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RESULTS OF ROCK-EVAL/TOC ANALYSIS OF CORE THROUGH THE LOWER CRETACEOUS: MONKMAN PASS AREA, NORTHEASTERN BRITISH COLUMBIA

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Geological Surveyof Canada Open File Report

This report contains the tabulated results of Rock-Eval/Toc Analysis of a composite core section from coal company diamond drill cores in the Foothills of northeastern British Columbia. The reader is referred to the attached manuscript (submitted for publication) by Leckie, Kalkreuth and Snowdon for details location and interpretation.

Under the sample identification column:

Monk8008 refers to coal company drillhole MO80-08 from which Shaftesbury and Boulder Creek Formation samples were collected.

Monk812 refers to coal company drillhole MDD81-02 from which Hulcross and Gates Formation samples were collected.

Monk 814 refers to coal company drillhole MUD81-04 from which Moosebar and Gething samples were collected.

Monk8011 refers to coal company drillhole MD80-11 from which Cadomin Formation and Minnes Group samples were collected.

RESULTS OF ROCK-EVAL/TOC ANALYSIS OF CORE THROUGH THE LOWER CRETACEOUS: MONKMAN PASS AREA, NORTHEASTERN BRITISH COLUMBIA

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ABSTRACT

Shale and coals from 1.2 km of core through most of the Lower Cretaceous preserved in Western Canada were analyzed for source rock potential and maturation levels. The Minnes Group, averaging 2.7% TOC, has some potential for gas generation from a limited number of samples. The Gething and Gates formations average 6.3 and 5.2% TOC, respectively, and some samples show potential for gas. The marine Moosebar and Hulcross formations have 1.5 and 1.7% TOC, respectively, and very low hydrocarbon yields on pyrolysis. These marine sediments contain dominantly Type III organic matter (OM) with lesser amounts of thermally degraded Type II. The Boulder Creek Formation has 1.1% TOC and poor source rock potential. Most Boulder Creek OM was oxidized during Late Albian sea level fluctuation when thick paleosols developed. Hydrogen Index (HI) for the marine sediments show a progressive decrease with depth from 132 to 61 mg HC/ g of TOC interpreted as due to thermal degradation of Type II OM with increased burial. These marine sediments may have generated limited amounts of oil. HI for nonmarine sediments is scattered with no apparent trend with depth. Tmax values are consistently lower for the marine samples of the Shaftesbury and Moosebar formations than adjacent nonmarine samples and for the upper portion of the Minnes Group. Despite a fairly large scatter, the vitrinite reflectances increase systematically with stratigraphic depths from 0.94% R_0max at the top of the Boulder Creek Formation to 1.5% R_0max in the Minnes Group. The reflectances indicate high volatile A bituminous and medium/low volatile bituminous coals.

From the coalification gradient (0.05% R_0max/100m depth), the end of oil generation for potential source rocks is indicated at the base of the Gething Formation.

INTRODUCTION

Lower Cretaceous sediments in the Foothills and western Interior Plains of western Canada consist of alternating sequences of marine and nonmarine siliciclastic detritus deposited into the western margins of a foreland basin. Most of the hydrocarbon production from Lower Cretaceous strata in northwestern Alberta and northeastern British Columbia is natural gas whereas there is minimal oil production which comes from the Upper Cretaceous (Fig. 1). The coarser clastic deposits form gas and oil reservoirs containing reserves up to 805 billion m^3 and 95 million m^3, respectively (British Columbia and Alberta, heavy oil excluded; Proctor and McCrossan, 1980; Wallace-Dudley et al., 1982; Lee et al., 1985). In spite of the immense volumes of hydrocarbon production from the Western Canada sedimentary basin, the quality and hydrocarbon source potential of these rocks has not been thoroughly documented. Oil source potential calculations are typically based on analyses of only a few samples over a large geographic area or a very thick geological section (e.g., Moshier and Waples, 1985; Welte et al., 1984). The total volume of Lower Cretaceous rock in western Canada is about 190,000 km^3 (45,000 mi^3), of which 65% is shale (Parsons, 1973) and it is generally assumed that these shales are good sources for hydrocarbons in the Cretaceous section. A second common assumption, although controversial, is that the Cretaceous shales were the dominant source for 1 trillion barrels of heavy oil or bitumen found in Lower Cretaceous sands in northern Alberta (Vigrass, 1968; Deroo et al., 1977; Energy Resources Conservation Board, 1980; Jones, 1981; Masters, 1984). Source rock-volume calculations led Moshier and Waples (1985) to conclude that Lower Cretaceous (Mannville equivalent) strata could not have been a sole source for the heavy oils unless there existed yet undiscovered, very organic rich Lower Cretacous strata in Alberta.

The purpose of this study is to identify possible hydrocarbon source rocks in the Lower Cretaceous of northeastern British Columbia and west-central Alberta and to evaluate their thermal maturity with respect to known gas and oil fields in this area (Fig. 1). Four closely-spaced coal company diamond drill cores in the Duke Mountain area of northeastern British Columbia (Fig. 2) were measured, sampled and combined to make a composite section 1200 m long. The base of the composite core section begins 335 m below the top of the Valanginian Minnes Group (Fig. 3) which in this area is 760 m thick (D. Stott, pers. comm. 1987). The top of the composite core extends 25 m above the base of the Albian Shaftesbury Formation, or about 140 m below the Fish Scale Zone which marks the top of the Lower Cretaceous. As such, the core represents most of the Lower Cretaceous section deposited and preserved in Western Canada. Although the samples used in this study are from the Foothills, there is hydrocarbon production from correlative units only a few tens of kilometres to the east and northeast (Fig. 1).

The amounts and types of organic matter (kerogen) in sedimentary rocks and the burial history of these rocks determines the formation of oil and gas (Karweil, 1955; Vassojevich, 1970; Dow, 1977; Powell and Snowdon, 1983; Fig. 4). In the present study, Rock-Eval/TOC analyses were used to determine quantity and type of kerogen, maturation levels and source rock potentials for all shale samples. In addition, all of the coal seams from the coal-bearing sequences and handpicked coalspars from marine and non-marine intervals were analysed for vitrinite reflectance to determine coal rank. Recent organic geochemical studies, including Rock-Eval analyses of marine Shaftesbury shales from the Deep Basin, have indicated a predominance of Type II/III kerogens at maturation levels within the oil window (Weiss, 1985).

GEOLOGICAL SETTING

Lower Cretaceous rocks in northeastern British Columbia and northwestern Alberta consist of alternating sequences of marine and nonmarine sediments deposited along the tectonically active western margins of the Cretaceous epeiric seaway. The depositional setting of the reservoir and source rocks (Fig. 3) have been described by Stott (1984), Jackson (1984) and Smith et al. (1984). The Gates and Boulder Creek formations are a major, third order coarse clastic cycle bracketed above and below by the marine Shaftesbury and Moosebar formations (Leckie, 1986). The Moosebar and Shaftesbury transgressions both appear to coincide with major eustatic fluctuations, however the Gates-Boulder Creek clastic wedge is interpreted to be the result of a major tectonic event which occurred in the rising Cordillera to the west (Leckie, 1986). Regionally, the nonmarine deposits of the

Gething, Gates and Boulder Creek formations thin to the north and northeast. The stratigraphic formations continue, albeit with different names (Fig. 3), from the Foothills into the Deep Basin where they form prolific reservoirs and seals.

Foothills deformation of Lower Cretaceous sediments occurred during the Laramide uplift between early Campanian and Late Eocene (Bally et al., 1966; Price, 1981) with most of the deformation occurring during the Paleocene (Kalkreuth and McMechan, 1984). It was during this interval that present coal ranks were established and hydrocarbons were generated and underwent migration (Deroo et al., 1977). In the Foothills, early Laramide uplift prevented deep burial and terminated the maturation whereas in the outer Foothills and Alberta syncline to the east, strata were progressively deeper buried and maturation continued (Kalkreuth and McMechan, 1984). Folding and faulting had no or only little impact on the preorogenic coal rank (Kalkreuth and Langenberg, 1986). Consequently, coal rank increases with stratigraphic depth at any given location independently of the structural position of the strata. Previous studies on Lower Cretaceous coals in the Foothills and Western Interior Plains have shown a wide variation in rank from high volatile A bituminous coals in the Foothills to semi-anthracites in the Alberta Syncline (Hacquebard and Donaldson, 1974; Karst and White, 1980; Kalkreuth, 1982; Kalkreuth and McMechan, 1984; Weiss, 1985; Kalkreuth and Langenberg, 1986).

Most of the hydrocarbon production from Lower Cretaceous strata in northwestern Alberta and northeastern British Columbia is natural gas whereas there is little oil production which comes from the Upper Cretaceous (Fig. 1). The distribution of Cretaceous gas fields (Fig. 1) in northwestern Alberta and northeastern British Columbia appears to have two underlying controlling factors. Many of the gas fields overlie the northeast-trending Peace River Arch which was a structural high during much of the Paleozoic but collapsed during the Mississippian and was a low through the Cretaceous at least until the Albian (Stelck, 1975; Stott, 1982; Cant, pers. comm., 1986). A second group of gas fields trends northwesterly and corresponds to the axis of the "Deep Basin" immediately east of the deformed belt.

METHODS

Rock-Eval/TOC

Channel samples were taken over 1.5 m intervals from shales and siltstones throughout the whole core. Samples from each interval were pulverized and about 100 mg analyzed using Rock--Eval/TOC following techniques outlined by Espitalie et al. (1985). The core was drilled using water as a lubricant, and therefore there is no mud contamination. The results of the Rock-Eval analyses were critically examined and samples having less than 0.1% TOC and/or less than 0.1 mg HC/g of rock for S2 were discarded from the data set because of the probability of large errors in the measured Tmax and derived parameters such as Hydrogen Index (S_2/TOC) and Production Index ($S_1/[S_1 + S_2]$). The remaining data (365 samples) have been plotted (Figures 5, 6, 7, 11 and 12) and summarized by formation in Table I.

The Rock-Eval/TOC results provide information about the dispersed OM in the core such as quantity and type of organic matter and level of thermal maturity (Table II). The parameter S1 is a measure of the amount of hydrocarbon liberated at 300°C and represents the volatile portion of the geologically generated bitumen. The S2 peak is the amount of hydrocarbon released during temperature programmed pyrolysis (300-600°C) and represents the bitumen which would be generated if burial and maturation continued. S1 and S2 are expressed in mg hydrocarbon/g of rock. S3 is the quantity of CO_2 formed by pyrolysis of the organic matter expressed in mg CO_2/g of rock. Tmax, in degrees Celcius, is the temperature of the maximum of the S2 peak and an estimate of thermal maturity. Total organic carbon is determined by oxidizing the pyrolysis residue in a second oven (600°C in air) and algorithmically summing the oxidized carbon with the carbon in the S1 and S2 hydrocarbon peaks. Although high TOC values may indicate good source rock potential, much of the OM may be essentially inert and thus have very little productivity due to sedimentary reworking, oxidation or advanced levels of maturation (Espitalie et al., 1985).

From the measured parameters, several useful derived parameters may be calculated. Hydrogen Index (HI) is the normalized S2 value (S2/TOC) expressed as mg HC/gm of TOC which allows the types of OM to be estimated (Table II). Oxygen index (OI) is the normalized S3 value (S3/TOC), expressed in mg CO_2/gm of TOC. Production Index or Transformation Ratio (PI=S1/[S1 + S2]) indicates the level of thermal maturation and also the presence of epigenetic hydrocarbons. S2/S3 indicates the type of organic matter (i.e., hydrogen-rich, oil-prone versus hydrogen-poor, gas prone) for low to moderately mature samples.

Types of OM can be determined on a cross plot of HI and OI which yields results comparable to the atomic H/C versus O/C Van Krevelen diagram (Fig. 5; Espitalie et al., 1977) and on a cross plot of HI and Tmax (Fig. 6; Espitalie et al., 1984). The OM plots on the HI vs OI diagram along kerogen evolution paths called Type I, II and III which are highly oil prone, gas and oil prone and gas prone, respectively. Type III OM can be further subdivided as to its origin from coal or dispersed organic matter (Espitalie et al., 1984). The Rock-Eval pyrolysis data shown in Figure 7 are tabulated by Leckie (1987).

Tmax obtained from Rock-Eval pyrolysis provides an indication of the level of thermal maturity (Fig. 4). The beginning of the "oil window" occurs at Tmax values of approximately 430° (Espitalie et al., 1985) and the main gas generation phase from Type II OM occurs at Tmax values of 450 to 455°C and from Type III OM at 465 to 470°C. End of oil generation is indicated by a Tmax value of approximately 465°C and values greater than 520°C indicate the dry gas zone (Teichmuller and Durand, 1983).

Vitrinite Reflectance

A total of 117 coals and handpicked coal spars from various lithologies were analysed for rank using vitrinite reflectance to quantify the level of thermal maturity of the sediments. The samples were crushed to a maximum particle size of 850um (20 mesh), mounted in epoxy resin, then ground and polished. Rank was determined by measuring maximum vitrinite reflectances using a Leitz MPV II microscope under standardized conditions as outlined in the International Handbook of Coal Petrography (ICCP, 1971) and A.S.T.M. rank classes assigned according to Davis (1978). The results, expressed in terms of arithmetic mean and standard deviation, are summarized in Tables III to V. The relationships of coal rank and vitrinite reflectances to hydrocarbon generation and destruction are illustrated in Figure 4.

RESULTS

Minnes Group

The upper Minnes Group recovered in this core is a 335 m thick succession of meandering fluvial, overbank, lacustrine sediments and commercial coal deposits. Bioturbated sediment and pyrite within some of the coals indicates local brackish water conditions. TOC content of the Minnes Group ranges from 0.36 to 12.29% and averages 2.69%. S1 ranges from 0.03 to 1.8 mg HC/g and S2 ranges from 0.19 to 27.86 mg HC/g indicating the presence of poor to very good source rock potential. HI values are less than 84 mg HC/g of TOC indicating a high level of thermal maturity and thus gas, would be the anticipated hydrocarbon product. This is supported by examination of the HI/OI and HI/Tmax cross plots (Figs. 5 and 6) which show that gas would be generated from dispersed OM and coals. The indicators of thermal maturation, Tmax (464 to 485°C), PI (0.04 to 0.39) and average R_0 values (1.33 to 1.50) indicate that the Minnes Group falls beyond the oil window well into the gas generation zone. Other formations discussed in this study overlie the Minnes Group and have experienced proportionately less burial and thermal stress and thus are at commensurately lower levels of maturity.

Cadomin Formation

The Cadomin Formation is an alluvial fan-braided river deposit (McLean, 1977; Varley, 1984a) sitting unconformably on the Minnes Group (Stott, 1979). The Cadomin Formation is 45 m thick and contains very little shale. No shale samples were collected. In the subsurface, the Cadomin Formation forms a laterally continuous sheet of sandstone and conglomerate 1.2 to 18.8 m thick and averaging 7.7 m (Varley, 1984b), with coal seams decimetres thick and having gas reserves of 16.9 billion cubic metres (Energy Resources Conservation Board, 1982). Varley (1984b) suggested that Cadomin gas accumulations were derived from coal beds within the Gething and Nikanassin formations. The average R_0max values of 1.31 to 1.33 indicates that the Cadomin Formation lies in the transition from oil generation to wet gas zone.

Gething Formation

The Gething Formation is a 136 m thick deltaic/coastal plain succession containing several economically significant coal seams. Much of the interval has brackish water-bay fill affinities (Gibson, pers. comm., 1987) and a major, northwards thickening marine tongue occurs in the upper half of the formation. The Gething Formation contains 3 coal seams greater than 1.5 m thick, ranging from 3.1 to 3.5 m thick (borehole MUD 81-04). The vitrinite reflectances of these seams ranges from 1.30 to 1.32% R_0max. Additional rank data from the Gething coals, collected from nearby coal exploration cores (locations shown in Fig. 2), show that vitrinite reflectance increases regularly with increasing stratigraphic depth (Fig. 10). The coalification gradients are relatively high, ranging from 0.16 to 0.27% R_0max/100 m depth.

The TOC content ranges from 0.12 to 23.48% with an average of 6.3%. S1 and S2 both have wide ranges, varying from 0.07 to 5.43 mg HC/g of rock and 0.45 to 36.3 mg HC/g of rock, respectively. This range indicates a highly variable source rock potential. The HI is generally less than 150 mg HC/g of TOC, with 3 values between 150 and 300 mg HC/g of TOC. Tmax values of 470 to 483°C, PI of 0.06 to 0.27 and average R_0max values of 1.24 to 1.31% indicate that the base of the Gething Formation is at the high maturity limit of the oil window.

