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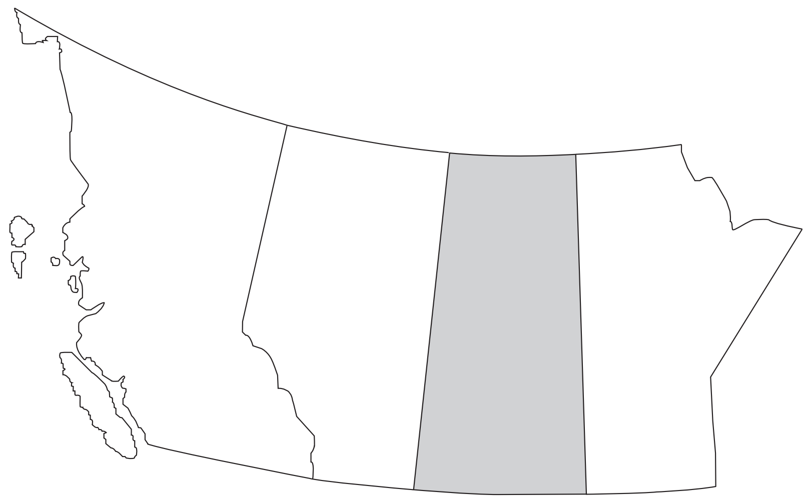

Non-Associated Natural Gas Resource Assessment Study

SASKATCHEWAN

Calgary 1998

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Foreword

The following report has been prepared by the National Energy Board ("NEB" or "the Board") to provide an analytical review of undiscovered gas resources in Saskatchewan. Saskatchewan Energy and Mines provided assistance and comments during the preparation of this report; however, the conclusions and interpretations presented are those of the Board.

The Board has established a methodology to determine and evaluate the remaining undiscovered potential for gas resources. A review of current practices and approaches by industry and other government departments involved in resource assessments determined that resource assessments are regional in nature and, as such, are difficult to apply to local project evaluations. Consequently, the Board has developed an approach that evaluates resource potential for regional purposes.

The Board will continue to rely on the regional resource assessments provided by the Geological Survey of Canada and will incorporate their results whenever practical. Also, the Board recognizes that resource assessment activity may be carried out by provincial agencies and other groups. These assessments will also be incorporated whenever practical.

This study was initiated by the Board to identify undiscovered non-associated gas potential in Saskatchewan. The study is part of the Board's ongoing effort to determine estimates of undiscovered gas potential in various parts of Canada. The conclusions and estimates derived from this study will be used in support of the Board's assessment of Western Canada gas supply.

The Board welcomes any comments on the design or use of the selected methodology, or on the results from this study, Non-Associated Natural Gas Resource Assessment - Saskatchewan. Comments should be directed to the Secretary of the Board by December 1, 1998.

National Energy Board

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Abbreviations and Definitions

AEUB	Alberta Energy and Utilities Board
CGPC	Canadian Gas Potential Committee
GSC	Geological Survey of Canada
ºF	degrees Fahrenheit
ha	hectares
Mcfd	thousand cubic feet per day
psia	pounds per square inch absolute
SEM	Saskatchewan Energy and Mines
Tcf	trillion cubic feet
Z	gas compressibility factor
$10^3m^3/d$	thousand cubic metres per day
10^9m^3	trillion cubic metres

Non-Associated Natural Gas Resource Assessment - Saskatchewan

Introduction

This assessment of undiscovered non-associated gas resources in Saskatchewan was done using the @Risk add-in for Excel. The methodology used in the assessment has been adapted from Roadifer, 1979. The general area of assessment, from Townships 1 to 70, Range 30 West of the Prime (1st) Meridian to the 4th Meridian, encompasses an area of about 35.2 million ha (87.1 million acres) or 136,045 square miles. There are numerous associated gas pools, along with solution gas volumes in other pools, present throughout the area. These quantities of gas are generally required to maintain oil productivity and are not presently available for domestic or foreign consumption. Therefore, assessments for associated and solution gas resources were not undertaken at this time.

Analysis

A statistical analysis was used to determine reservoir parameter inputs for each play group used in this study. Most reservoir parameters were identified from data in the Saskatchewan Department of Energy and Mines' Reservoir Annual Report 97-1 ("SEM", 1997). Information from the SEM report was divided by play groups in order to accumulate sufficient data and allow for statistical analysis to be done with the Excel Statistical Analysis toolpack. Well retrievals from the *geo*LOGIC Systems Ltd. GeoSCOUT database, grouped by play, were done to establish probability of hydrocarbons (success rates) for each group. These values were then entered into the @Risk program to generate cases for the undiscovered non-associated gas potential. The @Risk templates were designed using distribution functions which require maximum, minimum and most likely values for all input parameters. The resulting output is a cumulative distribution function which calculates gas-in-place, recoverable raw gas, marketable gas and gas liquids.

Resource Estimation using @Risk with Excel

The NEB has developed a series of templates created in Microsoft's "Excel" spreadsheet combined with Palisade's Corporation's "@RISK" add-in set of programs. @RISK links directly to Excel and adds risk analysis and modelling capabilities to Excel.

The probabilistic methodology (adapted from Roadifer, 1979) was used in the templates that were developed by NEB staff (Table 1). A probabilistic estimate of petroleum resources is achieved by multiplying independent, randomly selected values from input distributions for hydrocarbon volume, hydrocarbon yield and risk.

