GEOLOGICAL SURVEY OF CANADA
COMMISSION GEOLOGIQUE DU CANADA

Open File 2576

VITRINITE REFLECTANCE AND THERMAL MATURITY IN CRETACEOUS STRATA OF THE PEACE RIVER ARCH REGION: WEST-CENTRAL ALBERTA AND ADJACENT BRITISH COLUMBIA

David Marchioni[1] and Wolfgang Kalkreuth[2]

DECEMBER 1992

1 Petro-Logic Services
231 10A Street N.W.
Calgary, Alberta, T2N 1W7

2 Institute of Sedimentary and Petroleum Geology
3303-33 Street N.W.
Calgary, Alberta, T2L 2A7

CONTENTS

Note: **Tables I - VI are also available as Lotus Spread Sheets on separate diskette.**

1. INTRODUCTION

1.1 Purpose and Scope of the Study

The Peace River Arch region of west-central Alberta and adjacent eastern British Columbia is one of the more important oil and gas producing areas in the Western Canada Sedimentary Basin.

The present study was initiated to investigate the regional pattern of thermal maturity in the Cretaceous strata of the region and to contribute to studies of the paleothermal heat regime, and modelling of thermal maturation with time in respect to the periods of hydrocarbon expulsion. Structural and sedimentological evidence suggests that the Arch had collapsed or inverted by the Cretaceous and thermal maturation studies by Kalkreuth and McMechan (1988) to the west had indicated some influence of the structure on the pattern of thermal maturity in the Cretaceous sequence.

The objectives of the present study include:

- compilation of existing data on thermal maturity in the region
- generation of vitrinite reflectance data from selected petroleum exploration wells in order to define lateral and vertical variations in thermal maturity (including integration of existing information)
- mapping of thermal maturity in selected stratigraphic horizons

The scope of the study comprises:

- creation of an integrated, computer-based data set of thermal maturity parameters from published and unpublished sources
- examination and selection of samples of organic material from 58 petroleum wells
- vitrinite reflectance analyses of more than 250 samples from these wells and construction of reflectance-depth profiles and best fit lines in each well
- contour maps of maximum vitrinite reflectance at the top and base of the Bluesky/Gething Formation
- trend surface and residual maps on the base of the Bluesky/Gething
- coalification gradient map
- cross sections illustrating the disposition of iso-reflectance surfaces

The study area is located over the Peace River Arch (PRA),Fig. 1. Wells sampled in the study occupy an area bounded to the east by Range 18 west of the 4th meridian, to the west by 25W6, to the north by Tp96 and to the south by Tp65. Maps include data from areas slightly further west and south (approximately Lat. 55 to 57 and Long. 113 to 123; Fig. 1.

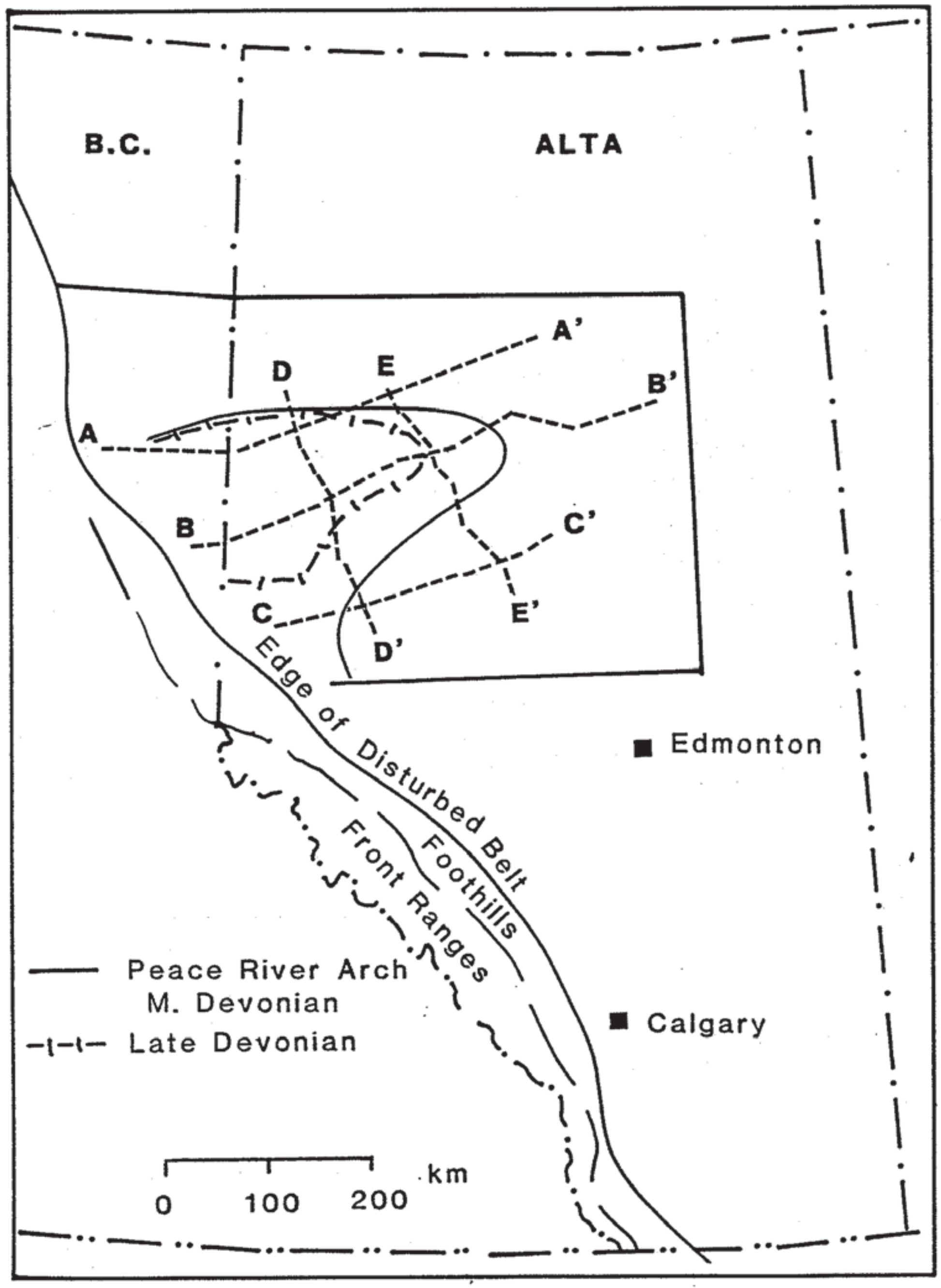

Fig. 1 Location of Study Area, Section Lines and Peace River Arch

1.2 Geological Setting

The Peace River Arch is a major crustal structure of northern Alberta and British Columbia consisting of an uplift of Precambrian rock associated with many faults that cut the overlying Devonian, Mississippian and Pennsylvanian sediments. The granitic basement of the area stands about 800 to 1000m above its regional elevation; (Cant, 1988).

The arch is a 140km wide uplift trending ENE-WSW from the Peace River region to the 5th meridian in north-central Alberta (Fig.1). Horst and graben structures parallel the axis in the axial region. The uppermost Devonian, the Wabamun, covers the Precambrian basement in almost all locations.

The first uplift of the structure is not clear but probably initiated during mid Cambrian. The arch was emergent by mid Devonian and normal faulting occurred. Mid to Late Devonian sediments onlap the arch which was finally buried by carbonate sediments at the end of Wabamun deposition. The Mississippian and Pennsylvanian were periods of block subsidence along fault boundaries, indicating that the Arch was inverting or collapsing.

Mesozoic deposition indicates continued regional subsidence on the Arch; there is a 100 to 150m positive thickness anomaly in the Mesozoic in this area. The Upper Mannville indicates 50 to 100m of extra subsidence in the region of the Arch (Cant,1988).

The Western Canada Sedimentary Basin developed as a S-W dipping asymmetric trough in Early Cretaceous. Stratigraphic and facies relationships for the Lower Cretaceous section are shown in Fig. 2.

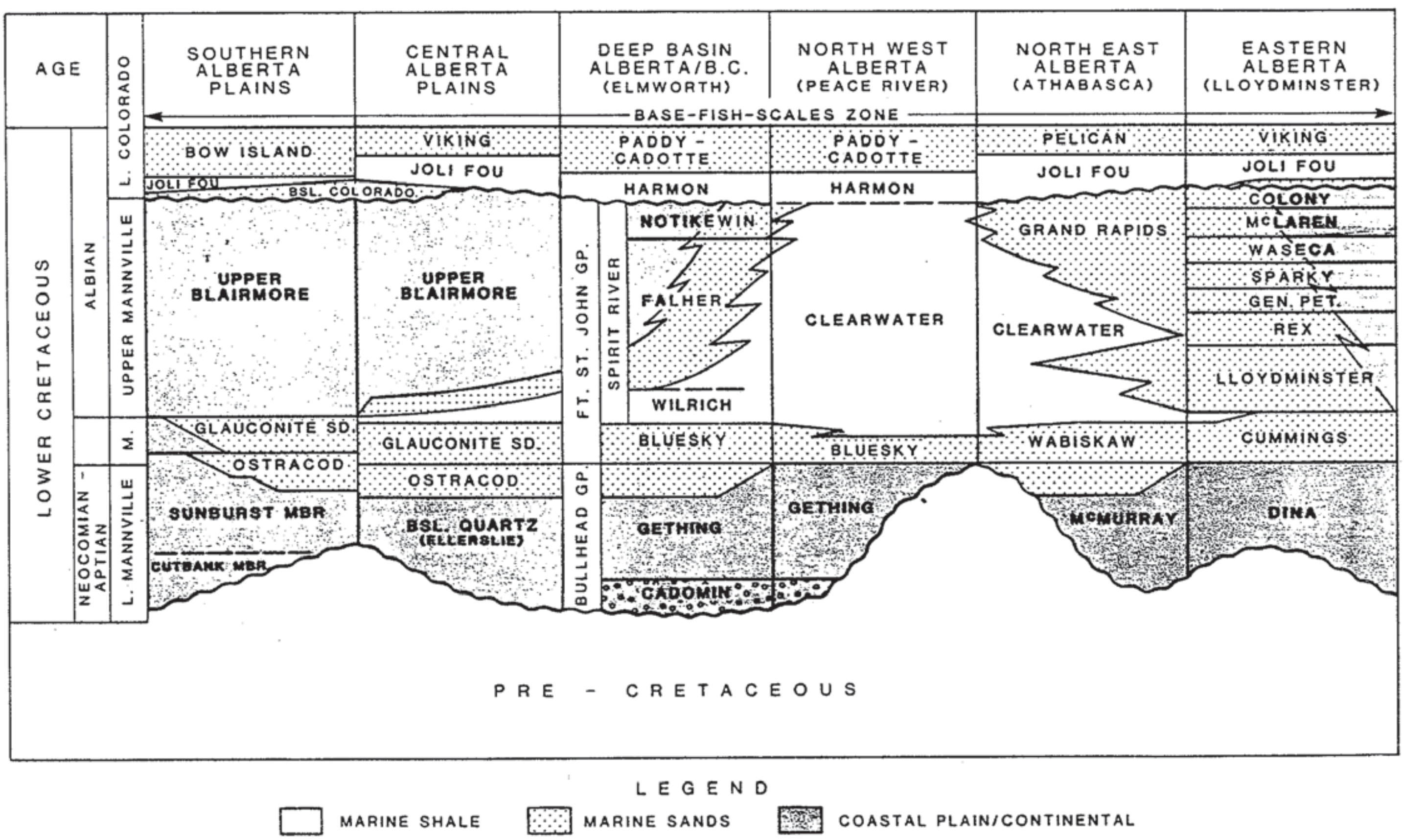

Fig. 2 Lower Cretaceous Stratigraphy and Facies (Jackson 1984)

The Mannville Group was deposited during a lower transgressive phase followed by a major influx of Cordilleran sediment during an upper, regressive phase. Two sub-basins for Lower Mannville deposition developed on either side of an axial high trend, extending from N.E. British Columbia to S-W Saskatchewan; to the west a foredeep trough and to the east a regional low due to subsurface leaching of Devonian salt beds. During deposition of the Upper Mannville, there was rapid subsidence in the Peace River Arch area which expanded a broad trough to form the Clearwater Formation shale basin, north of a prominent hinge line extending S-W from Tp80 on the 5th meridian to Tp60 at the eastern margin of the disturbed belt (Jackson 1984).

The "axial high trend" extends N-W through the study area from the S-E corner and, in this area, the Lower Mannville was not deposited. To the west this sequence thickens to more than 150m at the edge of the Disturbed Belt and eastward thins to less than 30m over much of the project area. The Upper Mannville thins from more than 350m in the west to less than 200m in the east (Figs. 3 & 4).

Jackson (1984) recognised three phases in the paleogeography of the Lower Mannville. During Cadomin and Lower Gething deposition, the region was of continental character with Cadomin piedmont fans in the west and fluvial Gething deposits over the remainder of the region. The Upper Gething was deposited during an initial transgression in a S-E direction which resulted in a coastal/continental plain covering much of the area with a narrow N-S trending zone of estuarine deposition along the 5th meridian. By uppermost Gething and Ostracod time the area was subject to marine deposition.

The Bluesky-Wabiskaw-Cummings sequence was deposited on shelf, beach and offshore bars. Thick coal sequences, capping beach and deltaic sequences prograding from the S.E. did not extend northward beyond Edmonton. Bluesky coals are restricted to a small portion of the south western part of the study area.

