12	405	1.20	30.45	6.51	497	106	31.65	.03
835	254.5	F	9.52	404	2.65	57.57	8.26	604	86	60.22	.04
840	256.0	F	8.36	406	1.71	45.72	6.43	547	76	47.43	.03

Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
846	257.9	F	5.31	404	.97	25.32	5.10	476	96	26.29	.03
853	260.0	F	4.61	405	.67	21.45	6.34	465	137	22.12	.03
858	261.5	F	3.69	409	.42	13.82	4.77	374	129	14.24	.02
866	264.0	F	7.12	408	1.09	31.14	6.82	437	95	32.22	.03
871	265.5	F	5.07	410	.52	20.78	2.59	409	51	21.30	.02
879	267.9	F	4.63	413	.65	23.63	2.63	510	56	24.28	.02
895	272.8	F	6.20	412	.99	23.30	2.97	375	47	24.29	.04
Western Petroleums #1 16-15-29-32WPM											
250	76.2	B	3.44	412	.40	7.80	2.13	226	61	8.20	.04
260	79.2	B	7.30	412	1.14	26.09	4.30	357	58	27.23	.04
271	82.6	B	7.66	412	1.97	36.53	4.89	476	63	38.50	.05
275	83.8	B	8.61	408	2.60	43.98	5.81	510	67	46.58	.06
278	84.7	B	6.14	414	1.58	27.93	4.67	454	76	29.51	.05
Imperial Oxbow 15-36-2-3W2M											
2698	822.4	F	9.57	413	2.10	57.76	2.20	603	22	59.86	.03
2703	823.9	F	8.23	414	1.90	54.00	2.80	656	34	55.90	.03
2710	826.0	F	4.99	411	.84	23.53	2.40	471	48	24.37	.03
2718	828.4	F	4.85	414	.72	26.41	2.17	544	44	27.13	.03
2723	830.0	F	6.38	411	.88	33.25	2.50	521	39	34.13	.03
2728	831.5	F	7.43	413	1.12	41.38	2.90	556	39	42.50	.03
2733	833.0	F	5.98	411	.76	30.03	2.40	502	40	30.79	.02
2740	835.2	F	6.47	413	.83	32.44	2.44	501	37	33.27	.02
2743	836.1	F	4.16	416	.46	14.53	2.35	349	56	14.99	.03
2750	838.2	F	9.05	416	.81	38.49	2.44	425	26	39.30	.02
2757	840.3	F	9.34	411	1.68	61.25	2.88	656	31	62.93	.03
2764	842.5	F	7.46	414	.94	33.03	2.79	442	37	33.97	.03
2770	844.3	F	5.37	410	.68	17.68	2.41	329	44	18.36	.04
2780	847.3	F	6.11	417	.61	22.23	2.16	363	35	22.84	.03
Bobjo Alameda #1 16-4-5-2W2M											
2103	641.0	B	1.74	424	.10	1.00	.44	57	25	1.10	.09
2126	648.0	B	2.74	424	.16	3.91	.93	142	33	4.07	.04
2135	650.8	B	6.57	411	.58	18.67	2.07	284	31	19.25	.03
Dome Talmage 11-36-10-13W2M											
2257	687.9	F	6.57	418	1.74	63.45	2.91	965	44	65.19	.03
2262	689.5	F	5.54	415	1.26	36.59	2.40	660	43	37.85	.03
2267	691.0	F	9.56	413	1.75	56.06	2.51	586	26	57.81	.03
2272	692.5	F	5.49	413	.44	7.82	1.03	142	18	8.26	.05
2280	694.9	F	7.49	418	.57	2.51	1.00	33	13	3.08	.18
2283	695.9	F	9.67	414	.67	18.54	1.29	191	13	19.21	.03
Imperial Findlater 16-4-21-25W2M											
1533	467.3	P	2.45	419	.26	1.90	.03	77	1	2.16	.12
1541	469.7	P	3.12	419	.37	5.06	.00	162	0	5.43	.06
1549	472.1	B	6.07	412	3.54	25.67	6.21	422	102	29.21	.12
1554	473.7	B	5.03	410	1.93	16.06	5.77	319	114	17.99	.10
1560	575.5	B	7.17	412	1.75	31.62	5.56	441	77	33.37	.05
1566	477.3	B	6.39	416	.92	20.64	3.68	323	57	21.56	.04
1573	479.5	B	5.80	415	.81	21.04	2.80	362	48	21.85	.02
1583	482.5	B	9.35	417	2.30	44.61	10.43	477	112	46.91	.04

Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1	S_2 mg/g	S_3	HI	OI	Pet Pot kg/t	PI
1590	484.6	B	9.80	402	1.46	28.77	5.31	293	54	30.23	.03
1601	488.0	M	1.74	410	.40	2.44	1.73	135	99	2.84	.13
1602	488.3	F	9.07	407	2.50	54.75	6.25	604	69	57.25	.04
1607	489.8	F	9.86	408	4.98	52.24	8.69	529	88	57.22	.08
1611	491.0	F	3.45	404	2.42	13.72	3.82	397	110	16.14	.14
1619	493.5	F	8.04	411	1.67	44.19	6.16	549	76	45.86	.03
1622	494.4	F	9.06	411	3.99	49.93	9.09	551	100	53.92	.07
1628	496.2	F	7.22	420	.46	3.05	.36	42	4	3.51	.13
1633	497.7	F	5.95	410	1.89	25.60	7.42	430	124	27.49	.06
1638	499.3	F	3.81	408	1.43	22.67	8.10	595	212	24.10	.05
1644	501.1	F	5.03	412	1.14	15.42	2.48	306	49	16.56	.06
1648	502.3	F	5.30	414	1.00	17.92	6.49	338	122	18.92	.05
1654	504.1	F	5.66	412	.47	14.04	3.09	248	54	14.51	.03
1659	505.7	F	5.24	414	.66	20.60	3.07	393	59	21.26	.03
Alwinsal Potash Shaft				3-28-33-23W2M							
950	289.6	P	3.87	412	.30	4.66	2.65	120	68	4.96	.06
955	291.1	P	1.34	422	.03	.50	.00	37	0	.53	.05
960	292.6	P	2.78	411	.20	2.67	.34	89	3	2.87	06
965	294.1	P	1.32	420	.00	.39	.00	29	0	.39	.00
970	295.7	P	1.98	417	.06	1.25	.00	63	0	1.31	.04
975	297.2	P	1.30	430	.03	.38	.00	29	0	.41	.07
980	298.7	P	1.84	420	.03	.62	.00	33	0	.65	.04
985	300.2	P	2.01	420	.06	1.26	.00	62	0	1.32	.04
990	301.8	B	6.90	410	.73	21.36	4.00	309	57	22.09	.03
995	303.3	B	6.23	411	.71	24.09	2.01	386	32	24.80	.10
1000	304.8	B	7.21	412	.81	28.06	2.95	389	40	28.87	.02
1005	306.3	B	7.06	410	1.20	30.43	3.22	431	45	31.63	.03
1010	307.8	B	7.44	414	.94	32.32	3.29	434	44	33.26	.02
1015	309.4	B	5.14	410	.61	19.54	2.72	380	52	20.15	.03
1020	310.9	B	5.24	410	.67	21.10	2.41	402	45	21.77	.03
1025	312.4	B	7.14	409	.90	27.92	3.27	391	45	28.82	.03
1030	313.9	B	5.50	410	.60	20.73	2.81	376	51	21.33	.02
1035	315.5	B	5.05	419	.42	18.55	2.00	367	39	18.97	.02
1040	317.0	B	6.00	411	.80	25.51	2.44	425	49	26.31	.03
1045	318.5	B	4.48	419	.39	11.58	1.75	258	39	11.97	.03
1050	320.0	B	4.75	412	.62	24.66	2.64	519	55	25.28	.02
1055	321.6	B	5.76	414	.57	25.03	2.95	434	51	25.60	.02
1060	323.1	B	6.16	411	.65	25.27	2.86	410	46	25.92	.02
1065	324.6	B	4.67	413	.56	18.51	1.61	396	34	19.07	.02
1070	326.1	B	6.84	409	1.04	32.67	2.74	477	40	33.71	.03
1075	327.7	B	6.31	411	.88	29.54	2.78	468	44	30.42	.02
1080	329.2	B	6.07	412	.72	27.93	2.68	460	44	28.65	.02
1085	330.7	M	.70	402	.00	.47	.37	67	52	.47	.00
1090	332.2	F	3.04	405	.38	10.16	1.75	334	58	10.54	.03
1095	333.8	F	7.76	409	.79	31.34	3.93	403	50	32.13	.02
1100	335.3	F	8.51	414	1.14	42.09	3.33	494	39	43.23	.03
1105	336.8	F	4.55	414	.39	10.09	1.61	221	35	10.48	.03
1113	339.2	F	6.15	402	1.16	18.53	2.32	301	37	19.69	.05
1115	339.9										

Imperial Okla #1 1-29-35-8W2M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1057	322.2	F	6.98	405	1.34	31.88	3.56	456	51	33.22	.04
1063	324.0	F	8.11	410	1.59	39.53	4.05	487	49	41.12	.04
1068	325.5	F	8.64	412	1.49	40.33	4.33	466	50	41.82	.04
1072	326.7	F	9.80	411	2.19	50.54	4.32	515	44	52.73	.04
1078	328.6	F	5.18	421	.63	20.90	3.05	403	58	21.53	.03
1085	330.7	F	10.05	411	2.07	56.19	4.01	559	39	58.26	.04
1098	334.7	F	7.70	399	1.15	23.22	2.37	301	30	24.97	.05

Sohio Allenbee Lintlaw 4-15-35-10W2M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1230	374.9	F	5.90	405	.70	7.98	2.48	135	42	8.68	.08
1235	376.4	F	5.13	407	.54	7.60	2.29	148	44	8.14	.07
1240	378.0	F	5.97	404	.71	8.91	2.98	149	49	9.62	.07
1247	380.1	F	6.05	409	.67	9.42	2.94	155	48	10.09	.07
1251	381.3	F	5.74	404	.77	11.14	3.29	194	57	11.91	.06
1256	382.8	F	2.34	405	.68	8.63	3.31	368	141	9.31	.07
1260	384.0	F	6.20	412	1.41	30.83	2.93	497	47	32.24	.04
1263	385.0	F	8.64	405	2.30	49.36	4.68	571	54	51.66	.04
1270	387.1	F	9.30	409	1.45	34.10	3.54	366	38	35.55	.04
1275	388.6	F	6.86	407	1.11	23.58	3.38	339	49	24.39	.05
1279	389.8	F	8.95	412	2.15	51.91	4.24	580	47	54.06	.04