This technique requires a set of input variables that are sampled using a random sampling method such as Monte Carlo. A stochastic estimate of resources can be achieved by multiplying computer generated numbers for volume, yield and risk. The variable input parameters for the NEB methodology are summarized as follows:

Hydrocarbon Area	Untested Play Area Fraction of Untested Play Area-in-Trap Areal Fill of Traps
Hydrocarbon Volume	Average Net Pay Porosity Hydrocarbon Saturation

Table 1. Estimation of Non-Associated Gas Resources

Area/Region	Saskatchewan
Play Name	Sample Play
Estimator Name	Assessor
Gas Depth	750 (feet)
Reservoir Temperature	53 (ºF)
Reservoir Pressure	322 (psi)

		Minimum	Most Likely	Maximum	Mean
A	Total Play Area (mm acres)	7.700	7.97	8.100	7.923
A'	Tested Play Area (mm acres)	2.857	2.86	2.863	2.860
B	Untested Play Area (mm acres)	4.843	5.11	5.237	5.063
C	Frac. of 'B' in Trap	0.150	0.240	0.350	0.247
D	Frac. of 'C' filled (areally)	0.750	0.800	0.850	0.800
E	Potential HC area (mm acres)				0.999
F	Porosity	0.050	0.130	0.270	0.150
G	HC Saturation	0.750	0.800	0.850	0.800
H	Gas Recovery Factor	0.650	0.750	0.850	0.750
I	Net Pay Average (feet)	6.0	10.0	28.0	14.67
J	Prob. of Hydrocarbons	0.150	0.200	0.250	0.200
K	Potential Gas Area (mm acres)				0.200
L	Gas Compressibility Factor (Z)	0.931	0.950	0.969	0.950
M	Gas-In-Place (Mcf/acre-ft)				122.7
N	Raw Gas Recovery (Mcf/acre-ft)				0.920
O	Sales Gas Recovery (Mcf/acre-ft)				0.851
P	Liquids Yield (Bbls/Mmcf)	0.5	1.0	1.5	1.000
Q	CO_2 Content (fraction)	0.005	0.010	0.015	0.012
R	Gas-to-BOE Conversion (Mcf/BOE)		6.000		
S	Surface Loss (fuel gas, etc)		0.080		

<u>Total Resource for the Play</u>

		Non-Assoc. Gas (Bcf)	Total Gas (Bcf)	Liquids (mmB)	BOE (mmBOE)	Sales Gas (Bcf)
	Gas-In-Place	359.56	359.56		60.44	
	Sales Gas	269.67	269.67	0.27	45.23	249.39

Yield	Recovery Factor Surface Loss Factor
Risk	Probability of Hydrocarbons

Input Parameters

Total Play Area

Area estimates for each play group were identified using well locations that had reported gas production or drillstem tests of 1.4 $10^3 m^3/d$ (50 Mcfd) or greater were achieved.

Untested Play Area

The untested play area is calculated by subtracting the area considered to be tested from the total defined play area. The tested area was determined by retrieval and mapping of all wells that penetrated the play and assigning a tested area to each well. In this study, for practical purposes, a well was considered to have tested one section (259 ha or 640 acres). In reality, the actual tested area, particularly in the Mannville play group, can significantly vary from the one-section assignment on a well-by-well basis.

Fraction of Play Area-in-Trap

The fraction of play area-in-trap is the fraction of the untested play area expected to have structural and/or stratigraphic closure. It is a consideration of trap density, generally based on analogy to other plays with similar geomorphic style. An assessment of this factor was made based on the experience of the assessment team.

Areal Fill of Traps

This is an estimate of the fraction of the closure that is expected to be hydrocarbon bearing. The estimate is based on analogy and experience and is dependent, to a considerable extent, on the type and geometry of the trap.

Hydrocarbon Volume

The mean parameters are the overall averages for all pools expected to be discovered. The input parameters such as net pay, porosity, hydrocarbon saturation and gas compressibility were taken from the SEM descriptive statistics of previously discovered pools.

Yield

The recovery and marketable gas factors for raw recoverable and marketable estimates were taken from SEM or Alberta Energy and Utilities Board ("AEUB", 1996) published averages for discovered pools.

Risk

This is the probability of occurrence that a trap will contain hydrocarbons and is generally known as the exploration success factor. Well retrievals from the GeoSCOUT database were done to establish historical success rates for each play. These rates were used as a guide in establishing the value used as the probability of hydrocarbons. For immature or conceptual plays that have very limited or no history, consideration of other factors such as hydrocarbon accumulation, hydrocarbon source rock, migration timing, the presence and types of of reservoir traps, will help in developing an estimate of the probability of hydrocarbons.

Estimates of probability of hydrocarbons (success rates) were determined for each case by identifying exploratory wells that penetrated part of the play group or terminated slightly below the case's geological base. In addition, gas production had to be greater than 100 10^3m^3 (3.5 Mmcf).

@RISK

The @RISK program is an add-in routine that adds simulation analysis capabilities to the Excel spreadsheet. The program allows the user to define uncertain cell values as probability distribution functions in the spreadsheet. The @Risk add-in has some 24 distribution functions that a study can incorporate in determining means of variable factors. In this study, a triangular distribution function was used for all reservoir variables (net pay, porosity, etc) that were entered into a gas equation. The triangular function simplifies input (minimum, most likely and maximum values for each parameter) and eliminates the need to describe probability distributions with parameters that are difficult to calculate.

The program executes Monte Carlo or Latin Hypercube simulations over a specified number of iterations (i.e. 3,000) and generate a cumulative frequency distribution that gives a range of probabilities for resource estimates (Figure 1). The Monte Carlo method is entirely random whereas the Latin Hypercube method is a stratified sampling process. The stratified process separates the overall range into several ranges and equal samples are taken from each range to ensure that sampling is even. The Latin Hypercube runs slightly faster on small computers and converges on the mean value more quickly, with a lower number of iterations needed than with the Monte Carlo method. For this study, the Latin Hypercube simulation was adopted.