Moosebar Formation

The Moosebar Formation is a 98 m thick marine shale and siltstone sequence. At its maximum point of transgression the Moosebar sea extended from the north across much of Alberta to south of Calgary (Taylor and Walker, 1984). The Moosebar Sea was boreal in nature and in this area was open to marginal marine conditions (McLean and Wall, 1981). The Moosebar shales were deposited in an offshore-transitional to offshore setting below the shoreface zone. Bioturbation is present throughout most of the formation indicating aerobic to disaerobic bottom-waters.

The Moosebar shales have an average TOC content of 1.48% and a range of 0.75 to 2.36%. However, S1 and S2 range from 0.07 to 0.43 mg HC/g and 0.24 to 1.28 mg HC/g, respectively, making the Moosebar Formation a poor potential source rock. The HI is low, less than 61 mg HC/g of TOC and any hydrocarbon generated from these marine shales would be gas. Tmax values of 440 to 473°C, PI of 0.06-0.36, and average R_0max $_0f$ 1.20 to 1.24 indicate that thermal maturation falls within the high maturity portion of the oil window. Although the Moosebar shales are lithologically described as marine, the organic facies may have been dominantly terrestrial. This is a relatively common occurrence in pro-deltaic shales and probably results from the overwhelming amount of terrestrial debris dumped into a deltaic environment and/or the occurrence of oxidizing bottom water permitting the biological reworking (oxidation) of the less refractory and more nutrient-rich marine organic matter. The level of thermal maturity is presently too high to reliably extrapolate back to the low maturity Hydrogen Index of this unit and hence infer the organic type. Nevertheless, the Tmax values exceed those normally attributed to high maturity Type II organic matter (~460 in Figure 15 of Espitalie et al., 1985) and thus may be inferred to be dominated by Type III OM on the basis of Tmax.

Gates Formation

The Gates Formation is a 280 m thick, dominantly nonmarine interval. There are 10 m of brackish water, estuarine-bay fill deposits in the middle portion of the formation and the lower 27 m consist of marine shoreface sandstones. Northwards, the Gates Formation becomes increasingly marine with several fourth order transgressive-regressive cycles. These fourth-order cycles form the wave-dominated Falher beaches (Leckie, 1986; Cant 1984; Smith et al., 1984) with estimated gas reserves of 96 billion m^3 (Energy Resources Conservation Board, 1985; British Columbia Ministry of Energy Mines and Petroleum Resources, pers. comm., 1986). Gas reserves contained in Gates Formation coal have been estimated as high as 1.4 trillion m^3 (Wyman, 1984). The Gates Formation in this borehole contains approximately 21 m of coal occurring in seams centimetres to metres thick. There are 8 seams greater than 1.5 m thick, ranging from 1.76 to 2.5 m thick (boreholes MDD 81-02 and MUD 81-04). The vitrinite reflectances range from 1.16 to 1.27% R_0max.

The average TOC content is 5.2% and ranges from 1.01 to 25.73%. The S1 and S2 values range from 0.06 to 4.81 mg HC/g of rock and 0.39 to 46.08 mg HC/g of rock, respectively. The high TOC and S2 hydrocarbon yielding samples must be considered as potential sources but the generally low HI values (Figs. 5 and 6) indicate that gas will be the expected product with some residual oil or condensate potential indicated for a few samples. Thermal maturation, as indicated by Tmax (451--

489°C), PI (0.03 to 0.2) and average $R^{o}max$ (1.07 to 1.27) puts the Gates Formation well into the lower part of the oil window and the upper part of the gas generation zone.

Hulcross Formation

The Hulcross Formation is 86 m thick and consists of finely interbedded marine shales, siltstones and sandstones that make up 8 minor coarsening upwards sequences. The Hulcross shales and siltstones were deposited in an offshore-transitional to offshore setting below the shoreface zone. Much of the formation is only minimally bioturbated and finely laminated sediment is preserved indicating that dysaerobic to anaerobic bottom conditions prevailed for long periods of time.

The TOC content of the Hulcross Formation varies from 0.21 to 3.01% and averages 1.71%. The S1 values of 0.19 to 1.0 mg HC/g of rock and S2 of 0.72 to 3.26 mg HC/g of rock indicate a poor to fair generative potential. HI ranges from 75 to about 134 mg HC/g of TOC and averages about 99 indicating that gas would be generated. The OM probably was originally a mixture of Type II and III material (Figs. 5 and 6). Tmax values of 443 to 470°C, PI of 0.11 to 0.33 and average R_0max values of 1.03 to 1.07 places the Hulcross Formation well within the oil window.

Boulder Creek Formation

The Boulder Creek Formation is a 111 m thick alluvial plain sequence sitting above 23 m of shoreface sandstone. The alluvial plain deposits contain 15 paleosols up to 6 m thick (Leckie and Foscolos, 1986) which played a significant role in affecting the source rock potential of the formation. Average vitrinite reflectances range from 0.93-1.07 R_0max. Additional rank data from nearby boreholes (locations and values shown in Figure 2) show comparable results.

The average TOC value is 1.14% with values ranging from 0.26 to 2.56%. However S1 values are all less than 0.26 mg HC/g of rock and S2 less than 2.6 mg HC/g of rock which indicates a poor source rock potential. All HI values but one are less than 150 mg HC/g of TOC indicating that whatever kerogen is present would only generate gas. The HI/OI (Fig. 5) and HI/Tmax (Fig. 6) cross plots show that the OM is dominantly Type III. The paleosols indicate long periods of exposure which resulted in oxidation of most organic material and thus the unusually low TOC content. The 3 samples containing coaly material (Fig. 6) are from black carbonaceous shales which are unaltered (unweathered) material lying between paleosols. The Tmax values of 442 to 462°C, PI of 0.06-0.25 and average R_0max of 0.95-1.07 all indicate that the Boulder Creek Formation lies within the oil generation window.

Shaftesbury Formation

The lower shales of the Shaftesbury Formation are marine in origin and were deposited during a regional sea level rise which occurred throughout much of North America. Sedimentation was primarily from suspension in an offshore depositional setting.

The samples have an average TOC value of 1.46% with a range of 1.12 to 1.85%. S1 and S2 values average 0.3 to 0.5 mg HC/g and 0.9 to 2.25 mg HC/g of rock indicating that the lower Shaftesbury shales have poor source rock potential. The low HI values, ranging from 91 to 132 mg HC/g of TOC with a mean of about 110 mg HC/g of TOC, indicate that this unit has only residual gas generation potential. The HI/Tmax cross plot (Fig. 6) indicates that OM consists of both Types II and III. The Tmax values of 440 to 447°C and PI of 0.17-0.27 indicate that the lower Shaftesbury lies in the upper part of the oil window.

DISCUSSION

Source rocks and their degree of evolution

Types of OM were determined using HI/OI and HI/Tmax cross plots (Figs. 5 and 6). Because of the moderate to high levels of thermal maturity, there appears to be little oil generative capacity still present in the samples. Although it is difficult to back-extrapolate along the HI versus OI maturation trends, a few samples in the Minnes Group and Gething and Gates Formations show a possible input of Type II OM on the HI versus Tmax cross plots. This could also be coal-derived Type III OM (Espitalie et al., 1985). All the samples contain dominantly Type III, gas prone OM. The marine sediments of the Moosebar Formation, which would be expected to contain Type II marine OM and thus have the potential to generate oil, contain solely Type III OM. The Shaftesbury Formation may have the potential to generate some oil. Some of the Type III OM having very low HI values may be the result of weathering of the terrestrial OM during sediment transport (Espitalie et al., 1985). Oxidizing bottom conditions and the large predominance of terrestrial organic input into the relatively nearshore depositional environments has apparently lead to the dominance of terrestrial OM throughout this sequence of rocks, including the marine shales. The relatively high levels of thermal maturity of many of the samples in this set preclude the definitive interpretation of the nature of the organic matter. That is, the HI and OI have been reduced through thermal maturation to the extent that they currently are at levels common to all types of organic matter and thus cannot be back-extrapolated with confidence. As such, the interpreted hydrocarbon potential (for oil versus gas) must be considered as referring to present and recent capacity and not necessarily precluding some oil source at a much earlier maturation stage.

Thermal Maturity

Rock-Eval- The maturation of the kerogen was determined from the Rock-Eval pyrolysis results and measurements of vitrinite reflectances. Generally, source rocks are mature and will generate oil at a Tmax temperature range of 435 to 460 ^{o}C (Tissot and Welte, 1984). The Tmax values for the shales in this study range from 440 to 480^{o}C (Fig. 7). For the marine shales, the base of the Moosebar Formation approximates the base of the oil window. For the nonmarine shales, the base of the oil window lies about halfway into the Gates Formation.

The conversion of kerogen to bitumen during hydrocarbon generation means that, with increased maturity, the S2 peak should decrease and S1 should increase. PI (S1/[S1 + S2]) values of 0.1 and 0.4 mark the entrance and exit to the oil window (Tissot and Welte, 1978; Hunt, 1979) in the absence of secondary hydrocarbon migration either out of or into the sample under examination. Since these source rock samples include both shales and siltstones it is assumed that limited secondary migration has occurred into the samples. There are no PI values greater than 0.6 which would be indicative of samples containing secondarily migrated hydrocarbons (Hagen and Surdam, 1984). Little or no control exists, however, to estimate the extent to which hydrocarbons have moved out of these samples. The results show a great deal of variability in the PI between the marine and nonmarine sediments. However, examination of Figure 7 shows that the PI for marine sediments has a consistently higher value for a given depth interval than for closely associated nonmarine sediment. This may be indicative of somewhat coarser-grained rocks in the nonmarine section and relatively more efficient expulsion of hydrocarbons due to higher permeabilities than the marine rocks. The PI for marine shales versus depth and PI for nonmarine sediments show a slight but progressive increase in PI with depth. All the marine samples have a PI range of 0.1 to 0.4 suggesting that they lie within the oil generative window. The nonmarine samples have consistently lower PI values indicating immature to mature conditions.

Rank determination Coalification gradients, from the four boreholes making up the composite section (Fig. 2), increase with stratigraphic depth as indicated by first order regression lines and vary from 0.04% R_0max/100 m in borehole MD80-08 in the southeast to 0.11% R_0max/100 m in borehole MD80-11 in the northwest. Variations in coalification gradients can be the result of varying present and/or paleogeothermal gradients (Bostick et al., 1979; Doebl et al., 1974), increased heat flows by magmatic intrusions (Buntebarth and Teichmuller, 1979) and/or changes in conductivities of the host rocks (Damberger et al., 1964).

In the Monkman Pass area, variations in the coalification gradients likely reflect changes in the conductivities of the host rocks, since for these closely spaced boreholes, the present and past geothermal gradients must have been very similar and intrusive bodies are not known to occur. Our results indicate that coalification gradients are also influenced by the nature and thickness of the coaly layer. In Figure 11, vitrinite reflectances for 1) coalspars collected from various lithologies, 2) thin coal seams ($<$20 cm) and 3) thick seams ($>$20 cm) are plotted versus depth. Although there is a scatter of data points and local overlaps of the vitrinite reflectances, three coalification gradients exist. At any stratigraphic level the thick seams ($>$20 cm) have the highest reflectances with a coalification gradient of 0.05% R_0max/100 m and correlation coefficient of 0.9294. The majority of coalspars fall to the left side of the diagram indicating lower reflectances, particularly in the samples from the marine Hulcross and Moosebar formations (Fig. 11). The coalspars have the lowest reflectance increase with depth (0.04% R_0max/100 m) and a low correlation coefficient (0.7470). An attempt was made to evaluate discrepancies in the vitrinite reflectances of the coalspars with respect to their host rocks (shales, sandstones, siltstones and conglomerates) but no significant trend in vitrinite reflectances according to lithology was detected, comparable to the results of Bostik and

Foster (1972). The thin seams (< 20 cm) follow an intermediate coalification path (Fig. 11) with a gradient of 0.06% R_0max/100 m and correlation coefficient of 0.878.

A preliminary explanation for the gradient differences is that thick seams, because of their low conductivity and greater heat capacities, act as heat collectors over long periods of time whereas thin seams and coalspars are less affected by transient heat flows and consequently have lower reflectances. Since coal has a lower thermal conductivity than most lithologies, the temperature gradient through a thicker seam will be higher than for either the overall stratigraphic section or specific non-coal bearing intervals such as shales or sandstones. As a result, the centre and bottom conditions of thick coal seams will tend to exist at temperatures slightly higher than those which would prevail for a non-coal lithology. A change of 2°C over 60 million years will result in a shift in vitrinite reflectance of 0.03 to 0.04% R_0 (Snowdon, Goodarzi and Osadetz, unpublished results). Although the differences in average coalification gradients might be considered to be of only a minor nature, it is important to stress that in exploration areas where only limited sample material is available, vitrinite reflectances obtained from coalspars might be far off the regional coalification trend. Minor faults shown in Figure 2 had minimal affect on coal rank. There is only one sample of sheared coal in the Minnes Group which shows signs of a somewhat increased maximum vitrinite reflectance value (1.68%) which might possibly be related to its position in the fault zone. Otherwise, the results show a regular increase with stratigraphic depth, independant of the structural position of the strata.

Correlation of Tmax values versus vitrinite reflectances

The maturation levels of the organic matter, as expressed by Tmax (°C) from Rock-Eval analyses and vitrinite reflectances (% R_0max) from optical analyses, were found to increase gradually with stratigraphic depth. Tmax values ranged from 440°C in the Shaftesbury Formation to 490°C in the shales from the Minnes Group. Vitrinite reflectances ranged from 0.83% (high volatile A bituminous) to 1.68% R_0max (low volatile bituminous) in coals and coalspars from Hulcross Formation and Minnes Group respectively.

Since the composite section is comprised of alternating intervals of marine strata interbedded with non-marine coal-bearing sequences it offers the rare opportunity to compare Tmax values obtained from the shales with reflectance levels determined on the coals. Good agreement between the two rank parameters would aid in future interpretations of Tmax levels in sequences were coaly materials are rare or absent.

Teichmuller and Durand (1983) have shown that for coals there exists a linear relationship between Tmax (°C) and vitrinite reflectances in the coalification range from 0.5 to 1.5% Ro (high volatile to low volatile bituminous). Figure 12 shows the correlation between Tmax values from shales and reflectance values of the coals for samples in the Monkman Pass area. The averaged vitrinite reflectances obtained from the regression line of all coal samples is plotted versus Tmax values in this diagram. The dashed lines indicate the range of Tmax and vitrinite reflectances for a number of unspecified coals as published by Teichmuller and Durand (1983). The data presented here show that there exists a fairly good relationship between vitrinite reflectances and Tmax values although for any given reflectance level there is a wide range of Tmax values and vice versa. There is also good agreement with previously published vitrinite reflectances/Tmax relationships (Teichmuller and Durand, 1983) since the bulk of the data points fall within the dashed lines (Fig. 12). Some of the extremely high or low Tmax values can be explained by variations in the organic matter content (Fig. 12). For example Tmax values in samples containing less than 0.5% organic carbon were frequently found to be characterized by reduced S2 peaks and increased Tmax values most likely caused by adsorption of the pyrolyzate by the mineral matrix (Katz, 1983; Espitalie et al., 1985; Peters, 1986). Tmax values for small S2 peaks (<0.2 mgHC/g TOC) were found to be unreliable and should be rejected (Peters, 1986). In fact, with respect to the corresponding vitrinite reflectance levels, two regression lines can be drawn for the two facies. Tmax values for the marine shales increase at a slower rate with increasing maturation while non-marine shales are characterized at the same or similar rank levels by higher Tmax values. The discrepancies in the Tmax values for the two facies may be related to slight variations in the type of organic material and mineral matrix effects (Espitalie et al., 1985; Peters, 1986). For the study area the upper limit for oil generation (1.30% vitrinite reflectance) corresponds to an averaged Tmax value of 466°C for the marine shales. The averaged Tmax value for the non-marine shales plot at 470 °C. The two Tmax values agree reasonably well with data published by Espitalie et al. (1984) indicating at 1.30% Ro and a Tmax value of 465°C.

The present data show that the Tmax values obtained from the shales clearly are indicative of maturation levels. However because of the wide range of Tmax values at any given maturation level they have to be interpreted in terms of trends rather than absolute values. Individual values may be far off the regional maturation trend (Fig. 12).