Grey Oil Syndicate #1 16-10-44-27W2M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1182	360.3	F	10.40	407	1.85	43.23	5.18	415	49	45.08	.04
1190	362.7	A	2.67	413	.29	3.02	.74	113	27	3.31	.09
1195	364.2	A	2.93	417	.35	3.78	.93	129	31	4.13	.09

Amoco Senate 10-9-3-28W3M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
2666	812.6	F	3.47	413	.26	7.90	1.04	227	29	8.16	.03
2670	813.8	F	3.59	414	.29	9.57	.19	266	5	9.68	.03
2674	815.0	F	3.14	418	.39	8.75	.58	278	18	9.14	.04
2679	816.6	F	5.22	408	.73	20.93	2.26	400	43	21.66	.03
2684	818.1	F	4.96	410	.65	17.87	2.64	360	53	18.52	.04
2690	819.9	F	4.04	411	.69	13.25	.75	327	18	13.94	.05
2700	823.0	F	3.41	404	.29	4.11	.00	120	0	4.40	.07
2710	826.0	F	3.55	407	.26	4.28	.00	120	0	4.54	.06

Braddock Crown #1 5-7-14-10W3M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
2621	798.9	F	2.42	415	.13	1.89	.81	78	33	2.02	.06
2629	801.3	F	2.81	419	.41	9.72	1.95	345	69	10.13	.04
2637	803.8	F	10.09	414	1.47	56.98	4.10	564	46	58.45	.03
2646	806.5	F	6.82	412	.80	29.54	3.55	433	52	30.34	.03
2654	808.9	F	2.32	427	.10	3.25	1.40	140	60	3.35	.03
2660	810.8	F	3.97	424	.25	10.90	1.19	274	29	11.15	.02
2667	812.9	F	4.37	404	.46	8.27	1.39	189	31	8.73	.05
2673	814.7	F	4.49	411	.19	3.21	.91	73	20	3.40	.06

NCO Horsham 6-1-16-29W3M

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1666	507.8	B	3.74	417	.27	5.06	2.75	135	73	5.33	.05
1668	508.4	B	4.18	418	.39	8.81	3.16	210	75	9.20	.04
1671	509.3	B	3.98	421	.43	9.09	2.22	228	55	9.52	.05
1676	510.8	B	3.05	417	.26	5.04	.52	165	17	5.30	.05

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1681	512.4	B	3.80	418	.43	8.60	2.33	226	61	9.03	.05
1686	513.9	B	1.71	417	.17	.95	.00	55	0	1.12	.15
1691	515.4	B	1.21	414	.09	.65	.00	53	0	.74	.12
1696	516.9	B	2.88	419	.22	2.20	.00	76	0	2.42	.09
1701	518.5	B	2.67	415	.16	1.18	.00	44	0	1.34	.12
1706	520.0	B	2.72	420	.37	1.44	.74	52	27	1.81	.20

Norcanols Pennant #1 4-14-18-16W3M

2414	735.8	F	5.02	414	1.02	26.89	2.52	535	50	27.91	.04
2418	737.0	F	3.04	415	.49	9.90	1.02	325	33	10.39	.05
2423	738.5	F	5.02	417	.55	17.92	2.39	356	41	18.47	.03
2427	739.8	F	3.03	413	.83	26.65	2.97	879	98	27.48	.03
2457	748.9	A	1.32	414	.00	.13	.09	9	6	.13	.00
2462	750.4	A	1.89	426	.03	.59	.00	28	0	.57	.05

Marvel Kamalta Plato 14-7-25-17W3M

1723	525.2	F	8.11	408	.75	31.54	3.71	385	45	32.29	.02
1726	526.1	F	6.29	408	.67	19.93	3.25	316	51	20.60	.03
1730	527.3	F	7.38	411	.85	28.81	3.35	390	45	29.66	.03
1732	527.9	F	4.80	412	.42	17.24	3.01	359	62	17.66	.02
1737	529.4	F	5.78	424	.23	8.76	2.08	151	39	8.99	.03
1742	531.0	F	2.12	421	.10	2.65	.63	125	29	2.75	.04
1747	532.5	F	2.12	418	.13	2.96	1.15	139	54	3.09	.04
1752	534.0	F	8.50	412	.50	17.52	2.97	206	34	18.02	.03
1758	535.8	F	7.46	414	.67	24.79	3.18	332	42	25.46	.03

Imperial Smiley 5-9-31-25W3M

1813	552.6	B	3.51	423	.32	5.35	1.62	152	46	5.67	.06
1827	556.9	B	3.96	408	.19	2.97	1.19	75	30	3.16	.06
1840	560.8	B	3.98	425	.03	.52	.19	13	4	.55	.05
1850	563.9	B	1.55	409	.10	.98	.40	63	25	1.08	.09
1860	566 9	B	1.36	416	.10	.98	.47	72	34	1.08	.09
1880	573.0	B	6.56	410	.16	1.30	.39	19	5	1.46	.11
1900	579.1	F	5 65	402	.61	8.88	2.71	157	48	9.49	.06
1910	582.2	F	5.63	402	.68	11.93	2.43	212	43	12.61	.05
1925	586.7	F	4.93	414	.62	16.49	2.85	334	58	17.11	.04
1951	594.7	F	5.78	411	1.64	21.77	2.28	377	39	23.41	.07
1955	595.9	F	4.61	412	.85	14.73	2.89	319	62	15.58	.05
1960	597.4	F	5.98	413	.53	5.26	1.86	87	31	5.79	.09

Cominco Vanscoy Potash Shaft 11-16-35-8W3M

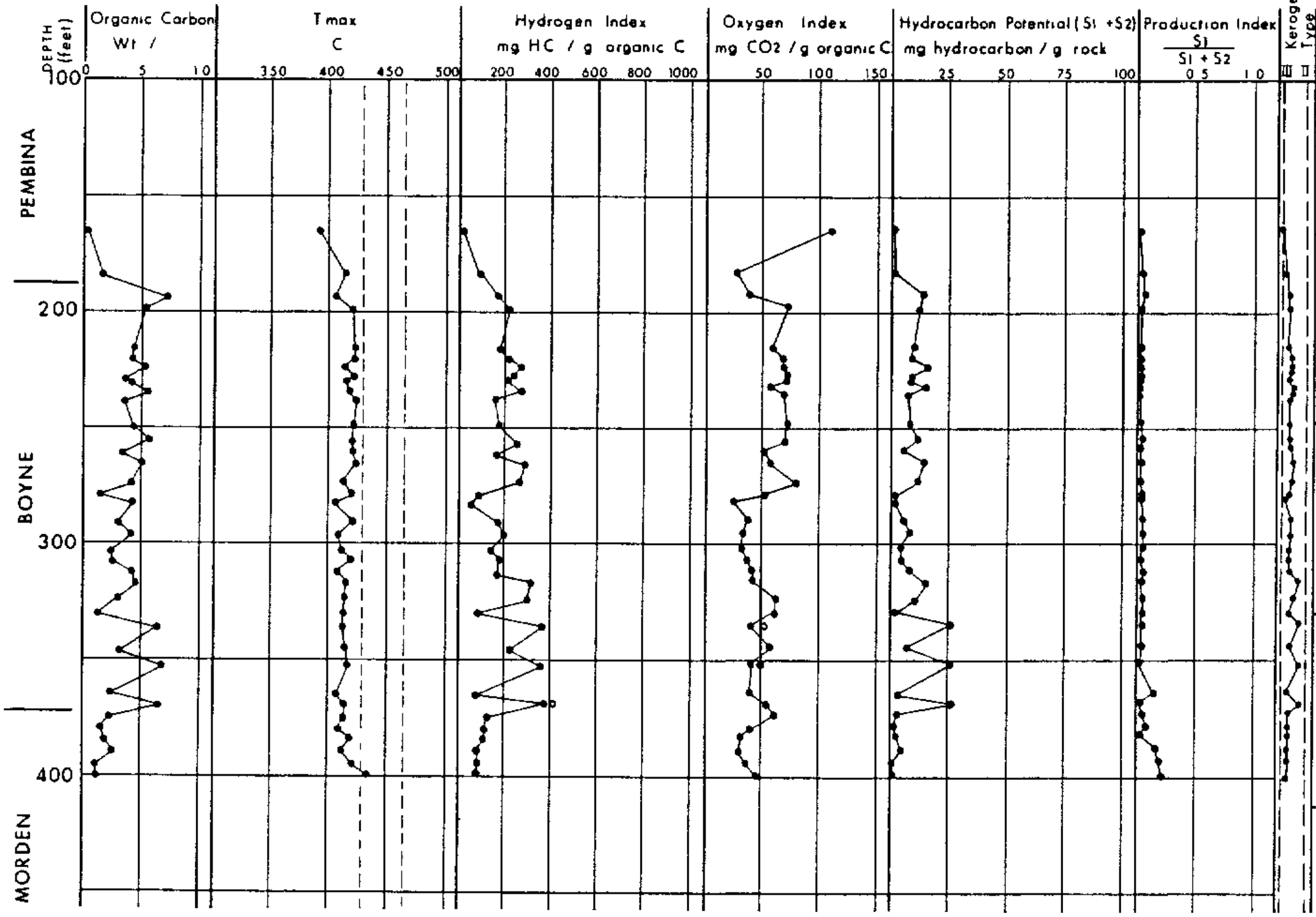
1170	356.6	P	2.56	410	.19	2.93	.86	114	33	3.12	.06
1175	358.1	P	2.40	419	.13	3.09	.84	128	35	3.22	.04
1180	359.7	P	2.55	415	.13	3.55	.63	139	24	3.68	.03
1185	361.2	P	2.08	417	.12	3.13	.37	150	17	3.25	.03
1190	362.7	P	2.16	415	.13	2.61	.59	120	27	2.74	.04
1195	364.2	P	3.08	416	.18	4.91	1.09	159	35	5.09	.03
1200	365.8	P	3.09	417	.19	4.84	1.09	157	35	5.03	.03
1205	367.3										
1215	370.3	B	7.19	413	.94	35.07	3.93	487	54	36.01	.02
1220	371.9	B	6.40	410	.82	30.07	3.40	469	53	30.89	.02
1225	373.4	B	6.54	410	1.00	31.81	3.52	486	53	32.81	.03

