National Energy Board

Office national de l'énergie

Natural Gas Resource Assessment Northeast British Columbia

A Working Document by the National Energy Board

Calgary
January 1994
(revised November 1999)

Canada

Natural Gas

Resource Assessment -

Northeast British Columbia

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Foreword

The following working paper is being distributed by the Board to make the Board's analytical processes and procedures known to the public, and to solicit comments from industry and other government agencies on the specifics on how the Board evaluates undiscovered resources.

The Board has identified a need for a methodology to determine and evaluate potential gas resources and trend gas for specific project needs. A review of current practices and approaches by industry or other government departments involved in resource assessment has concluded that existing resource assessments are regional in nature and as such are difficult to apply to project specific evaluations. Consequently, the Board embarked on an internal study to develop and implement an approach for Board regulatory requirements that will evaluate resource potential for area-specific or project-specific 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. Additionally, the Board recognizes the resource assessment activity being carried out by provincial agencies. Particularly, the Board has employed the data and results that were made available by the Alberta Energy Resources Conservation Board in the recent study, Ultimate Potential and Supply of Natural Gas in Alberta (ERCB 92-A).

However, given that the Board is required to analyze specific supplies associated with defined areal limits, the regional-based or play-based methodologies do not yield adequate detail. Additionally, the Board's regulatory responsibilities in the northern frontier basins includes the evaluation of discoveries that are often poorly delineated and offer only a limited amount of reservoir and geological data. The Board's methodology is equally applicable to pool or field growth as it is to area-specific potential or basin-specific potential. The results of the analyses are presented in cumulative distribution curves that offer a clearer picture of the uncertainty or risk associated with any resource estimate.

The intent then for this working paper is to describe the Board's proposed methodology which will be used to supplement existing resource assessment reports and methodologies. The specific project area, northeastern British Columbia, was chosen as an example application for the methodology. The conclusions and estimates derived from this study however will be used in support of the Board's ongoing assessment of Western Canada gas supply and was completed to complement an existing study available for Alberta.

The Secretary of the Board welcomes comments on the design or use of the methodology, or on the results from the associated study, Natural Gas Resource Assessment - British Columbia.

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Chapter 1: Natural Gas Resource Assessment of Northeast British Columbia

1.1 Introduction

An assessment of the undiscovered natural gas resources was done for Northeast British Columbia using the @RISK add-in for Excel. The methodology used in this assessment has been adapted from Roadifer, 1979. The area of assessment, shown in figure 3, comprises a total area of 124 122 square kilometres (48,485 square miles). Generalized structural sub-divisions used in the play definitions are also shown on figure 3. A total of 38 plays with undiscovered gas potential were defined within this region. The assessment does not include the inner foothills where Triassic and older rocks are exposed. This inner foothills belt may have some potential, however, we did not have enough information to make an assessment at this time.

1.2 Analysis

The study focused on natural gas potential and, as a result, the play areas were defined with gas in mind. However, the resource estimation template does give an estimate of all related products, including oil, gas liquids and sulphur.

The report is based on a synthesis of the December 31, 1992 pool data as published by the British Columbia Ministry of Energy, Mines and Petroleum Resources (BCEMPR). The information from the BCEMPR hydrocarbon reserves file was subdivided by formation and a descriptive statistical analysis done on the data using a Excel statistical analysis toolpack add-in. This statistical analysis was used as the input for the reservoir parameters for each formation. Well retrievals from the Geowell database by formation were done to establish success rates for each play. These values were entered in a series of Excel templates constructed using @RISK add-in functions. The templates then determine a range of undiscovered resource potential estimates. The Excel template was designed using the triangular distribution function which requires a maximum, most likely and minimum value for all the input parameters. Output is a cumulative distribution function that is calculated for oil-in-place, recoverable oil, gas-in-place, recoverable raw gas, marketable gas and sulphur.