During Upper Mannville time western sourced clastics built a northward thinning wedge of coastal and continental sediments in a series of progradational pulses (Falher and Notikewin Members). Coastal plain progradation (and associated coal deposition) did not extend northward beyond an approximately E-W zone in the vicinity of Tp80 to 90 at uppermost Notikewin. Limits of coal formation in lower units occur progressively further to the south.

The overlying Lower Colorado Group (Late Albian) comprises the basal marine shales of the Harmon Formation, overlain by the Paddy/Cadotte formed during a major regressive pulse. These units are essentially shoreline continental and near-shore marine sediments over most of the area. Lower delta plain and intertidal mud flats of the Paddy Member are restricted to the extreme south west of the area.

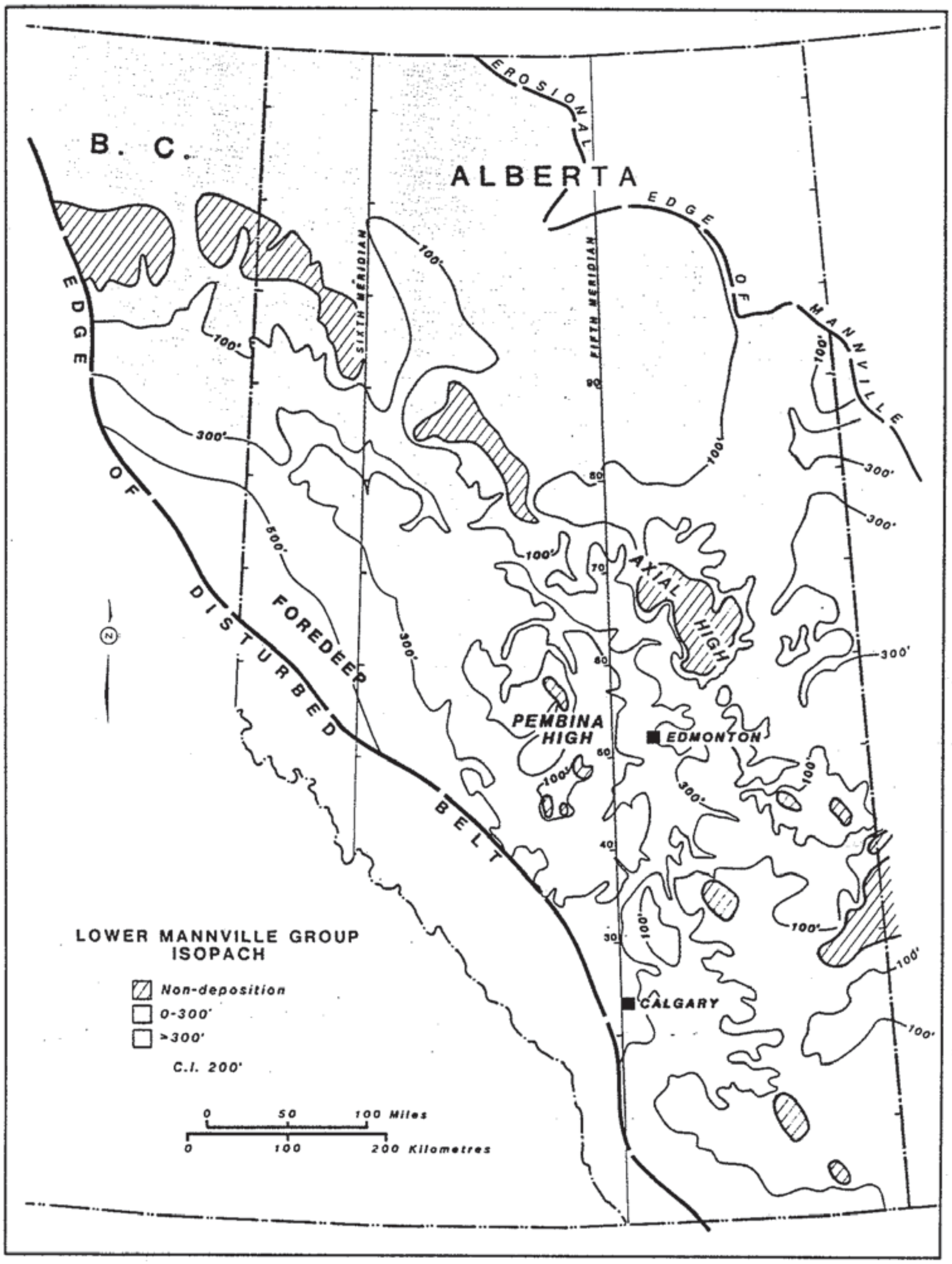

Fig. 3 Lower Mannville isopach, illustrating thicker basin fill in areas of greater subsidence, and in channels incised into the pre-Mannville surface. (Jackson 1984)

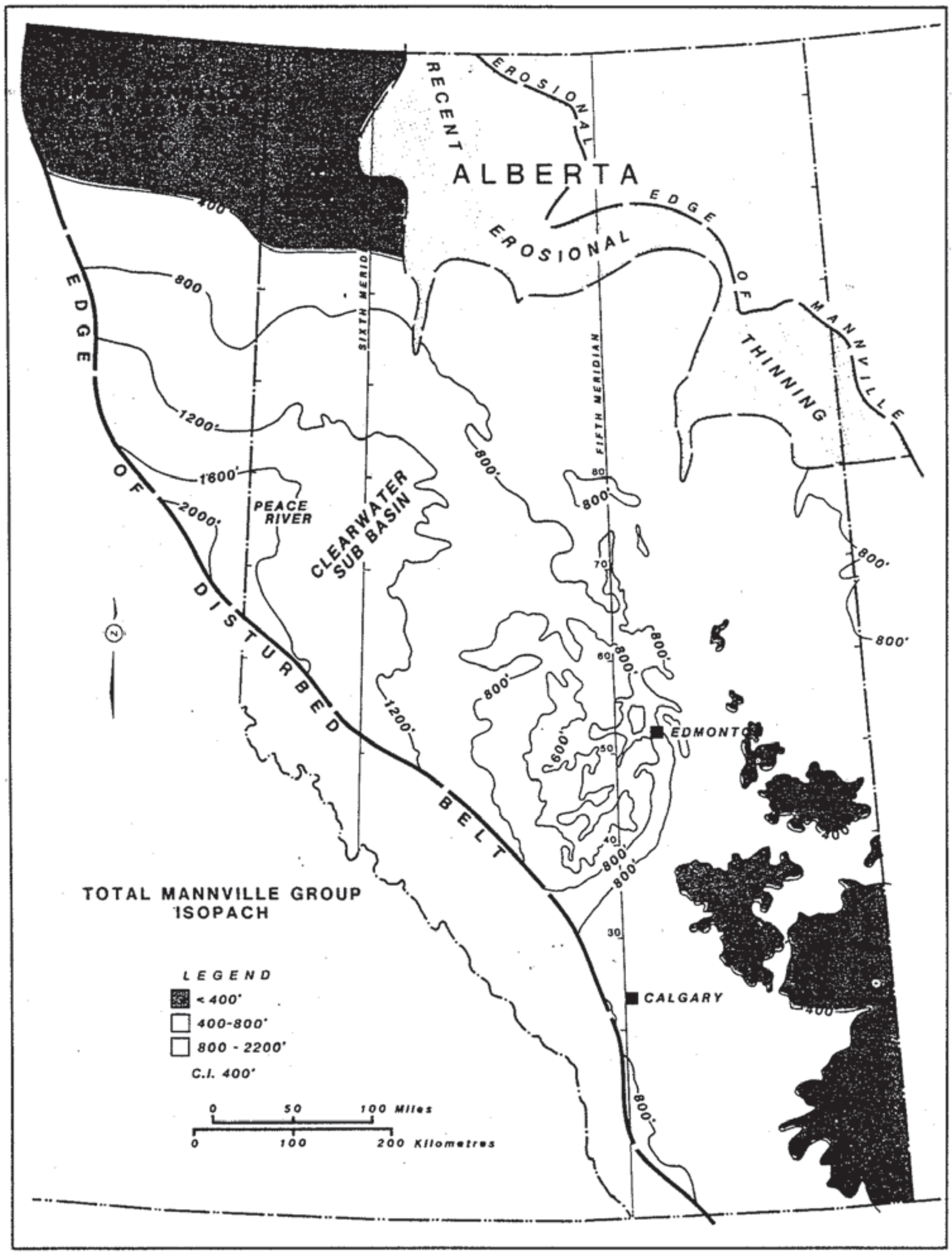

Fig. 4 Total Mannville Group isopach, illustrating thicker basin fill into areas of greater subsidence. Of note is the development of the Clearwater Formation shale depocenter in north-western Alberta during deposition of the upper Mannville. (Jackson 1984)

From late Albian to Campanian time the Colorado/Shaftsbury sea spread across the PRA region and much of North America. The mainly continental sequence of the uppermost Cretaceous and Paleocene sub-crops are located to the south of the study area and are generally south of 55° latitude.

2 METHODOLOGY

2.1 Well Selection

To provide broad coverage of the PRA region on a regularly spaced grid, it was decided to sample wells along three latitudinal section lines parallel to the axis of the arch and two longitudinal section lines normal to them (Fig. 5). It was intended to sample one well every two to three range subdivisions (i.e. 12 to 18 miles apart).

The northern and southern section lines were chosen such that the western extremity was in the region occupied by the arch and to the east they trend off the arch structure (Fig. 5). The axial section-line extends much further eastward than the nose of the arch. The latitudinal lines were also oriented such that their mid-section lay over the arch and they were off the arch at each extremity (Fig. 5). The intent was to highlight possible influences of the Arch by sampling in both the areas underlain by the arch and those areas marginal to it.

The SWELLS data base was used to select well locations based on optimising the following parameters:

- proximity to selected section lines and regular spacing along the lines
- penetration of the stratigraphic succession to at least the base of the Cretaceous
- availability of retained cuttings over a wide stratigraphic interval

2.2 Nature of Samples

In terms of data generation and compilation, the primary aim of this study was to extend eastward the work of Kalkreuth and McMechan (1988). These authors published coalification gradients and vitrinite reflectance maps of Cretaceous and Jurassic strata. These maps were based on sampling of coal and petroleum wells and outcrop sections in north-eastern British Columbia, to the west of the Peace River Arch region. Data from this study was then integrated with data generated in this project.

The earlier study was primarily based on the analysis of coal from cuttings samples and, in order to maintain consistency, it was decided to use cuttings samples wherever possible in this study. In most petroleum wells, cores are cut in only a limited number of stratigraphic units. Consequently, cores rarely serve to provide samples throughout the sequence penetrated. Cuttings are taken at regular intervals during drilling and, when retained in storage facilities, can provide samples over a wide stratigraphic interval. Cuttings offer the

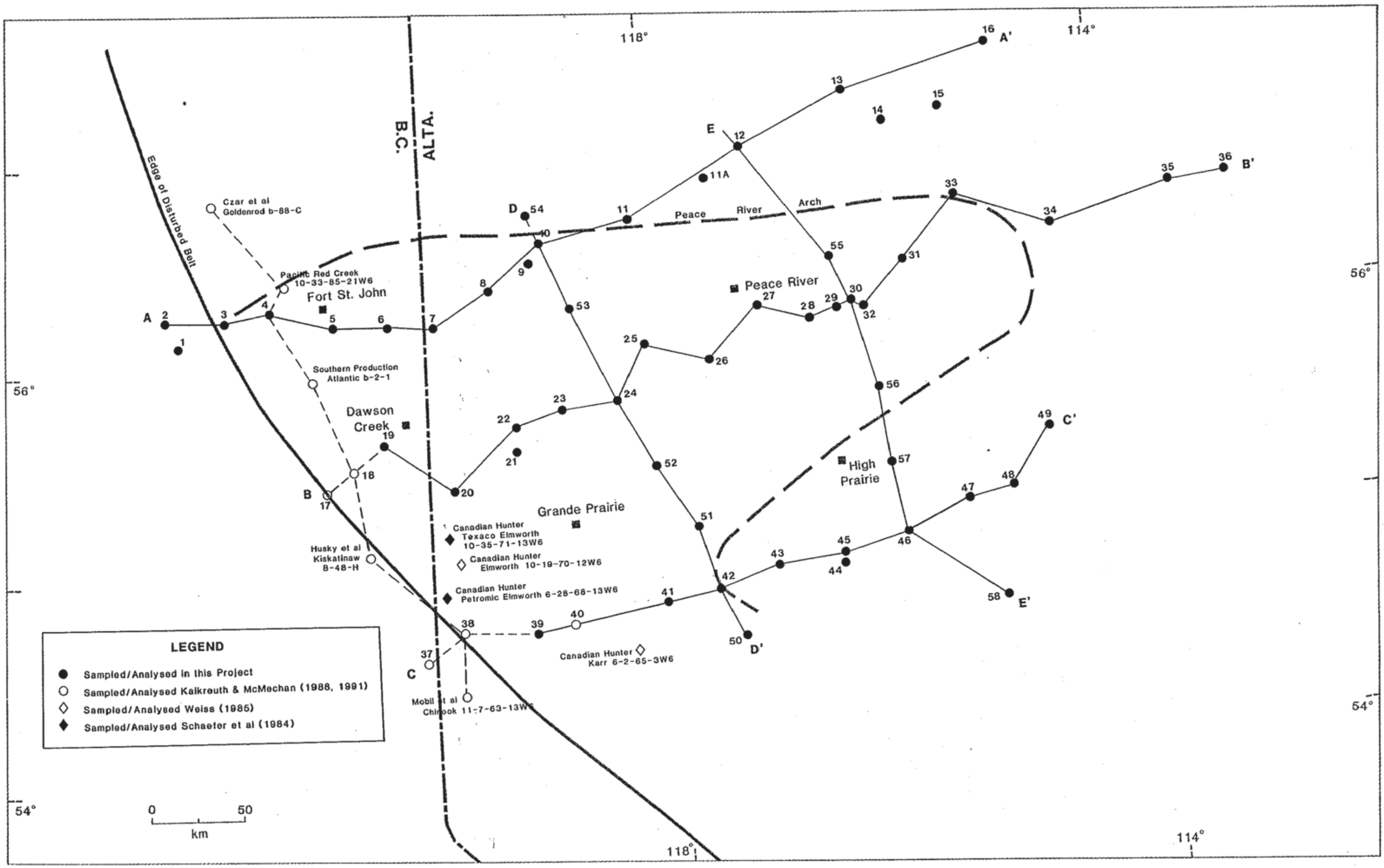

Fig. 5 Well locations and cross-sections, Peace River Arch area, for well identification see Tables I-VI.

best potential for generating a reflectance profile of a well which is required for the determination of coalification gradients, for modelling of thermal history and for interpolating reflectance values at horizons not sampled.