Gas Equation

The following gas equation was used and must be run using the imperial measurement system at this time.

Gas-in-place = 43,560 *x* Area(million acres) *x* Net Pay(feet) *x* Porosity *x* Gas Saturation *x* GVF

where GVF = 520/(460 + Temperature(°F)) *x* Pressure(psia)/14.65 *x* 1/Z

Estimates of Established Non-Associated Gas Reserves

Gas pool development in Saskatchewan has been ongoing since 1934 when the first non-associated gas pool was reported to be on production. Since then, the discovered volume of initial established non-associated gas reserves has increased to an estimated 164.9 10^9m^3 (5.8 Tcf) while SEM remaining established non-associated gas reserves now stand at 73.6 10^9m^3 (2.6 Tcf).

Saskatchewan - Sample Play		
Iterations	3000	
Minimum	39.07	Bcf
Maximum	888.02	Bcf
Mean	250.35	Bcf
Prob. of Mean	41.9 %	
Std. Deviation	128.96	Bcf
Mode	145.2	Bcf
Percentile Values (%)		Bcf
100		0
95		92
90		113
85		128
80		141
75		155
70		167
65		182
60		195
55		209
50		223
45		239
40		256
35		275
30		295
25		317
20		346
15		375
10		423
5		501
0		888

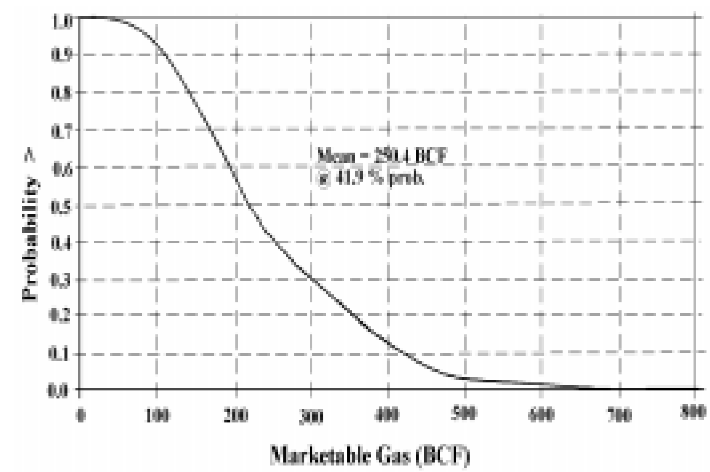

Figure 1. Distribution of Resource Probability

Estimates of Undiscovered Non-Associated Gas Potential

This study initially reviewed well data tests available for all areas in Saskatchewan. Six play groups (Table 2) were identified as having non-associated gas potential. Areas showing wells with reported gas flows from specific zones were then mapped. Individual play group boundaries (Figures 3 to 7) were arbitrarily set outside of these proved areas to include additional areas that are likely to have reasonable expectations for hydrocarbon discoveries. For lands outside of the identified study areas, there may still be very immature or conceptual plays not assessed by this study.

Many of the play groups (Figure 2) tend to have large play areas with significant undrilled acreage remaining to be exploited. The Milk River-Medicine Hat-Second White Specks, Belly River and the Viking play groups (Figures 3 and 4) are predominantly gas-prone. The Mannville play group (Figure 5) contains an increasing proportion of oil plays compared to the shallower play groups. Jurassic and Mississippian plays (Figures 6 and 7) have smaller play areas that are sparsely drilled and appear to have low gas success rates due to an increased oil presence. Below the Mississippian sediments, the deeper plays are considered to be oil-prone with only associated and solution gas potential. Therefore, these plays were not reviewed by this study.

due to an increased oil presence. Below the Mississippian sediments, the deeper plays are considered to be oil-prone with only associated and solution gas potential. Therefore, these plays were not reviewed by this study.

Table 2. Estimates of Marketable Non-Associated Gas Potential[1]
$10^9 m^3$ (Tcf)

Play Group	Mean	P90	P50	P10
Belly River	1.8 (0.05)	1.0 (0.03)	1.7 (0.05)	2.6 (0.08)
MR-MH-2WS [2]	1.0 (0.03)			
Viking	14.1 (0.50)	6.9 (0.24)	12.9 (0.45)	22.9 (0.81)
Mannville	26.0 (0.92)	13.0 (0.46)	24.0 (0.85)	41.7 (1.47)
Jurassic	2.3 (0.08)	1.0 (0.04)	2.0 (0.07)	3.9 (0.14)
Mississippian	1.1 (0.04)	0.4 (0.02)	0.8 (0.04)	2.0 (0.07)
Total	**45.6 (1.61)**	**21.0 (0.74)**	**39.3 (1.39)**	**69.3 (2.89)**

[1] Numbers in this table have been rounded
[2] Modified from a Geological Survey of Canada ("GSC") estimate - see Table 3

Remaining undrilled areas amount to the equivalent of 3,525 sections for the Belly River gas play, 11,100 sections for the Viking play and some 13,300 sections for the Mannville play. The Jurassic play has some 3,670 sections available while the Mississippian play has 880 sections to be tested. No estimate of undrilled area for the Milk River-Medicine Hat-Second White Specks play was developed due to the high percentage of play resource already discovered.