The output from the templates, using the mean and standard deviation, were summed to give an overall cumulative distribution of marketable gas and recoverable oil estimates for Northeast British Columbia. Total undiscovered marketable gas is expected to be 33.2 trillion cubic feet (Tcf) at a probability of 43 percent. It should be noted that the summation of the curves from the 38 plays tends to give a steep curve which implies a greater certainty than is warranted by data for each individual play. Consequently, the standard deviation was adjusted to give a more realistic distribution.

Eight of the 38 plays, with oil potential, were also summed and a cumulative distribution generated using an adjusted standard deviation. The total undiscovered recoverable oil is estimated to be 200 million barrels at a probability of 42 percent. The curves suggest a 95 percent probability of an undiscovered marketable gas resource of 17 Tcf, at least, and no less than an undiscovered recoverable oil potential of 90 million barrels. These values should be used with caution.

Table 1

Northeast British Columbia - Ultimate Gas Resources

Plays Ranked By Undiscovered Marketable Gas Resource Size

Formation	Play Name	Ranking	Geologic Age	Structural Area
Pardonet/Baldonnel	Grizzly Foothills	1	Triassic	Grizzly Foothills
Miss./Devonian	Beaver River	2	Devonian	Liard Basin
Pine Point	Clarke	3	Devonian	Plains
Halfway/Doig	Plains	4	Triassic	Plains
Pardonet/Baldonnel	NW Foothills	5	Triassic	NW Foothills
Gething/Cadotte	Deep Basin	6	Cretaceous	Deep Basin
Pardonet/Baldonnel	Plains	7	Triassic	Plains
Debolt/Shunda	NW Foothills	8	Mississippian	NW Foothills
Dunlevy	Grizzly Foothills	9	Cretaceous	Grizzly Foothills
Halfway/Doig	Grizzly Foothills	10	Triassic	Grizzly Foothills
Slave Point	Clarke Platform	11	Devonian	Plains
Bluesky/Gething	Plains	12	Cretaceous	Plains
Jean Marie	Platform	13	Devonian	Plains
Halfway/Doig	NW Foothills	14	Triassic	NW Foothills
Belloy	Plains - PRA	15	Permian	Plains
Pine Point	Helmet	16	Devonian	Plains
Belloy	Grizzly Foothills	17	Permian	Grizzly Foothills
Slave Point	Clarke Barrier	18	Devonian	Plains
Dunlevy	Plains	19	Cretaceous	Plains
Wabamun	South Plains	20	Devonian	Plains
Charlie Lake	Plains	21	Triassic	Plains
Debolt/Shunda	North Plains	22	Mississippian	Plains
Kiskatinaw	Plains	23	Mississippian	Plains
Cretaceous	Liard Basin	24	Cretaceous	Liard Basin
Charlie Lake	NW Foothills	25	Triassic	NW Foothills
Debolt/Shunda	South Plains	26	Mississippian	Plains
Permo-Carb.(Mattson)	Liard Basin	27	Mississippian	Liard Basin
Belloy	North Plains	28	Permian	Plains
Jean Marie	Helmet	29	Devonian	Plains
Belloy/Montney	Ring	30	Permian	Plains
Slave Point	Kotcho Barrier	31	Devonian	Plains
Belloy	NW Foothills	32	Permian	NW Foothills
Sulphur Point	Clarke	33	Devonian	Plains
Charlie Lake	Grizzly Foothills	34	Triassic	Grizzly Foothills
Slave Point	Helmet Barrier	35	Devonian	Plains
Banff	Plains	36	Mississippian	Plains
Upper Devonian	North Plains	37	Devonian	Plains
Slave Point	Helmet Platform	38	Devonian	Plains

1.3 Conclusions

Based on the mean values for undiscovered potential, the ultimate values are estimated to be 50.6 Tcf for marketable gas and 592 million barrels for recoverable oil. In addition, the undiscovered hydrocarbon by-products potential are estimated to be 171 million barrels of gas liquids and 78 million long tons of sulphur. Figures 1 and 2 show cumulative distribution curves of the ultimate marketable gas and recoverable oil for Northeast British Columbia.