Cuttings samples have two disadvantages relative to core:

1. samples may contain material caved from higher levels (and lower maturity) in the well
2. samples have frequently been subjected to extremes of heating during the drying stage of sample retention

Cores, on the other hand, have not been heated and depths are relatively accurate. This suggests that a combination of cuttings (to provide a significant depth coverage) and of cores (to provide control on sample depth) would offer the optimum sampling procedure. This approach however is also subject to some anomalies. Coal seams are rarely recovered in petroleum well cores and samples are usually derived from coal spars in coarse clastics or from organic rich fine grained clastics. Coal horizons identified on logs and represented as abundant cuttings in samples are generally relatively thick. Differences in vitrinite reflectance have been reported between thick and thin coal seams at the same stratigraphic level (Kalkreuth & McMechan, 1984); thick seams yielding higher values. This reflectance discrepancy has been ascribed to differences in heat retention/thermal conductivity between coals and surrounding strata. Samples derived from cores might be expected to yield reflectance values even lower than thin coals (i.e typical of extremely thin coals)

2.3 Sampling for Vitrinite Reflectance Analyses

The majority of samples were hand-picked from cuttings samples, usually chosen where logs indicated the presence of coals and sample vials contained abundant coal fragments. The aim was to choose coal samples throughout the sequence penetrated. In the north and east, where the sequence contains limited coal, samples were taken where coal was present in cuttings vials, even where logs did not clearly indicate the presence of a seam. One well was fully cored (Imperial Spirit River, 12-20-78-6W6) and a few had a large number of cores giving a wide stratigraphic range of samples (e.g. Bear Villa No. 1, 78-74-14W5) and in these cases samples were restricted to core. In addition, in several wells, both core and cuttings samples were used. Few samples were taken below the base of the Cretaceous as it was intended to use coals for analyses rather than dispersed organics from clastics.

In the east of the study area where the Bluesky/Gething section is thin and/or dominantly marine, coal intersections were absent or were too thin to be revealed in logs or in cuttings vials. In these cases cores were sampled to provide a source of reflectance data. In most cases, coal spars or accumulations of carbonaceous fragments on bedding planes provided suitable samples. Core and cuttings samples are differentiated in the tabulated reflectance data (Tables I to VI).

2.4 Vitrinite Reflectance Analyses

Random reflectance (without polarizer) was determined on samples below 0.6% Rrand and on samples where vitrinite fragments were so small as to preclude stage rotation. At higher reflectance values, maximum reflectance was determined. In general, as many measurements as possible were made on each sample to a maximum of 50. In the majority of samples, 30 to 50 measurements were made to establish the arithmetic mean and standard deviation.

All random reflectance values were adjusted to Rmax using the relationship derived by Weiss (1985) from coals in the Cretaceous section of Alberta:

$$Rmax = 1.12 * Rrandom - 0.05$$

Reflectance data for all samples analyzed are tabulated in Tables I to VI which are ordered according to section lines and also include data on well locations, reflectance depth regression equations and coalification gradients.

2.5 Reflectance Data from Other Sources

Kalkreuth and McMechan (1988) studied the regional coalification pattern in Cretaceous strata of the Rocky Mountain Foothills and Foreland between Grande Cache in the south and the Peace River area in the north. A few wells from this data set were incorporated into the western parts of section lines used as the basis for this study.

Reflectance data on wells from the PRA region are included in studies by Schaefer et. al. (1984) and Weiss (1985). Two wells were selected from each study for incorporation into this project (Table VII). In these wells there was a large number of cuttings samples over a wide stratigraphic interval including the Lower Cretaceous succession. In each case the reflectance data were replotted and reflectance-depth regressions fitted.

2.6 Restrictions on Sample Selection

As previously outlined, the Early Cretaceous section thins and becomes increasingly influenced by marine conditions to the north and east of the study area. Consequently, coals become fewer and thinner within the sequence in these areas. It is difficult to find coals which are thick enough to be recorded at the scale of petroleum well-logs, if present at all. It was necessary, in order to produce samples across the area, to select coals from cuttings without log verification and in several cases to take samples from cores.

In many cases, it was apparent from visual inspection of cuttings, that samples had been subjected to extreme heat during drying. Coal cuttings often showed evidence of expansion, gas release and fluid phase. Wherever possible, such samples were not included, but this feature is so widespread that it is virtually impossible to create a cuttings-based sample set without selecting coal grains from heated vials. In such cases, grains were selected that had retained the cubic outlines and high gloss surfaces typical of natural coal and grains showing features of heating were discarded.

The SWELLS data base was searched for wells drilled in the study area from the beginning of 1983, when samples were no longer subjected to extreme heat during drying. The search identified some 3000 wells. A check of cuttings availability for a random selection of these wells revealed that in general, a narrow stratigraphic interval only had been sampled. This is probably due to the assumption that adequate cuttings representation is provided by older wells nearby.

This presents a difficult situation for organic petrographic studies. Many wells drilled prior to 1983 have been subjected to extreme heat during drying at the E.R.C.B. storage facility; requiring care in sampling and analysis and the possibility of anomalous results.

2.7 Restrictions on Analysis

In samples showing microscopic evidence of abnormal heating (bright rims on grain margins and along internal fractures), measurement was restricted to those grains showing no visible evidence of heating. Samples indicating extreme heating (vacuoles, semi-coke texture etc.) were rejected. The need for this selective analysis reduced the number of reliable samples in the data set and lead to a need for resampling in several cases.

In this study, samples derived from core were generally found to have reflectance values significantly lower than cuttings at the same depth or than values interpolated from best fit lines to cuttings samples. A correlation was derived for the relationship between reflectance values measured in core and cuttings at the same depth:

$$Rmax\ (core) = 1.028*Rmax\ (cuttings) - 0.089 \quad (Fig.\ 6)$$

This relationship was used to adjust values derived from cores; all reflectance values used in maps, sections and models are set to a standard "cuttings basis".

This reflectance differential is considered to be the result of two factors:

1. different conductivity of different host strata (coal versus clastics)
2. where samples have been heated during drying producing in certain instances coke-like structures

Even where heat effects are not visible under the microscope, reflectance may still have been elevated slightly. There is evidence in this study to indicate that in samples showing evidence of heating, restriction of measurements to only those grains showing no visible heat effects may still yield anomalously high values.

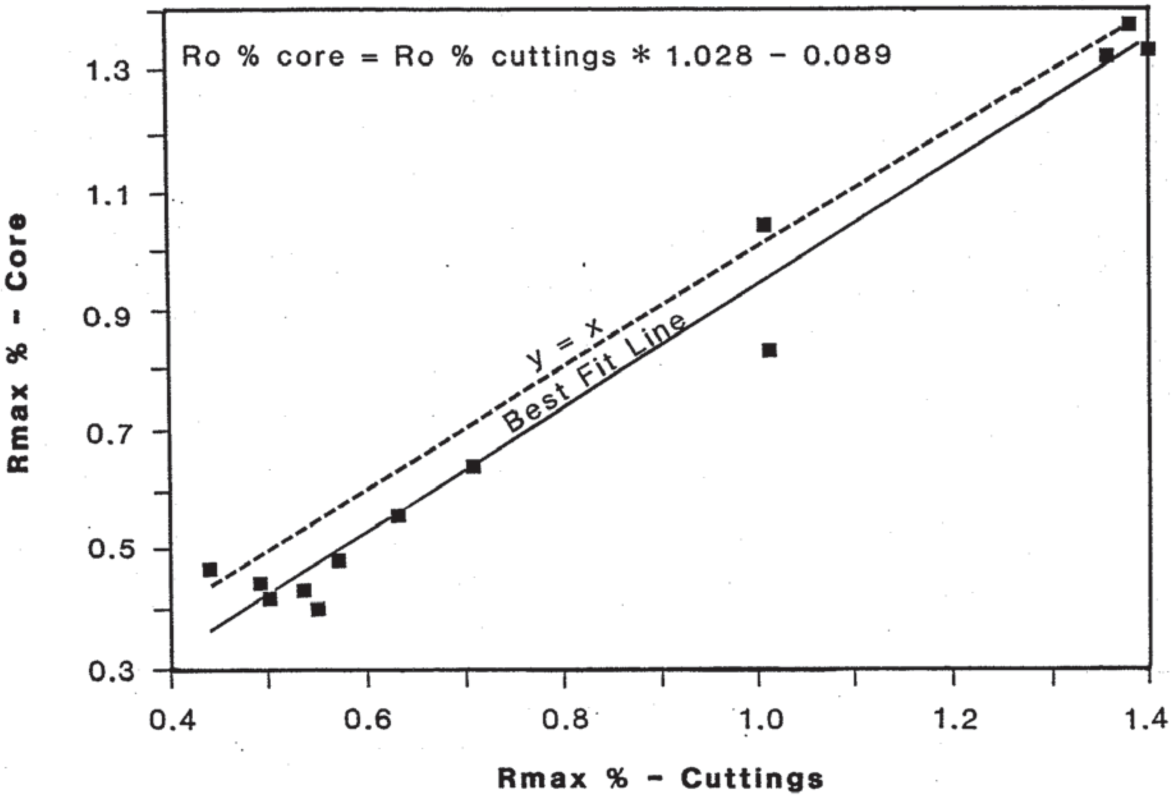

Fig. 6 Relationship between reflectance values derived from core and cuttings

2.8 Restrictions on Externally Sourced Reflectance Data

Data provided from Kalkreuth & McMechan (1988) were considered comparable to the data set generated in this study because:

a) analytical methods were standardised between the two data sets by use of the same sample preparation techniques, the same reflectance standards and either the same microscope or microscopes standardised against each other
b) most samples were derived from coal cuttings

Limitations on the integration of other data include:

a) limited knowledge of sampling, sample preparation and analytical techniques
b) only one or two samples per well are available

3 RESULTS AND DISCUSSION

3.1 Compilation of Reflectance Data

The samples selected in each well and information related to the measured vitrinite reflectance for each sample are listed in Tables I to VI (Tables I - VI are also available as Lotus Spread Sheets on separate diskette).

The reflectance data have been plotted on reflectance depth plots for each well. The data have been filtered where necessary to take account of caved samples and anomalous heating. Samples considered to realistically represent the maturation level were then used as the basis for the calculation of best-fit equations to represent the depth-reflectance relationship. In most cases samples were from a relatively small depth range and best fit equations are of first order. In a few wells in the west, where a relatively large number of samples were obtained over a large stratigraphic interval, the best fit was found to be second order.

Best fit equations were used to calculate the reflectance at selected stratigraphic horizons; specifically the top and base of the Bluesky/Gething Formation. In addition, these equations served to calculate the depth in each well to the 0.55% and 1.3% reflectance levels and to provide the coalification gradient in each well.

Reflectance contour maps have been prepared for the base and top of the Bluesky/Gething Formation (Figs. 7 and 8). A second order trend surface map based on the reflectances was established for the base of the Bluesky/Gething Formation (Fig. 9) and residual values are shown in Fig. 10. A map of the distribution of coalification gradients is shown in Fig. 11. Three cross sections illustrating formation boundaries and the disposition of the 0.55% and 1.3% iso-reflectance lines are shown in Figs. 12, 13 and 14.

3.2 Maximum Reflectance Contours - Base of Bluesky/Gething Formation

Fig. 7 is a contour plot of maximum vitrinite reflectance at the base of the Bluesky/Gething Formation (or equivalent). Reflectance values at each well have been interpolated from regression fits to reflectance-depth data in the well and the depth to the base of the Gething as shown by formation picks in the SWELLS data base. No attempt has been made to verify and/or adjust these formation boundaries. The map includes data derived from the present study, from Kalkreuth & McMechan (1988), Weiss (1985) and Schaefer et. al. (1984).

This map highlights the following features:

a) a "ridge" of high values trending SE-NW along the Outer Foothills as identified by Kalkreuth and McMechan (1988); maximum values are of the order of 2.5% Data from this study has made only minor modification to this region of high reflectance.