Variation with depth

Increasing thermal maturation can be seen over the 1.2 km vertical profile represented by the samples in this set (Figs. 7, 8 and 11). Separate regression lines calculated for the marine samples and the nonmarine (Fig. 8) show that the Tmax values are consistently lower for the marine samples and the rate of increase is lower. There are slight differences in types of OM between the marine and nonmarine sediments which may affect Tmax values. Type III OM has a more complex structure than Type II OM and a wider temperature range is observed for Tmax during cracking of the kerogen (Espitalie et al., 1985). The two maturation trends may result from the thermal conductivity properties of the different lithologies, as discussed above in relation to thick coal seams, different hydrodynamic properties which have controlled temperatures, or alternatively, the difference may result from the difference in fundamental chemical properties of terrestrial versus marine OM.

The Hydrogen Index distribution shows considerable differences between those of the nonmarine sediments and those of the marine sediments. The regression line for the marine samples shows a regular, and relatively rapid decrease of HI with depth (Fig. 9) whereas the regression line through HI values from nonmarine samples indicates no particular systematic change as a function of depth and a very low correlation coefficient. The high negative corrrelation of HI and depth for the marine sections indicates that the OM is thermally sensitive and also that the level of maturity is such that limited active thermal degradation (petroleum generation; i.e., gas) is occurring. The lack of correlation and obvious scatter of the nonmarine HI data results from the variable presence of reworked, oxidized and pristine organic matter, a situation expected for nearshore to fluvial deposits.

Kerogen HI values from the marine sediments progressively decrease from 132 in the Shaftesbury Formation to 61 mg HC/g of TOC in the Moosebar Formation.

CONCLUSIONS

Shale and coals from 1.2 km of core through most of the Lower Cretaceous preserved in Western Canada were analyzed for source rock potentials and maturation levels. The average TOC is 3.05%. The Minnes Group, averaging 2.7% TOC, has fair to very good potential for gas generation. The Gething and Gates formations average 6.3 and 5.2% TOC, respectively, with fair to very good gas source potential. The marine Moosebar and Hulcross formations have 1.5 and 1.7% average TOC contents, respectively, and poor to fair source rock potential. The Boulder Creek has 1.1% TOC and poor source rock potential. Most Boulder Creek OM was oxidized during Late Albian sea level fluctuation when thick paleosols developed. HI for the marine sediments shows a progressive decrease with depth from 132 to 61 mg HC/ g of TOC interpreted as due to thermal degradation with increased burial. These marine sediments may have generated limited amounts of oil. HI for nonmarine sediments remains constant with depth. Despite a fairly large scatter, the vitrinite reflectances increase systematically with stratigraphic depths from 0.94% R_0max at the top of the Boulder Creek Formation to 1.5% R_0max in the Minnes Group. The end of oil generation for potential source rocks is indicated at the base of the Gething Formation.

Although much of the core lies within the oil window, none of the formations are notably oil prone. The Moosebar and Hulcross marine strata have poor generative potential and the nonmarine Minnes Group and Gething, Gates and Boulder Creek formations will have generated gas with only minor amounts of oil. Oxidizing bottom conditions and the large predominance of terrestrial organic matter into the relatively nearshore depositional setting of the marine sediments has lead to the dominance of terrestrial OM throughout this sequence of rocks, including the marine shales. As such, it will be domininantly gas that will be, or has been, generated. It has been suggested by others that Lower Cretaceous sediments were the source for heavy oil deposits in northeastern Alberta. The oil was not likely derived from northeast British Columbia or northwestern Alberta.

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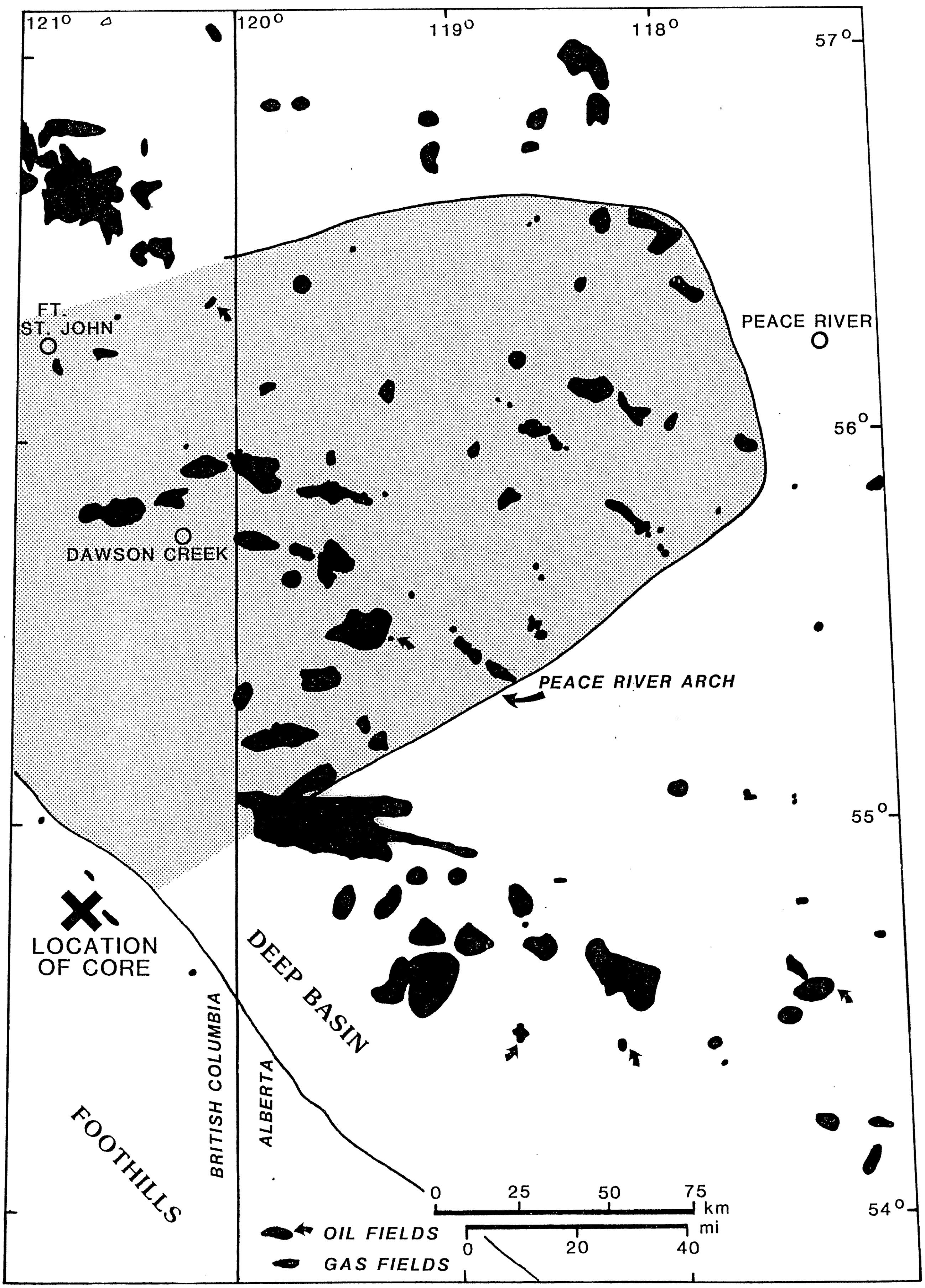
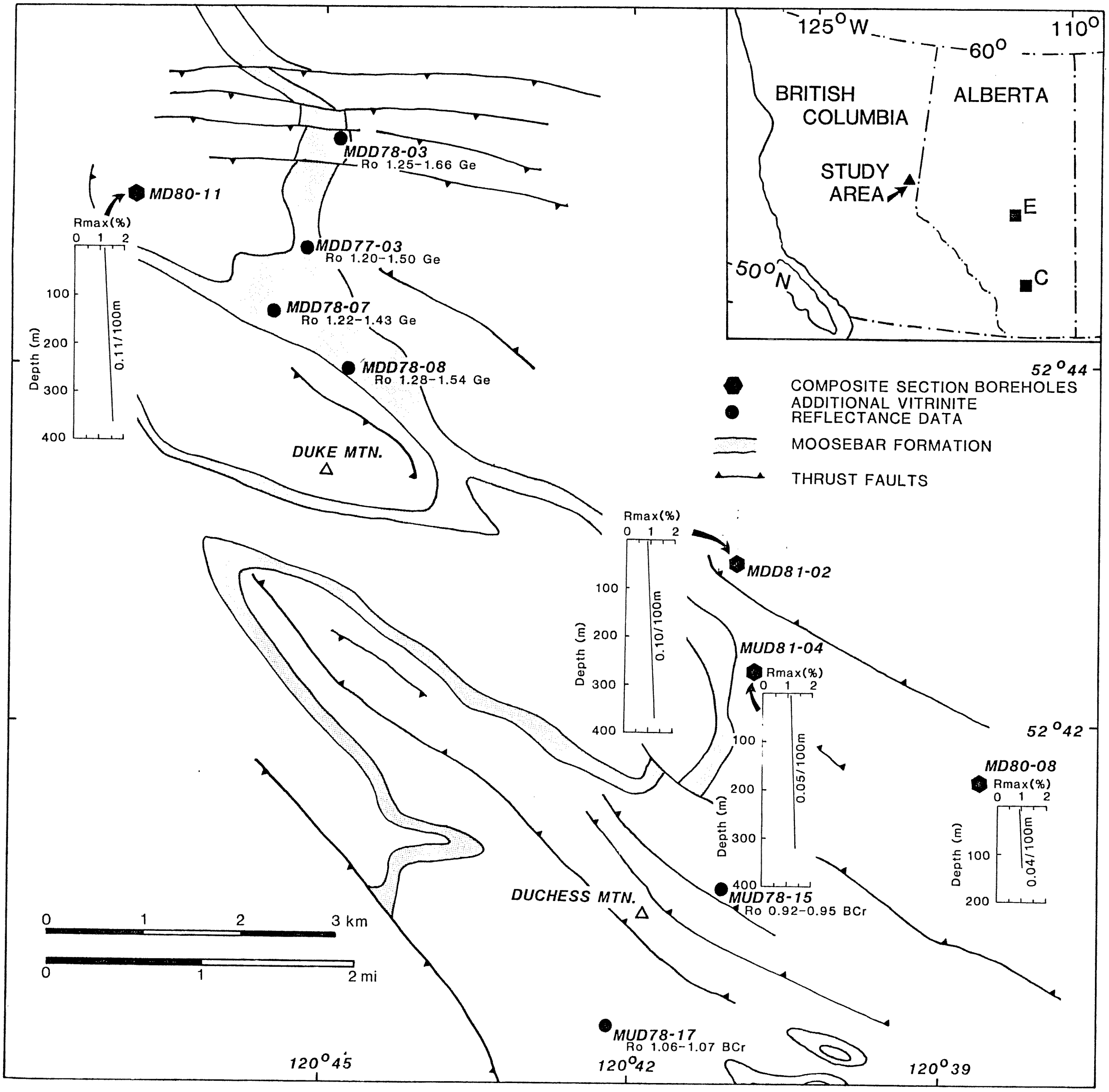
FIGURES

TABLES

Leckie et al Fig 1.





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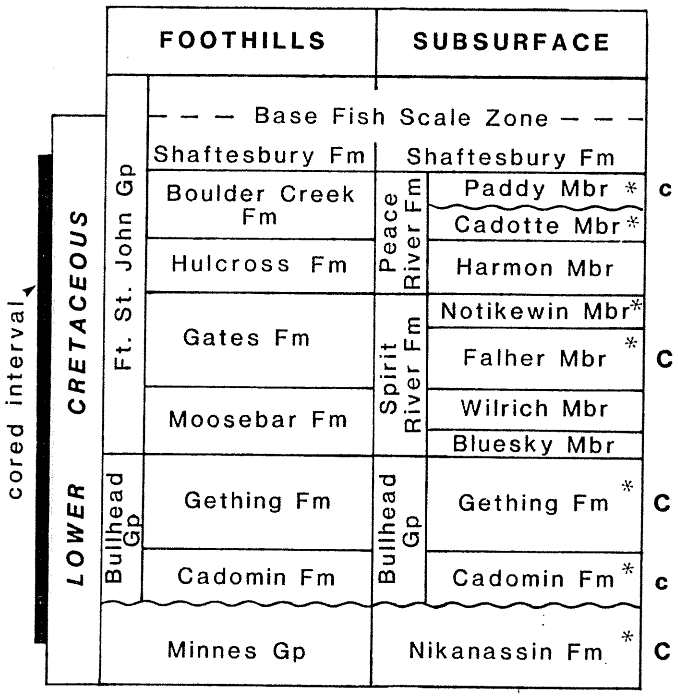
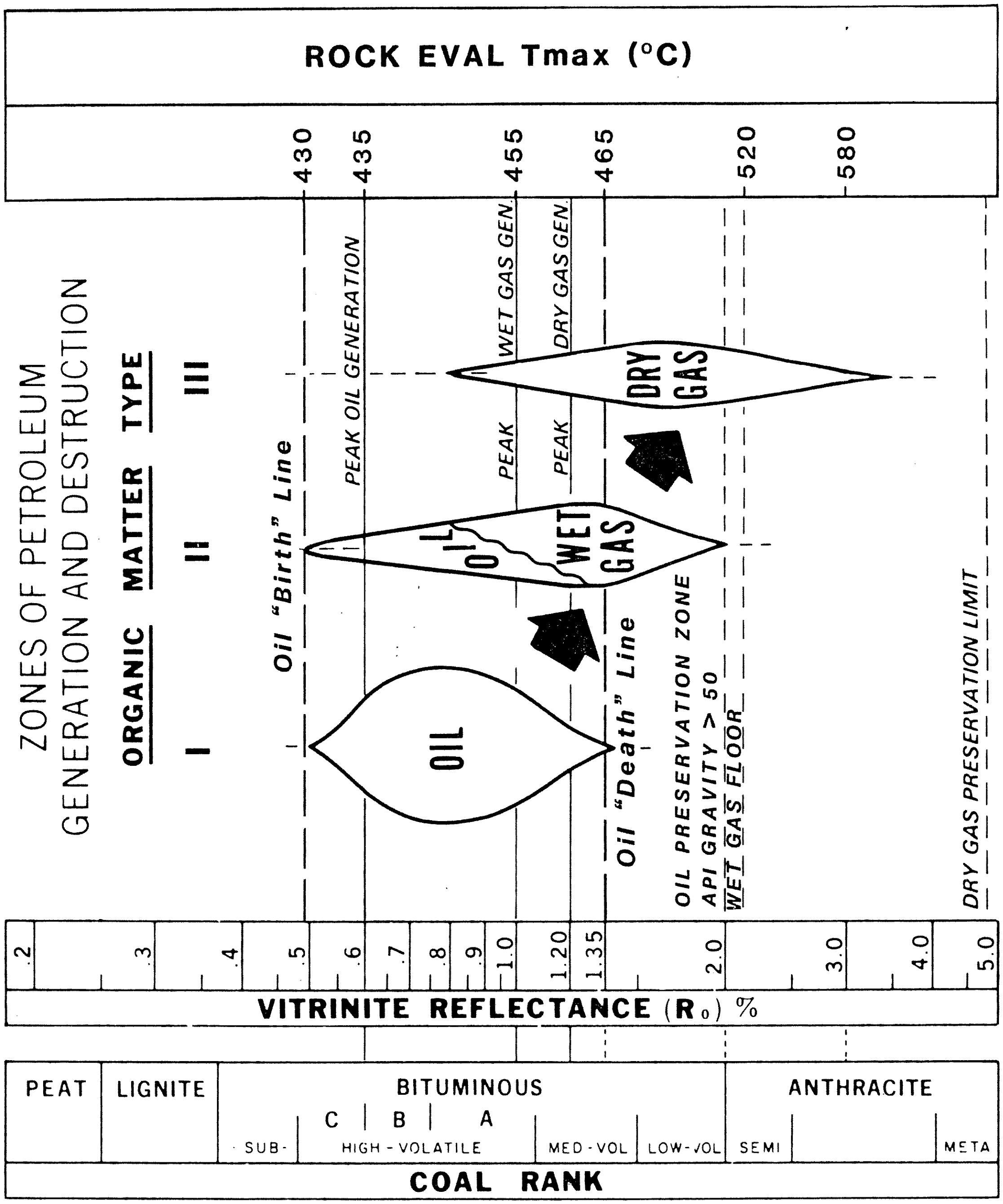