Table 1 is a listing of the assessed plays ranked by undiscovered marketable gas showing geologic age and structural area. Table 2 is the tabulation of natural gas resources by geologic age and structural area. The distribution of these plays are shown as pie charts in figures 4 and 5 and cumulative distribution curves in figures 8 to 17.

By structural area (Table 2), the Plains area has the largest single area estimate of undiscovered marketable gas reserves (14.8 Tcf) or 54 percent of the play's ultimate resource potential. This is 45 percent of Northeast British Columbia's undiscovered remaining marketable gas potential (33.2 Tcf). The Grizzly Foothills, Northwest Foothills and Liard Basin are expected to contribute 50 percent of Northeast British Columbia's remaining marketable gas potential.

By geologic age (Table 2), the Triassic and Devonian formations have 70 percent of Northeast British Columbia's discovered natural gas reserves estimate. The Triassic group is expected to contain 43 percent of Northeast British Columbia's remaining marketable gas potential while the Devonian formations may have 28 percent of the potential.

Table 2

Northeast British Columbia - Ultimate Natural Gas Resources

By Geological Age

	Discovered (Bcf)			Undiscovered (Bcf)			Ultimate (Bcf)		
	GIP	Rec. Gas	Mkt Gas	GIP	Rec. Gas	Mkt Gas	GIP	Rec. Gas	Mkt Gas
Cretaceous	4022.6	3324	3056.6	8297.8	6623.4	5009	12320	9947.4	8065.6
Triassic	9758.5	7749.8	6398.2	22476.8	18298	14160	32235	26047.4	20558.1
Permian	1501.4	1244.7	1194.8	2587.3	2257.3	1996	4088.7	3502	3190.8
Mississippian	1294	946.5	889.3	4274.3	3182.3	2840.5	5568.3	4128.8	3729.9
Devonian	9865.1	7109.3	5603.4	16245.6	11226	9217.8	26111	18335.5	14821.2
TOTAL	**26441.6**	**20374**	**17142.3**	**53881.7**	**41587**	**33223**	**80323**	**61961.1**	**50365.6**

By Structural Area

	Discovered (Bcf)			Undiscovered (Bcf)			Ultimate (Bcf)		
	GIP	Rec. Gas	Mkt Gas	GIP	Rec. Gas	Mkt Gas	GIP	Rec. Gas	Mkt Gas
Liard Basin	303.3	208.3	174.7	5119.8	3390.1	2903.9	5423.1	3598.4	3078.6
Plains/PRA	19504.9	15011	12799.6	23027.7	17596	14837	42533	32606.6	27636.9
Deep Basin	867.1	680.4	615.9	3159.6	2464.4	1848.3	4029.8	3144.8	2464.2
NW Foothills	3023.1	2320.3	2056.7	6732.5	5288.2	4615.9	9755.6	7608.5	6672.6
Grizzly Foothills	2743.2	2154.8	1495.5	15842.1	12848	9017.8	18585	15003	10513.3
TOTAL	**26441.6**	**20375**	**17142.3**	**53881.7**	**41587**	**33223**	**80232**	**61961.1**	**50365.6**