Comparisons to Other Estimates

In an attempt to compare marketable gas potential estimates (Table 3), this study adopted from various GSC reports, portions of the Upper Cretaceous gas-in-place estimates presented by Hamblin and Lee (1997), the Mannville gas-in-place estimates developed by Warters et al (1997) and Carboniferous gas-in-place estimates provided by Barclay et al (1997). The portion adopted out of the original estimates was based on the percentage of play area estimated by this study to be in Saskatchewan.

The Canadian Gas Potential Committee Saskatchewan estimates ("CGPC", 1997) were developed by extrapolating CGPC Alberta play estimates. There was no separate stochastic evaluation attempted by the CGPC for any of the Saskatchewan gas plays.

Table 3. Other Estimates of Marketable Gas Potential[3]
$10^9 m^3$ (Tcf)

Play Group	CGPC	GSC (modified)[4]
Belly River	2.1 (0.07)	3.0 (0.11)
MR-MH-2WS	3.7 (0.13)	1.0 (0.03)
Viking	7.6 (0.27)	n/a
Mannville	40.6 (1.44)	35.4 (1.25)
Jurassic	n/a	n/a
Mississippian	n/a	2.9 (0.10)
Total	**57.2 (2.01)**	**42.3 (1.49)**

3 Numbers in this table have been rounded
4 This study prorated critical GSC gas-in-place estimates by area and applying AEUB recovery efficency and surface loss factors from similar gas pools in Alberta

The Belly River play group estimates for this study and the CGPC are in reasonable agreement. The GSC modified estimate is higher, a difference that may be due to a larger area than that which this study estimated to be assigned. The CGPC judged the Saskatchewan estimate to be about fifteen percent of its Alberta estimate.

For the Milk River-Medicine Hat-Second White Specks gas plays, this study modified a GSC estimate (Hamblin and Lee, 1997) that indicated potential gas additions would likely be from infill drilling in very small pools. Therefore, large discoveries that increase the expected potential estimate are not anticipated, since the GSC indicated that 99 percent of the resource base has been discovered. The higher CGPC estimate for these three plays is due to CPGC assigning between 10 and 30 percent of its Alberta assessments to the Saskatchewan estimates.

This study's estimate for the Viking gas play is higher than the CGPC estimate. The CGPC estimate is an extrapolation of the Arps-Roberts methodology used for the same plays located in Alberta while this study used the modified Roadifer approach. The difference may be due to this study estimating a higher percentage of area likely to have gas potential (than that considered by the CPGC study) compared to the total play area. This study suggests that Saskatchewan would have a higher percentage of productive area than that which may be found in Alberta.

All three studies show differences in estimates of marketable gas potential for the Mannville play that reflect uncertainty associated with this play group. This study's estimate appears to be based on a smaller area than the other two reports. In addition, associated and solution gas volumes reflected in other studies are not included in this study.

The Jurassic and Mississippian gas plays are relatively small in terms of volume since oil is the predominant fluid type typically found in the reservoirs. This study's combined estimate for the two plays is close to the GSC modified Mississippian estimate - the GSC estimate for Jurassic plays is not available. However, as in the case of the Mannville play, the GSC estimate contains associated and solution gas volumes while this study did not evaluate the plays for those resources. There were no estimates of undiscovered non-associated gas potential for Saskatchewan's Jurassic or Mississippian play areas in the CGPC report.

Conclusions

This study's mean estimate of undiscovered marketable non-associated gas potential for Saskatchewan is 45.6 10^9m^3 (1.6 Tcf) or 22 percent of the ultimate non-associated gas potential. The range of undiscovered marketable non-associated gas potential is from 21.0 10^9m^3 (0.7 Tcf) with a 90 percent chance of the area contains that amount up to 69.3 10^9m^3 (2.9 Tcf) that has a 10 percent chance of occurrence. Much of the mean gas potential estimate, amounting to 40.1 10^9m^3 (1.4 Tcf), is forecast to be from non-associated Viking and Mannville gas pools.

The CGPC and GSC estimates appear to support the position that Viking and Mannville play groups will provide the bulk of the marketable gas potential.

Individual play comparisons do vary as a result of the different methods used in determining gas play potential. In assessing gas potential, parameters such as area, fraction of hydrocarbon fill and probability of hydrocarbons are critical to any assessment technique. Estimation of these parameters can have a significant impact on the final assessment.

There remain large tracts of sparsely drilled areas in Saskatchewan, between this study's play boundaries and the subcrop or outcrop of the formations, that may contain conceptual or very immature plays.