* Potential Reservoirs

C, c Coal Bearing strata, common, rare

Leckie et al Fig 3

Leckie et al Fig 4



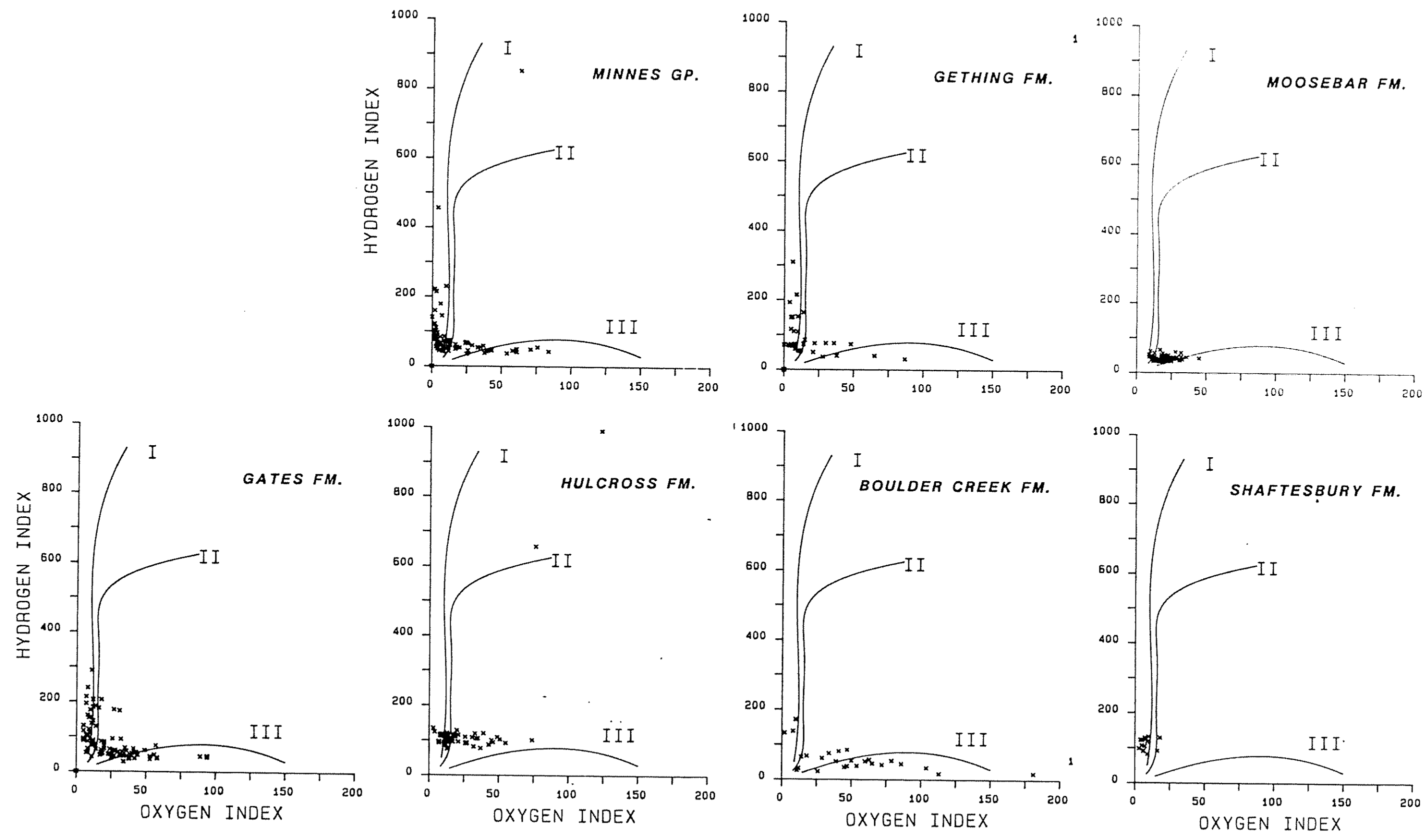


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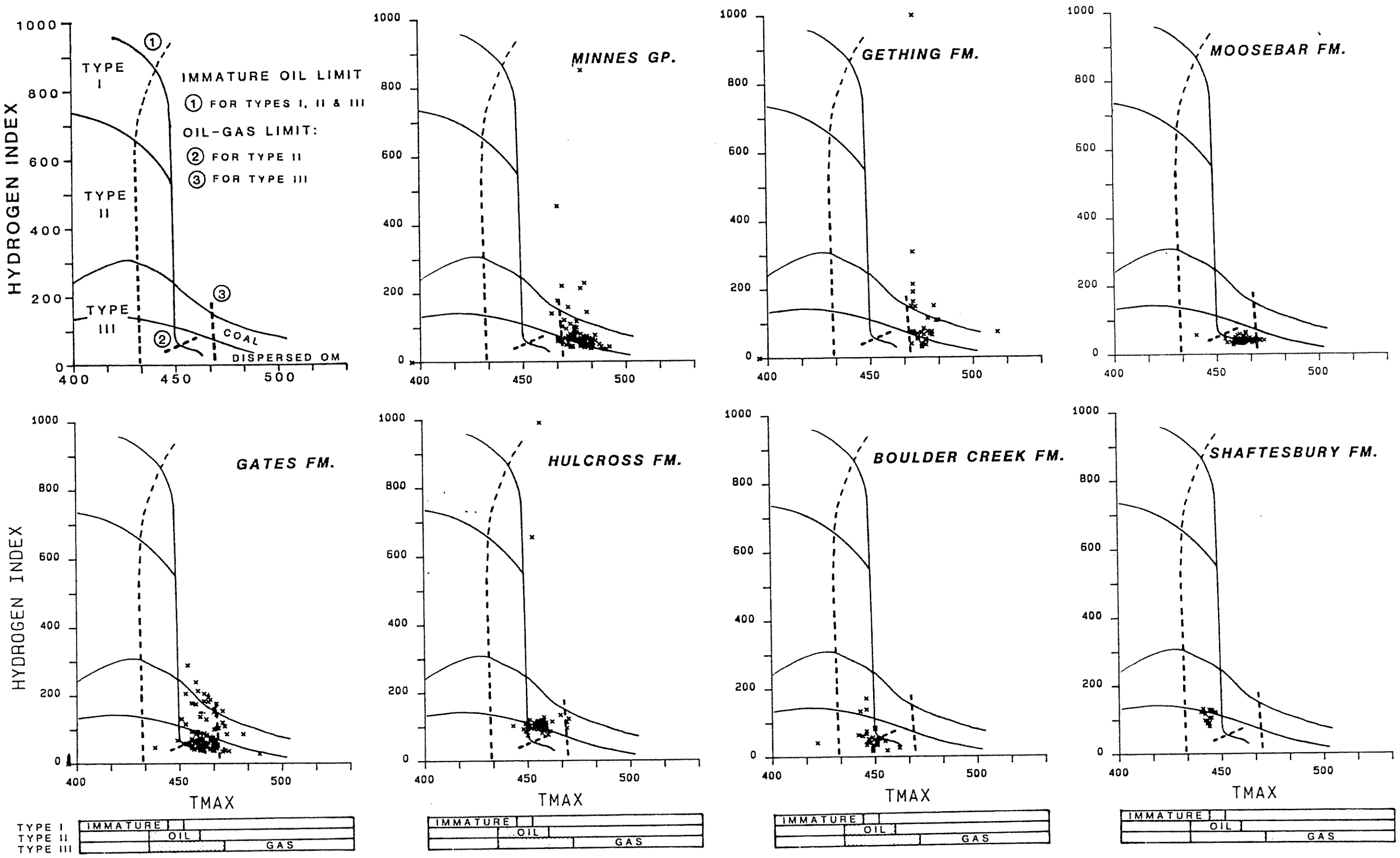
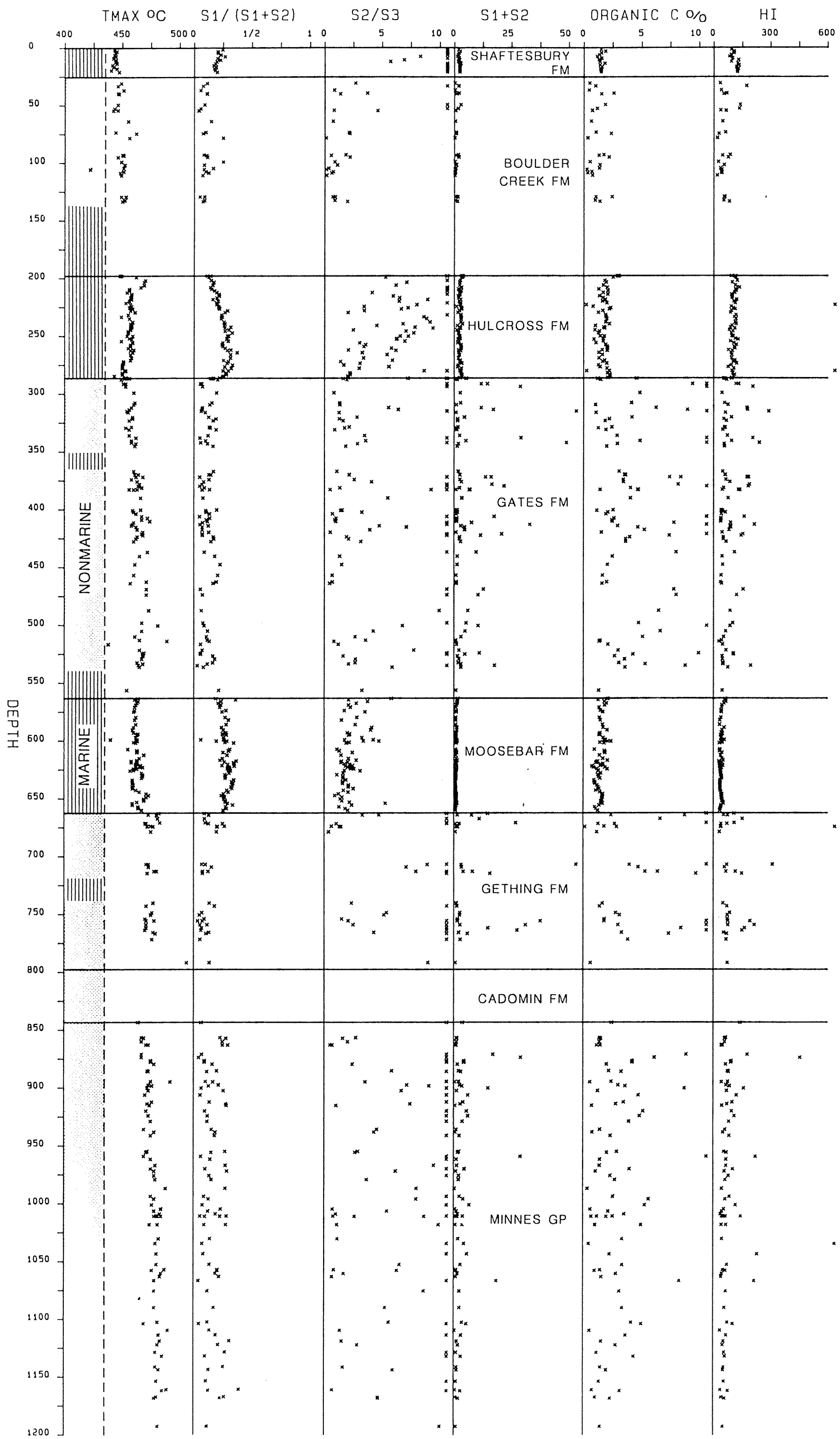
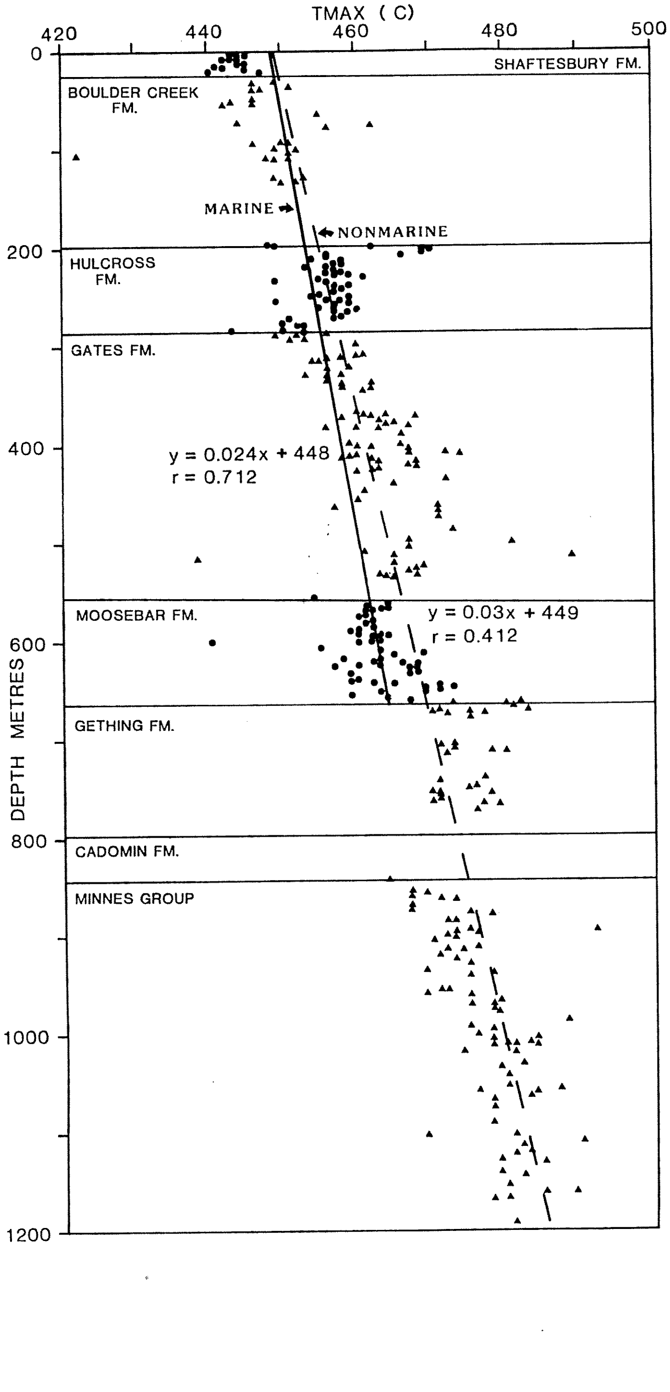
Fig 5



Leckie et al Fig 6

Leckie et al Fig 7





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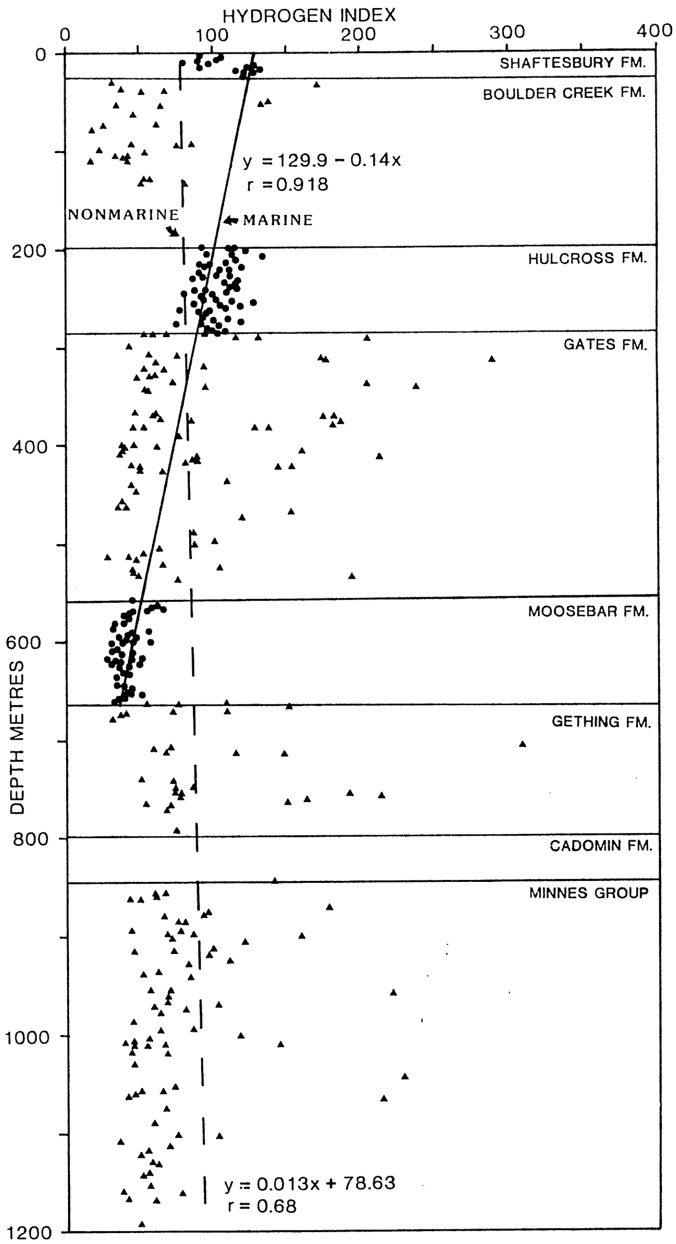