1.4 References

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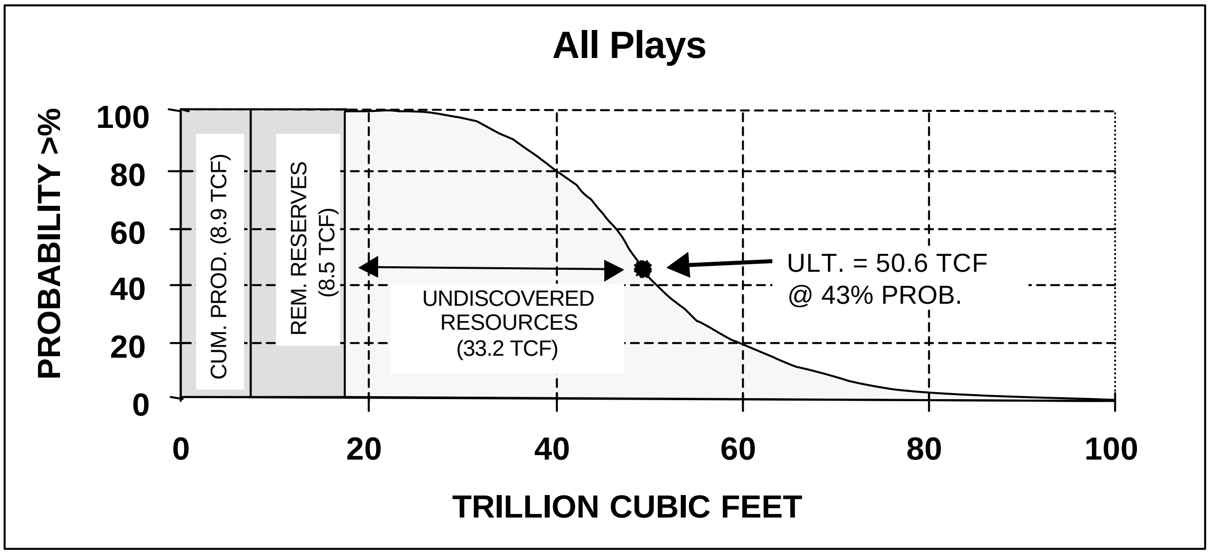


Figure 1. Distribution of ultimate marketable gas resources.
Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