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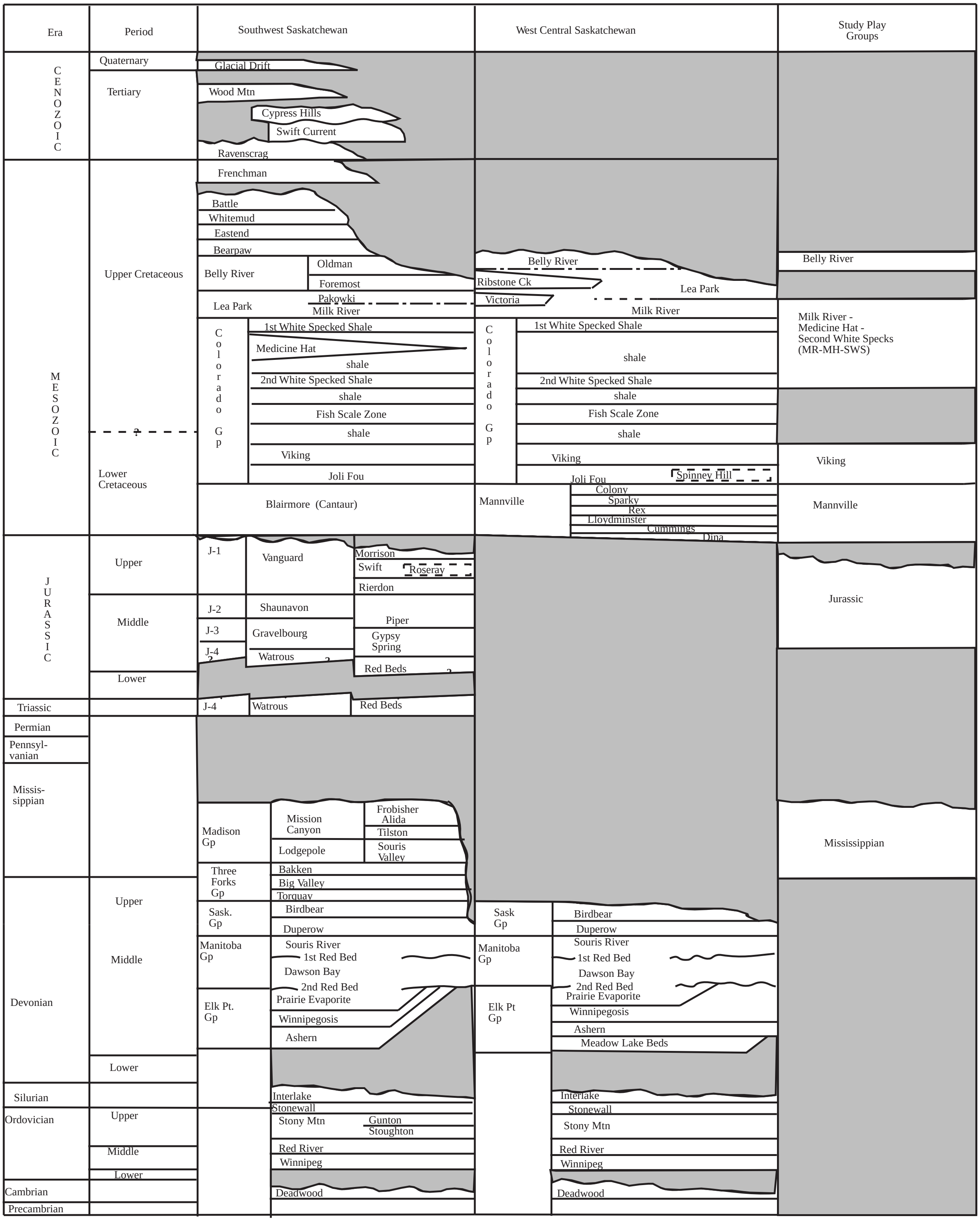

Figure 2. Stratigraphic Correlation Chart of Western Saskatchewan (modified from SEM, 1997)