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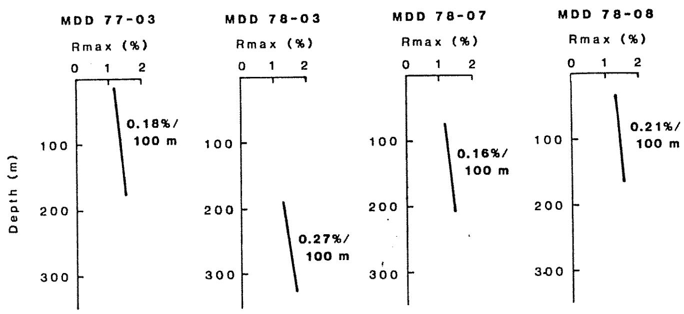

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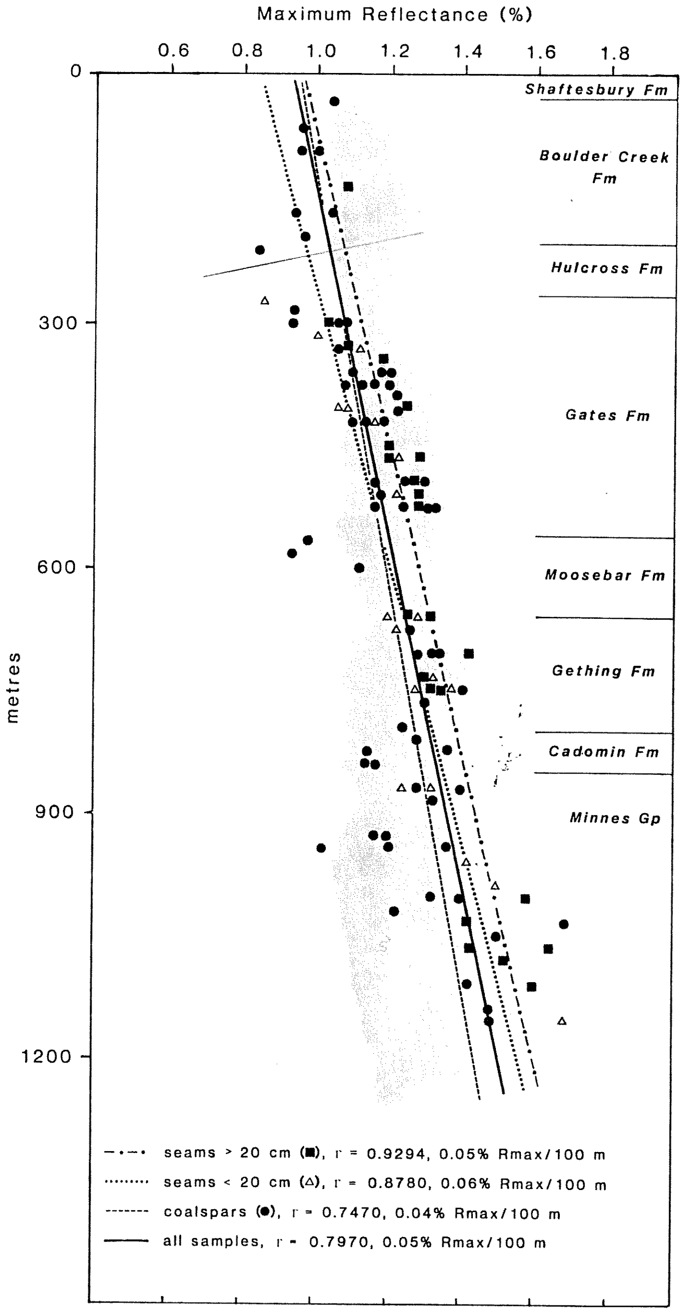

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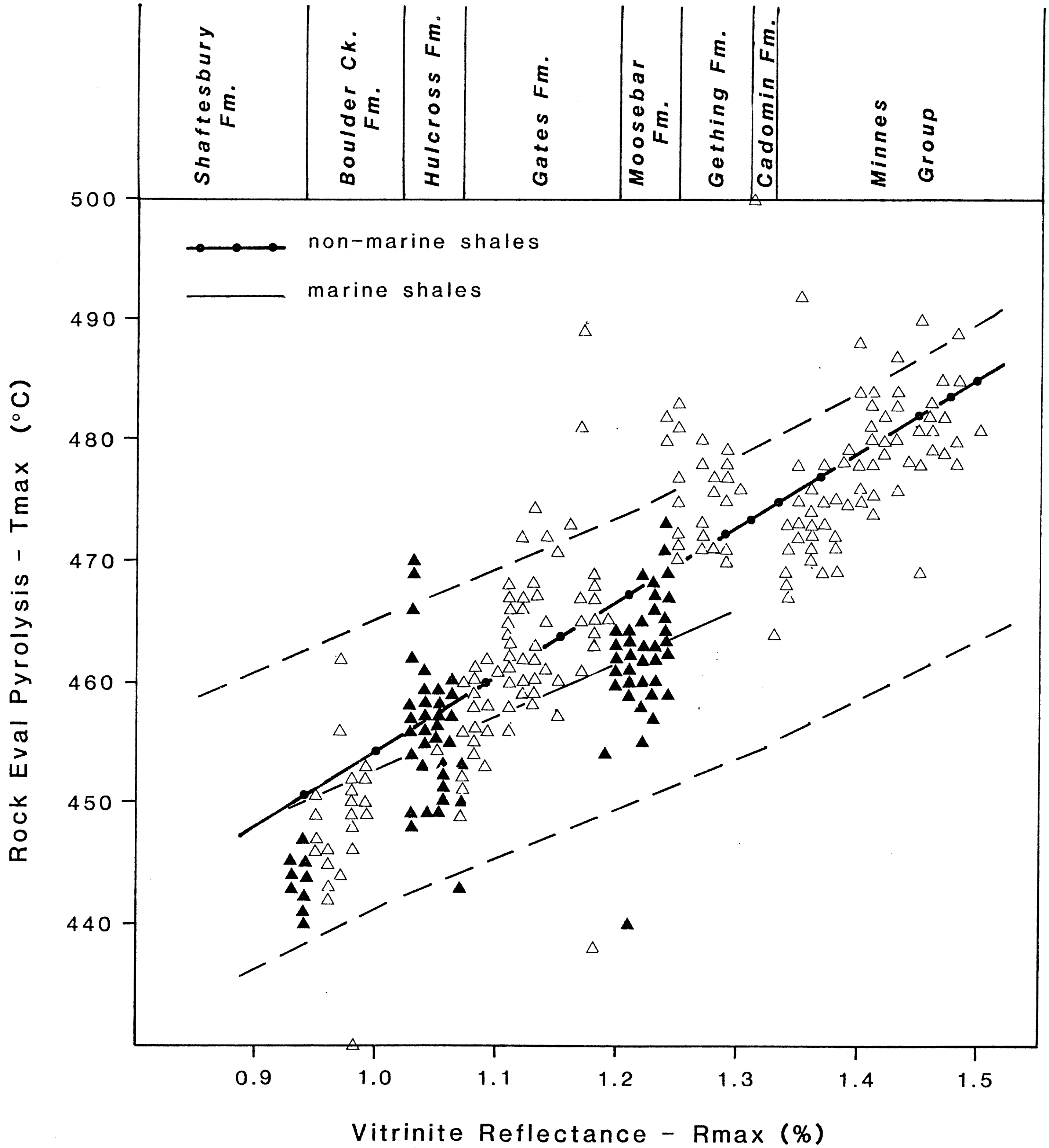

Leckie et al Fig 12

Table I: Summary of results of Rock-Eval/TOC and vitrinite reflectance analyses.

Formation	No. of Samples		TOC		PI		S1 + S2		S1		S2		S3		HI		OI		Type of Organic Matter	Ro max (%)
	Pyrolysed	Coal	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ		
Shaftesbury	14	0	1.46	0.18	0.20	0.03	2.03	0.39	0.40	0.61	1.62	0.35	0.12	0.05	109.78	17.37	8.07	4.29	II III	
Boulder Creek	27	9	1.14	0.67	0.10	0.05	0.82	0.72	0.07	0.07	0.74	0.65	0.54	0.44	58.55	39.93	63.33	77.79	III	0.94-1.07
Hulcross	61	1	1.71	0.52	0.25	0.58	2.42	0.65	0.58	0.18	1.83	0.56	0.37	0.26	99.44	133.47	23.79	20.49	II III	1.03-1.07
Gates	86	47	5.20	4.3	0.11	0.49	7.34	11.53	0.54	0.66	6.79	10.90	0.93	0.55	90.07	55.78	25.33	19.43	II* III	1.07-1.20
Moosebar	67	3	1.48	0.34	0.28	0.05	0.86	0.27	0.23	0.65	0.62	0.22	0.30	0.18	40.92	7.87	19.88	6.98	III	1.20-1.24
Gething	32	22	6.3	6.38	0.12	0.06	9.87	15.92	0.75	1.05	9.12	14.95	0.72	0.50	92.75	62.12	38.69	120.57	II* III	1.24-1 31
Cadomin	0	6																		
Minnes	78	29	2.69	2.14	0.16	0.08	3.3	5.2	0.34	0.28	2.95	4.95	0.31	0.29	104.32	143.58	28.97	99.74	II III	1.33-1.50
Total Core	365	117	3.05	3.49																

* minor, $\bar{x}$ = mean, σ = standard deviation

Table II. Rock-Eval Interpretive Guidelines

a) Source Rock Generative Potential

Quality	TOC (Wt %)	S1 (mg HC/g rock)	S2 (mg HC/g rock)
poor	0 - 0.5	0 - 0.5	0 - 2.5
fair	0.5 - 1.0	0.5 - 1.0	2.5 - 5.0
good	1 - 2	1 - 2	5 - 10
very good	>2	>2	10

b) Type of Hydrocarbon Generated

Type	HI (mg HC/g of TOC)	S2/S3*
gas	0 - 150	0 - 3
gas and oil	150 - 300	3 - 5
oil	>300	>5

*assumes Ro = 0.6%

c) Level of Thermal Maturation

Maturation	PI (S1/S1 + S2)	Tmax (°C)	Ro (%)
top oil window	~0.1	430 - 445*	~0.5
bottom oil window	~0.4	~465	~1.3

*varies with type of OM

Table III. Vitrinite Reflectance data, thicknesses of coal seams and A.S.T.M. rank classes for samples from boreholes Petro Canada MD 80-08 and MDD 81-02.

Borehole	Formation	Depth (m)	Thickness (m)	Pellet No.	Maximum Reflectance %			A.S.T.M. Rank Classes
					Mean	S	N	
MD 80-08	Boulder Creek	33.08	_*	746/85	1.03	0.04	50	High volatile A bituminous
MD 80-08	Boulder Creek	71.56	_*	747/85	0.95	0.06	50	High volatile A bituminous
MD 80-08	Boulder Creek	94.92	_*	748/85	1.00	0.05	50	High volatile A bituminous
MD 80-08	Boulder Creek	100.80	_*	749/85	0.96	0.05	50	High volatile A bituminous
MD 80-08	Boulder Creek	137.30	0.70	2/86	1.07	0.05	50	High volatile A bituminous
MDD 81-02	Boulder Creek	11.70	_*	742/85	0.93	0.04	50	High volatile A bituminous
MDD 81-02	Boulder Creek	14.03	_*	743/85	1.03	0.04	50	High volatile A bituminous
MDD 81-02	Boulder Creek	14.24	_*	744/85	1.04	0.04	50	High volatile A bituminous
MDD 81-02	Boulder Creek	46.79	_*	9/86	0.95	0.02	50	High volatile A bituminous
MDD 81-02	Hulcross	53.74	_*	745/85	0.83	0.05	50	High volatile A bituminous
MDD 81-02	Gates	125.07	0.07	11/86	0.88	0.05	25	High volatile A bituminous
MDD 81-02	Gates	126.08	_*	12/86	0.94	0.03	50	High volatile A bituminous
MDD 81-02	Gates	149.70	0.66	13/86	1.03	0.05	50	High volatile A bituminous
MDD 81-02	Gates	150.36	_*	14/86	1.07	0.04	50	High volatile A bituminous
MDD 81-02	Gates	151.96	_*	15/86	0.93	0.04	50	High volatile A bituminous
MDD 81-02	Gates	153.33	_*	16/86	1.06	0.04	50	High volatile A bituminous
MDD 81-02	Gates	158.28	0.27	17/86	1.00	0.05	25	High volatile A bituminous
MDD 81-02	Gates	175.96	0.48	18/86	1.07	0.06	25	High volatile A bituminous
MDD 81-02	Gates	177.05	0.13	19/86	1.12	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	180.59	_*	20/86	1.05	0.06	50	High volatile A bituminous
MDD 81-02	Gates	199.12	0.60	21/86	1.17	0.07	50	Medium volatile bituminous
MDD 81-02	Gates	202.72	_*	22/86	1.18	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	208.30	_*	632/86	1.10	0.03	50	Medium volatile bituminous
MDD 81-02	Gates	210.36	_*	633/86	1.20	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	216.00	_*	634/86	1.12	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	216.67	_*	635/86	1.16	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	218.17	_*	636/86	1.10	0.05	25	Medium volatile bituminous
MDD 81-02	Gates	219.67	_*	637/86	1.20	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	222.61	_*	639/86	1.11	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	228.47	_*	638/86	1.07	0.06	50	High volatile A bituminous
MDD 81-02	Gates	244.48	_*	640/86	1.22	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	245.92	_*	641/86	1.21	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	249.72	0.10	642/86	1.06	0.04	50	High volatile A bituminous
MDD 81-02	Gates	253.58	0.18	643/86	1.09	0.06	50	High volatile A bituminous
MDD 81-02	Gates	253.97	1.95	644/86	1.23	0.06	50	Medium volatile bituminous
MDD 81-02	Gates	260.71	_*	645/86	1.11	0.04	25	Medium volatile bituminous
MDD 81-02	Gates	266.12	_*	646/86	1.13	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	268.10	3.50	647/86	1.16	0.06	50	Medium volatile bituminous
MDD 81-02	Gates	275.22	_*	648/86	1.17	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	304.37	2.50	649/86	1.20	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	307.37	2.50	650/86	1.22	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	309.07	2.50	651/86	1.20	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	327.29	4.50	652/86	1.27	0.05	50	Medium volatile bituminous
MDD 81-02	Gates	338.86	_*	653/86	1.30	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	339.52	_*	654/86	1.26	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	343.46	_*	655/86	1.23	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	348.41	_*	656/86	1.16	0.06	50	Medium volatile bituminous
MDD 81-02	Gates	349.08	1.35	657/86	1.25	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	352.33	_*	658/86	1.27	0.04	50	Medium volatile bituminous
MDD 81-02	Gates	356.63	_*	659/86	1.17	0.04	25	Medium volatile bituminous
MDD 81-02	Gates	369.15	1.76	660/86	1.27	0.04	50	Medium volatile bituminous

S = standard deviation
N = number of measurements
_* = coalspar

Table IV. Vitrinite Reflectance data, thicknesses of coal seams and A.S.T.M. rank classes for samples from borehole Petro-Canada MUD 81-04

Borehole	Formation	Depth (m)	Thickness (m)	Pellet No.	Maximum Reflectance % Mean	S	N	A.S.T.M. Rank Classes
MUD 81-04	Gates	11.67	2.50	663/85	1.27	0.03	50	Medium volatile bituminous
MUD 81-04	Gates	15.42	0.09	664/85	1.22	0.04	50	Medium volatile bituminous
MUD 81-04	Gates	18.30	_*	665/85	1.29	0.05	50	Medium volatile bituminous
MUD 81-04	Gates	22.94	_*	666/85	1.24	0.05	50	Medium volatile bituminous
MUD 81-04	Gates	24.50	_*	667/85	1.31	0.04	50	Medium volatile bituminous
MUD 81-04	Gates	27.05	_*	668/85	1.15	0.04	50	Medium volatile bituminous
MUD 81-04	Moosebar	70.56	_*	669/85	0.98	0.07	25	High volatile A bituminous
MUD 81-04	Moosebar	76.80	_*	670/85	0.94	0.03	25	High volatile A bituminous
MUD 81-04	Moosebar	97.85	_*	671/85	1.12	0.03	50	Medium volatile bituminous
MUD 81-04	Gething	153.25	0.22	673/85	1.19	0.04	50	Medium volatile bituminous
MUD 81-04	Gething	153.40	0.20	674/85	1.27	0.04	50	Medium volatile bituminous
MUD 81-04	Gething	153.27	0.22	675/85	1.32	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	154.63	0.02	676/85	1.25	0.04	50	Medium volatile bituminous
MUD 81-04	Gething	157.99	0.07	677/85	1.26	0.07	25	Medium volatile bituminous
MUD 81-04	Gething	158.30	_*	678/85	1.31	0.04	50	Medium volatile bituminous
MUD 81-04	Gething	162.27	0.60	679/85	1.26	0.07	50	Medium volatile bituminous
MUD 81-04	Gething	167.67	0.60	680/85	1.31	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	174.09	_*	681/85	1.25	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	177.00	0.07	682/85	1.21	0.03	50	Medium volatile bituminous
MUD 81-04	Gething	196.20	1.33	683/85	1.41	0.10	25	Medium volatile bituminous
MUD 81-04	Gething	200.82	_*	684/85	1.31	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	203.67	_*	24/86	1.33	0.06	50	Medium volatile bituminous
MUD 81-04	Gething	205.37	_*	25/86	1.28	0.04	50	Medium volatile bituminous
MUD 81-04	Gething	288.93	3.50	26/86	1.30	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	296.82	>0.20	27/86	1.32	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	304.60	3.10	28/86	1.32	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	309.47	3.22	29/86	1.34	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	312.75	0.14	30/86	1.27	0.05	50	Medium volatile bituminous
MUD 81-04	Gething	312.45	0.14	31/86	1.38	0.08	50	Medium volatile bituminous
MUD 81-04	Gething	317.45	_*	32/86	1.39	0.06	50	Medium volatile bituminous
MUD 81-04	Gething	320.08	_*	33/86	1.29	0.06	50	Medium volatile bituminous

S = standard deviation
N = number of measurements
_* = coalspar

Table V. Vitrinite Reflectance data, thicknesses of coal seams and A.S.T.M. rank classes for samples from borehole Petro-Canada MD 81-11.