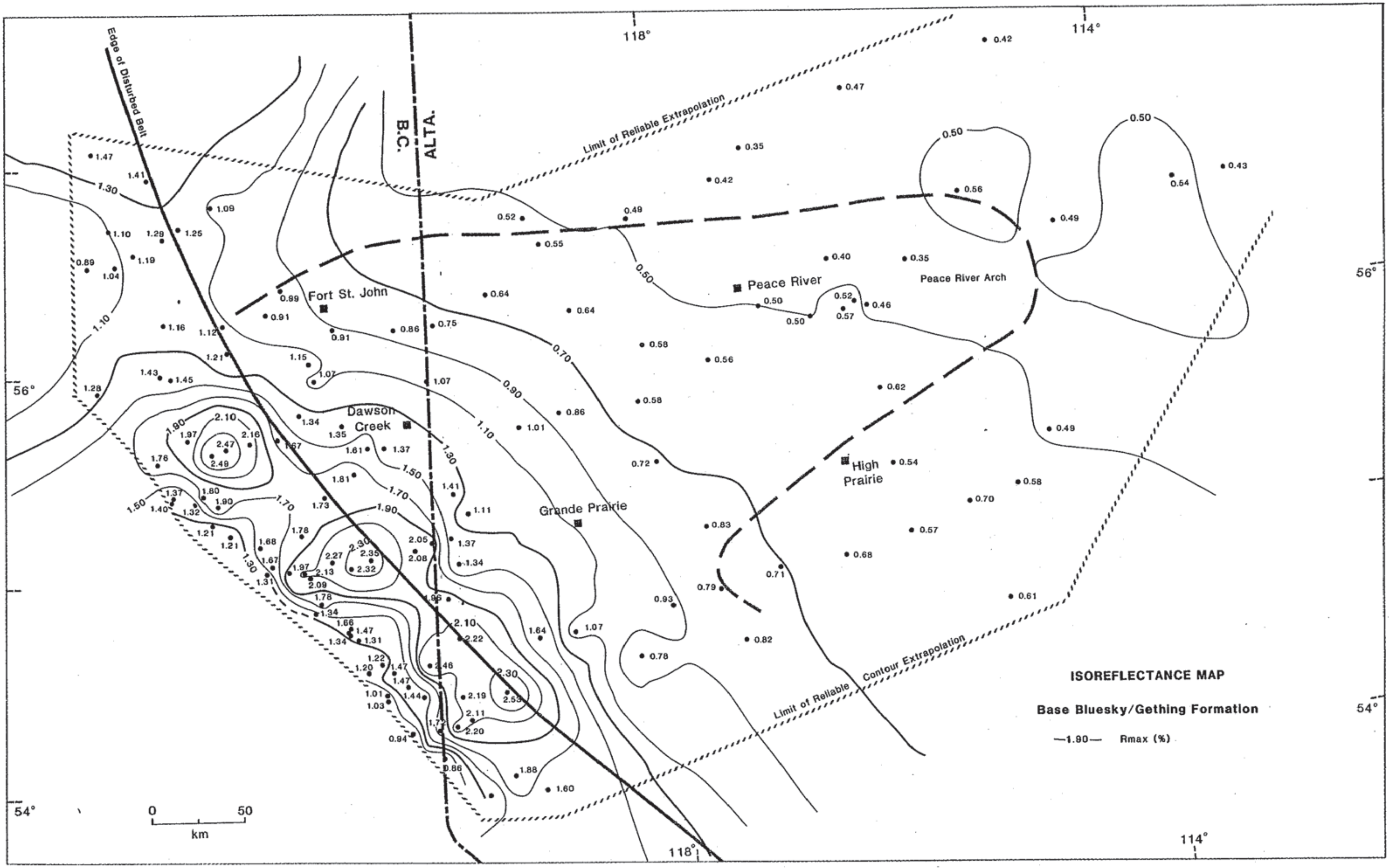

Fig. 7 Isoreflectances for base of Bluesky/Gething Formation, Peace River Arch area.

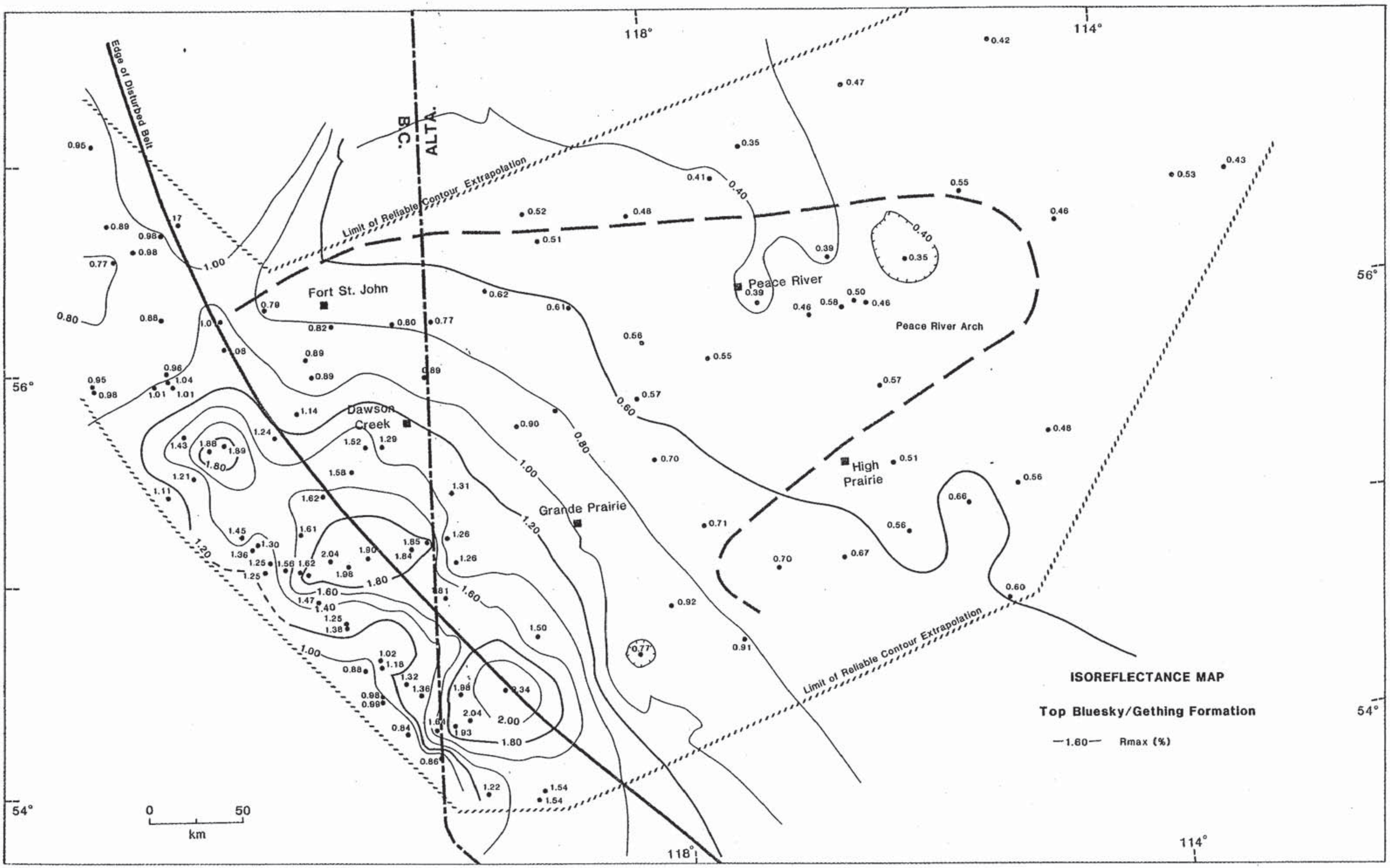

Fig. 8 Isoreflectances for top of Bluesky/Gething Formation, Peace River Arch area.

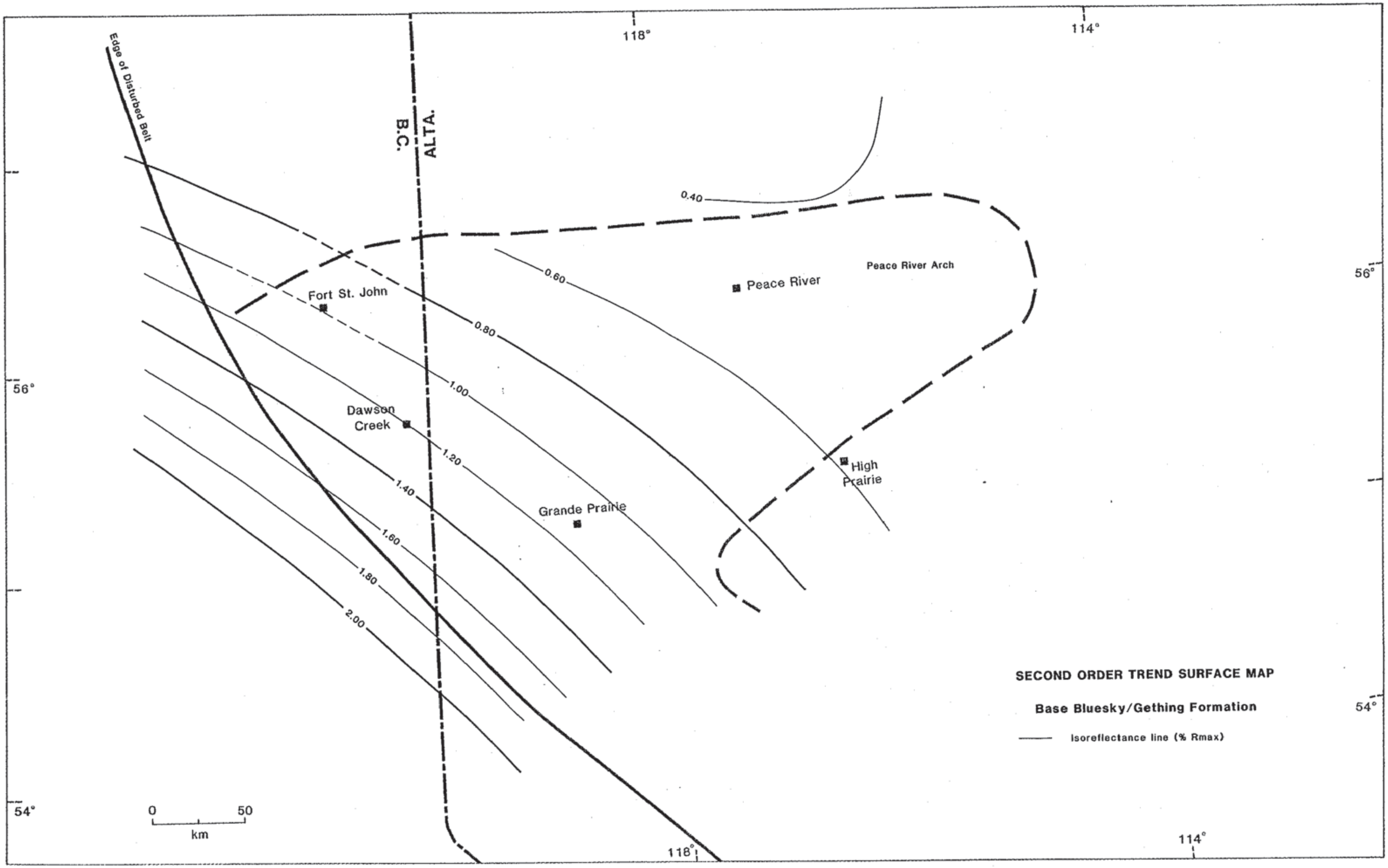

Fig. 9 Second order trend surface analysis based on vitrinite reflectance levels at base of Bluesky/Gething Formation, Peace River Arch area.

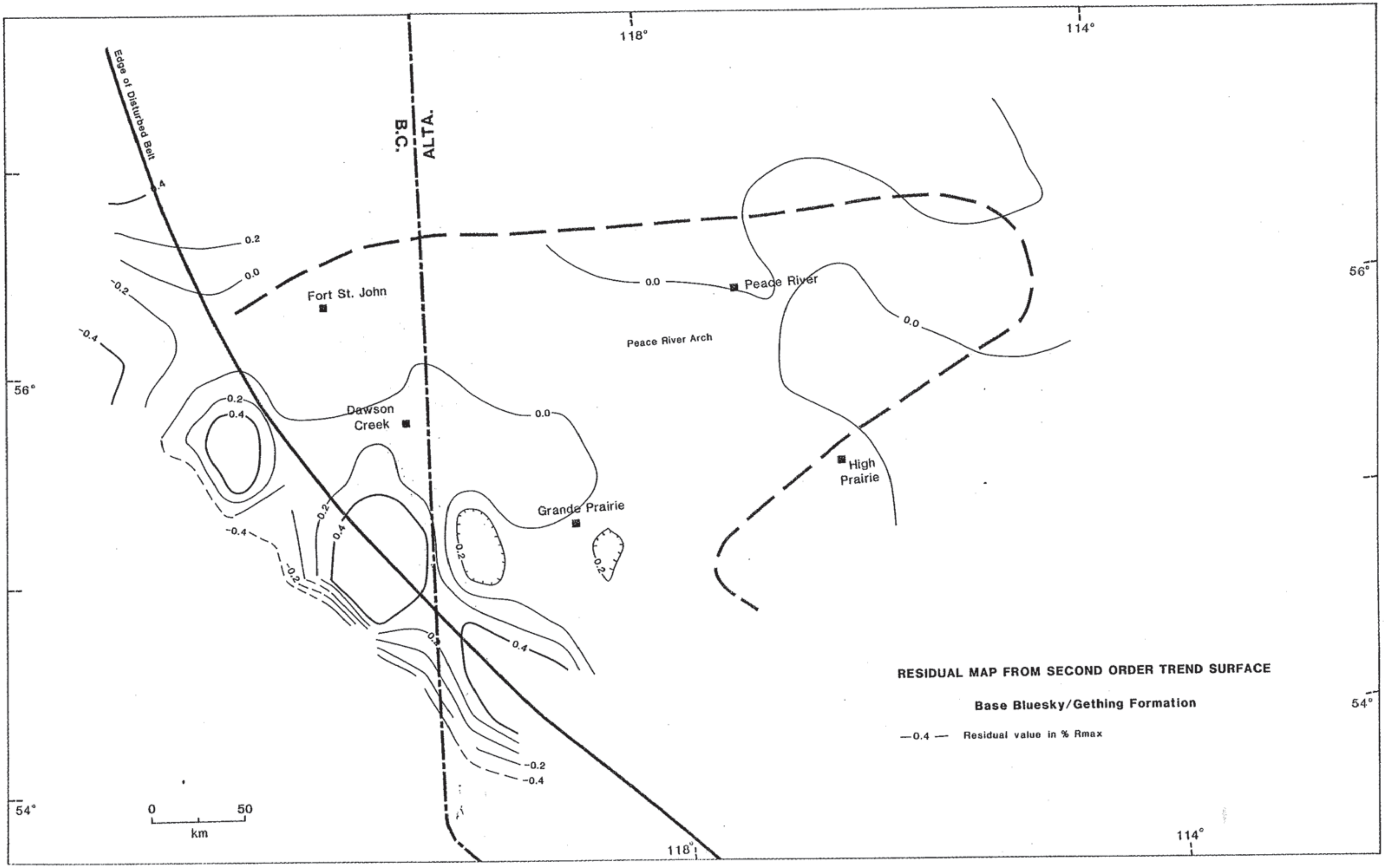

Fig. 10 Map showing residual reflectance values from 2nd order trend surface, base Bluesky/Gething Formation, Peace River Arch area.