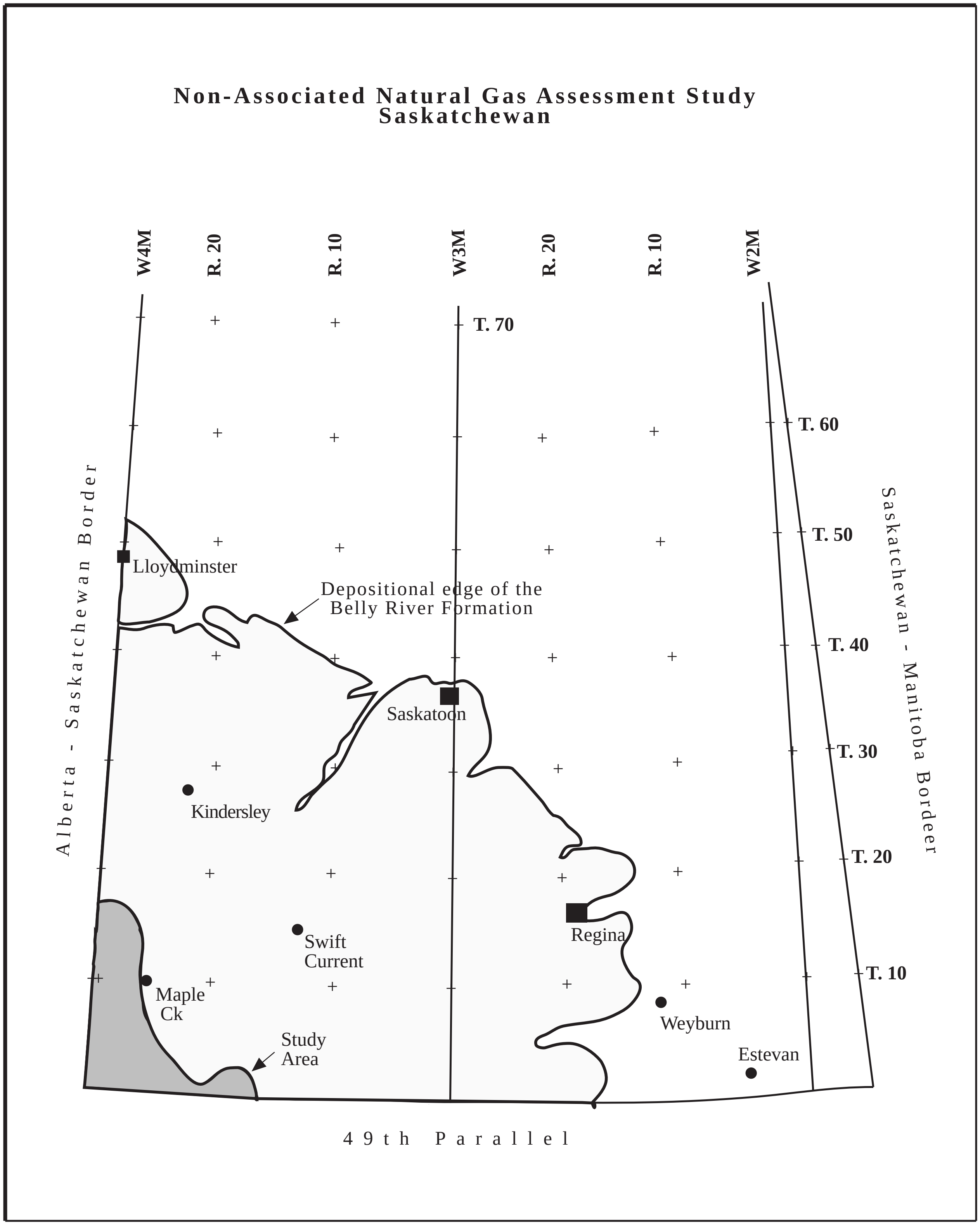

Figure 3
Distribution of the Belly River Formation

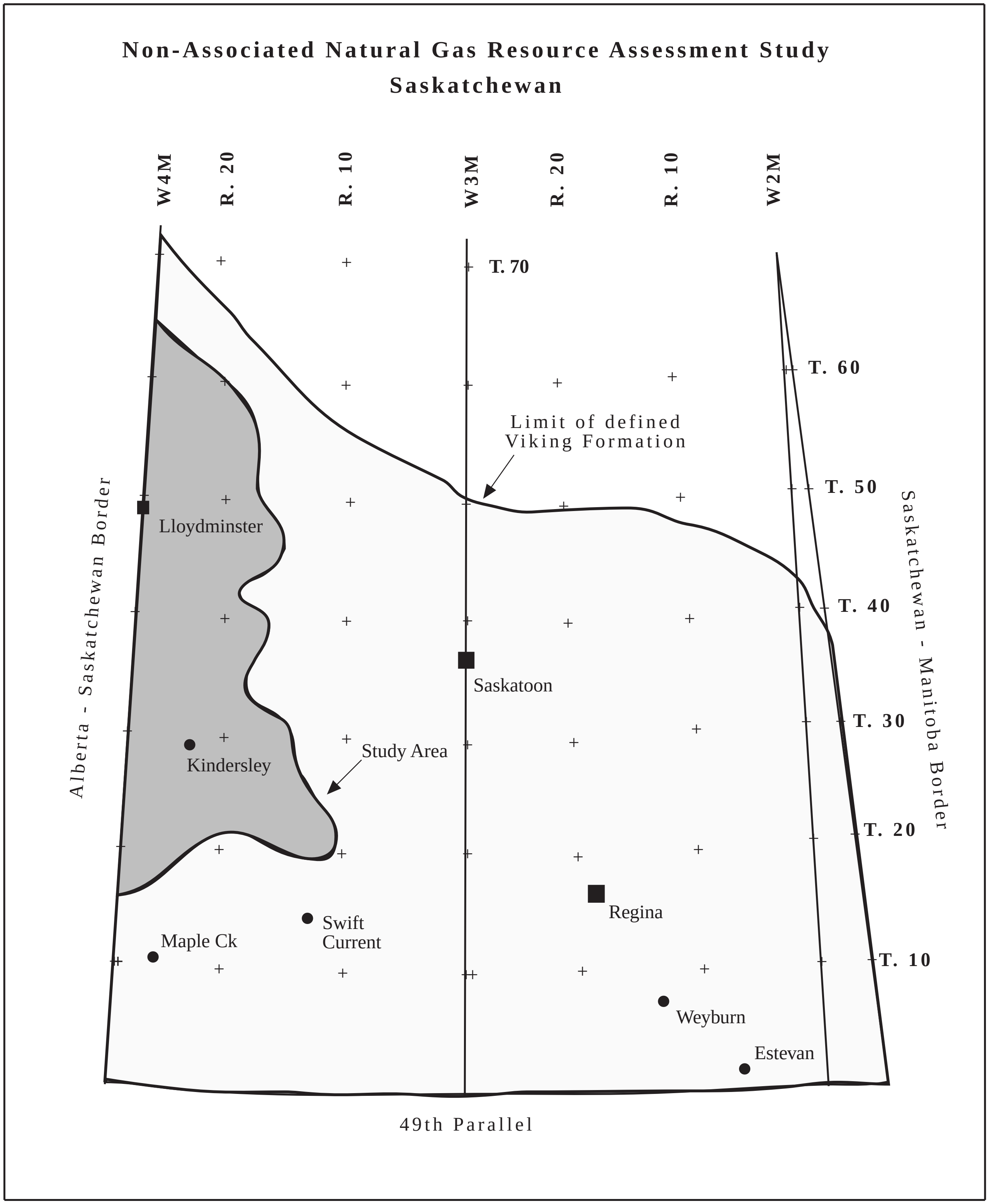

Figure 4