Borehole	Formation/ Group	Depth (m)	Thickness (m)	Pellet No.	Maximum Reflectance %			A.S.T.M. Rank Classes
					Mean	S	N	
MD 81-11	Cadomin Fm.	9.08	_*	686/85	1.24	0.05	50	Medium volatile bituminous
MD 81-11	Cadomin Fm.	14.14	_*	687/85	1.27	0.05	50	Medium volatile bituminous
MD 81-11	Cadomin Fm.	32.90	_*	688/85	1.36	0.04	50	Medium volatile bituminous
MD 81-11	Cadomin Fm.	37.77	_*	689/85	1.14	0.05	50	Medium volatile bituminous
MD 81-11	Cadomin Fm.	45.80	_*	690/85	1.13	0.04	50	Medium volatile bituminous
MD 81-11	Cadomin Fm.	53.94	_*	691/85	1.15	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	72.70	0.07	692/85	1.23	0.05	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	76.00	0.10	693/85	1.31	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	77.10	_*	694/85	1.28	0.05	35	Medium volatile bituminous
MD 81-11	Minnes Gr.	79.26	_*	695/85	1.40	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	87.94	_*	608/86	1.32	0.05	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	96.74	_*	609/86	1.31	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	134.95	_*	610/86	1.20	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	137.80	_*	611/86	1.15	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	152.00	_*	612/86	1.02	0.03	50	High volatile A bituminous
MD 81-11	Minnes Gr.	155.90	_*	613/86	1.19	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	159.30	_*	614/86	1.36	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	171.55	0.10	615/86	1.42	0.05	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	203.00	0.10	616/86	1.49	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	205.50	_*	617/86	1.50	0.05	50	Low volatile bituminous
MD 81-11	Minnes Gr.	208.45	_*	607/86	1.39	0.06	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	210.94	_*	618/86	1.32	0.03	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	216.70	0.79	619/86	1.58	0.07	50	Low volatile bituminous
MD 81-11	Minnes Gr.	229.60	_*	620/86	1.21	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	240.85	_*	621/86	1.67	0.05	50	Low volatile bituminous
MD 81-11	Minnes Gr.	250.83	0.30	622/86	1.41	0.08	25	Medium volatile bituminous
MD 81-11	Minnes Gr.	260.90	_*	623/86	1.49	0.06	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	267.69	0.45	624/86	1.42	0.05	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	273.99	0.21	625/86	1.64	0.06	50	Low volatile bituminous
MD 81-11	Minnes Gr.	293.00	0.40	626/86	1.52	0.05	50	Low volatile bituminous
MD 81-11	Minnes Gr.	315.00	_*	627/86	1.41	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	321.50	0.19	628/86	1.60	0.06	50	Low volatile bituminous
MD 81-11	Minnes Gr.	344.59	_*	629/86	1.47	0.04	50	Medium volatile bituminous
MD 81-11	Minnes Gr.	363.95	0.11	630/86	1.68	0.06	50	Low volatile bituminous
MD 81-11	Minnes Gr.	365.25	_*	631/86	1.48	0.04	50	Medium volatile bituminous

S = standard deviation
N = number of measurements
_* = coalspar

MONKMAN 80-08 0 1200 25 .50

SAMPLE IDENTIFICATION		DEPTH	ORG.C	PI	S1+S2	TMAX	S1	S2	S3	HI	OI
		-0.01	Shaftesbury Formation								
MONK8008.SPECIAL	: 51.2	1.50	1.48	.24	1.80	443	.44	1.36	.09	91	6
MONK8008.SPECIAL	: 49.5	3.00	1.85	.20	2.47	445	.50	1.97	.10	106	5
MONK8008.SPECIAL	: 49.8	4.50	1.50	.20	1.96	444	.40	1.56	.12	104	7
MONK8008.SPECIAL	: 49.4	6.00	1.33	.23	1.57	443	.36	1.21	.08	90	6
MONK8008.SPECIAL	: 50.4	7.50	1.12	.27	1.24	444	.33	.91	.11	81	9
MONK8008.SPECIAL	: 50.8	9.00	1.52	.20	1.86	442	.37	1.49	.05	98	3
MONK8008.SPECIAL	: 49.6	10.50	1.27	.23	2.13	444	.48	1.65	.24	129	18
MONK8008.SPECIAL	: 49.5	12.00	1.37	.19	1.55	444	.30	1.25	.22	91	16
MONK8008.SPECIAL	: 51.5	13.50	1.79	.18	2.75	445	.50	2.25	.15	125	8
MONK8008.SPECIAL	: 49.9	15.00	1.37	.17	2.18	441	.36	1.82	.14	132	10
MONK8008.SPECIAL	: 49.6	16.50	1.54	.19	2.23	442	.42	1.81	.14	117	9
MONK8008.SPECIAL	: 49.0	18.00	1.41	.17	2.21	445	.38	1.83	.10	129	7
MONK8008.SPECIAL	: 50.1	19.50	1.44	.18	2.16	440	.39	1.77	.07	122	4
MONK8008.SPECIAL	: 50.0	21.00	1.47	.20	2.24	447	.44	1.80	.08	122	5
		-25.50	Boulder Creek Formation								
MONK8008.SPECIAL	: 49.4	30.72	.49	.11	.18	449	.02	.16	.06	32	12
MONK8008.SPECIAL	: 49.2	33.08	.99	.08	1.84	446	.14	1.70	.10	171	10
MONK8008.SPECIAL	: 50.9	36.77	.44	.06	.18	451	.01	.17	.21	38	47
MONK8008.SPECIAL	: 50.5	39.44	2.56	.11	1.95	446	.21	1.74	.47	67	18
MONK8008.SPECIAL	: 49.8	40.02	1.51	.11	.90	447	.10	.80	.60	52	39
MONK8008.SPECIAL	: 50.8	49.36	1.83	.09	2.78	446	.25	2.53	.15	138	8
MONK8008.SPECIAL	: 50.5	52.72	1.14	.06	1.61	443	.09	1.52	.03	133	2
MONK8008.SPECIAL	:100.1	54.23	.73	.04	.27	446	.01	.26	.33	35	45
MONK8008.SPECIAL	: 49.8	54.52	.71	.04	.48	442	.02	.46	.10	64	14
MONK8008.SPECIAL	: 50.2	63.80	.63	.15	.34	455	.05	.29	.41	46	65
MONK8008.SPECIAL	: 52.3	73.37	1.03	.10	.70	444	.07	.63	.30	61	29
MONK8008.SPECIAL	: 52.1	74.49	2.34	.08	.66	462	.05	.61	.28	26	11
MONK8008.SPECIAL	: 49.9	78.19	.33	.25	.08	456	.02	.06	.60	18	181
MONK8008.SPECIAL	: 50.2	92.86	1.71	.08	1.60	450	.13	1.47	.81	85	47
MONK8008.SPECIAL	: 50.2	93.38	1.29	.11	.66	451	.07	.59	1.11	45	86
MONK8008.SPECIAL	: 50.5	94.92	2.16	.11	1.85	446	.21	1.64	.75	75	34
MONK8008.SPECIAL	: 49.4	98.99	.52	.25	.16	449	.04	.12	.14	23	26
MONK8008.SPECIAL	: 50.6	101.67	1.37	.09	.82	452	.07	.75	.69	54	50
MONK8008.SPECIAL	: 51.6	104.51	1.33	.16	.55	451	.09	.46	1.39	34	104
MONK8008.SPECIAL	: 51.6	105.53	.26	.08	.12	422	.01	.11	1.04	42	400
MONK8008.SPECIAL	: 50.1	107.53	.68	.10	.30	451	.03	.27	.37	39	54
MONK8008.SPECIAL	: 49.5	108.59	.33	.13	.16	448	.02	.14	.24	42	72
MONK8008.SPECIAL	: 51.0	110.75	.74	.07	.14	449	.01	.13	.84	17	113
MONK8008.SPECIAL	: 50.3	129.29	2.42	.09	1.46	453	.13	1.33	1.92	54	79
MONK8008.SPECIAL	: 52.1	129.29	1.03	.05	.62	449	.03	.59	.65	57	63
MONK8008.SPECIAL	: 50.6	132.39	.97	.09	.56	452	.05	.51	.59	52	60
MONK8008.SPECIAL	: 50.6	133.33	1.37	.07	1.21	450	.09	1.12	.57	81	41
		-197.90	Hulcross Formation								
MONK812.SPECIAL	: 49.6	197.91	2.91	.11	3.68	449	.42	3.26	.24	112	8
MONK812.SPECIAL	: 50.0	197.91	3.01	.14	3.28	448	.46	2.82	.24	93	7
MONK812.SPECIAL	: 50.8	198.93	2.53	.13	3.34	462	.43	2.91	.55	115	21
MONK812.SPECIAL	: 49.8	201.77	1.80	.15	2.60	470	.38	2.22	.08	123	4
MONK812.SPECIAL	: 49.6	203.30	1.92	.17	2.23	469	.38	1.85	.26	96	13
MONK812.SPECIAL	: 50.5	205.88	1.67	.16	2.29	469	.37	1.92	.31	114	18
MONK812.SPECIAL	: 49.8	207.79	2.01	.14	3.15	466	.44	2.71	.08	134	3
MONK812.SPECIAL	:100.0	209.28	1.28	.15	1.74	456	.26	1.48	.11	115	8
MONK812.SPECIAL	: 50.0	210.74	2.08	.18	2.96	456	.52	2.44	.22	117	10
MONK812.SPECIAL	: 49.9	212.24	1.66	.19	2.26	454	.44	1.82	.44	109	26
MONK812.SPECIAL	: 50.0	213.74	2.06	.21	2.42	458	.52	1.90	.16	92	7
MONK812.SPECIAL	: 49.5	215.24	1.34	.22	1.67	458	.36	1.31	.22	97	16
MONK812.SPECIAL	: 50.0	216.74	1.64	.20	1.94	457	.38	1.56	.24	95	14

61	MONK812.SPECIAL	: 50.2	218.24	1.85		.16	2.66	458	.43	2.23	.25	120	13
62	MONK812.SPECIAL	: 49.9	219.74	1.59		.21	2.12	456	.44	1.68	.26	105	16
63	MONK812.SPECIAL	: 49.4	221.24	1.97		.20	2.75	453	.54	2.21	.18	112	9
64	MONK812.SPECIAL	: 49.8	222.74	.21		.19	2.58	457	.50	2.08	.26	990	123
65	MONK812.SPECIAL	:100.3	224.24	.79		.21	.91	458	.19	.72	.21	91	26
66	MONK812.SPECIAL	: 50.6	225.38	2.31		.21	3.04	456	.65	2.39	.33	103	14
67	MONK812.SPECIAL	: 50.7	226.38	2.19		.22	3.15	459	.69	2.46	.37	112	16
68	MONK812.SPECIAL	: 49.7	227.88	1.62		.29	2.14	457	.62	1.52	.44	93	27
69	MONK812.SPECIAL	: 49.9	229.38	1.25		.27	1.50	461	.40	1.10	.54	87	43
70	MONK812.SPECIAL	: 49.9	231.56	1.87		.24	2.88	455	.68	2.20	.18	117	9
71	MONK812.SPECIAL	: 50.5	233.26	1.90		.24	2.72	449	.66	2.06	.24	108	12
72	MONK812.SPECIAL	: 49.9	234.76	1.98		.23	3.00	456	.70	2.30	.26	116	13
73	MONK812.SPECIAL	: 50.4	237.76	1.87		.26	2.83	459	.73	2.10	.23	112	12
74	MONK812.SPECIAL	: 49.9	239.26	2.20		.27	3.52	457	.94	2.58	.38	117	17
75	MONK812.SPECIAL	: 50.4	240.76	.99		.26	1.28	458	.33	.95	.21	95	21
76	MONK812.SPECIAL	: 50.1	242.08	1.70		.32	2.18	458	.69	1.49	.19	87	11
77	MONK812.SPECIAL	: 50.1	243.00	1.79		.26	2.68	457	.71	1.97	.21	110	11
78	MONK812.SPECIAL	: 50.3	244.53	.95		.30	1.10	457	.33	.77	.31	81	32
79	MONK812.SPECIAL	: 50.4	245.60	1.34		.27	1.83	455	.49	1.34	.19	100	14
80	MONK812.SPECIAL	: 50.8	247.16	1.26		.33	1.73	455	.57	1.16	.15	92	11
81	MONK812.SPECIAL	: 49.9	249.89	1.41		.29	2.02	454	.58	1.44	.22	102	15
82	MONK812.SPECIAL	: 50.2	249.89	1.76		.30	2.38	459	.71	1.67	.23	94	13
83	MONK812.SPECIAL	: 49.9	251.95	1.66		.28	2.62	456	.74	1.88	.30	113	18
84	MONK812.SPECIAL	: 50.0	252.61	.87		.28	1.56	458	.44	1.12	.18	128	20
85	MONK812.SPECIAL	: 50.3	254.24	1.67		.29	2.07	449	.61	1.46	.21	87	12
86	MONK812.SPECIAL	: 49.9	255.75	1.04		.25	1.46	459	.36	1.10	.36	105	34
87	MONK812.SPECIAL	: 50.1	257.26	1.88		.24	2.96	457	.71	2.25	.63	119	33
88	MONK812.SPECIAL	: 50.4	258.86	2.00		.25	2.87	457	.71	2.16	.63	108	31
89	MONK812.SPECIAL	: 50.4	260.36	2.05		.27	3.09	455	.83	2.26	.39	110	19
90	MONK812.SPECIAL	: 50.6	261.86	1.58		.32	1.79	460	.57	1.22	.59	77	37
91	MONK812.SPECIAL	: 49.8	262.36	2.01		.29	2.78	457	.80	1.98	.32	98	15
92	MONK812.SPECIAL	: 50.0	264.13	1.29		.37	1.88	459	.70	1.18	.36	91	27
93	MONK812.SPECIAL	: 50.0	265.89	1.60		.32	2.22	457	.70	1.52	.28	95	17
94	MONK812.SPECIAL	: 50.0	268.83	1.31		.31	1.78	458	.56	1.22	.36	93	27
95	MONK812.SPECIAL	: 49.9	270.79	1.79		.25	2.68	457	.68	2.00	.34	111	18
96	MONK812.SPECIAL	: 50.9	271.85	1.63		.30	2.36	451	.70	1.66	1.21	101	74
97	MONK812.SPECIAL	: 50.1	273.40	1.97		.29	3.32	451	.95	2.37	.77	120	39
98	MONK812.SPECIAL	: 49.8	274.89	1.26		.33	1.74	450	.58	1.16	.70	92	55
99	MONK812.SPECIAL	:100.4	276.41	1.40		.26	1.44	450	.38	1.06	.19	75	13
100	MONK812.SPECIAL	:100.4	276.41	1.40		.26	1.44	450	.38	1.06	.19	75	13
101	MONK812.SPECIAL	: 49.7	277.73	2.00		.32	3.11	450	1.00	2.11	.70	105	35
102	MONK812.SPECIAL	:100.7	279.91	2.20		.25	2.84	452	.71	2.13	.16	96	7
103	MONK812.SPECIAL	: 50.5	279.91	.25		.30	2.33	453	.69	1.64	.19	656	76
104	MONK812.SPECIAL	:100.7	279.91	2.20		.25	2.84	452	.71	2.13	.16	96	7
105	MONK812.SPECIAL	: 50.1	281.72	2.04		.28	2.84	450	.79	2.05	.93	100	45
106	MONK812.SPECIAL	: 49.7	283.19	2.24		.28	3.39	450	.94	2.45	1.10	109	49
107	MONK812.SPECIAL	: 49.9	284.39	2.25		.25	3.12	443	.78	2.34	1.16	103	51
108	MONK812.SPECIAL	: 49.8	285.90	2.08		.22	2.52	453	.56	1.96	.96	94	46
109			-286.40		Gates Formation								
110	MONK812.SPECIAL	: 99.9	286.50	4.55		.17	5.18	456	.86	4.32	.26	94	5
111	MONK812.SPECIAL	: 50.5	286.50	1.22		.14	.76	456	.11	.65	.09	53	7
112	MONK812.SPECIAL	: 99.9	286.50	4.55		.17	5.18	456	.86	4.32	.26	94	5
113	MONK812.SPECIAL	:100.9	286.64	1.19		.15	.84	452	.13	.71	.44	59	36
114	MONK812.SPECIAL	:100.1	287.58	1.47		.20	1.27	449	.26	1.01	.52	68	35
115	MONK812.SPECIAL	: 99.6	291.24	10.39		.05	14.44	451	.79	13.65	.59	131	5
116	MONK812.SPECIAL	: 50.2	291.24	9.40		.07	11.72	453	.79	10.93	.47	116	5
117	MONK812.SPECIAL	: 99.6	291.24	10.39		.05	14.44	451	.79	13.65	.59	131	5
118	MONK812.SPECIAL	: 49.7	293.57	12.99		.07	28.83	453	2.11	26.72	2.35	205	18
119	MONK812.SPECIAL	: 49.9	298.94	4.82		.19	2.58	460	.50	2.08	2.58	43	53
120	MONK812.SPECIAL	: 49.7	307.58	4.10		.15	2.73	461	.42	2.31	1.77	56	43