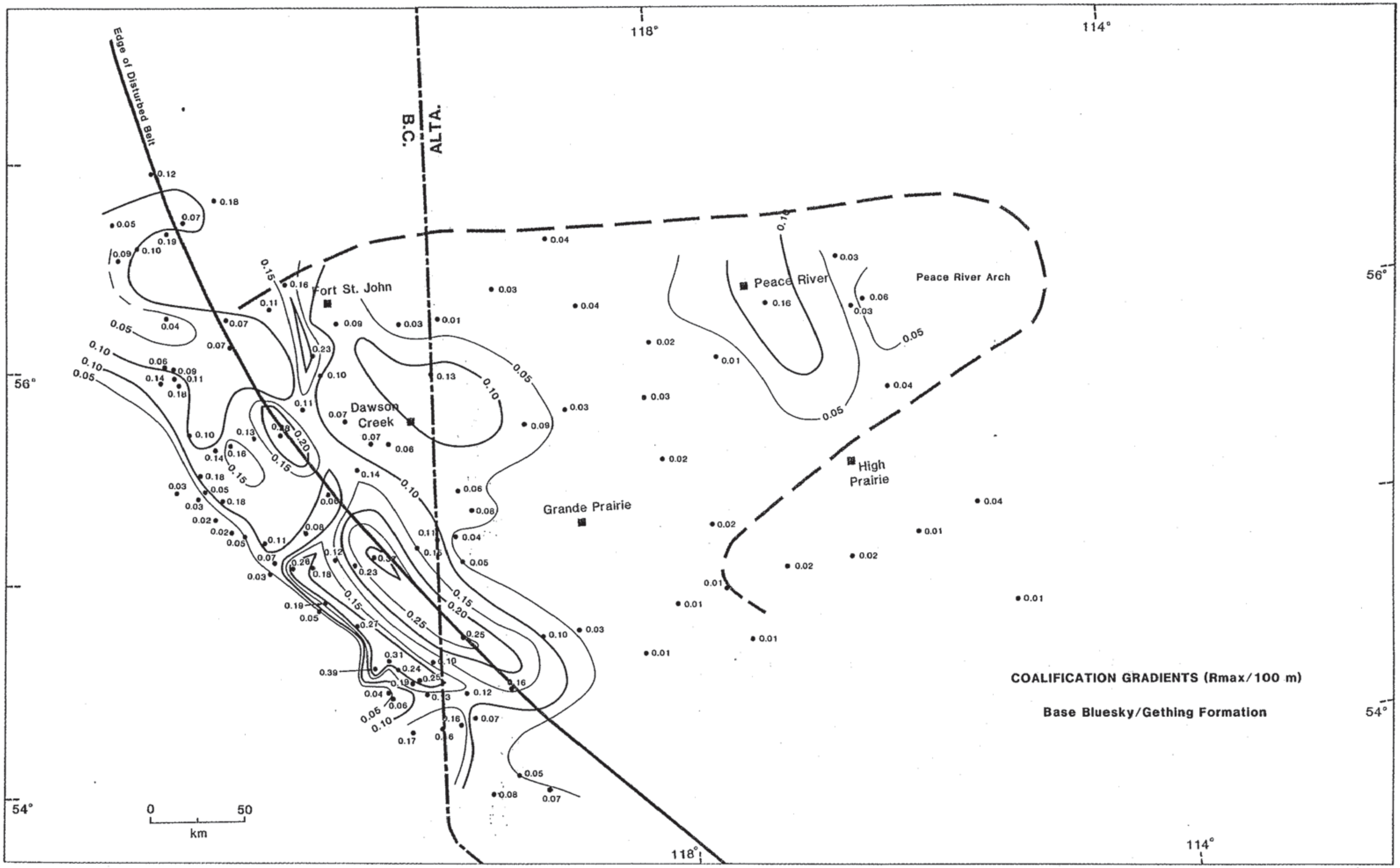

Fig. 11 Map showing coalification gradients (% Rmax/100 m) for Lower Cretaceous strata, Peace River Arch area.

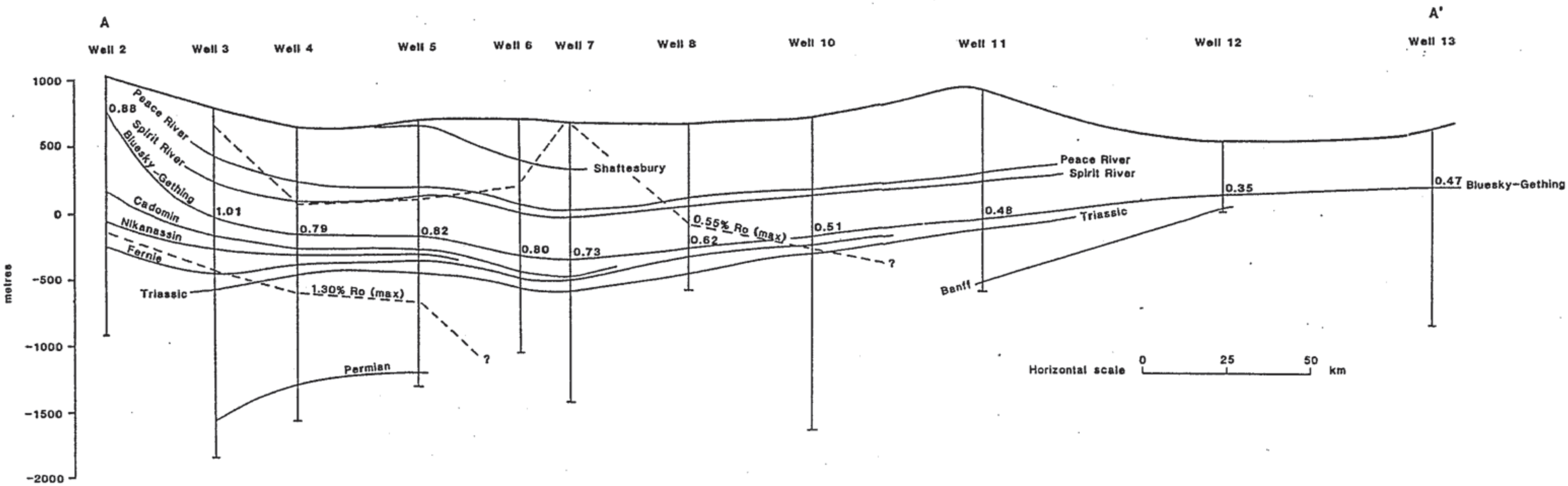

Fig. 12 Cross-section A-A[1], Peace River Arch area showing iso-reflectance lines for the onset of oil generation (0.55% Ro) and the end of oil generation (1.30% Ro), for well locations see Fig. 5.

b) isoreflectance lines paralleling this ridge (and regional strike) and declining to the east. Spacing of isoreflectance lines increases eastward as reflectance declines rapidly from more than 2.5% on the "ridge" to 1.3%, more gradually to 0.7% and even more gradually to 0.5%. In much of the eastern and north-eastern part of the area the reflectance at the base of the Bluesky/Gething is between 0.4%Rmax and 0.7%. Kalkreuth and McMechan (1988) suggest that this eastward decrease in maturation is largely due to thinning of the Cretaceous-Tertiary sedimentary wedge (e.g. see Figs. 3 and 4).

c) rapid decrease in reflectance to the west across the inner foothills, identified by Kalkreuth and McMechan (1988) and ascribed to a westward decrease in the depth and duration of burial beneath Maastrichtian-Eocene foredeep deposits, as well as to a westward decrease in paleogeothermal gradients.

d) a "saddle-like" feature northwest of Fort St. John (Fig. 7) overlying the northern flank of the Arch. Isoreflectance lines show a change in orientation from NW-SE to N-S and then to SW-NE, northward from Dawson Creek. There is an indication that the high reflectance "ridge" may continue with a northerly trend in the north-west corner of the area. This feature was indicated in the data of Kalkreuth and McMechan (1988) and has been confirmed and extended easterly in this study.

   This change in isoreflectance orientation parallels the orientation of the underlying Precambrian surface. North of the Arch this surface strikes N-S and to the south strikes NW-SE (Cant, 1988). Bachu & Burwash (1990) have shown that heat flow from the basement is the controlling factor in the thermal regime of the Western Canada Basin. Isotemperature lines at the top of the Precambrian show a similar marked change in orientation near the Peace River Arch (Issler 1990).

   Kalkreuth and McMechan (1988) ascribed this anomaly to reduced burial by Maastrichtian to Eocene foredeep deposits in the north as compared to the south. In particular, they identified a zone of rapid northward thinning of this wedge in the region of the reflectance anomaly and suggested that thinning may have been caused by the presence of underlying basement flexures or fault blocks with north-side-up movement.

3.3 Maximum Reflectance Contours - Top Bluesky/Gething Formation

Rmax contours at the top of the Bluesky/Gething Formation are shown in Fig. 8. The pattern of reflectance distribution is very similar to that shown at the base of this unit. In the west, contours at the top of the formation are transposed westerly relative to contours of the same value at the base. In the east there is conformity of reflectance values at both horizons because the unit is so thin that there is no significant increase in reflectance from top to base.

3.4 Trend Surface Analysis: Reflectance levels and residual values at base of the Bluesky/Gething Formation

Trend surfaces of second to fourth order were computed for the maximum reflectance values at the base of the Bluesky/Gething formation. The second order surface gave an 83.92% "explanation" between actual and computed values. Higher order surfaces indicated little improvement in "fit" (only 3.34% increase from order two to four) and it was decided to plot contours of the less complex surface (Fig. 9) and residuals for the second order equation (Fig. 10). The contour map of the trend surface indicates a NW-SE oriented regional trend of maximum reflectance increasing regularly to the SW. There is a minor increase in gradient at higher levels of reflectance in the SW and a marked decrease in gradient to the east of the 0.6% contour. This pattern is very similar to the regional trend shown on the reflectance contour map, (Fig. 7). The change in trend in the NW part of the area that is revealed in that map is not highlighted by the second order surface. There is some indication of this feature on the higher order surfaces. The 1.8% trend surface contour approximates the location of the "ridge" of maximum reflectance values shown on the reflectance contour map (Fig. 7) indicating that the trend surface underestimates the actual values along the ridge by approximately 0.5% to 0.7%.

The residuals map (Fig. 10), illustrates the difference between the gridded surface of actual values and the trend surface (2nd order). Positive residuals indicate areas where the trend surface is of lower value than the actual surface. This plot highlights the presence of a high reflectance zone in which actual reflectance is significantly higher than might be predicted based on the regional trend surface. This zone corresponds to the high reflectance "ridge" of Fig. 7. To the SW of this zone, residuals decrease markedly over a narrow area, reflecting the decrease of reflectance at a greater rate than would be expected from the trend surface. This feature is at the limit of data and the fitted surface has been little influenced by the reflectance decrease near the SW limits. The residuals highlight the change of reflectance orientation in the NW, by the presence of a zone of positive values, and also the anomalously low reflectance values to the south of Grande Prairie (Figs. 7 and 8).

3.5 Coalification Gradients

The rate of increase of reflectance with depth varies with reflectance level, as evidenced in deep wells with a wide reflectance range, where best fit regression equations are generally of second order. Even at similar reflectance levels, coalification gradients can vary due to variation in geothermal gradient (Bostick et.al. 1979; Teichmüller and Teichmüller, 1986), thermal conductivity of the host rock and overlying strata (Damberger, 1966, Jones et.al. 1972). Consequently, any interpretation of coalification gradients should be restricted to zones of similar maturity and lithology. There is a wide range of reflectance between wells in the study area and, although no definitive conclusions can be drawn from calculated gradients in wells which intersect sequences of different maturity, a reflectance-depth gradient map has been constructed to show very general trends in coalification across the area (Fig. 11). In most cases these gradients have been calculated for the Early Cretaceous part of the section.

The reflectance-depth gradient map shows that over most of the eastern half of the area, reflectance increase is in the range of 0.02 to 0.04% Rmax/100m (Fig. 11). In the west, gradients increase rapidly to a NW-SE trending "ridge" of high values where gradients exceed 0.2% Rmax/100m. This zone of high gradients coincides approximately with the location of the zone of high reflectance values at the base of the Bluesky/Gething Formation (Fig. 7). There is an apparent change in orientation of the high gradient zone to N-S to the west of Dawson Creek.