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1230	374.9	B	4.72	411	.50	19.22	2.75	407	58	19.72	.02
1235	376.4	B	5.54	410	6.64	23.23	2.90	419	52	29.87	.22
1240	378.0	B	5.08	409	.56	20.81	2.61	409	51	21.37	.02
1245	379.5	B	5.77	408	.71	27.78	2.98	481	51	28.49	.02
1250	381.0	B	3.92	415	.32	13.01	1.83	331	46	13.33	.02
1255	382.5	B	4.86	412	.47	17.84	2.61	367	53	18.31	.02
1260	384.0	B	6.06	413	.56	26.66	2.50	439	41	27.22	.02
1265	385.6	B	4.74	417	.43	15.11	1.95	318	41	15.54	.02
1270	387.1	B	4.21	416	.33	12.32	1.75	292	41	12.65	.02
1275	388.6	F	4.63	417	.47	14.99	1.74	323	37	15.46	.03
1280	390.1	F	4.53	418	.39	15.11	1.85	333	40	15.50	.02
1285	391.7	F	5.34	419	.37	18.10	2.47	338	46	18.47	.02
1290	393.2	F	4.95	419	.38	16.74	1.99	338	40	17.12	.02
1295	394.7	F	5.85	417	.46	20.86	2.39	356	40	21.32	.02
1300	396.2	F	5.51	419	.39	16.13	2.50	292	45	16.52	.02
1305	397.8	F	5.30	418	.34	14.84	1.85	280	34	15.18	.02
1310	399.3										
Duperow Crown #1		**4-9-35-16W3M**									
1862	567.5	F	3.46	420	.40	9.40	1.56	271	45	9.80	.04
1869	569.7	F	4.35	414	.54	14.76	2.29	339	52	15.30	.04
1882	573.6	F	6.16	417	.94	26.93	2.62	437	42	27.87	.03
1889	575.8	F	4.91	415	.77	21.66	2.20	441	44	22.43	.03
Eagle Hill #2		**3-6-36-14W3M**									
1701	518.5	P	1.84	421	.06	1.35	.88	73	47	1.41	.04
1709	520.9	P	2.04	426	.10	1.75	.68	85	33	1.85	.05
1719	524.0	B	4.18	417	.42	12.80	2.54	306	60	13.22	.03
1726	526.1	B	4.32	414	.36	11.91	2.34	275	54	12.27	.03
1737	529.4	B	5.06	415	.56	16.53	2.34	326	46	17.09	.05
1744	532.8	B	5.11	418	.70	21.52	2.33	421	45	22.22	.03
1749	533.1	B	5.84	419	.65	23.57	2.78	403	47	24.22	.03
1755	534.9	B	4.45	411	.93	14.71	2.67	330	60	15.64	.06
1761	536.8	B	3.26	422	.45	7.61	1.40	233	42	8.06	.07
1772	540.1	B	4.68	421	.52	14.80	1.75	316	37	15.32	.03
1780	542.5	B	4.43	421	.39	12.79	1.72	288	38	13.18	.03
Verbata #2		**7-24-41-24W3M**									
1220	371.9	B	4.91	421	.47	18.33	2.27	373	46	18.80	.02
1227	374.0	B	5.12	416	.58	19.28	2.69	376	53	19.80	.03
1235	376.4	B	9.84	414	.51	14.05	3.02	142	30	14.56	.04
1242	378.6	B	5.72	419	.47	12.43	1.74	217	30	12.90	.04
1248	380.4	B	5.83	417	.38	12.98	2.17	222	37	13.36	.03
1255	382.5	B	7.33	414	.72	25.86	2.78	352	37	26.58	.03
1262	384.7	B	5.85	418	.50	18.99	2.18	324	37	19.49	.03
1268	386.5	B	5.18	416	.51	18.60	2.43	359	46	19.11	.03
1275	388.6	B	5.07	418	.39	15.46	2.15	304	42	15.85	.02
1281	390.4	B	4.06	416	.67	11.71	1.91	288	47	12.28	.05
1300	396.2	M	3.65	419	.51	8.74	3.87	239	106	9.25	.06
1306	398.1	F	5.13	421	.51	19.83	2.20	386	42	20.34	.03
1311	399.6	F	5.60	396	.83	10.23	2.70	182	48	11.06	.08
1322	403.0	F	5.75	413	1.05	25.06	3.31	435	57	26.11	.04

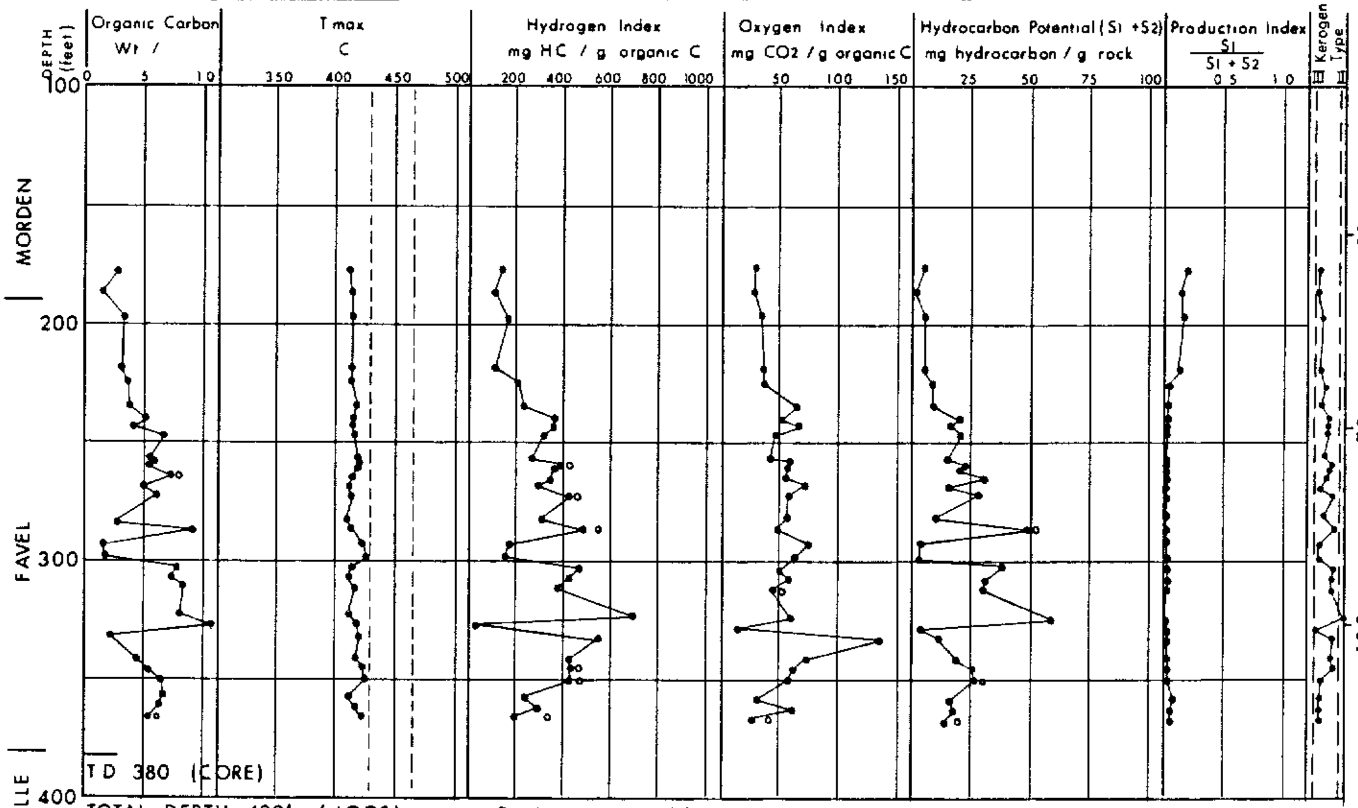
Depth (ft)	(m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
1326	404.2	F	6.28	416	.94	28.44	3.27	452	52	29.38	.03
1331	405.7	F	6.94	409	1.23	29.21	5.66	420	81	30.44	.04
1342	409.0	F	7.28	412	1.28	31.21	3.75	428	51	32.29	.04
1352	412.1	A	1.41	427	.06	1.11	.36	78	25	1.17	.05
St. Wahlberg #1			14-31-55-21W3M								
982	299.3	F	11.73	405	3.63	76.14	6.33	649	54	79.77	.05
987	300.8	F	8.85	411	1.60	38.83	4.	438	50	40.43	.04
Flotten Lake #2			4-10-65-17W3M								
275	83.8	B	9.35	411	1.74	40.33	5.43	431	58	42.07	.04
308	93.9	B	9.40	407	2.87	50.50	5.01	537	53	53.37	.05
315	96.0	M	2.01	411	.18	1.21	1.21	60	60	1.39	.13
323	98.5	M	1.99	406	.12	.50	.63	25	31	.62	.19
333	101.5	F	6.93	412	1.78	32.47	4.81	469	69	34.25	.05
340	103.6	F	9.59	407	3.08	48.07	5.40	501	56	51.15	.06
344	104.9	F	5.90	410	1.11	22.92	4.07	388	68	24.03	.05
352	107.3	A	2.68	411	.21	1.90	1.59	70	59	2.11	.10
Cdn. Sup. Oxley			6-33-11-28W4M								
	2364.7	F	1.88	442	.63	1.84	.30	97	15	2.47	.25
	2367.0	F	1.81	440	.51	1.33	.25	73	13	1.84	.27
	2369.5	F	1.92	438	.57	1.34	.10	69	5	1.91	.29
	2371.9	F	1.01	439	.19	.62	.06	61	5	.81	.23
	2374.4	F	1.89	438	.71	1.76	.13	93	6	2.47	.28
	2376.8	F	1.85	432	.63	1.49	.19	80	10	2.12	.29
	2379.2	F	2.03	436	.78	2.21	.19	108	9	2.99	.26
	2381.4	F	1.92	437	.58	1.29	.16	67	8	1.87	.31
	2383.9	F	2.68	439	.91	2.56	.33	95	12	3.47	.26
	2386.3	F	2.30	439	.62	1.09	.06	47	2	1.71	.36
	2388.7	F	3.12	441	1.15	2.82	.27	90	8	3.97	.28
	2391.2	F	2.78	440	1.30	3.23	.30	116	10	4.53	.28
	2393.6	F	1.79	436	.53	1.17	.16	65	8	1.70	.31
	2394.8	F	2.87	436	1.79	4.44	.47	154	16	6.23	.28
	2397.3	F	2.71	437	1.76	4.59	.64	169	23	6.35	.27
Amoco B-1 Youngstown				6-34-30-8W4M							
2268	691.3	F	4.14	416	3.23	8.93	1.00	215	24	12.16	.28
2276	693.7	F	4.37	417	1.86	11.18	1.30	255	29	13.04	.14
2289	697.7	F	5.03	417	5.37	18.43	1.49	366	29	23.80	.23
*2309	703.8	F	5.75	412	9.16	31.03	2.17	539	37	40.19	.23
2329	709.9	F	5.71	406	14.46	24.01	1.90	420	33	38.49	.38
2340	713.2	F	4.79	408	7.95	15.19	1.65	317	34	23.14	.34
2353	717.2	F	4.03	411	6.76	6.80	1.42	168	35	13.56	.50
2361	719.6	F	5.11	413	3.44	12.52	1.83	245	35	15.96	.22
2372	723.0	F	4.92	413	8.87	10.54	2.25	214	45	19.41	.48
2389	728.2	F	6.02	417	17.20	19.56	2.45	324	40	36.76	.47
2403	732.4	F	5.72	414	31.86	25.86	2.66	452	46	57.72	.55
2414	735.8	F	5.38	416	7.16	17.58	2.11	326	39	24.74	.29
2426	739.4	F	5.31	414	9.23	30.79	2.28	579	42	40.02	.23
2437	742.8	F	5.30	416	3.42	40.00	2.28	754	43	43.42	.08