121	MONK812.SPECIAL	: 99.6	309.20	1.01	.14	.88	460	.12	.76	.58	75	57
122	MONK812.SPECIAL	: 49.8	311.86	6.22	.07	11.72	458	.84	10.88	1.96	174	31
123	MONK812.SPECIAL	: 50.4	313.46	8.96	.07	17.06	456	1.19	15.87	2.48	177	27
124	MONK812.SPECIAL	: 50.7	314.83	25.73	.06	79.28	454	4.81	74.47	3.05	289	11
125	MONK812.SPECIAL	:100.0	315.94	1.06	.10	.72	455	.07	.65	.52	61	49
126	MONK812.SPECIAL	: 49.9	320.03	4.14	.13	4.42	459	.56	3.86	1.36	93	32
127	MONK812.SPECIAL	: 99.7	321.50	2.21	.19	1.47	459	.28	1.19	.93	53	42
128	MONK812.SPECIAL	:100.8	323.03	1.84	.16	1.46	456	.24	1.22	.76	66	41
129	MONK812.SPECIAL	:100.5	328.54	2.43	.13	1.68	458	.22	1.46	.68	60	27
130	MONK812.SPECIAL	: 99.8	329.35	1.26	.14	.85	453	.12	.73	.42	57	33
131	MONK812.SPECIAL	:100.2	330.84	1.91	.19	1.15	456	.22	.93	1.07	48	56
132	MONK812.SPECIAL	:100.1	335.91	2.87	.12	2.38	456	.29	2.09	.60	72	20
133	MONK812.SPECIAL	: 50.1	337.94	13.41	.05	29.13	462	1.51	27.62	1.73	205	12
134	MONK812.SPECIAL	: 50.8	340.49	4.84	.10	5.07	458	.51	4.56	1.27	94	26
135	MONK812.SPECIAL	: 50.0	342.09	19.25	.06	48.90	458	2.82	46.08	1.64	239	8
136	MONK812.SPECIAL	:100.1	343.04	2.90	.12	1.79	462	.21	1.58	.55	54	18
137	MONK812.SPECIAL	:100.0	345.14	1.97	.16	1.34	461	.22	1.12	.61	56	30
138	MONK812.SPECIAL	:100.1	366.91	3.04	.17	1.72	460	.29	1.43	1.34	47	44
139	MONK812.SPECIAL	:100.3	369.80	3.51	.13	2.48	464	.32	2.16	1.01	61	28
140	MONK812.SPECIAL	:100.4	369.88	3.60	.15	2.53	461	.37	2.16	1.00	60	27
141	MONK812.SPECIAL	:101.0	371.86	8.38	.05	16.15	462	.79	15.36	1.03	183	12
142	MONK812.SPECIAL	: 50.5	371.86	7.41	.05	13.71	468	.70	13.01	.80	175	10
143	MONK812.SPECIAL	:100.1	374.06	3.41	.13	2.53	458	.33	2.20	.85	64	24
144	MONK812.SPECIAL	: 50.4	376.00	3.42	.08	3.18	463	.27	2.91	.71	85	20
145	MONK812.SPECIAL	: 49.8	378.17	8.15	.07	16.44	465	1.16	15.28	1.16	187	14
146	MONK812.SPECIAL	: 50.1	379.67	11.37	.05	21.74	464	1.07	20.67	1.87	181	16
147	MONK812.SPECIAL	: 50.6	381.17	4.02	.09	2.34	467	.21	2.13	1.62	52	40
148	MONK812.SPECIAL	:101.5	382.64	1.41	.14	.74	456	.10	.64	1.33	45	94
149	MONK812.SPECIAL	:100.0	382.77	4.64	.07	6.84	460	.48	6.36	.53	137	11
150	MONK812.SPECIAL	:100.6	382.77	4.70	.07	6.58	463	.48	6.10	.66	129	14
151	MONK812.SPECIAL	:100.4	389.97	4.02	.08	3.34	466	.26	3.08	.56	76	13
152	MONK812.SPECIAL	:100.0	400.26	2.53	.20	1.22	466	.24	.98	.64	38	25
153	MONK812.SPECIAL	:101.2	400.70	1.13	.10	.59	459	.06	.53	.38	46	33
154	MONK812.SPECIAL	:100.5	402.21	2.08	.11	1.42	460	.15	1.27	.39	61	18
155	MONK812.SPECIAL	:100.2	403.64	1.91	.13	.89	462	.12	.77	1.12	40	58
156	MONK812.SPECIAL	: 50.8	405.98	10.34	.05	17.45	467	.84	16.61	.90	160	8
157	MONK812.SPECIAL	: 99.9	407.42	2.61	.14	1.17	472	.16	1.01	1.00	38	38
158	MONK812.SPECIAL	:100.1	408.79	2.43	.11	1.02	467	.11	.91	1.03	37	42
159	MONK812.SPECIAL	:100.0	410.17	2.46	.12	1.03	474	.12	.91	.94	36	38
160	MONK812.SPECIAL	:100.1	411.22	7.79	.08	7.57	460	.58	6.99	.41	89	5
161	MONK812.SPECIAL	: 50.0	412.85	14.64	.05	32.94	459	1.74	31.20	1.10	213	7
162	MONK812.SPECIAL	:101.4	413.98	2.92	.12	2.89	458	.36	2.53	.53	86	18
163	MONK812.SPECIAL	: 50.5	415.08	4.66	.07	4.52	462	.33	4.19	.59	89	12
164	MONK812.SPECIAL	:100.5	417.42	5.22	.07	4.56	463	.33	4.23	1.07	81	20
165	MONK812.SPECIAL	:100.8	419.53	1.52	.13	.78	468	.10	.68	1.36	44	89
166	MONK812.SPECIAL	: 51.8	421.02	12.52	.07	20.72	467	1.50	19.22	1.17	153	9
167	MONK812.SPECIAL	: 50.7	422.21	7.38	.07	11.53	468	.84	10.69	.94	144	12
168	MONK812.SPECIAL	:102.3	423.57	3.95	.17	2.39	463	.40	1.99	1.04	50	26
169	MONK812.SPECIAL	:100.4	425.29	3.60	.17	2.21	462	.38	1.83	.87	50	24
170	MONK812.SPECIAL	:101.0	427.62	3.61	.15	2.79	460	.41	2.38	.75	65	20
171	MONK812.SPECIAL	: 50.1	436.72	7.97	.09	9.55	472	.85	8.70	.83	109	10
172	MONK812.SPECIAL	:101.0	440.30	2.46	.18	1.34	465	.24	1.10	.84	44	34
173	MONK812.SPECIAL	: 99.8	447.50	2.04	.23	1.24	461	.28	.96	.65	47	31
174	MONK812.SPECIAL	:100.1	456.69	1.61	.21	.78	460	.16	.62	.94	38	58
175	MONK812.SPECIAL	:101.6	462.50	1.98	.19	.88	471	.17	.71	1.05	35	53
176	MONK812.SPECIAL	:101.3	463.70	1.58	.16	.79	457	.13	.66	1.50	41	94
177	MONK812.SPECIAL	: 51.8	468.87	7.78	.06	12.75	471	.71	12.04	.86	154	11
178	MONK812.SPECIAL	: 50.5	473.67	7.98	.07	10.39	471	.77	9.62	.73	120	9
179	MONK812.SPECIAL	: 99.1	487.29	6.45	.06	5.95	473	.38	5.57	.56	86	8
180	MONK812.SPECIAL	:101.1	497.98	4.72	.08	5.16	467	.40	4.76	.38	100	8

Gates Formation

181	MONK812.SPECIAL	: 20.6	500.36	10.89	.09	10.38	481	.92	9.46	1.40	86	12
182	MONK812.SPECIAL	:100.5	504.96	6.59	.12	4.73	467	.56	4.17	.98	63	14
183	MONK812.SPECIAL	:102.0	509.91	5.07	.11	2.99	461	.32	2.67	1.00	52	19
184	MONK812.SPECIAL	: 99.9	512.93	1.44	.12	.69	465	.08	.61	.17	42	11
185	MONK812.SPECIAL	: 99.6	513.83	1.35	.13	.45	489	.06	.39	.47	28	34
186	MONK812.SPECIAL	:100.7	516.50	2.09	.06	1.05	438	.06	.99	.82	47	39
187	MONK812.SPECIAL	: 99.7	521.53	2.97	.07	2.09	465	.15	1.94	.25	65	8
188	MONK812.SPECIAL	:100.1	524.03	9.94	.05	10.97	469	.59	10.38	.84	104	8
189	MONK812.SPECIAL	: 99.3	525.03	4.24	.06	4.64	468	.27	4.37	.31	103	7
190	MONK812.SPECIAL	:102.2	526.53	2.66	.16	1.41	468	.23	1.18	.73	44	27
191	MONK812.SPECIAL	:101.2	529.23	3.52	.18	2.01	467	.36	1.65	.61	46	17
192	MONK812.SPECIAL	:100.2	532.41	3.02	.16	1.79	463	.29	1.50	.56	49	18
193	MONK812.SPECIAL	: 99.7	533.49	5.29	.12	2.95	468	.34	2.61	1.24	49	23
194	MONK812.SPECIAL	:100.9	534.76	8.78	.03	17.63	464	.51	17.12	.63	194	7
195	MONK812.SPECIAL	: 99.7	-536.26	3.56	.08	2.94	465	.24	2.70	.46	75	12
196			-563.26	Moosebar Formation								
197	MONK814.SPECIAL	:101.1	556.260	1.31	.21	.75	454	.16	.59	.18	45	13
198	MONK814.SPECIAL	:101.0	563.380	2.08	.19	1.58	464	.30	1.28	.22	61	10
199	MONK814.SPECIAL	:101.1	564.390	1.27	.36	1.19	461	.43	.76	.36	59	28
200	MONK814.SPECIAL	: 99.5	565.910	1.79	.24	1.53	464	.36	1.17	.31	65	17
201	MONK814.SPECIAL	: 99.5	567.410	1.97	.21	1.38	463	.29	1.09	.39	55	19
202	MONK814.SPECIAL	: 99.5	568.940	1.82	.23	1.07	462	.25	.82	.39	45	21
203	MONK814.SPECIAL	: 99.5	570.830	1.35	.22	.76	461	.17	.59	.26	43	19
204	MONK814.SPECIAL	:100.8	573.690	1.46	.28	.79	461	.22	.57	.33	39	22
205	MONK814.SPECIAL	: 99.3	574.890	1.66	.24	.94	460	.23	.71	.20	42	12
206	MONK814.SPECIAL	:100.2	579.690	1.37	.27	.74	462	.20	.54	.19	39	13
207	MONK814.SPECIAL	: 98.3	581.990	1.45	.30	.70	461	.21	.49	.33	33	22
208	MONK814.SPECIAL	:101.1	585.820	1.64	.28	.75	462	.21	.54	.20	32	12
209	MONK814.SPECIAL	: 98.5	588.390	1.69	.24	1.25	460	.30	.95	.23	56	13
210	MONK814.SPECIAL	: 99.8	590.610	2.03	.26	1.25	459	.32	.93	.23	45	11
211	MONK814.SPECIAL	: 99.8	592.990	1.44	.28	.83	460	.23	.60	.30	41	20
212	MONK814.SPECIAL	:100.0	593.990	1.35	.25	.85	464	.21	.64	.29	47	21
213	MONK814.SPECIAL	:100.0	594.790	1.39	.28	.71	463	.20	.51	.24	36	17
214	MONK814.SPECIAL	:100.3	597.230	1.70	.26	.93	462	.24	.69	.21	40	12
215	MONK814.SPECIAL	: 99.9	599.050	1.78	.26	1.09	463	.28	.81	.19	45	10
216	MONK814.SPECIAL	: 99.9	599.050	1.89	.06	1.16	440	.07	1.09	.62	57	32
217	MONK814.SPECIAL	: 99.7	600.250	2.09	.19	1.18	463	.23	.95	.20	45	9
218	MONK814.SPECIAL	: 99.7	600.250	2.36	.29	1.29	463	.37	.92	.27	38	11
219	MONK814.SPECIAL	:100.5	601.280	1.43	.27	.89	460	.24	.65	.30	45	20
220	MONK814.SPECIAL	:100.0	601.790	1.77	.35	.84	462	.29	.55	.29	31	16
221	MONK814.SPECIAL	:100.0	607.290	.95	.31	.48	455	.15	.33	.30	34	31
222	MONK814.SPECIAL	:100.4	608.530	1.80	.30	.83	463	.25	.58	.45	32	25
223	MONK814.SPECIAL	:100.4	608.530	1.80	.30	.83	463	.25	.58	.45	32	25
224	MONK814.SPECIAL	:100.4	610.050	1.84	.25	1.11	463	.28	.83	.34	45	18
225	MONK814.SPECIAL	: 99.7	612.310	1.39	.29	.73	469	.21	.52	.36	37	25
226	MONK814.SPECIAL	:100.5	615.190	1.67	.25	1.01	465	.25	.76	.36	45	21
227	MONK814.SPECIAL	: 99.9	616.710	2.07	.23	1.37	463	.31	1.06	.38	51	18
228	MONK814.SPECIAL	:100.0	617.440	1.25	.37	.57	458	.21	.36	.24	28	19
229	MONK814.SPECIAL	: 99.8	618.290	1.18	.26	.72	463	.19	.53	.26	44	22
230	MONK814.SPECIAL	:100.0	618.790	1.07	.35	.55	458	.19	.36	.25	33	23
231	MONK814.SPECIAL	: 99.8	619.790	1.70	.35	.86	463	.30	.56	.32	32	18
232	MONK814.SPECIAL	: 99.7	620.260	1.50	.29	.78	462	.23	.55	.25	36	16
233	MONK814.SPECIAL	: 99.8	621.290	1.49	.24	.98	466	.24	.74	.30	49	20
234	MONK814.SPECIAL	:100.1	621.740	.75	.35	.37	462	.13	.24	.13	31	17
235	MONK814.SPECIAL	: 99.9	622.780	.88	.30	.54	468	.16	.38	.16	43	18
236	MONK814.SPECIAL	: 99.6	622.790	1.85	.31	1.13	466	.35	.78	.38	42	20
237	MONK814.SPECIAL	:100.1	624.060	1.17	.29	.62	460	.18	.44	.19	37	16
238	MONK814.SPECIAL	:100.0	624.290	2.05	.31	1.02	463	.32	.70	.27	34	13
239	MONK814.SPECIAL	:100.3	625.510	1.27	.30	.70	460	.21	.49	.28	38	22
240	MONK814.SPECIAL	:100.3	625.830	1.30	.32	.69	457	.22	.47	.15	36	11