In the east there is a local zone of relatively high gradients in the region of the Peace River heavy oil pool (Fig. 11). This anomaly is essentially due to the gradient calculated in the Numac Tangent Well (11-30-80-23W5). Samples in this well are all derived from core and have reliable depths, but come from a restricted depth interval. It has been suggested (D.Issler pers. comm.) that high gradients might be expected in this area as a result of anomalous heating by the outflow of the waters that carried oil into the Peace River pool. This anomaly requires further investigation before any conclusions as to its extent and origin can be made.

3.6 Hydrocarbon Generation Zones

Although different organic matter types generate hydrocarbon products at different levels of thermal maturity, some generalisations can be drawn regarding zones of hydrocarbon generation and destruction based on vitrinite reflectance values. Kalkreuth and McMechan (1988) chose the following correlations:

Rmax	=	0.55%; onset of oil generation
	=	0.80%; onset of gas generation (from oil or gas prone kerogen)
	=	1.3%; end of oil generation
	=	2.0% limit of preservation of light oil
	=	2.2% limit of preservation of wet gas
	=	4.8%; limit of dry gas preservation

Examination of the reflectance contours at the base of the Bluesky/Gething Formation (Fig. 7) shows the 1.3% reflectance contour trending north westerly through Dawson Creek. Most of the area studied to the west shows reflectance above this level and source rocks at or below the Early Cretaceous in this area, are beyond the oil generation window. Along the "ridge" of high reflectance values, Rmax exceeds 2.2% and in this limited area it could be expected that only dry gas is preserved. Between 1.3% and 2.2% Rmax can be considered a zone of potential preservation of wet gas for basal Cretaceous strata.
The 0.55% Rmax contour trends WNW through the north eastern portion of the area. This indicates that over much of the area, to the west of this line, suitable source rocks at and below the base of the Gething have generated oil. Between the 0.55% and 1.3% contours,

rocks near the base of the Bluesky/ Gething are within the oil window, a zone in which oil may have been generated and preserved in reservoirs. For strata stratigraphically younger, the "oil window" lies further to the west (e.g. see Fig. 8) and in older strata it is transposed easterly.

Hydrocarbon generation zones can also be illustrated on cross sections. Uncorrected cross sections along lines AA[1], BB[1] and CC[1] are shown in Figs. 12, 13 and 14. These sections illustrate selected formation tops and the depth at which the 0.55% and 1.3% iso-reflectance surfaces occur in the sampled wells. The 1.3% surface can be estimated in only the western part of the area. The 0.55% surface is, in general, sub-horizontal over much of the area. As a consequence of the westward structural dip, this surface intersects the succession at progressively older stratigraphic levels eastward across the basin. In the west of section BB′, at Esso Bissette (12-3-77-16W6), strata below the Turonian-Cenomanian Doe Creek Member are at levels of maturity greater than the onset of oil generation at 0.55%Rmax. In the east at Imperial Heart River (2-9-83-15W5) the 0.55% surface lies within the lower part of the Mississippian Debolt Formation. In the extreme east at Texex et al. Livock (6-78-87-22W4) the entire sedimentary section above Precambrian basement has not attained maturity equivalent to 0.55% Rmax. Oils reservoired in this area have migrated updip from western sources.

3.7 Summary

Based on the determination of vitrinite reflectances in 58 petroleum wells across the Peace River Arch area the regional trends in maturation patterns within the Bluesky/Gething Formation are as follows:

1. Isoreflectance maps for top and base of the formation show the gradual decrease of reflectances from a maximum at the eastern edge of the disturbed belt to relatively low maturation levels to the east.

2. Trend surface and residual maps show the general NW-SE oriented trend of the isoreflectance lines with reflectances increasing regularly to the southwest. Positive residuals outline the ridge of high maturation at the eastern edge of deformation . Negative residuals south of Grande Prarie indicate an area of comparatively low maturity, as compared to the regional trend.

3. The distribution of vitrinite reflectances for the base and top of the formation as well as the vertical variations of vitrinite reflectances in three stratigraphic cross-sections indicate that Bluesky/Gething strata over much of the central and eastern part of the Peace River Arch lies within the oil generative window. In the very east strata are immature, whereas in the disturbed belt to the west most of the strata is overmature in terms of oil generation capacity.

4 ACKNOWLEDGEMENTS

M. Tomica of the Organic Petrography section undertook all sample preparation; K.Nairn and D.Lepard of Computer Services assisted with advice on accessing the SWELLS data base and preparing computer generated maps as did M. Stanilands; the staff of the Core and Sample Section, in particular A. Coates, provided information on cuttings availability and provided cuttings for sampling; some of the samples analyzed were collected by J. Barclay, D.Issler and D. Leckie; K. Osadetz provided a computer file of published and unpublished reflectance data for the Western Canada Sedimentary Basin.

5 REFERENCES

Bachu, S. and R.A. Burwash, 1990: Geothermal Regime in the Western Canada Sedimentary Basin; Canadian Society Petroleum Geologists Convention, May 1990 (abstract)

Cant, D.J., 1988: Regional structure and development of the Peace River Arch, Alberta: a Palaeozoic failed-rift system?; Bull. Canadian Petroleum Geology, v.36, 3, p.284-295

Issler D., 1990: Evidence for anomalous Tertiary heating in the Peace River Arch region from apatite fission track analysis; Canadian Society Petroleum Geologists Convention, May 1990 (abstract)

Bostick, N., S. Cashman, R. McCulloh, and C. Waddell, 1979: Gradients of vitrinite reflectance and present temperatures in Los Angeles and Ventura Basins, California; in P.A. Scholle and P.R. Schluger, eds., Aspects of Diagenesis; SEPM Special Publication 26, p.17-43

Damberger, H., 1966: Die Abhängigkeit des Inkohlunsgradienten vom Gesteinsaufbau : Zeitschrift der Deutschen Geologischen Gesellschaft, v.117, p.8

Jackson, P.C., 1984: Paleogeography of the Lower Cretaceous Mannville Group of Western Canada; in Elmworth- Case Study of a Deep Basin Gas Field; J.A. Masters (ed); AAPG Memoir 38, p. 49-78

Jones, J., D. Murchison, and S. Saleh, 1972: Variation of vitrinite reflectivity in relation to lithology; in H.R. v. Gaertner and H.Wehner, eds., Advances in Organic Geochemistry (1971), p.601-612

Kalkreuth, W., and M. McMechan, 1984: Regional patten of thermal maturation as determined from coal rank studies, Rocky Mountain Foothills and Front Ranges north of Grande Cache, Alberta - implications for petroleum generation: Canadian Petroleum Geology Bulletin, v.32, p.249-271

Kalkreuth, W., and M. McMechan, 1988: Burial history and thermal maturity, Rocky Mountain Front Ranges, Foothills, and Foreland, East-Central British Columbia and adjacent Alberta, Canada; AAPG Bulletin, v.72, p.1395-1410

Pearson, David E., and Associates Ltd., 1985: Vitrinite Reflectance Over the Peace River Arch; unpublished report to Geological Survey of Canada; D.S.S. Contract # OSG85-00184

Schaefer, R., D. Welte, and H. Pooch, 1984: Geochemistry of low molecular weight hydrocarbons from two exploration wells of the Elmworth gas field (Western Canada Basin); Organic Geochemistry, v.6. p.695-701

Smith, D., C. Zorn, and R. Sneider, 1984: The paleogeography of the Lower Cretaceous of Western Alberta and Northeastern British Columbia, in and adjacent to the Deep Basin of the Elmworth area; in Elmworth- Case Study of a Deep Basin Gas Field; J.A. Masters (ed); AAPG Memoir 38, p. 79-114

Teichmüller R., and M. Teichmüller, 1986: Relations between coalification and paleogeothermics in Variscan and Alpidic foredeeps of western Europe; in G. Buntebarth and L. Stegena, eds., Lecture Notes in Earth Sciences, v.5, Paleogeothermics, Berlin, Springer-Verlag, p.53-78, 205-228

Weiss, H.M., 1985: Geochemische und petrographische Untersuchungen am organischen Material kretazischer Sedimentgesteine aus dem Deep Basin, Westkanada: Unpublished Ph.D. dissertation, Rheinische-/Westfälische-Technische Hochschule, Aachen; 261p.

Wright, G.N., ed., 1984: The Western Canada sedimentary basin - a series of geological sections illustrating basin stratigraphy and structure; Canadian Society of Petroleum Geologist, Geological Association of Canada, Calgary.

6. APPENDIX

Legend for Tables I-VI

Sample #:	refers to pellet number system used at ISPG * denotes core sample
Rrandom (%):	mean random vitrinite reflectance value obtained from dispersed organic matter; for these samples maximum reflectances were calculated using the formula shown on page 12
Rmax (%):	mean maximum vitrinite reflectance value obtained from coal
#:	number of reflectance measurements recorded
S.D.:	standard deviation of the mean reflectance value

Comments - the following notations maybe present to indicate:

2 poptns:	more than one vitrinite population present
bit/inert:	sample consists of bitumen and inertinite
dom:	dispersed organic matter
mode:	reflectance value based on mode
* :	sample slightly heat affected, see chapter 2.2
** :	sample moderately heat affected, see chapter 2.2
*** :	sample severely heat affected

TABLE I: NORTHERN E-W SECTION EXPLORATION WELLS (A-A')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE GETH
1	RICHFIELD BRENOT CRK	343/90		299	NIKANASSIN		1.02	40	0.06		WELL EXTENSIVELY FAULTED		
	D-23-G/94-B-1	* 1423/89		506	"		0.73	50	0.05		CORRELATIONS UNCERTAIN		
		* 1424/89		586	"		1.13	23	0.07		(D. Stott., pers comm)		
	N: 6,218,014	344/90		799	"		0.90	39	0.05				
	E: 552,674						1.07	11	0.04				
		* 1425/89		850	"		1.12	40	0.04				
		345/90		957	"		0.91	50	0.05				
		* 1426/89		1239	"		1.04	3	-				
2	CZAR BUTLER	355/90		340	GETHING		0.96	50	0.09	2 poptns	BASED ON FIVE SAMPLES	0.047	594
	c-12-C/94-B-8	356		440	"		0.92	50	0.06		Rm=0.00047D+0.76 (r=0.73)		
		357		565	"		1.05	28	0.04	2 poptns	TOP BLUE/GETHING, 252m=0.88		
	N: 6,235,552	358		695	"		1.03	60	0.06		BASE GETHING, 846m=1.16		
	E: 545,102	359		770	"		1.17	46	0.05	2 poptns			
		360		935	CADOMIN		1.08	16	0.03	"			
		352		1190	NIKANASSIN		1.16	23	0.05	"		0.047	
		353		1555	CHARLIE LAKE		-	-	-	bit/inert			
3	IMP PAC GROUNDBIRCH	347/90	2100	640	SPIRIT R	0.84	0.89	36	0.06	dom	BASED ON TOP 3 SAMPLES	0.070	149
	5-5-84-24W6	348	2990	911	GETHING		1.06	40	0.08		Rm=.0007*DEPTH+.44 (r=0.98)		
		349	3160	963	"		1.13	50	0.06		TOP BLUE/GETHING 1.01		
	N: 6,234,704	350	3790	1155	NIKANASSIN	0.74	0.77	40	0.07	dom	BASE GETHING 1.12		
	E: 576,659	351	3990	1216	"		1.04	50	0.06				
4	HOME ATTACHIE	362/90	2650	808	GETHING		0.80	50	0.05		BASED ON TOP 3 SAMPLES	0.114	103
	7-22-84-22W6	363/90	2900	884	"		0.88	50	0.04		Rm=.00114*D-0.1216 (r=0.98)		
		364/90	3080	939	CADOMIN		0.95	60	0.11	mode	TOP BLUE/GETHING, 799.5m=0.79		
	N: 6,240,040	* 1256/89	6704	2043	TAYLOR/GOLATA	1.08	1.15	50	0.08	dom mode	BASE GETHING, 902.2m=0.91		
	E: 600,200	* 1257/89	6705	2044	"		1.30	50	0.07				
		365/90	3320	1012	NIKANASSIN		0.70	50	0.03				