Depth (ft)	Depth (m)	Zone	TOC %	Tmax °C	S_1 mg/g	S_2 mg/g	S_3 mg/g	HI	OI	Pet Pot kg/t	PI
2446	745.5	A	1.62	432	.55	2.40	.97	148	54	2.95	.19
2456	748.6	A	1.28	426	.77	1.14	.93	89	72	1.91	.40
*2318	706.5	F	6.22	409	8.89	29.29	2.54	470	40	38.18	.23
LCM et al Bashaw	10-34-42-22W4M										
	1035.7	F	2.70	419	.44	6.34	.79	234	29	6.78	.08
	1039.6	F	2.80	427	.32	3.63	.39	129	13	3.95	.08
	1043.2	F	3.01	420	.58	8.60	.55	285	18	9.18	.06
	1048.4	F	4.14	420	.96	20.13	.99	486	23	21.09	.05
	1052.4	F	2.34	421	.39	4.42	.75	186	32	4.81	.08
	1054.0	F	4.20	418	.71	17.12	1.33	407	31	17.83	.04
	1056.5	F	5.70	420	1.37	37.32	1.37	654	24	38.69	.04
	1059.7	F	4.57	417	.88	18.09	1.19	395	26	18.97	.05
	1061.8	F	1.81	423	.52	6.74	.78	372	43	7.26	.03
	1063.7	F	2.91	422	.50	6.13	.81	210	27	6.63	.08
	1065.8	F	3.12	424	.42	5.47	.72	175	23	5.89	.07
	1067.6	F	4.92	419	.85	15.26	1.28	310	26	16.11	.05
Anderson et al Paradise	10-22-47-3W4M										
1342	409.0	P	2.29	421	.46	2.24	.70	97	30	2.70	.17
1348	410.9	P	2.18	412	.19	2.42	.59	111	27	2.61	.07
1357	413.6	B	2.26	420	.19	3.25	.67	143	29	3.44	.06
1364	415.7	B	4.55	408	.51	7.22	1.30	158	28	7.73	.07
1368	417.0	B	5.24	403	.83	11.46	1.59	218	30	12.29	.07
1375	419.1	B	5.52	405	.99	17.84	1.65	323	29	18.83	.05
1381	420.9	B	5.56	405	.83	15.93	1.80	286	32	16.76	.05
1389	423.4	B	4.67	404	.83	13.40	1.66	286	35	14.23	.06
1398	426.1	B	2.00	403	.91	15.77	1.96	788	98	16.68	.05
1401	427.0	M	2.54	422	.22	4.54	1.38	178	54	4.76	.05
1405	428.2	F	3.17	409	.55	18.27	1.92	576	60	18.82	.03
1411	430.1	F	6.24	413	1.11	31.89	2.98	511	47	33.00	.03
1416	431.6	F	6.59	405	.96	31.83	3.47	483	52	32.79	.03
1422	433.4	F	7.28	408	.89	30.43	2.81	417	38	31.32	.03
1425	434.3	F	5.77	409	1.35	33.34	2.16	577	37	34.69	.03
1428	435.3	F	6.26	413	1.19	39.86	3.24	636	51	41.05	.02
1434	437.1	F	5.40	408	1.07	23.33	2.58	432	47	24.40	.04
1441	439.2	F	4.62	417	.80	11.24	2.04	243	44	12.04	.06
1446	440.8	F	7.84	406	1.34	37.37	2.49	476	31	38.71	.03
1451	442.3	A	1.38	419	.10	1.13	.53	81	38	1.23	.08
1457	444.1	A	1.51	421	.06	.94	.47	62	31	1.00	.06

ATLANTIC REFINING # 4 CORE HOLE 1-27-1-6 WPM



ATLANTIC REFINING # 2 CORE HOLE 16-11-8-11 WPM

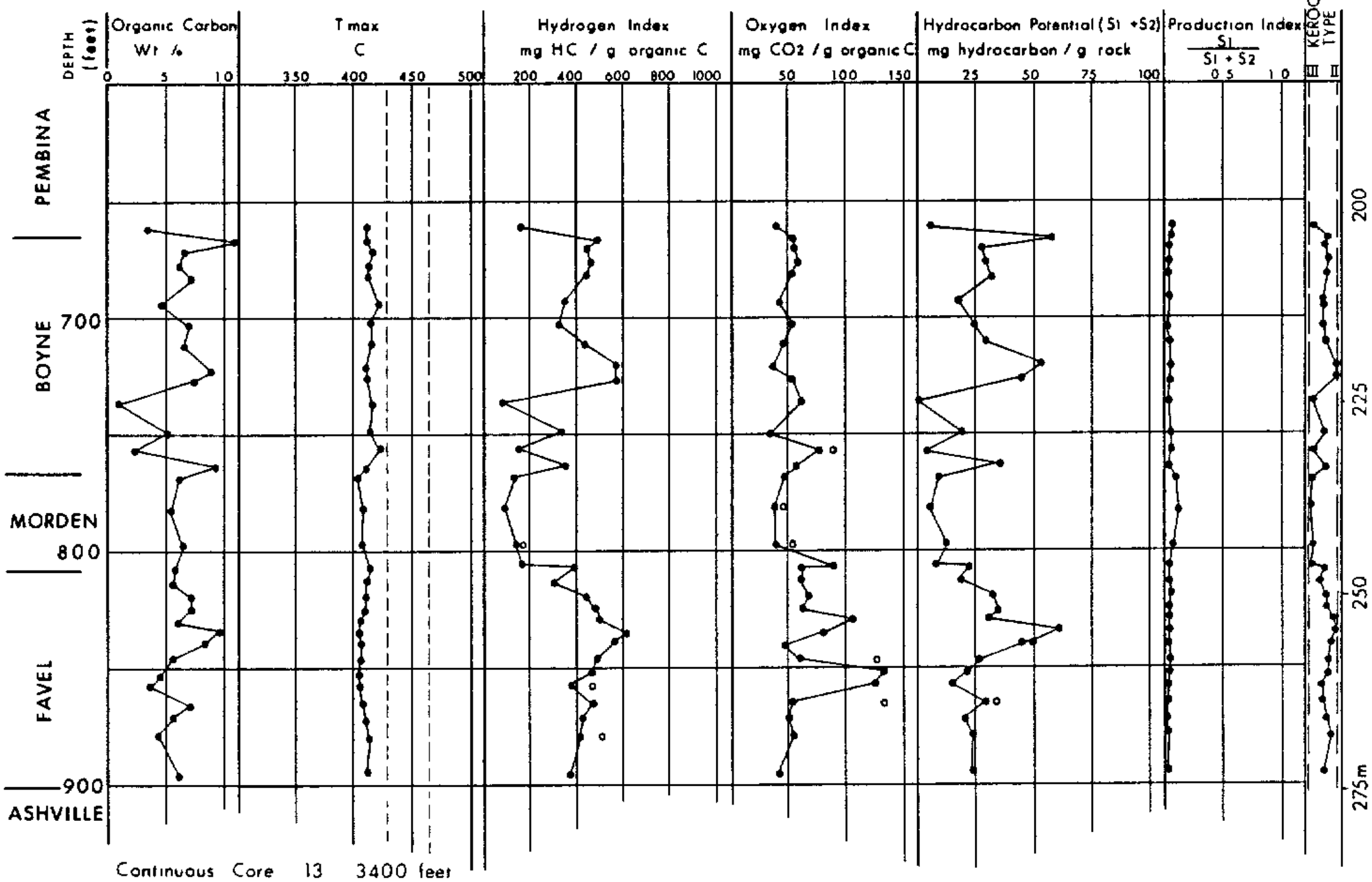


TOTAL DEPTH 400' (LOGS)

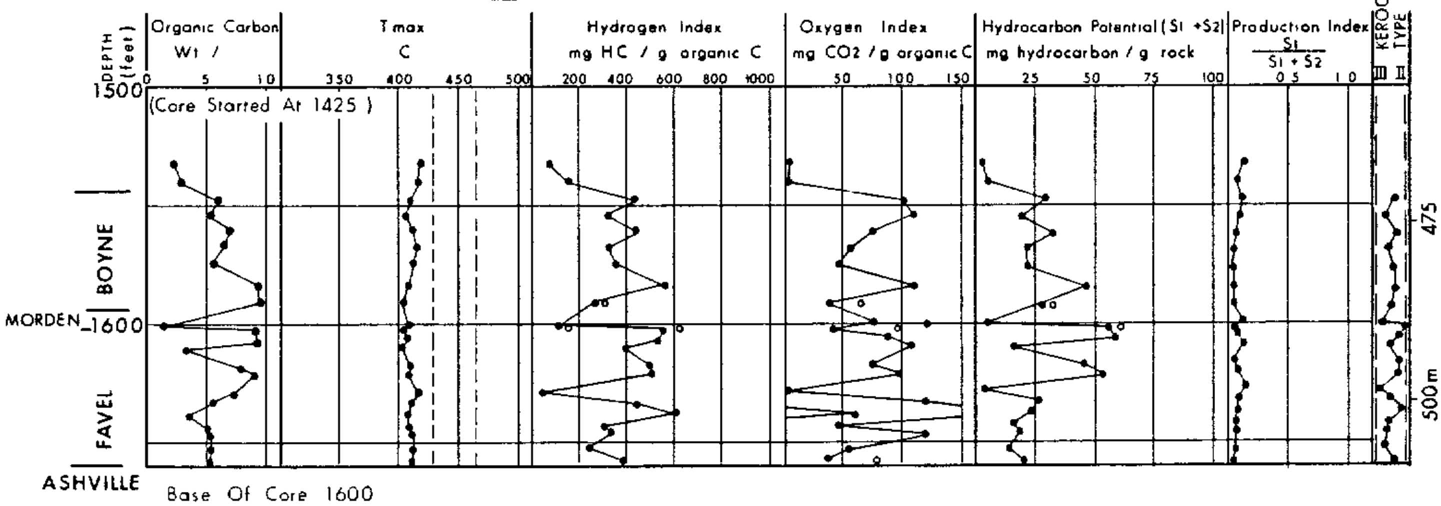
Depths not corrected for measurement errors