Distribution of the Viking Formation

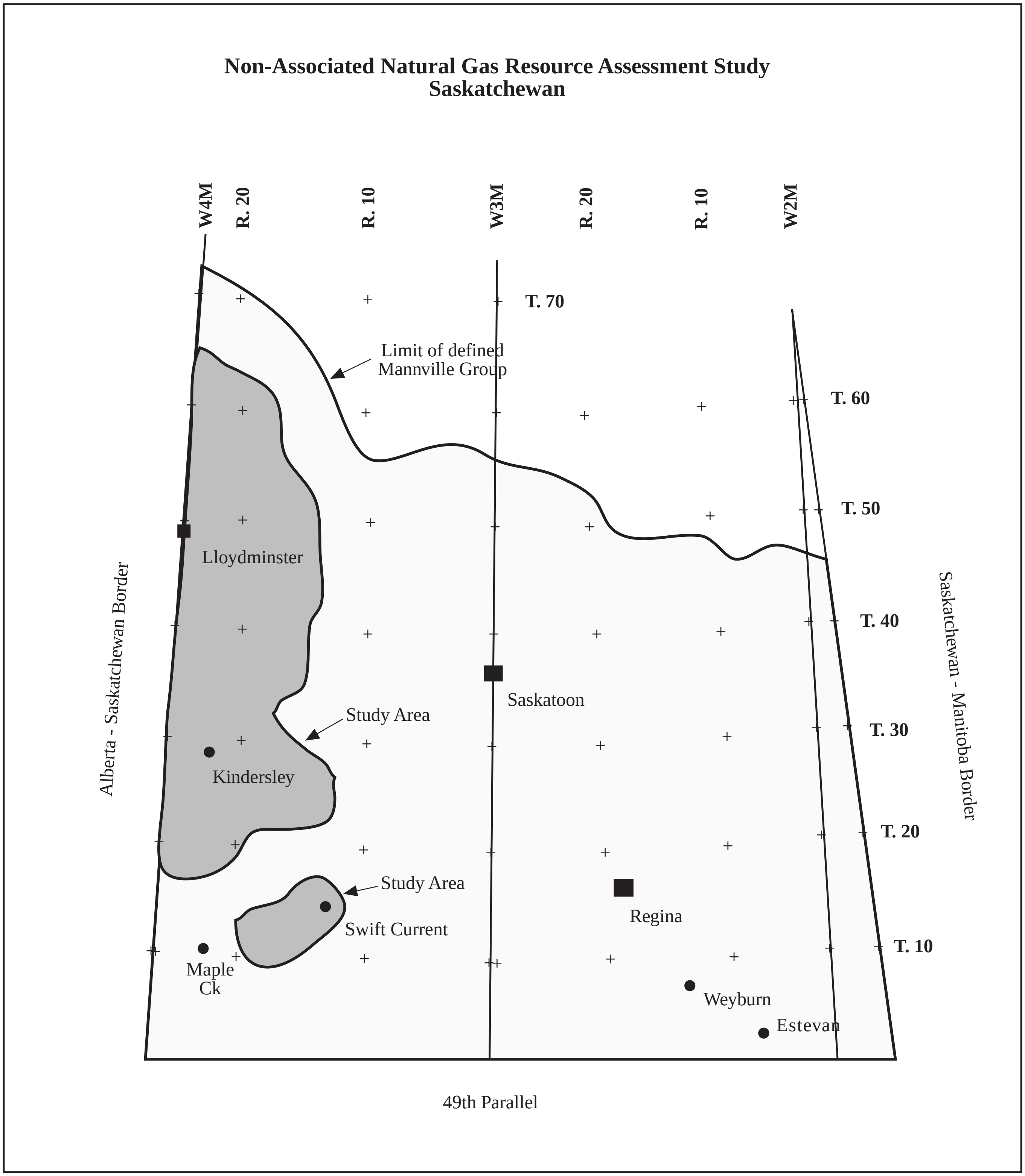

Figure 5
Distribution of the MannvilleGroup

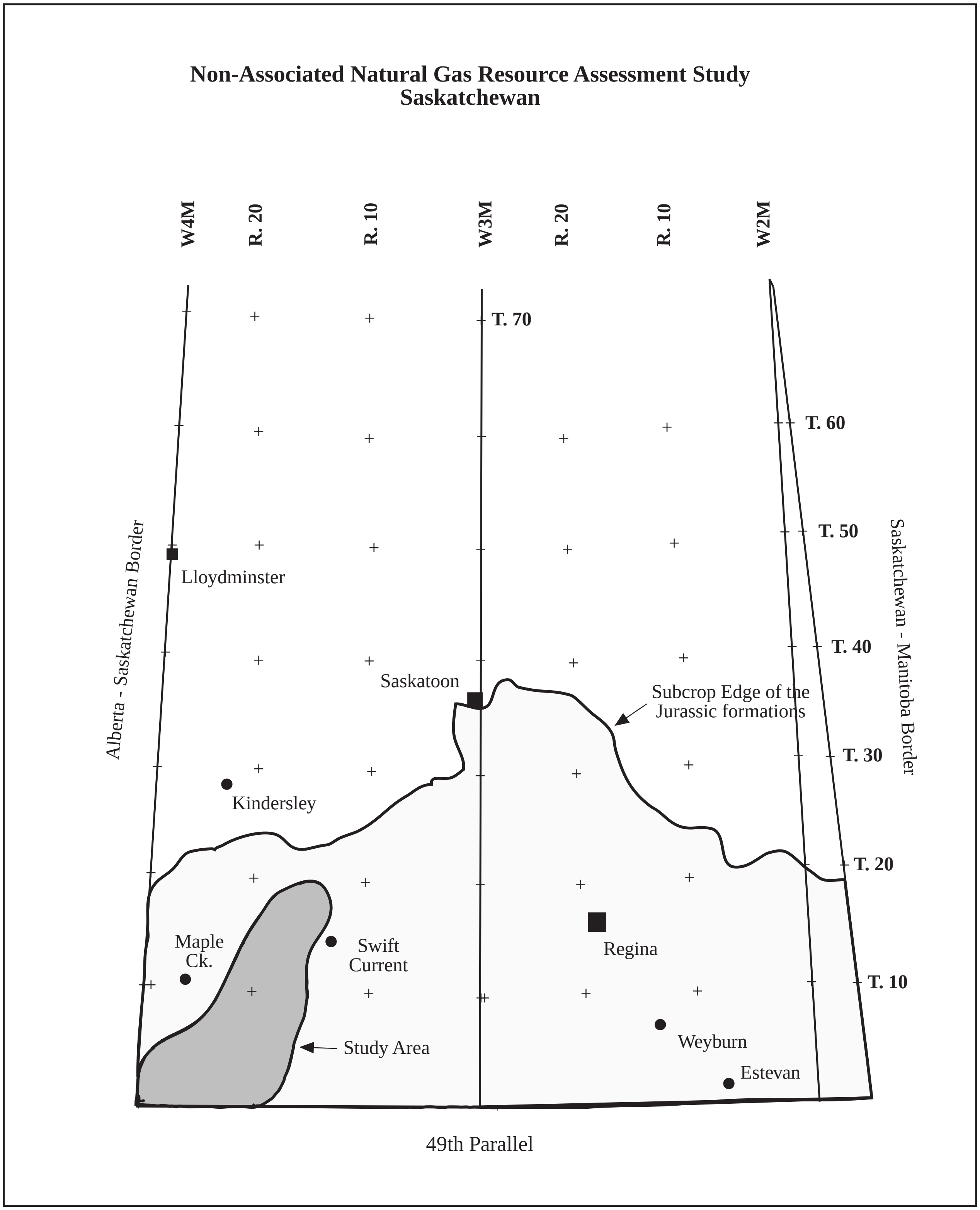