TABLE I: NORTHERN E-W SECTION EXPLORATION WELLS (A-A')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE GETH
5	PEX FORT ST JOHN	370/90	2950	899	GETHING		0.87	50	0.06		BASED ON ALL SAMPLES	0.095	103
	3-29-83-18W6	371/90	3210	978	CADOMIN		0.86	50	0.05		Rm=0.000953-0.018 (r=1)		
	N: 6,232,538	372/90	3430	1045	NIKANASSIN		1.00	22	0.04	2 poptns	TOP BLUE/GETH, 874.2m=0.82		
	E: 635,929	* 1254/89	8497	2590	GOLATA		2.24	50	0.10		BASE GETHING, 977.2m=0.91		
6	DOME ALCES	378/90		720	SPIRIT R	0.67	0.70	60	0.05		BASED ON 5 SAMPLES	0.032	129
	6-22-83-15W6	379/90		1055	BULLHEAD		0.77	50	0.05		Rm=0.000469D+0.319		
		380/90		1080	"		0.80	50	0.05		TOP BLUE/GETHING, 1015m=0.80		
	N: 6,232,476	381/90		1120	"		0.86	50	0.06		BASE GETHING, 1144.5m=0.86		
	E: 668,639	383/90		1800	MONTNEY		0.87	40	0.04				
		* 1235/89		2351	DEBOLT	1.32	1.43	2	-				
		1234/89		2351	DEBOLT		1.32	10	0.05				
7	IMP PAN AM CHERRY PT	366/90	3510	1070	GETHING		0.73	50	0.04	**	BASED ON: EXCL 368,	0.017	112
	6-26-83-13W6	367	3530	1076	"	0.76	0.81	11	0.04	2 poptns	AVG OF 366&377,		
		368	3670	1119	"		0.83	39	0.04		CORE ADJUST 1224&25		
	N: 6,234,508	369	4920	1500	DAIBER		0.81	50	0.04		Rm=0.000174D+0.548 (r=0.93)		
	E: 317,686	* 1224/89	6590	2009	GOLATA	0.76	0.80	26	0.04		TOP BLUE/GETH, 1043m=0.73		
											BASE GETHING, 1155.2m=0.75		
8	BAYSEL UNION EUREKA	373/90	50	15	?	0.73	0.77	4	-	dom ?contam	BASED ON BASAL 3	0.033	64
	6-11-85-10W6	374	860	262	?	0.41	0.41	5	0.04	dom	Rm=0.00033D+0.309		
		375	2160	658	SPIRIT R	0.49	0.50	5	0.01	dom	TOP BLUE/GETH, 951.6m=0.62		
	N: 6,247,945	377	3280	1000	GETHING	0.63	0.66	4	0.03	dom	BASE GETHING, 1015.3m=0.64		
	E: 347,569												
9	SHELL WORSLEY SOUTH	354/90	2950	899	GETHING	0.52	0.53	50	0.04	**	BASED ON 3 POINTS	0.042	80
	10-19-87-7W6										Rm=0.00042D+0.149 (r=0.99)		
											TOP BLUE/GETH, 869.9m=0.51		
10	SHELL WORSLEY	449/90	2750	838	SPIRIT R	0.49	0.50	29	0.04	**	BASE GETHING, 949.5m=0.55		
	9-26-87-7W6	450	2910	887	"								
		* 523	3090	942	GETHING	0.51	0.52	19	0.03	dom			
	N: 6,260,607	451	3140	957	GETHING	0.54	0.55	44	0.04	**			
	E: 371,254	452	3250	991	CADOMIN	0.46	0.47	47	0.05				
						0.65	0.68	3	0.02				

TABLE I: NORTHERN E-W SECTION EXPLORATION WELLS (A-A')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE GETH
11	B.A. WHITEMUD R.	342/90	640	195	?	0.46	0.46	40	0.04		BASED ON 3 POINTS	0.009	59
	13-26-88-2W6	678/90	3130	954		0.47	0.48	25	0.03		TOP BLUE/GETHING, 932.7m=0.48		
	N: 6,280,688	343/90	3180	969	GETHING	0.49	0.50	40	0.03		BASE GETHING, 992.1m=0.49		
	E: 425,997												
11A	MOBIL NORTH STAR	340/90	630	192	NOTEKEWIN	0.41	0.41	40	0.02		MEAN BASAL 4 SAMPLES=0.41	0.005	35
	12-18-90-22W5	* 658/90	1485	453	BLUE/GETH	0.35	0.35	50	0.03		AT 462m incl core adjust		
		* 659/90	1513	461	BLUE/GETH	0.37	0.37	25	0.06		TOP BLUESKY, 443m=0.41		
	N: 6,295.904	361/90	1530	466	BLUE/GETH	0.39	0.39	3	-	dom	BASE BLUESKY, 478m=0.41		
	E: 469,099	* 660/90	1550	472	BLUE/GETH	0.30	0.30	50	0.04				
12	CDN RES CHESCK	* 647/90	1360	415	GETHING	0.27	0.27	10	0.08		TOP BLUE/GETH, 397m=0.35		31
	7-5-92-20W5	* 646/90	1590	485	BANFF					bitumen	BASE GETHING, 428m=0.35		
	N: 6,311,747										(ADJUST FOR CORE)		
	E: 489,121												
13	DEKALB MURPHY BISON												
	10-30-94-14W5	* 666/90		441	BLUESKY	0.42	0.42	50	0.03		MEAN VALUE 0.39 AT 449m		34
		* 674/90		453	BLUESKY	0.35	0.35	25	0.06		TOP, 443m=0.47		
		* 667/90		454	BLUESKY	0.33	0.33	15	0.05		BASE, 477m=0.47		
14	TEXEX SAWN	384/90	1660	506	SPIRIT R.		0.30	-	-	2 poptns			
	6-29-92-12W5						0.67	-	-				
15	HON UNION LAFOND	* 663/90	1250	381		EXAMINED; NO MEAS'TS							34
	12-4-95-9W5	* 664/90	1265	386		"							
		* 665/90	1340	408		"							
16	AMOCO SENEX												
	7-16-96-6W5	* 661/90		346	BLUESKY	0.37	0.37	50	0.04		MEAN=0.343 at 357m		31
		* 662/90		368	BLUESKY	0.32	0.32	50	0.03		TOP, 345.5m=0.42		
											BASE, 376.5m=0.42		

* CORE SAMPLES

TABLE II: CENTRAL E-W SECTION EXPLORATION WELLS (B-B')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE/GETH
17	CANHUNTER ESSO WASP	118/84		950	DUNVEGAN		0.90	50	0.05		TOP BLUE/GETH =1.62	0.060	189
	B-4-L/93-P-7	119/84		2320	GETHING		1.70	50	0.08		BASE GETHING =1.73		
		120/84		2355	GETHING		1.70	50	0.07				
	N: 6,143,141	121/84		2395	GETHING		1.74	50	0.09				
	E: 631,541	121/84		2430	GETHING		1.69	50	0.08				
18	HOME WAINOCO SUNDOWN	123/84		1806	FALHER		1.23	50	0.03		TOP BLUE/GETH =1.70	0.140	133
	C-34-B/93-P-10	124/84		1815	FALHER		1.20	50	0.06		BASE GETHING =1.81		
		125/84		1839	FALHER		1.24	50	0.04				
	N: 6,156,158	126/84		2058	GETHING		1.72	50	0.06				
	E: 646,944	127/84		2097	GETHING		1.74	50	0.05				
		128/84		2136	GETHING		1.77	50	0.07				
		132/84		2325	UPPER MINNES		1.89	50	0.10				
		133/84		2370	UPPER MINNES		2.00	50	0.10				
19	ESSO BISSETTE	1/90		675	DUNVEGAN	0.61	0.63	50	0.08		Rm=0.00064D+0.142 (r=0.96)	0.064	131
	12-3-77-16W6	* 1406/89		812	"		0.64	50	0.03		TOP BLUE/GETH =1.29		
		* 1407		1294	PADDY	0.79	0.83	38	0.04		BASE GETHING =1.37		
	N: 6,169,426	* 1408		1300	CADOTTE	0.79	1.04	40	0.04		(with core adjust)		
	E: 663,508	2/90		1385	SPIRIT R.		1.04	42	0.05				
		3/90		1760	BLUESKY		0.95	18	0.05				
		4/90		1785	GETHING		1.34	40	0.04				
		* 1409/89		1899	CADOMIN		1.37	50	0.07				
		* 1410/89		1931	NIKANASSIN		1.33	50	0.06	mode			
		8/90		1965	"		1.40	40	0.06				
20	TEXACO SINCLAIR	23/90		925	DUNVEGAN	0.67	0.70	35	0.05		Rm=0.00068D+0.061 (r=0.99)	0.068	156
	11-18-74-12W6			1365	FISH SCALES	0.68	0.68	30	0.03	?caved	TOP BLUE/GETH, 1834m=1.31		
		24/90		1395	"		1.08	8	0.03		BASE GETHING, 1990m=1.41		
	N: 6,144,001	25/90		1510	SPIRIT R.		1.06	50	0.05				
	E: 320,542	* 649/90		1886	GETHING		1.32	50	0.03				
		1389/90		1920	GETHING		1.40	50	0.05				
		650/90		2015	CADOMIN		1.33	44	0.05				
		26/90											

TABLE II: CENTRAL E-W SECTION EXPLORATION WELLS (B-B')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE/GETH
21	GULF SADDLE HILLS	35/90		755	DUNVEGAN	0.53	0.54	22	0.04	**, mode		-	-
	7-36-77-9W6	36/90		800	"	0.57	0.58	40	0.04				
	N: 6,162,176	* 1381/90		1172	PADDY	0.58	0.60	40	0.04				
	E: 358,222												
22	PHILLIPS KSITUAN	651/90	3610	1100	CADOTTE	0.53	0.54	50	0.04		Rm=0.00091D-0.467 (r=0.98)	0.091	132
	7-36-77-9W6	654/90	3970	1210	NOTEKEWIN	0.60	0.62	50	0.04		TOP BLUE/GETH, 1503.9M=0.90		
		652/90	4420	1347	"		0.76	50	0.04		BASE GETHING, 1620m=1.01		
	N: 6,176,285	655/90	5070	1545	GETHING		0.91	50	0.07				
	E: 358,668	656/90	5160	1573	"		0.95	50	0.05				
	.	657/90	5230	1594	"		1.02	50	0.10				
23	IMP SPIRIT RIVER	* 80/90	1160	354	DUNVEGAN	0.45	0.46	40	0.03		Rm=0.000345D+0.344 (r=0.85)	0.035	134
	12-20-78-6W6	* 1368/89	1350	411	"	0.51	0.52	40	0.04		TOP BLUE/GETH, 1161.3m=0.81		
		* 1370/89	3086	941	"		0.64	40	0.05		BASE GETHING,1295.4m=0.86		
	N: 6,182,525	* 82/90	3385	1032	CADOTTE		0.61	40	0.03				
	E: 380,768	* 1371/89	3980	1213	GETHING	0.76	0.80	40	0.04				
		* 1372/89	4020	1225	"		0.85	50	0.04				
		* 1373/89	4180	1274	"	0.71	0.75	40	0.03				
24	B.P. BELLOY	* 1112/88		511	CADOTTE	0.44	0.44	50	0.03		Rm=0.00037D+0.244 (2 SMPLS)	0.037	55
	6-34-78-2	* 1376/89		515	"	0.48	0.49	50	0.05		TOP BLUE/GETH,893.5m=0.56		
		33/90		560	SPIRIT R.	0.45	0.45	50	0.04	*	BASE GETHING, 948.5m=0.59		
	N: 6,184,576	* 1377/89		906	GETHING	0.47	0.48	40	0.03				
	E: 423,530	34/90		940	GETHING	0.57	0.59	50	0.04	*			
25	CAVALIER WHITELAW	22/90		470	CADOTTE	0.47	0.48	5	0.03		Rm=0.00023D+0.369	0.023	81
	6-31-81-1W6	* 1378/89		513	SPIRIT R.	0.44	0.44	40	0.02		TOP BLUE/GETHING, 837.2m=0.56		
		20/90		545	"	0.37	0.36	3	-		BASE GETHING, 918.2m=0.58		
	N: 6,213,331	18/90		865	GETHING	0.52	0.53	40	0.02				
	E: 428,446	21/90		905	GETHING	0.59	0.61	40	0.03				

TABLE II: CENTRAL E-W SECTION EXPLORATION WELLS (B-B')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE/GETH
26	NUMAC TANGENT	32/90	1180	360	PEACE R.	0.48	0.49	50	0.05	**	Rm=0.0001	0.018	41
	11-30-80-23W5	31/90	2010	613	SPIRIT R.	0.46	0.47	24	0.02	**	TOP BLUE/GETH,733m=0.55		
						0.51	0.52	22	0.03	**	BASE GETHING, 733.9m=0.56		
	N: 6,202,157	* 1380/89	2425	739	GETHING	0.50	0.51	40	0.04		(with core adjust)		
	E: 463,062	29/90	2465	751	"	0.48	0.49	40	0.04	**			
27	CANOXY HARMON	* 1399/89	1875	572	GETHING	0.33	0.33	25	0.02		Rm=0.00161D-0.599 (r=0.76)	0.161	73
	13-17-83-20W5	* 1400/89	1911	582	"	0.32	0.32	30	0.03		TOP BLUE/GETH, 563.3m=0.39		
		* 1401/89	2072	632	"	0.45	0.46	50	0.04		BASE GETHING, 635.8m=0.50		
	N: 6,228,055	* 1402/89	2097	639	BELLOY	0.40	0.40	30	0.02		ADJ FOR CORE 0.39		
	E: 491,818										(with core adjust 0.50)		
28	TRANSOCEAN HARMON	* 83/90	2325	709	BULLHEAD GP	0.38	0.38	50	0.02		BASE ON GRADIENT IN HEART R	-	66
	10-23-82-18W5	* 89/90	2347	715	BULLHEAD GP	0.42	0.42	50	0.04		TOP BLUE/GETH, 688m=0.46		
	N: 6,219,943										BASE GETHING, 754m=0.50		
	E: 518,924										(with core adjust)		
29	C.S. BEARHEAD #1	* 532/90	1227	374	PEACE RIVER	0.41	0.41	19	0.04		Rm=0.00038D+.247 (r=0.86)	0.038	41
	8-34-82-16W5	* 533/90	1243	379	"	0.37	0.37	40	0.02		TOP GETHING, 632m=0.56		
		457/90	1320	402	"	0.54	0.55		-		BASE GETHING, 675m=0.57		
	N: 6,222,632	* 534/90	1496	456	"	0.42	0.42	17	0.04		(ADJ FOR CORE)		
	E:536,859												
30	IMP HEART R.	* 525	2150	655	GETHING	0.41	0.41	30	0.05		BASED ON ALL MEAS'D SAMPLES	0.061	43
	2-9-83-15W5	* 524	2153	656	"	0.45	0.45	40	0.04		Rm=0.000614D+0.116 (r=0.85)		
		454	2220	677	"	0.53	0.54	20	0.06	mode	TOP GETHING, 632.5M=0.50		
		455	2720	829	SHUNDA	0.61	0.64	2	-		BASE GETHING, 675.1M=0.53		
		456	3020	920	BANFF	0.64	0.67	1	-		(with core adjust)		
31	NORCEN LUBICON										TOP & BASE BLUE/GETH=0.35	-	28
	14-4-85-12W5	610/90		435	GETHING	0.27	0.27	8	0.02		(with core adjust)		
	N: 6,244,845												
	E: 571,865												