121 9m

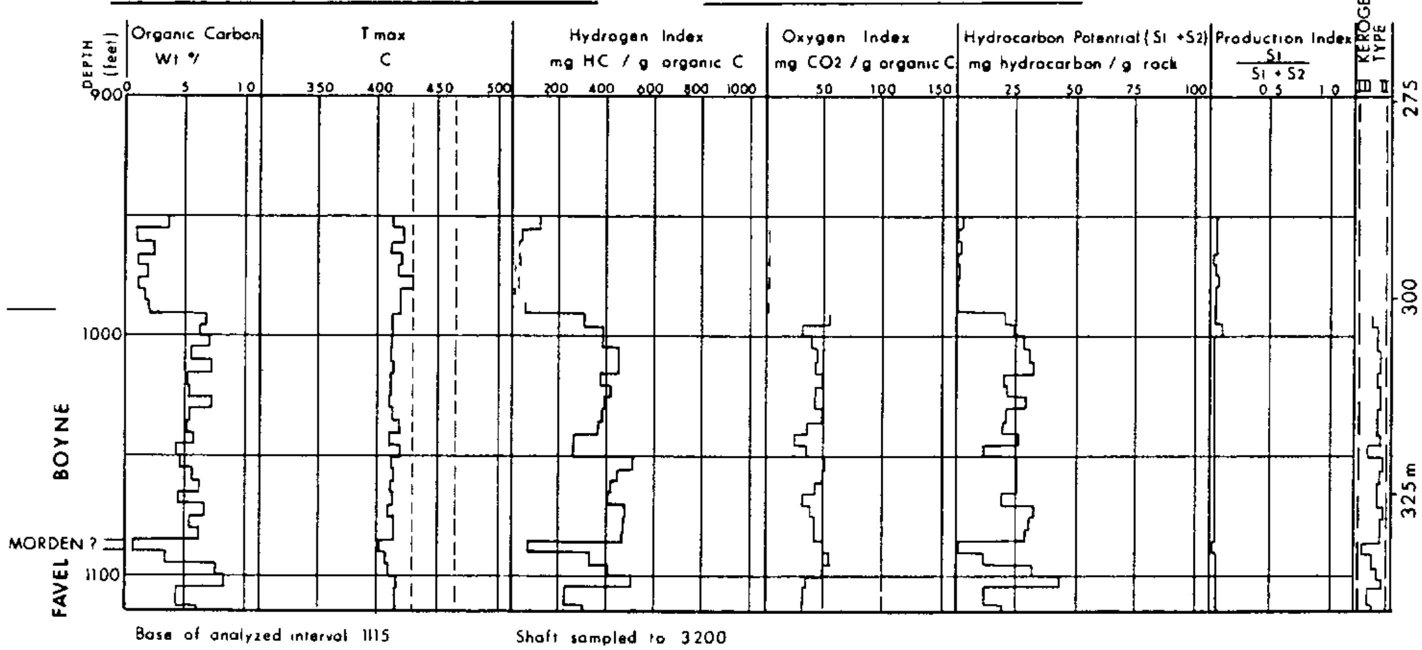
INTERNATIONAL YARBO 17S COREHOLE 1-24-20-33 WPM