Figure 6
Distribution of Jurassic Formations

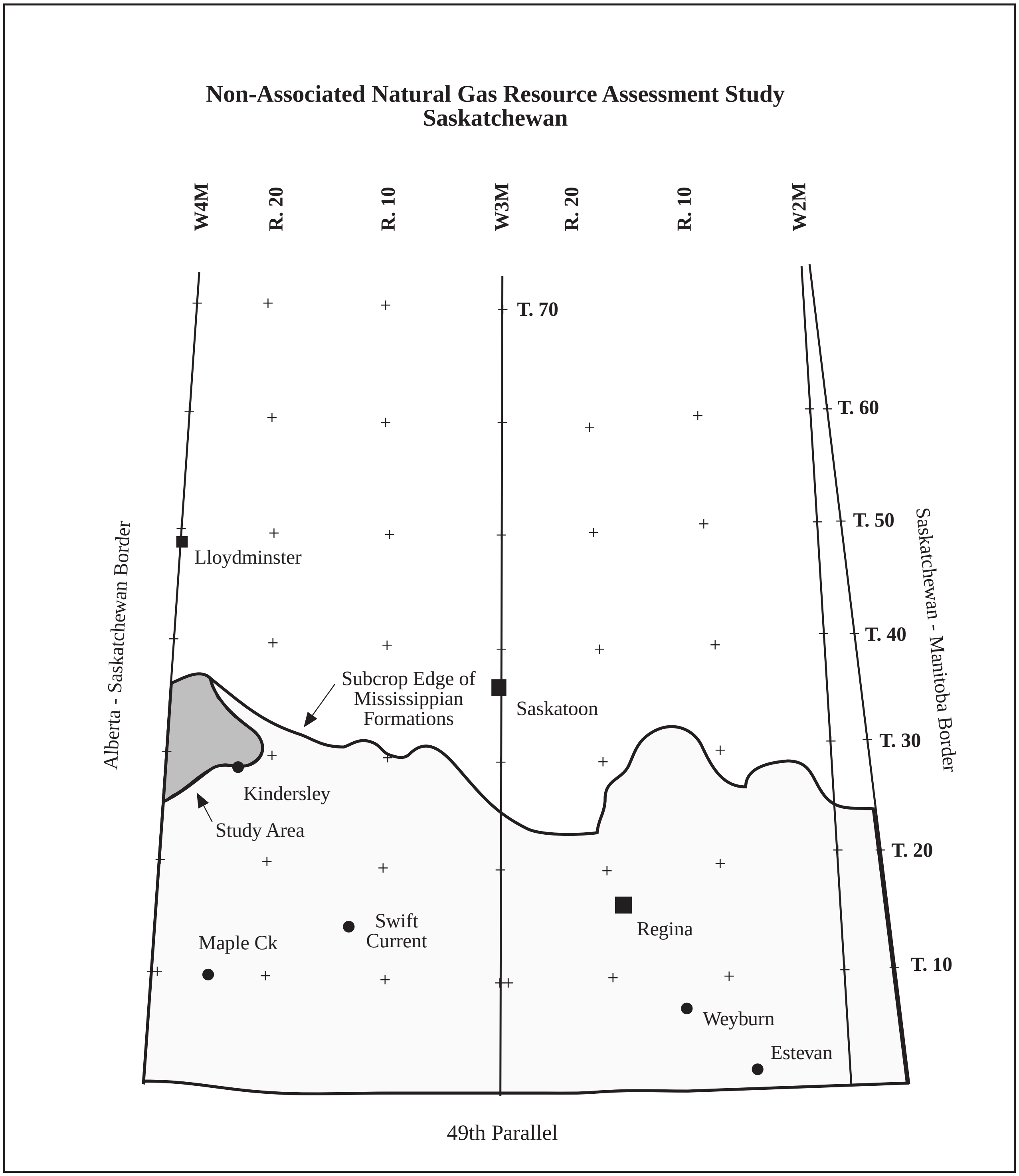

Figure 7
Distribution of Mississippian Formations