TABLE II: CENTRAL E-W SECTION EXPLORATION WELLS (B-B')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE/GETH
32	TENN AI HEART R. N: 6,223,319 E: 549,588	* 1393/90		619	BULLHEAD	0.39	0.39	40	0.03		TOP & BASE BLUE/GETH=0.46 (with core adjust)	-	24
33	UNION RED EARTH 10-14-88-9W5 N: 6,277,669 E: 603,459	528/90 529/90 530/90		1200 1218 1242	WABISKAW " "	0.48 0.50 0.36	0.49 0.51 0.36	2 65 20	- 0.03 0.04		? MEAN=0.475 @1220m TOP BLUE/GETH, 378.9m=0.55 BASE GETHING, 405.4m=0.56	-	27
34	H.B. MARIA 11-11-86-4W5 N: 6,257,998 E: 653,020	689/90 526/90	1900 1917	579 584	WABISKAW WABISKAW	0.39 0.48	0.39 0.49	7 3	0.07 -		? MEAN=0.42 @581m CORE ADJUST=0.49 TOP BLÜE/GETH, 554.1m=0.47 BASE BLUE/GETH, 582.5m=0.49	-	28?
35	TEXEX ET AL LIVOCK 6-28-87-22W4 N: 6,272,003 E: 349,348	* 1398/89 27/90 * 1397/89	418 575 1022	127 175 312	GRAND RAPIDS CLEARWATER WABISKAW	0.38 0.43 0.52	0.38 0.43 0.53	40 5 17	0.02 0.02 0.03	 *** 	TOP BLÜE/GETH, 293.2m=0.53 BASE GETHING, 311.5m=0.54 (with core adjust)	0.081	18
36	UNION SALESKI 11-29-87-19W4 N: 6,271,803 E:377,089	* 81/90		242	WABISKAW	0.35	0.35	1	-		TOP & BASE BLUE/GETH=0.43 (with core adjust)	-	14

* cored sample

TABLE III:SOUTHERN E-W SECTION EXPLORATION WELLS (C-C')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE GETH
37	CDN SUP. WAPITI	704/85		810	CARDIUM		0.86	50	0.05		TOP BLUE/GETH 2.34	0.100	116
	a-38-H/93-I-9	716/85		1745	DUNVEGAN		1.08	50	0.03		BASE GETHING 2.45		
		717/85		1880	DUNVEGAN		1.07	50	0.03				
	N: 6,055,115	705/85		2575	BOULDER CK		1.67	50	0.09				
	E: 687,888	718/85		2690	GATES		1.75	50	0.06				
		719/85		2770	GATES		1.87	50	0.08				
		720/85		2850	GATES		1.89	50	0.08				
		721/85		2900	GATES		2.08	50	0.10				
		700/85		3025	GETHING		2.36	50	0.09				
		701/85		3060	GETHING		2.27	50	0.11				
		702/85		3080	GETHING		2.40	50	0.12				
		703/85		3105	GETHING		2.45	50	0.12				
		722/85		3280	MINNES		2.50	50	0.11				
		723/85		3345	MINNES		2.60	50	0.10				
38	AMOCO A1 NOSE	706/85		216	WAPITI		0.69	50	0.04		TOP BLUE/GETH 2.00	0.025	160
	8-19-66-12W6	707/85		497	WAPITI		0.83	50	0.04		BASE GETHING 2.22		
		192/85		786	WAPITI		0.82	50	0.05				
	N:6,067,500	708/85		832	WAPITI		0.76	50	0.05				
	E: 320,200	709/85		2765	GATES		1.59	50	0.08				
		710/85		2853	GATES		1.76	50	0.04				
		711/85		2920	GATES		1.89	50	0.07				
		712/85		2984	GATES		1.88	50	0.06				
		696/85		3088	GETHING		1.91	50	0.08				
		697/85		3118	GETHING		2.02	50	0.07				
		698/85		3146	GETHING		2.16	50	0.11				
		699/85		3231	GETHING		2.28	50	0.13				
		713/85		3304	MINNES		2.03	50	0.06				
		714/85		3542	MINNES		2.29	50	0.13				
39	AMOCO STEEP CREEK	113/90		2300	PADDY		1.18	50	0.05		Rm=0.00104D-1.196 (r=0.96)	0.104	130
	11-13-66-8W6	119		2370	SPIRIT R		1.29	50	0.06		TOP BLUE/GETH, 2594.6m=1.50		
		120		2430	"		1.39	50	0.05		BASE GETHING, 2724m=1.64		
	N;6,064,449	121		2555	"		1.40	50	0.06				
	E: 359,877	123		2745	GETHING		1.70	45	0.05				
		124		2835	CADOMIN		1.75	22	0.04				
		122		2665	"		1.68	8	0.10				

TABLE IV: CENTRAL N-S SECTION EXPLORATION WELLS (D-D')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (ft)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK (m) BLUE/GETH
50	PEX ANTE CREEK	511/90	1510	460	?	0.60	0.62	50	0.05		BASED ON 4 SAMPLES	0.012	111
	10-13-65-23W5	512	1590	485	?	0.64	0.67	9	0.09	***	Rm=0.000126D+0.57 (r=0.94)		
		513	1810	552	?	0.64	0.67	60	0.08	**	BASED ON 5 SAMPLES		
	N: 6,053,158	514	3950	1204	CARDIUM	0.59	0.61	34	0.06	*	Rm=0.000116D+0.59 (r=0.94)		
	E: 470,108	515	5230	1594	PEACE R.	0.76	0.80	54	0.07	**	EITHER ALTERNATIVE:		
		516	5590	1704	SPIRIT R.	0.58	0.60	28	0.05		TOP BLUE/GETH, 1902.6m=0.81		
		517	6470	1972	GETHING	0.78	0.82	50	0.06		BASE GETHING, 2013.2m=0.82		
		518	6610	2015	CADOMIN	0.76	0.80	50	0.05				
51	MOBIL GC CLOUSTON	505/90		205	?	0.43	0.43	11	0.02		BASED ON SAMPLES 1,2,3,5	0.020	150
	10-26-71-25W5					0.53	0.54	39	0.03	2 poptns	(all except 2 filtered)		
		506/90		390	?	0.57	0.59	50	0.05		Rm=0.000203D+0.502 (r=0.99)		
	N: 6,114,652	507/90		1095	PADDY	0.52	0.54	39	0.03		TOP BLUE/GETH, 1445m=0.80		
	E:453,736					0.68	0.71	11	0.03	2 poptns	BASE GETHING, 1595.3m=0.83		
		508/90		1275	SPIRIT R.	0.53	0.55	40	0.04				
		509/90		1475	GETHING	0.67	0.70	16	0.04	**			
						0.77	0.81	44	0.08	** 2 poptns			
		510/90		1530	GETHING	0.59	0.61	50	0.06				
52	SHELL PUSKWASKAU	492/90	1200	366	DUNVEGAN	0.45	0.46	40	0.03		BASED ON TOP 5 SAMPLES	0.029	70
	13-16-75-1W6	493	2800	853	SPIRIT R.	0.63	0.65	32	0.07	**	(excl #492/90)		
		494	3430	1045	SPIRIT R.	0.71	0.74	38	0.04		Rm=0.00029D+0.372 (r=0.84)		
	N: 6,151,225	495	3750	1143	BLUESKY	0.53	0.55	30	0.03		TOP BLUE/GETHING,1131.7M=0.70		
	E: 430,508	496	3850	1173	GETHING	0.66	0.69	40	0.05		BASE GETHING, 1201.5M=0.72		
		497	3970	1210	CADOMIN	0.66	0.68	40	0.05				
		498	6710	2045	PEKISKO	0.73	0.76	25	0.03				
53	AMMIN HINES CREEK	519/90		825	SPIRIT R.	0.55	0.57	16	0.03	***	Rm=0.00043D+0.233	0.043	48
	6-5-84-5W6	520		925	GETHING	0.63	0.66	30	0.05	**	TOP BLUE/GETHING, 887m=0.61		
	N: 6,235,216	521		1400	GOLATA	0.79	0.83	20	0.06		BASE GETHING, 935m=0.64		
	E: 391,265												
54	GULF CLEAR HILLS	499/90	50	15	?	0.46	0.46	50	0.06		BASED ON 5 SMPLS (1 filt'd)	0.007	80.00
	12-7-89-7W6	500	1570	479	DUNVEGAN	0.45	0.46	40	0.05		Rm=0.00008D+0.425		
		501	2060	628	SHAFTESBURY	0.49	0.50	40	0.04		TOP BLUE/GETH, 1187.8m=0.52		
	N: 6,286,455	502	3130	954	NOTEKEWIN	0.42	0.42	35	0.04		BASE GETHING, 1268m=0.53		
	E: 370,603	503	3990	1216	GETHING	0.51	0.52	40	0.04		5 SAMPLES (unfilt'd)		
		504	4020	1225	GETHING	0.50	0.51	23	0.05	shale	Rm=0.00005D+0.456		
											TOP BLUE/GETH = 0.52		
											BASE GETHING = 0.61		

* cored samples

TABLE V: EASTERN N-S SECTION EXPLORATION WELLS (E-E')

WELL #	WELL NAME & LOCATION	SAMPLE #	DEPTH (f)	DEPTH (m)	STRATIGRAPHIC UNIT	Rrand (%)	Rmax (%)	#	S.D.	COMMENTS	Ro(%) Calculations From Regression Lines	GRADIENT% Rm(%)/100m	THICK (m) BLUE/GETH
55	CHEVRON IOE L. BUFF	604/90	1990	607	GETHING	0.40	0.40	40	0.03		Rm=0.000324D+0.204 (2smpls)	0.032	41
	13-20-85-16W5	605/90	2900	884	BANFF	0.48	0.49	10	0.02		TOP BLUE/GETHING =0.39		
	N: 6,249,308										BASE GETHING =0.40		
	E: 530,890												
56	G.E.I. HEART R.	608/90		420	PEACE R.	0.42	0.42	18	0.03	2 poptns	Rm=0.000428D+0.285	0.042	68
	7-18-78-14W5	609/90		725	BLUESKY	0.58	0.60	10	0.02		(gradient based on unpubl'd		
	N: 6,179,364										data; r=0.97)		
	E: 552,754										TOP BLUE/GETH, 702m=0.59		
											BASE GETHING, 770m00.62		
57	BEAR VILLA #1	606/90	1130	344	?	0.53	0.54	4	-		? MEAN OF CORES=0.443 @ 760m	N/A	48
	7-8-74-14W5	* 668/90	2295	700	MANNVILLE	0.49	0.50	40	0.03		TOP BLUE/GETH, 777.8m=0.51		
		* 671/90	2327	709	MANNVILLE	0.46	0.47	26	0.03		BASE GETHING, 826m=0.54		
	N: 6,138,813	* 673/90	2471	753	MANNVILLE	0.41	0.41	40	0.03		(with core adjust 0.52)		
	E: 556,194	* 669/90	2667	813	GETHING	0.42	0.42	50	0.03				
		* 670/90	2705	824	GETHING	0.43	0.43	40	0.03				
58	GULF SWAN HILLS	598/90		1255	MANNVILLE	0.59	0.61	50	0.06		Rm=0.00012D+0.428 (r=0.98)	0.012	83
	11-11-66-9W5	599/90		1295	MANNVILLE	0.57	0.59	40	0.04		(top 3; 1 & 2 avg'd)		
		600/90		1395	MANNVILLE	0.59	0.61	40	0.04		TOP BLUE/GETH, 1423m=0.60		
	N: 6,062,582	601/90		1530	BANFF	0.61	0.63	39	0.05		BASE GETHING, 1506m=0.61		
	E: 612,667	602/90		1640	EXSHAW	0.52	0.53	6	-				

* cored samples

TABLE VI: WELLS FROM PUBLISHED SOURCES

WELL NAME & LOCATION	SOURCE	Ro(%) Calculations From Regression Line	GRADIENT Rm(%)/100m	THICK M BLUE/GETH
CANHUNTER ELMWORTH 10-19-70-12W6 N: 6,106,999 E: 320,253	1	Rm=0.000513D+0.09 (r=0.99) TOP BLUE/GETH, 2279M = 1.26 BASE GETHING, 2429.5M =1.34	0.051	151
CANHUNTER KARR 6-2-65-3W6 N: 6,050,193 E: 413,391	1	Rm=0.00014D+0.435 (r=0.96) TOP BLUE/GETH, 2364M = 0.77 BASE GETHING, 2491M = 0.78	0.014	127
CANHUNTER PETROMK ELM 6-28-68-13W6 N: 6,088,842 E: 312,845 E: 663,508	2	Rm=0.00121-1.512 (r=0.99) TOP BLUE/GETH, 2736M = 1.80 BASE GETHING, 2870M = 1.96	0.007	134
CANHUNTER TEXACO ELM 10-35-71-13W6 N: 6,119,845 E: 316,488	2	Rm=0.00047D+0.266 (r=0.98) TOP BLUE/GETH,2191M= 1.30 BASE GETHING, 2347.5M =1.37	0.047	157

1= WEISS, 1985
2 = SCHAEFER ET. AL., 1984