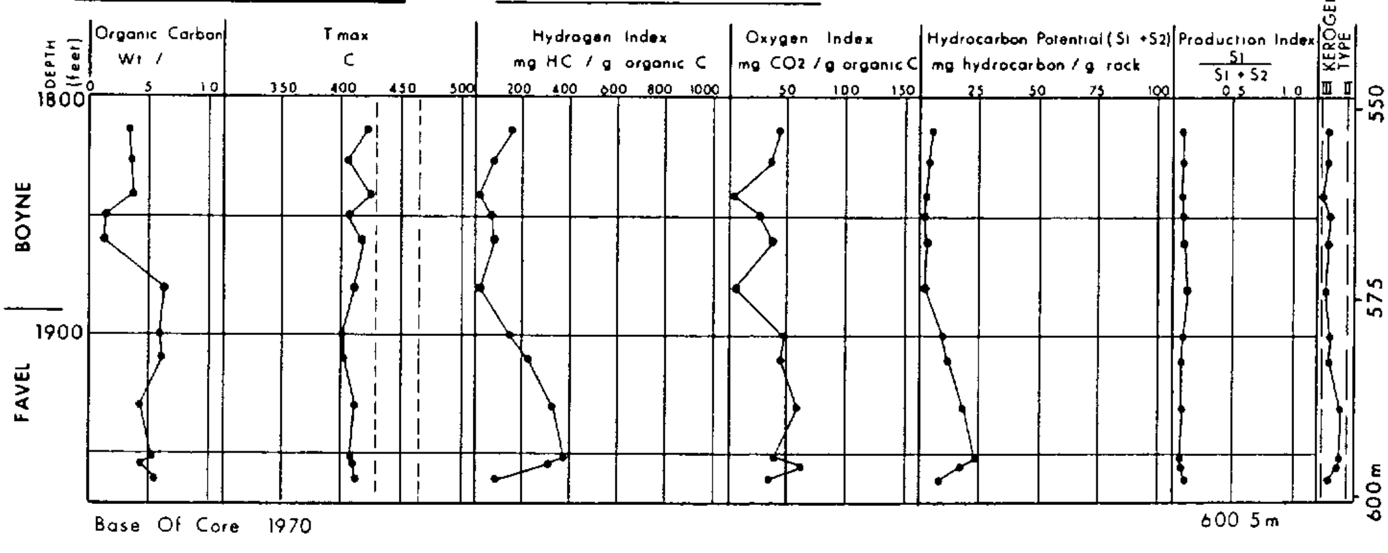
IMPERIAL FINDLATER 16-4-21-25 W2M



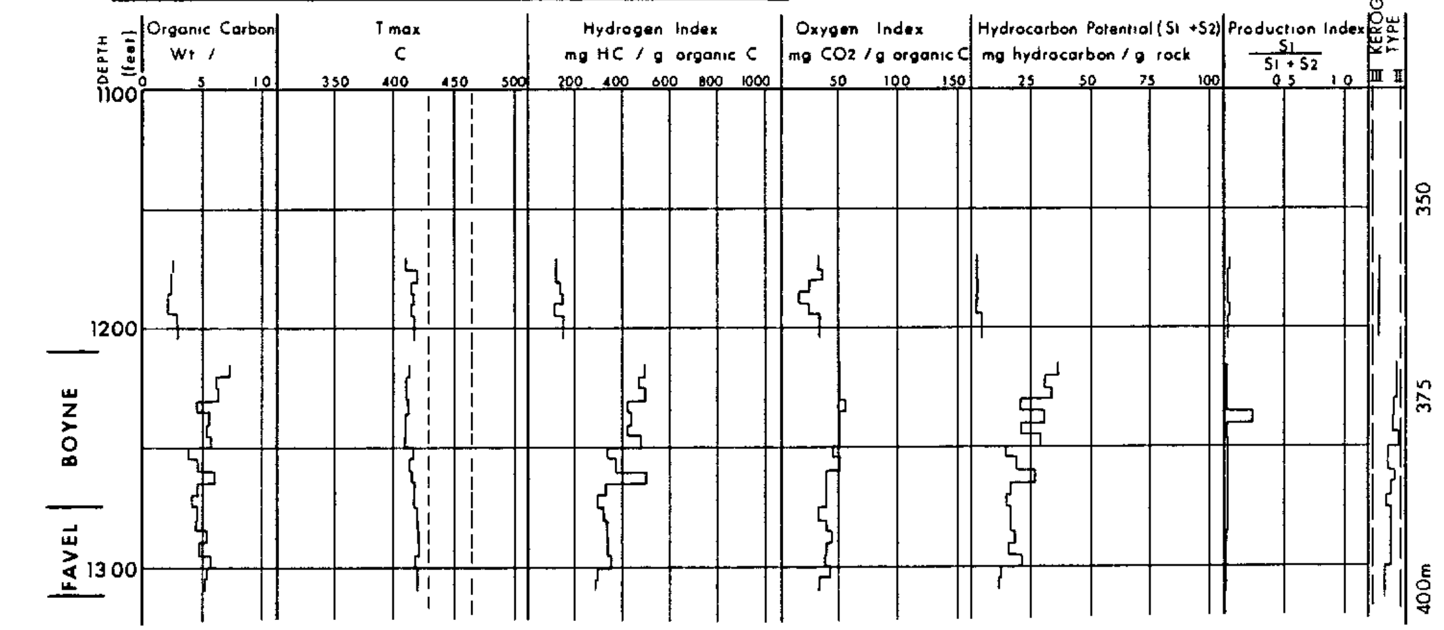
ALWINSAL POTASH SHAFT 3-28-33-23 W2M



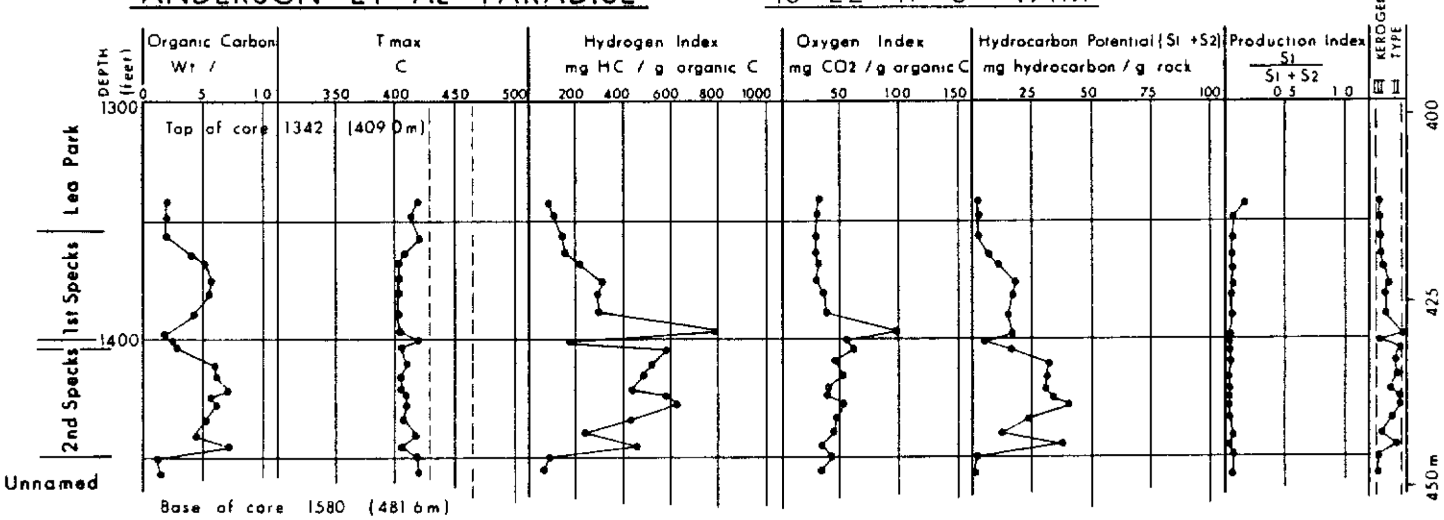
IMPERIAL SMILEY 5-9-31-25 W3M

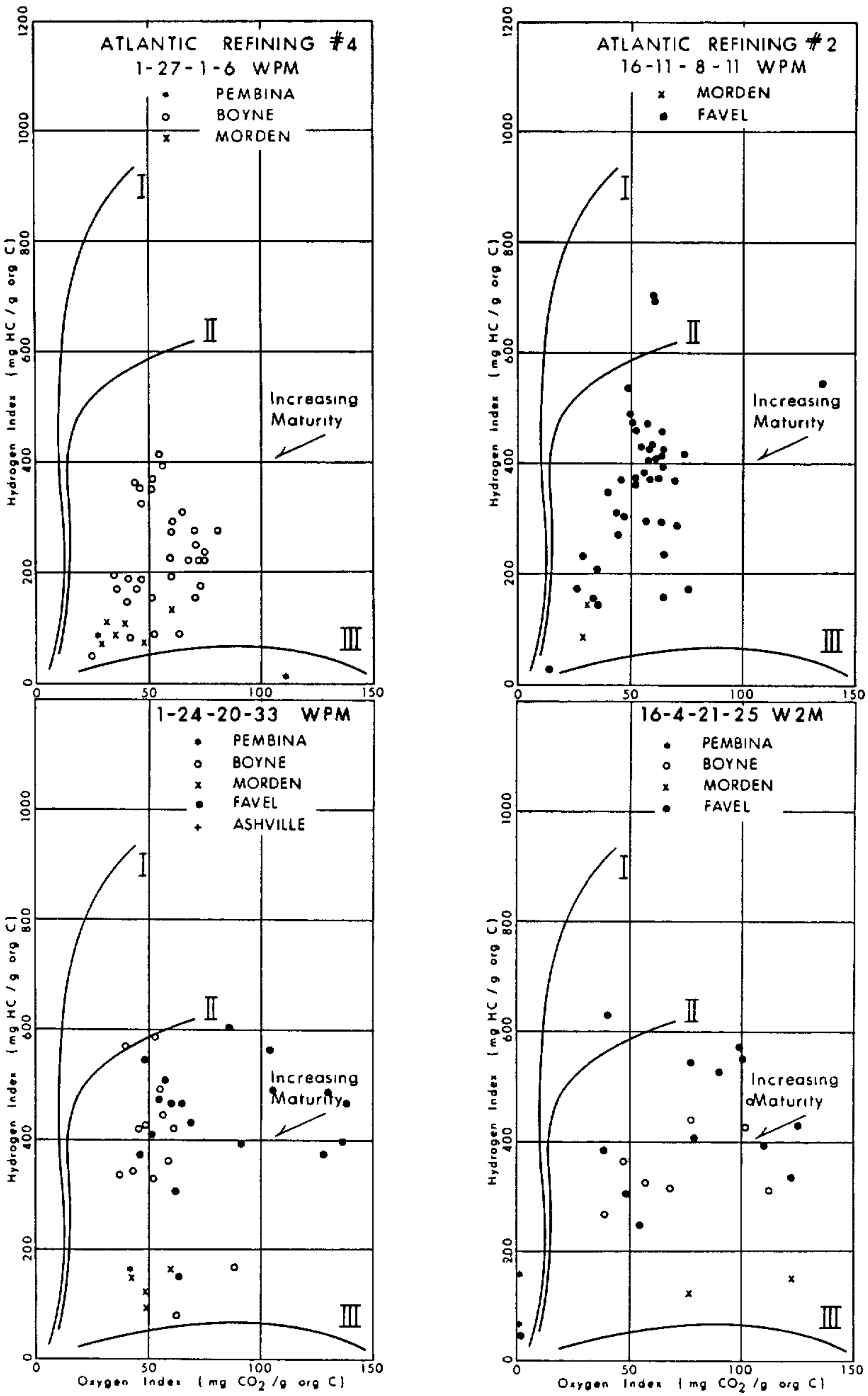


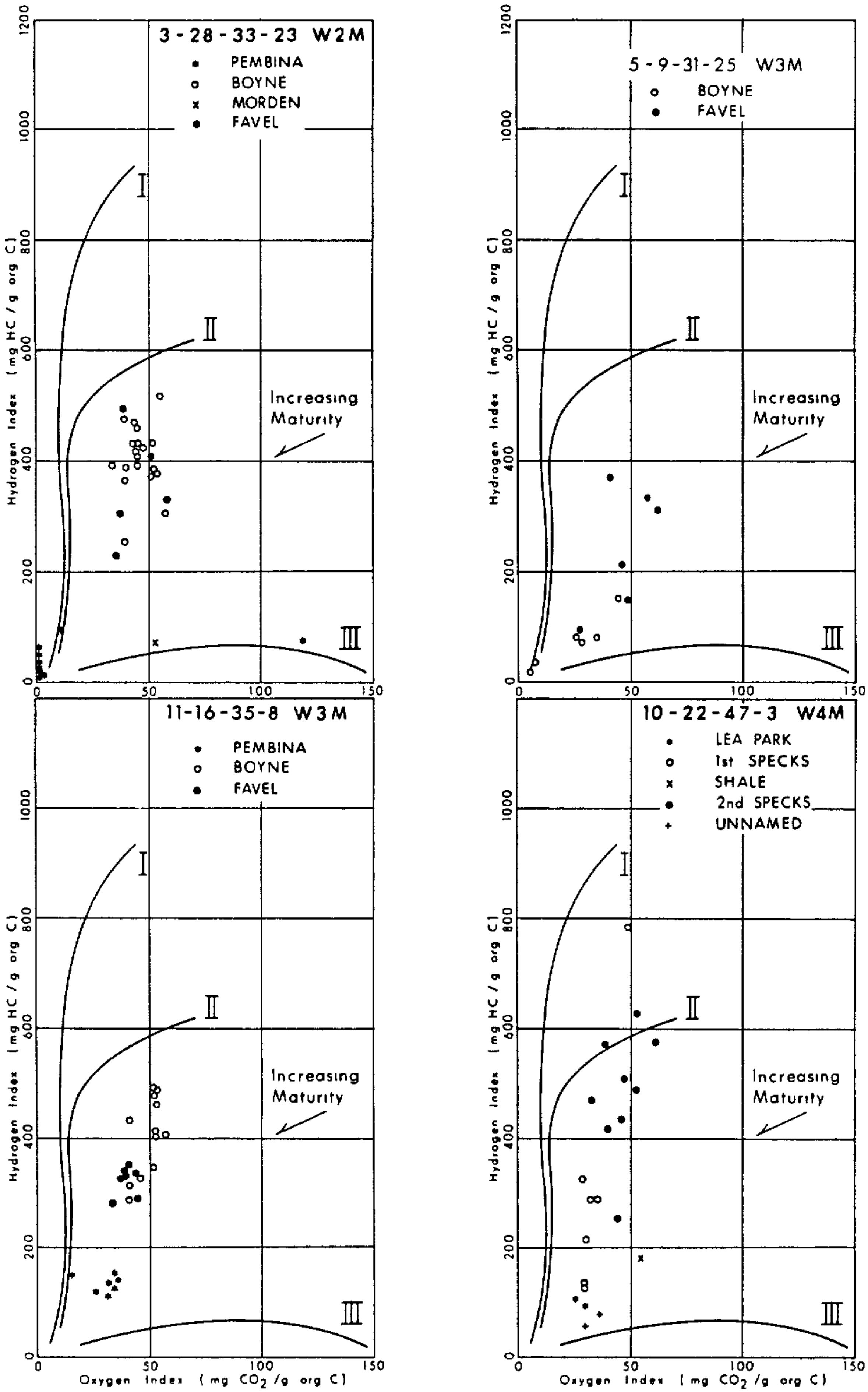
COMINCO VANSCOY POTASH SHAFT 11-16-35-8 W3M