					Moosebar Formation								
241	MONK814.SPECIAL	: 99.7	627.760	1.49		.31	.85	467	.26	.59	.36	39	24
242	MONK814.SPECIAL	: 99.9	629.250	1.24		.27	.63	468	.17	.46	.42	37	33
243	MONK814.SPECIAL	: 99.8	630.750	1.32		.28	.80	468	.22	.58	.36	43	27
244	MONK814.SPECIAL	: 99.6	632.250	1.43		.27	.85	467	.23	.62	.38	43	26
245	MONK814.SPECIAL	: 99.9	633.750	.91		.35	.49	459	.17	.32	.17	35	18
246	MONK814.SPECIAL	:100.5	635.250	.99		.33	.49	459	.16	.33	.21	33	21
247	MONK814.SPECIAL	: 99.7	636.750	.99		.34	.53	459	.18	.35	.22	35	22
248	MONK814.SPECIAL	: 99.5	638.250	1.18		.33	.60	460	.20	.40	.19	33	16
249	MONK814.SPECIAL	:100.3	639.750	1.26		.32	.65	459	.21	.44	.21	34	16
250	MONK814.SPECIAL	:100.3	641.250	1.34		.33	.72	459	.24	.48	.19	35	14
251	MONK814.SPECIAL	:100.6	642.750	1.06		.29	.49	462	.14	.35	.21	33	19
252	MONK814.SPECIAL	: 99.8	644.250	1.41		.30	.77	465	.23	.54	.26	38	18
253	MONK814.SPECIAL	: 99.9	645.750	1.67		.26	1.01	471	.26	.75	.61	44	36
254	MONK814.SPECIAL	:100.2	647.250	1.61		.24	.88	473	.21	.67	.74	41	45
255	MONK814.SPECIAL	:100.2	648.750	1.63		.27	.90	471	.24	.66	.43	40	26
256	MONK814.SPECIAL	:100.3	650.250	1.58		.26	.97	469	.25	.72	.52	45	32
257	MONK814.SPECIAL	:100.6	651.750	1.50		.27	.92	469	.25	.67	.44	44	29
258	MONK814.SPECIAL	: 99.9	652.970	1.52		.27	1.06	463	.29	.77	.35	50	23
259	MONK814.SPECIAL	: 99.8	653.970	1.64		.29	1.20	459	.35	.85	.16	51	9
260	MONK814.SPECIAL	: 99.7	655.470	1.36		.34	.83	459	.28	.55	.23	40	16
261	MONK814.SPECIAL	:100.1	656.970	.97		.27	.51	464	.14	.37	.29	38	29
262	MONK814.SPECIAL	:100.1	658.470	1.07		.28	.53	464	.15	.38	.21	35	19
263	MONK814.SPECIAL	:100.2	659.970	1.23		.25	.55	467	.14	.41	.20	33	16
264			-662.490		Gething Formation								
265	MONK814.SPECIAL	: 6.0	662.690	12.28		.09	14.66	482	1.33	13.33	1.33	108	10
266	MONK814.SPECIAL	:101.0	663.890	2.37		.13	1.47	473	.19	1.28	.27	54	11
267	MONK814.SPECIAL	: 14.0	664.090	8.74		.13	7.64	480	1.00	6.64	2.00	75	22
268	MONK814.SPECIAL	: 15.5	667.250	6.60		.09	11.03	481	1.03	10.00	.70	151	10
269	MONK814.SPECIAL	: 5.9	670.710	22.20		.10	26.94	483	2.71	24.23	1.69	109	7
270	MONK814.SPECIAL	:100.2	671.460	2.68		.13	2.19	471	.28	1.91	.10	71	3
271	MONK814.SPECIAL	:100.5	671.560	1.27		.25	.68	470	.17	.51	.49	40	38
272	MONK814.SPECIAL	: 99.6	673.690	1.77		.27	.98	475	.26	.72	1.16	40	65
273	MONK814.SPECIAL	: 99.7	674.110	.12		.20	1.50	472	.30	1.20	.83	1000	691
274	MONK814.SPECIAL	: 99.9	674.110	2.85		.21	1.36	477	.28	1.08	.82	37	28
275	MONK814.SPECIAL	: 50.2	678.570	1.16		.20	.46	475	.09	.37	1.01	31	87
276	MONK814.SPECIAL	: 49.9	706.680	23.48		.07	78.21	471	5.43	72.78	1.60	309	6
277	MONK814.SPECIAL	: 51.2	706.870	3.95		.10	3.08	473	.31	2.77	.31	70	7
278	MONK814.SPECIAL	: 50.9	709.060	4.71		.16	3.28	473	.51	2.77	.39	58	8
279	MONK814.SPECIAL	: 50.0	712.860	6.38		.08	7.98	478	.62	7.36	.34	115	5
280	MONK814.SPECIAL	: 50.0	712.860	5.30		.13	4.00	480	.50	3.50	.44	66	8
281	MONK814.SPECIAL	: 49.7	714.560	9.72		.08	15.66	472	1.18	14.48	.50	148	5
282	MONK814.SPECIAL	: 50.2	740.220	1.63		.14	.96	477	.13	.83	.35	50	21
283	MONK814.SPECIAL	: 49.6	742.760	1.39		.18	1.22	471	.22	1.00	.01	71	0
284	MONK814.SPECIAL	: 49.9	748.440	2.77		.07	2.56	476	.18	2.38	.44	85	15
285	MONK814.SPECIAL	: 50.0	750.400	3.11		.05	2.40	475	.12	2.28	.44	73	14
286	MONK814.SPECIAL	: 51.6	753.890	1.79		.09	1.44	470	.13	1.31	.87	73	48
287	MONK814.SPECIAL	: 50.9	755.560	18.82		.03	37.57	471	1.27	36.30	.94	192	4
288	MONK814.SPECIAL	: 50.1	755.560	1.77		.08	1.46	478	.11	1.35	.65	76	36
289	MONK814.SPECIAL	: 49.2	758.940	2.98		.12	2.59	471	.30	2.29	.91	76	30
290	MONK814.SPECIAL	: 50.2	758.940	13.72		.05	31.17	471	1.69	29.48	1.33	214	9
291	MONK814.SPECIAL	: 49.6	761.640	8.41		.07	14.81	471	1.02	13.79	1.18	163	14
292	MONK814.SPECIAL	: 51.4	763.640	17.12		.06	27.56	470	1.73	25.83	1.08	150	6
293	MONK814.SPECIAL	: 50.2	765.580	3.28		.13	2.04	477	.27	1.77	.41	53	12
294	MONK814.SPECIAL	: 49.7	766.530	7.35		.11	5.83	479	.62	5.21	.48	70	6
295	MONK814.SPECIAL	: 50.4	771.590	3.83		.05	2.74	476	.15	2.59	.17	67	4
296	MONK814.SPECIAL	: 50.1	791.730	.61		.13	.52	512	.07	.45	.05	73	8
297			-797.70		Cadomin Formation								
298			-843.410		Nikanassin Formation								
299	MONK8011	:101.6	843.490	2.43		.07	3.66	464	.24	3.42	.01	140	0
300	MONK8011	: 99.4	856.440	1.37		.23	1.18	467	.27	.91	.33	66	24

301	MONK8011	:100.0	857.060	1.51	Cadomin Formation	.28	1.25	469	.35	.90	.56	59	37
302	MONK8011	:100.2	860.050	1.39	Nikanassin Formation	.25	1.12	467	.28	.84	.41	60	29
303	MONK8011	:101.0	862.910	1.46		.25	.96	471	.24	.72	1.05	49	71
304	MONK8011	:100.5	862.910	1.16		.30	.71	473	.21	.50	.98	43	84
305	MONK8011	:100.4	870.990	8.87		.07	17.05	467	1.20	15.85	.62	178	6
306	MONK8011	:100.5	873.590	6.11		.04	29.14	467	1.28	27.86	.30	455	4
307	MONK8011	:100.1	876.420	4.18		.09	4.42	475	.41	4.01	.11	95	2
308	MONK8011	:101.3	877.690	4.21		.09	4.30	475	.40	3.90	.09	92	2
309	MONK8011	:101.3	879.490	1.99		.16	1.55	478	.25	1.30	.53	65	26
310	MONK8011	: 99.6	885.130	2.19		.20	2.05	472	.41	1.64	.28	74	12
311	MONK8011	:100.5	885.870	3.26		.11	2.96	473	.34	2.62	.08	80	2
312	MONK8011	:100.1	894.430	2.39		.10	2.04	475	.21	1.83	.08	76	3
313	MONK8011	:100.3	894.760	.57		.17	.30	492	.05	.25	.07	43	12
314	MONK8011	:100.3	897.390	2.99		.21	2.56	473	.55	2.01	.28	67	9
315	MONK8011	:100.7	898.230	3.60		.13	3.55	476	.46	3.09	.34	85	9
316	MONK8011	:100.0	900.070	8.72		.07	14.90	472	.98	13.92	.19	159	2
317	MONK8011	:101.4	902.360	1.24		.26	1.17	473	.30	.87	.13	70	10
318	MONK8011	:100.3	906.090	4.73		.06	6.09	470	.35	5.74	.10	121	2
319	MONK8011	: 99.5	912.140	3.46		.14	3.97	476	.54	3.43	.10	99	2
320	MONK8011	:101.2	913.710	2.79		.28	2.78	472	.77	2.01	.27	72	9
321	MONK8011	:100.7	915.080	.73		.28	.46	474	.13	.33	.32	45	43
322	MONK8011	:101.0	919.890	5.13		.10	5.48	471	.53	4.95	.23	96	4
323	MONK8011	:101.0	924.020	4.84		.12	6.07	473	.73	5.34	.17	110	3
324	MONK8011	: 99.7	928.870	3.91		.12	3.67	475	.43	3.24	.15	82	3
325	MONK8011	: 99.9	935.840	1.42		.16	1.03	469	.16	.87	.19	61	13
326	MONK8011	:100.2	938.160	.76		.19	.48	478	.09	.39	.09	51	11
327	MONK8011	:100.2	941.170	2.33		.18	2.37	475	.43	1.94	.15	83	6
328	MONK8011	:100.5	954.820	2.87		.27	2.18	472	.59	1.59	.54	55	18
329	MONK8011	: 99.9	955.660	2.01		.15	1.64	471	.25	1.39	.52	69	25
330	MONK8011	:101.1	959.080	12.29		.06	29.02	469	1.80	27.22	.33	221	2
331	MONK8011	:101.0	961.580	1.42		.14	1.12	475	.16	.96	.06	67	4
332	MONK8011	: 99.4	966.890	1.40		.27	1.31	479	.36	.95	.10	67	7
333	MONK8011	:101.2	969.920	3.96		.10	4.52	475	.45	4.07	.11	102	2
334	MONK8011	: 99.2	971.840	1.06		.29	.87	478	.25	.62	.10	58	9
335	MONK8011	:100.8	975.690	2.31		.13	2.15	478	.29	1.86	.05	80	
336	MONK8011	:100.0	979.180	2.70		.15	2.01	479	.31	1.70	.46	62	
337	MONK8011	: 99.3	986.810	.36		.27	.22	488	.06	.16	.02	44	5
338	MONK8011	:100.4	993.670	2.54		.09	2.37	475	.21	2.16	.08	85	3
339	MONK8011	:100.6	995.900	5.61		.13	4.03	478	.52	3.51	.44	62	7
340	MONK8011	: 99.8	1001.06	5.27		.08	6.68	476	.51	6.17	.08	117	1
341	MONK8011	:101.7	1004.62	.60		.23	.43	484	.10	.33	.46	55	76
342	MONK8011	: 99.9	1006.35	2.14		.13	1.12	478	.14	.98	.18	45	8
343	MONK8011	:100.6	1008.83	3.51		.19	1.68	483	.32	1.36	1.34	38	38
344	MONK8011	:101.0	1010.66	1.17		.28	.74	480	.21	.53	.68	45	58
345	MONK8011	: 99.7	1010.66	2.52		.06	3.87	481	.22	3.65	.18	144	7
346	MONK8011	:100.2	1010.92	.69		.23	.48	478	.11	.37	.14	53	20
347	MONK8011	:100.2	1010.92	1.97		.10	1.44	484	.14	1.30	.15	65	7
348	MONK8011	:100.1	1018.08	1.01		.28	.61	474	.17	.44	.40	43	39
349	MONK8011	:100.7	1018.08	4.96		.09	3.71	481	.34	3.37	.34	67	6
350	MONK8011	: 99.6	1030.21	3.33		.14	1.77	482	.25	1.52	1.34	45	40
351	MONK8011	: 99.5	1034.33	.47		.07	4.32	479	.32	4.00	.30	851	63
352	MONK8011	: 99.8	1043.26	2.25		.08	5.64	480	.47	5.17	.23	229	10
353	MONK8011	:100.7	1052.50	3.34		.14	2.79	480	.38	2.41	.37	72	11
354	MONK8011	: 99.6	1056.96	1.44		.21	.92	487	.19	.73	.89	50	61
355	MONK8011	:102.1	1057.62	.97		.20	.79	476	.16	.63	.10	64	10
356	MONK8011	:100.1	1060.22	2.79		.19	1.55	484	.29	1.26	.75	45	26
357	MONK8011	: 99.9	1062.96	1.55		.22	.82	483	.18	.64	.96	41	61
358	MONK8011	:100.9	1066.38	8.27		.04	18.53	478	.77	17.76	.27	214	3
359	MONK8011	:100.6	1075.33	3.09		.12	2.35	478	.28	2.07	.24	66	7
360	MONK8011	: 99.5	1089.72	3.33		.17	2.36	478	.41	1.95	.37	58	11

361	MONK8011	:101.0	1102.38	4.11	Cadomin Formation	.12	3.50	481	.42	3.08	.55	74	13
362	MONK8011	:100.1	1103.65	4.98	Nikanassin Formation	.05	5.36	469	.25	5.11	.10	102	2
363	MONK8011	:102.1	1109.36	.54		.14	.22	490	.03	.19	.14	35	25
364	MONK8011	:100.1	1113.50	3.63		.19	3.05	482	.58	2.47	.16	68	4
365	MONK8011	: 99.8	1118.68	1.53		.31	1.20	483	.37	.83	.55	54	35
366	MONK8011	:102.6	1121.95	2.77		.21	1.75	481	.37	1.38	.48	49	17
367	MONK8011	:100.7	1128.42	1.14		.27	.89	479	.24	.65	.05	57	4
368	MONK8011	:100.7	1131.83	4.32		.10	2.95	485	.29	2.66	.20	61	4
369	MONK8011	:100.1	1141.10	1.46		.25	1.06	479	.27	.79	.49	54	33
370	MONK8011	: 99.7	1143.58	1.96		.13	1.16	482	.15	1.01	.17	51	8
371	MONK8011	: 99.8	1153.46	1.35		.11	.84	480	.09	.75	.05	55	3
372	MONK8011	:102.4	1160.81	.75		.39	.46	489	.18	.28	.41	37	54
373	MONK8011	: 99.9	1161.58	3.13		.13	2.77	485	.35	2.42	.07	77	2
374	MONK8011	:101.1	1167.14	1.01		.26	.57	480	.15	.42	.09	41	8
375	MONK8011	:101.2	1168.15	2.29		.23	1.76	478	.40	1.36	.29	59	12
376	MONK8011	:100.7	1192.56	1.42		.11	.79	481	.09	.70	.07	49	4