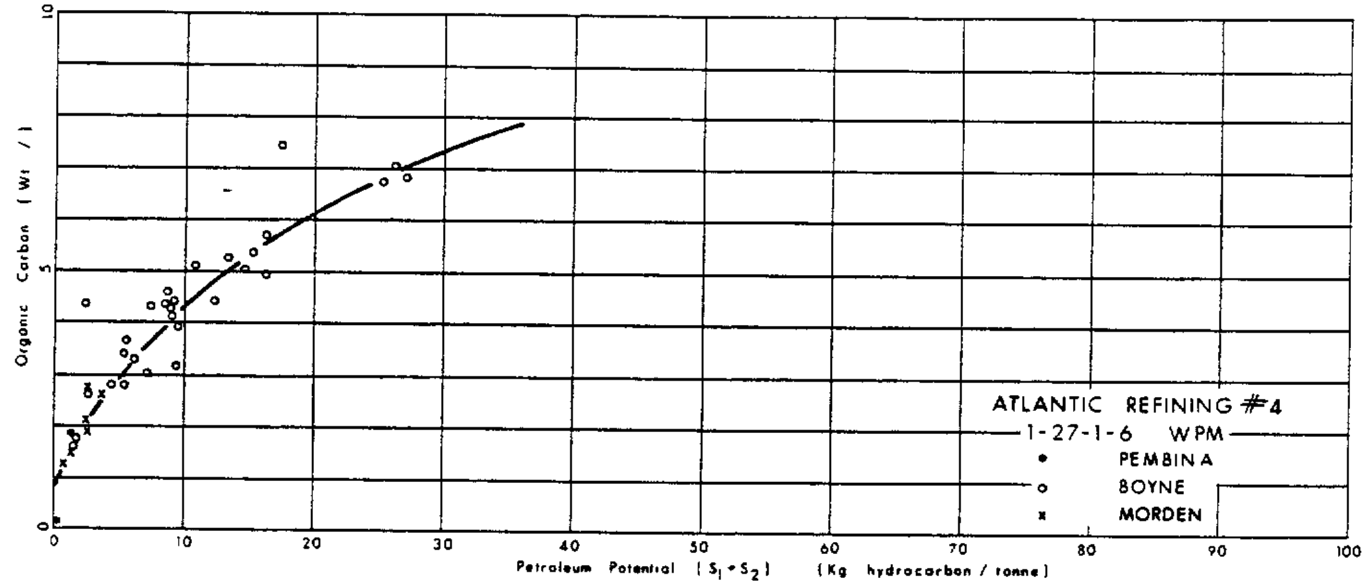


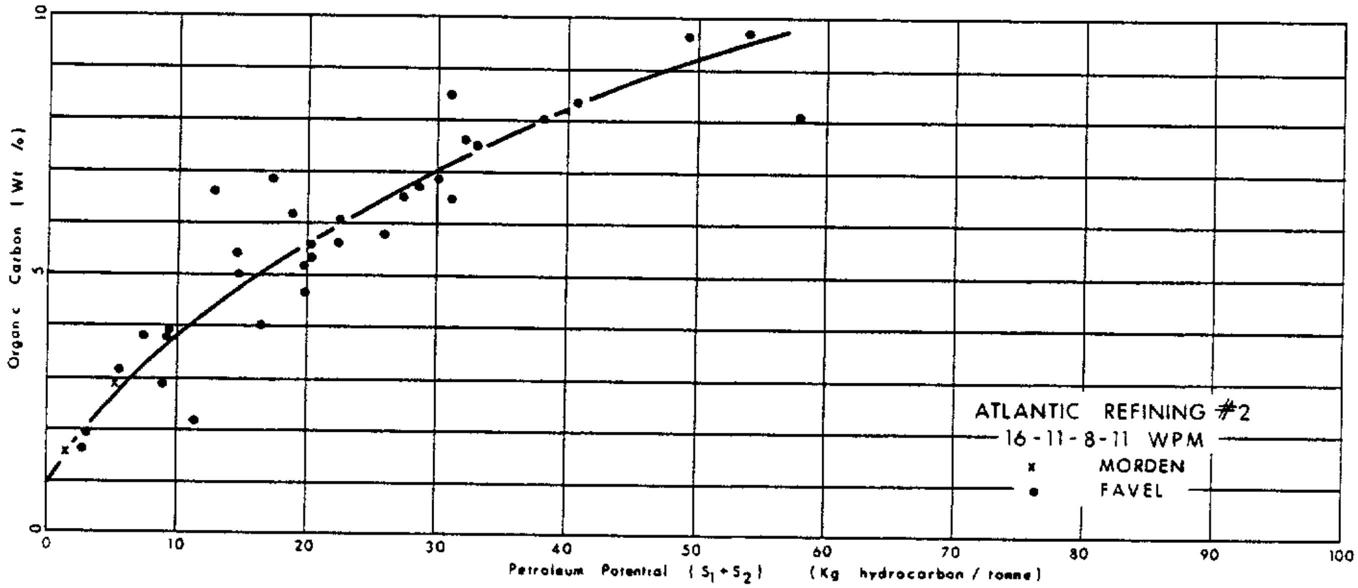
ANDERSON ET AL PARADISE 10-22-47-3 W4M

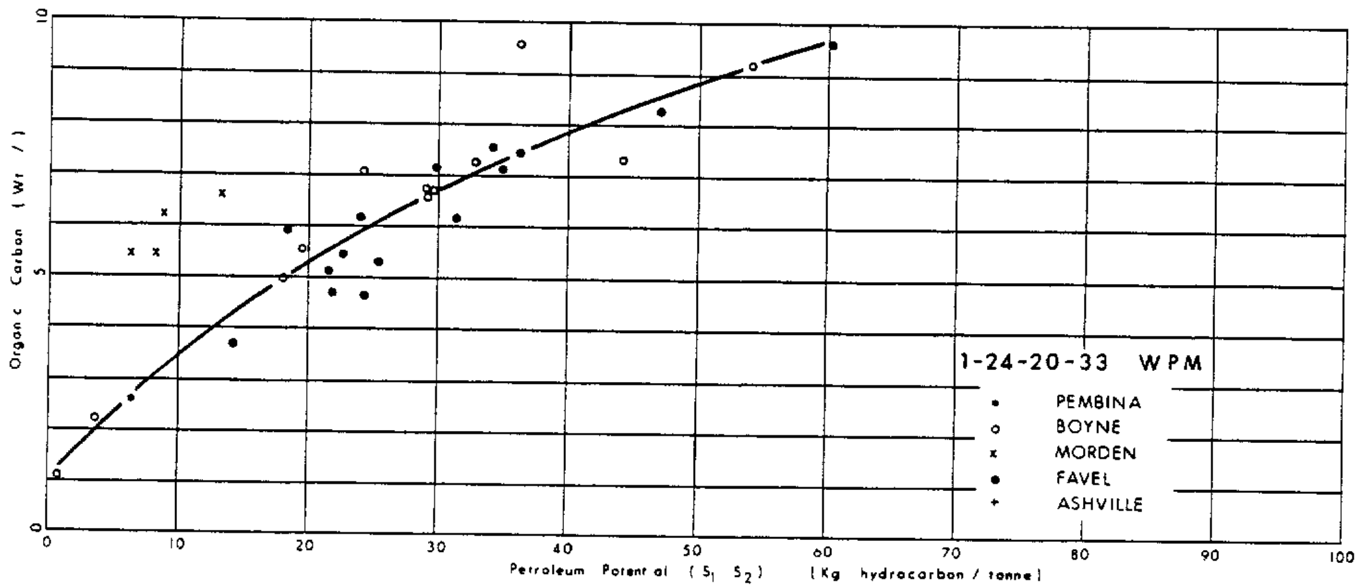


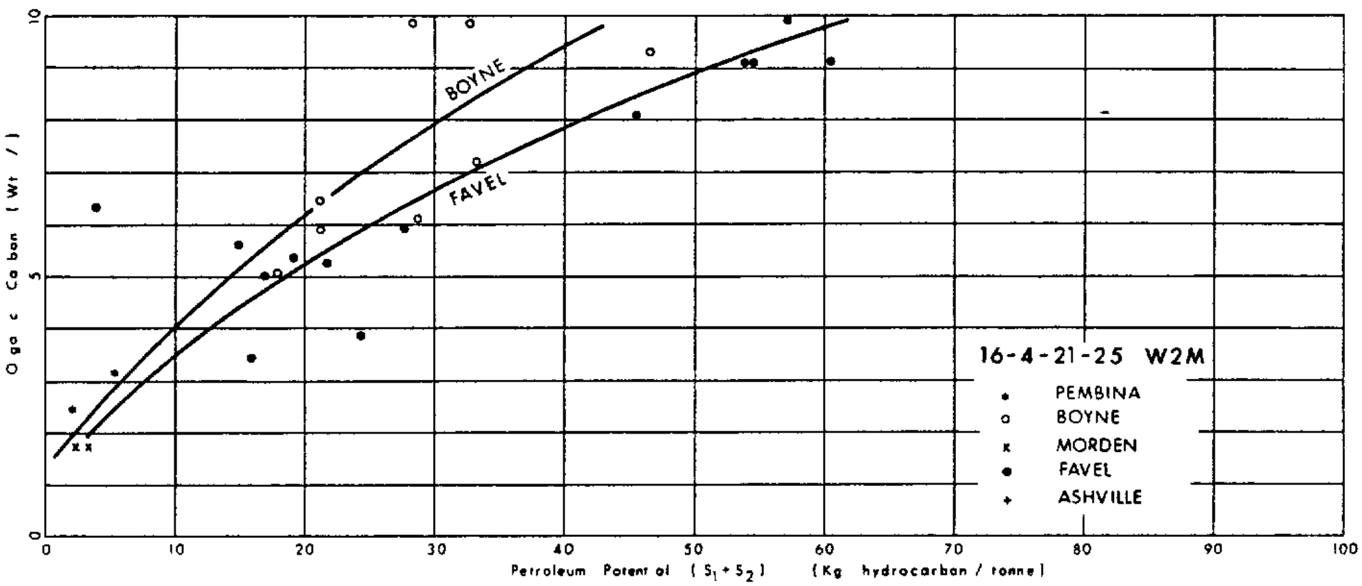

ATLANTIC REFINING #4
1-27-1-6 WPM
PEMBINA
BOYNE
MORDEN
Increasing Maturity
ATLANTIC REFINING #2
16-11-8-11 WPM
MORDEN
FAVEL
1-24-20-33 WPM
PEMBINA
BOYNE
MORDEN
FAVEL
ASHVILLE
16-4-21-25 W2M
PEMBINA
BOYNE
MORDEN
FAVEL
I
II
III
Hydrogen Index (mg HC / g org C)
Oxygen Index (mg CO2 / g org C)
0
50
100
150
200
400
600
800
1000
1200

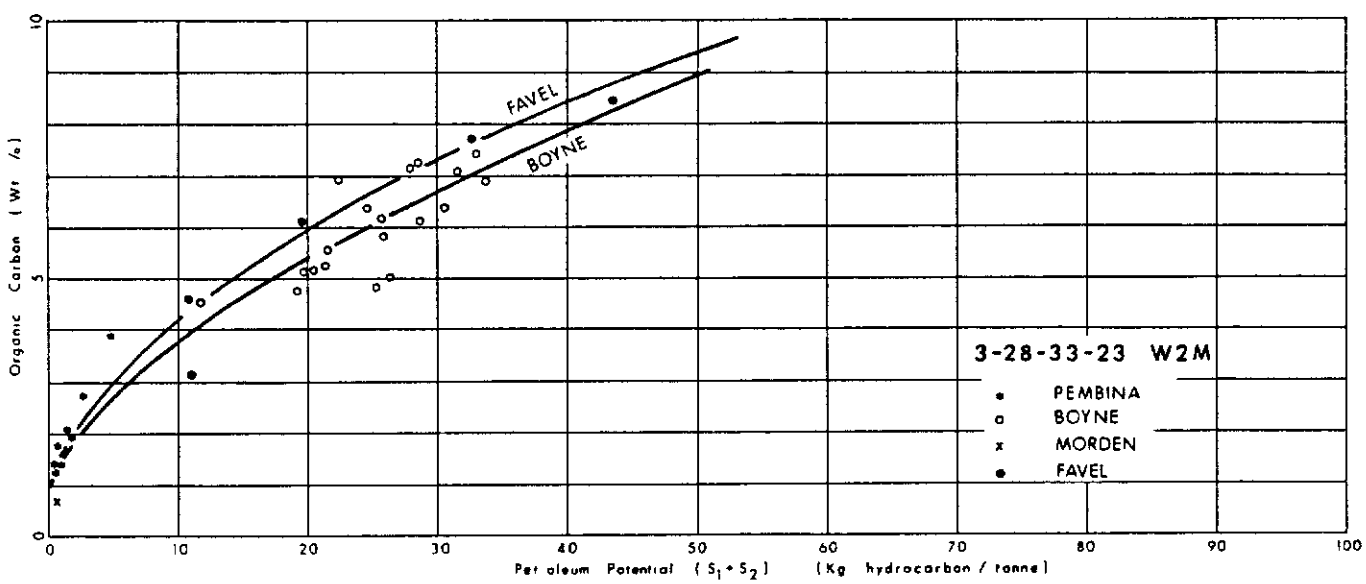

3-28-33-23 W2M
PEMBINA
BOYNE
MORDEN
FAVEL
5-9-31-25 W3M
BOYNE
FAVEL
11-16-35-8 W3M
PEMBINA
BOYNE
FAVEL
10-22-47-3 W4M
LEA PARK
1st SPECKS
SHALE
2nd SPECKS
UNNAMED
I
II
III
Increasing Maturity
Hydrogen Index (mg HC / g org C)
Oxygen Index (mg CO_2 /g org C)
0
200
400
600
800
1000
1200
50
100
150

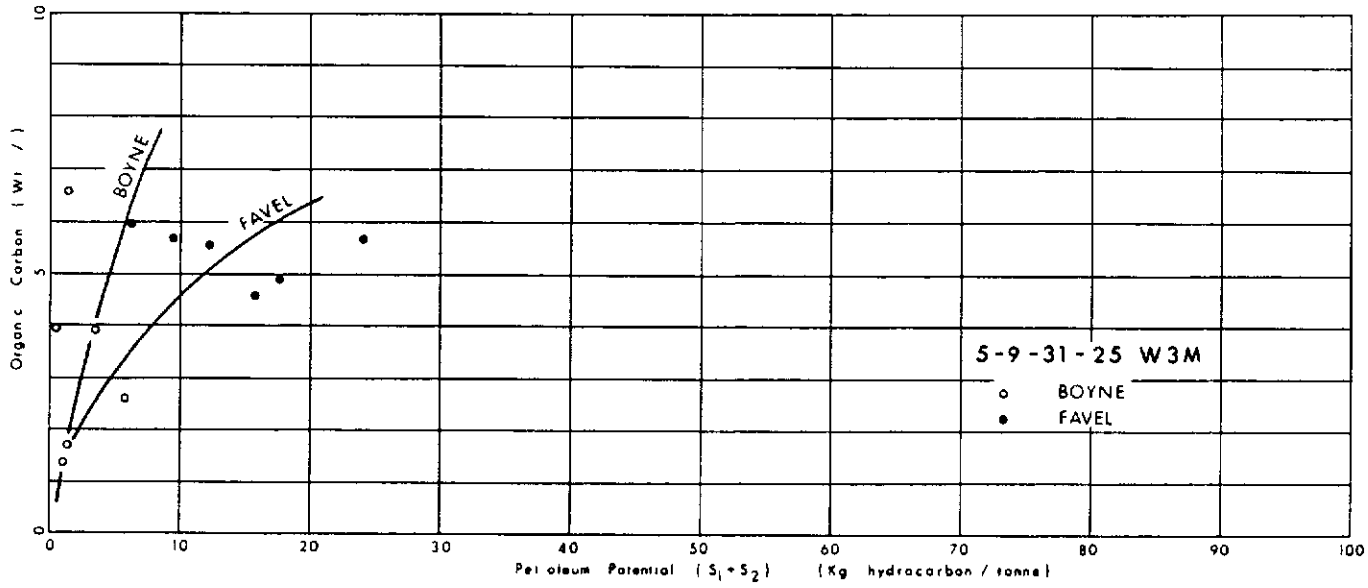

ATLANTIC REFINING #4
1-27-1-6 WPM
PEMBINA
BOYNE
MORDEN
Organic Carbon (Wt %)
Petroleum Potential (S_1+S_2) (Kg hydrocarbon / tonne)


ATLANTIC REFINING #2
16-11-8-11 WPM
MORDEN
FAVEL
Organic Carbon (Wt %)
Petroleum Potential (S_1+S_2) (Kg hydrocarbon / tonne)

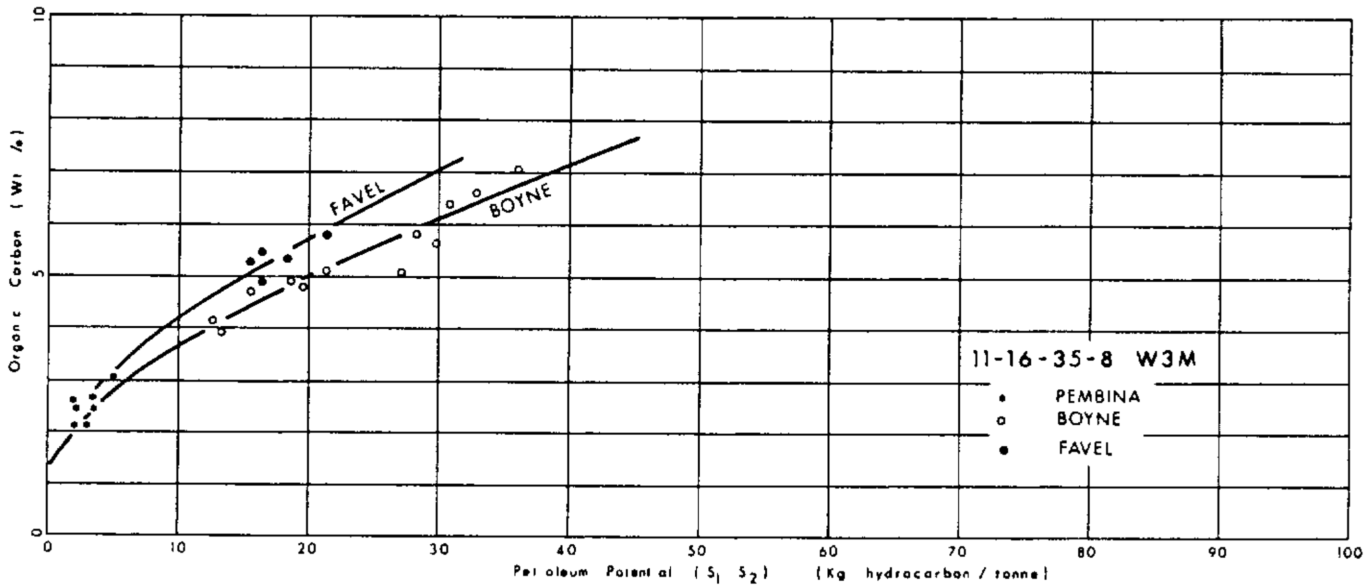

1-24-20-33 WPM
PEMBINA
BOYNE
MORDEN
FAVEL
ASHVILLE
Organic Carbon (Wt %)
Petroleum Potential (S_1+S_2) (Kg hydrocarbon / tonne)


16-4-21-25 W2M
PEMBINA
BOYNE
MORDEN
FAVEL
ASHVILLE
BOYNE
FAVEL
Petroleum Potential ($S_1 + S_2$) (Kg hydrocarbon / tonne)

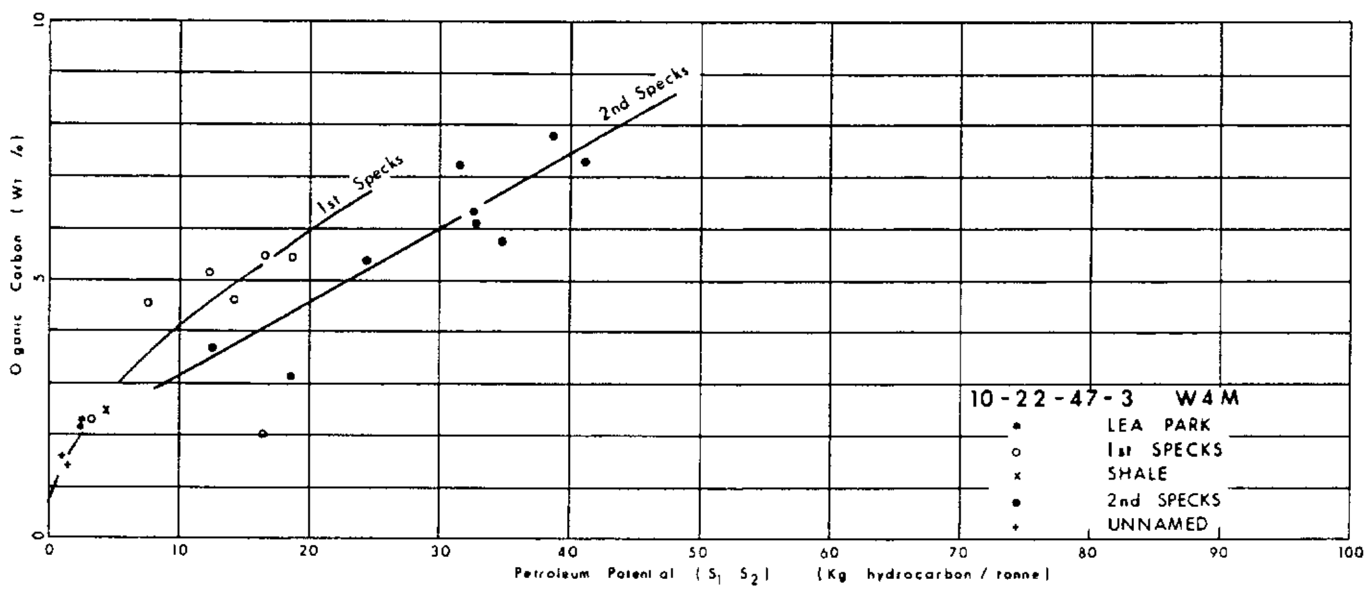

3-28-33-23 W2M
PEMBINA
BOYNE
MORDEN
FAVEL
FAVEL
BOYNE
Organic Carbon (Wt %)
Petroleum Potential ($S_1 + S_2$) (Kg hydrocarbon / tonne)



BOYNE
FAVEL
5-9-31-25 W3M
BOYNE
FAVEL
Organ c Carbon (Wt %)
Pet oleum Potential (S1 + S2) (Kg hydrocarbon / tonne)



FAVEL
BOYNE
11-16-35-8 W3M
PEMBINA
BOYNE
FAVEL
Organ c Carbon (Wt %)
Pet oleum Potent al (S1 S2) (Kg hydrocarbon / tonne)



1st Specks
2nd Specks
10-22-47-3 W4M
LEA PARK
1st SPECKS
SHALE
2nd SPECKS
UNNAMED
Organic Carbon (Wt %)
Petroleum Potent al (S1 S2) (Kg hydrocarbon / tonne)