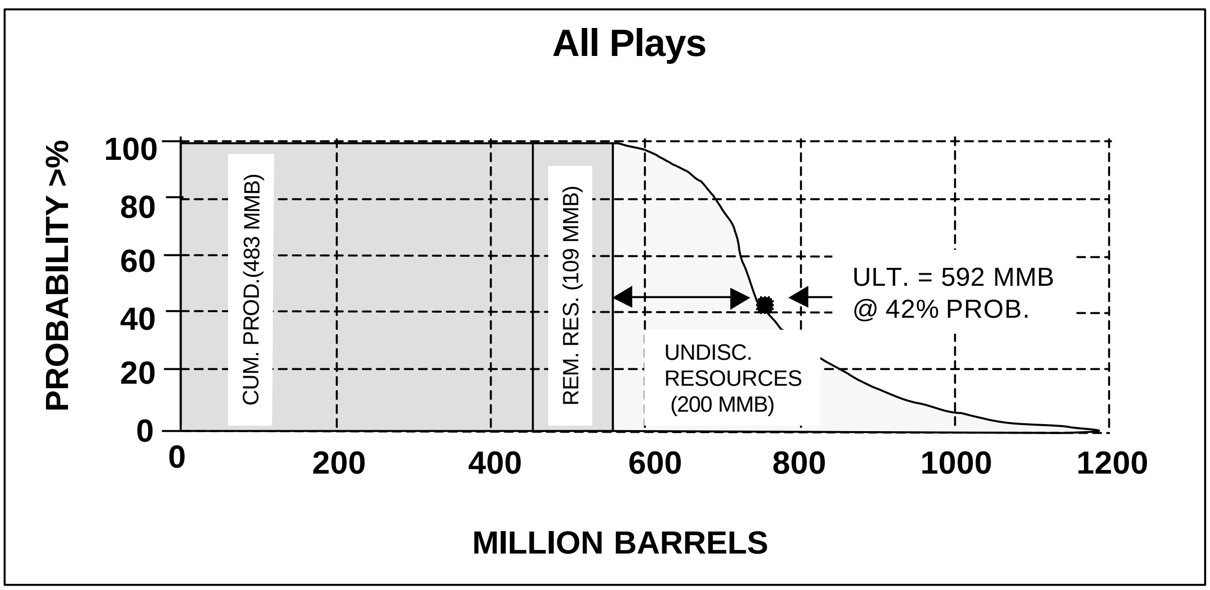
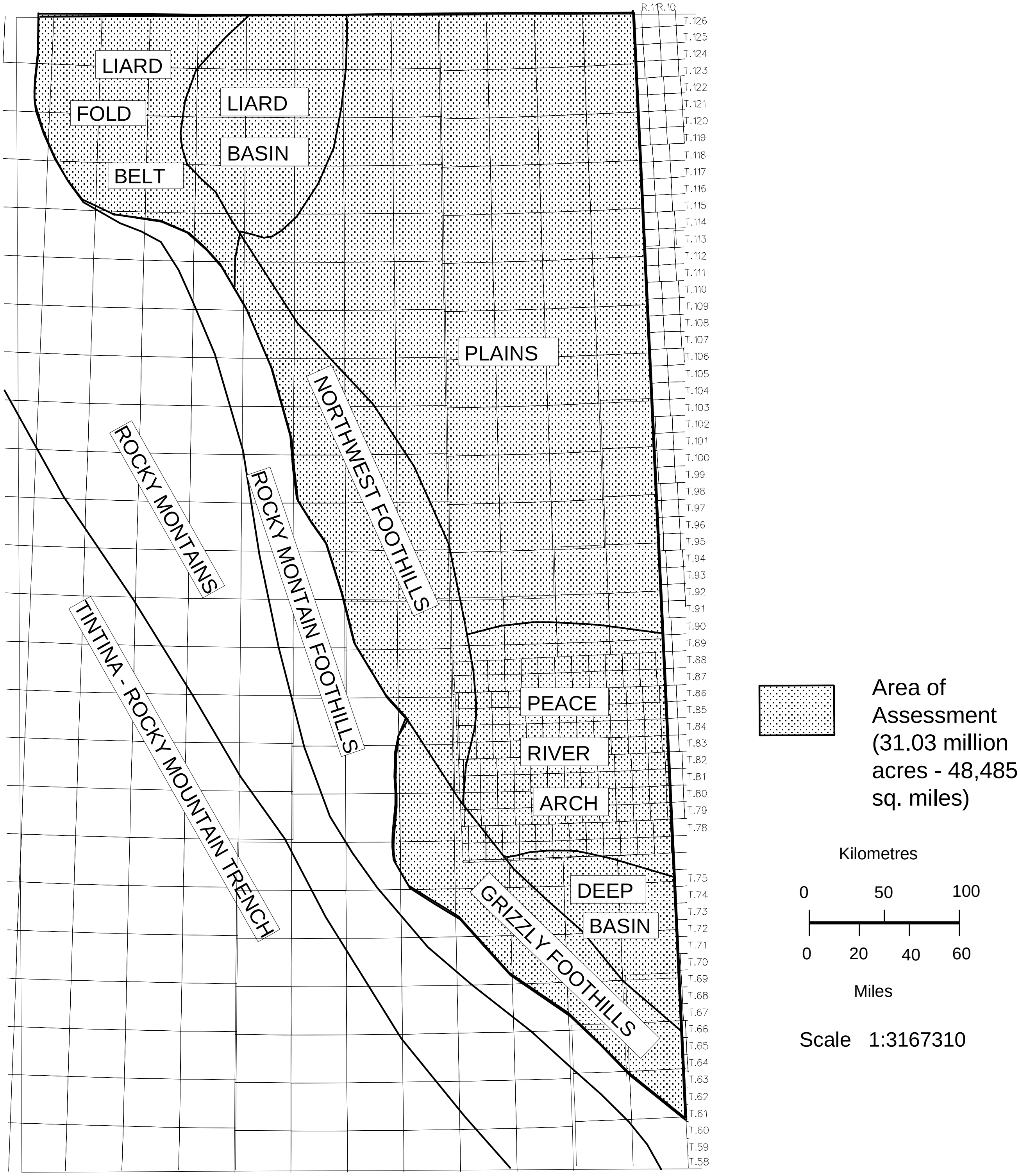


Figure 2. Distribution of ultimate recoverable oil resources.
Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).



*map courtesy of Riley's Datashare - Geowell program

Figure 3. Generalized structural areas showing areas of assessment

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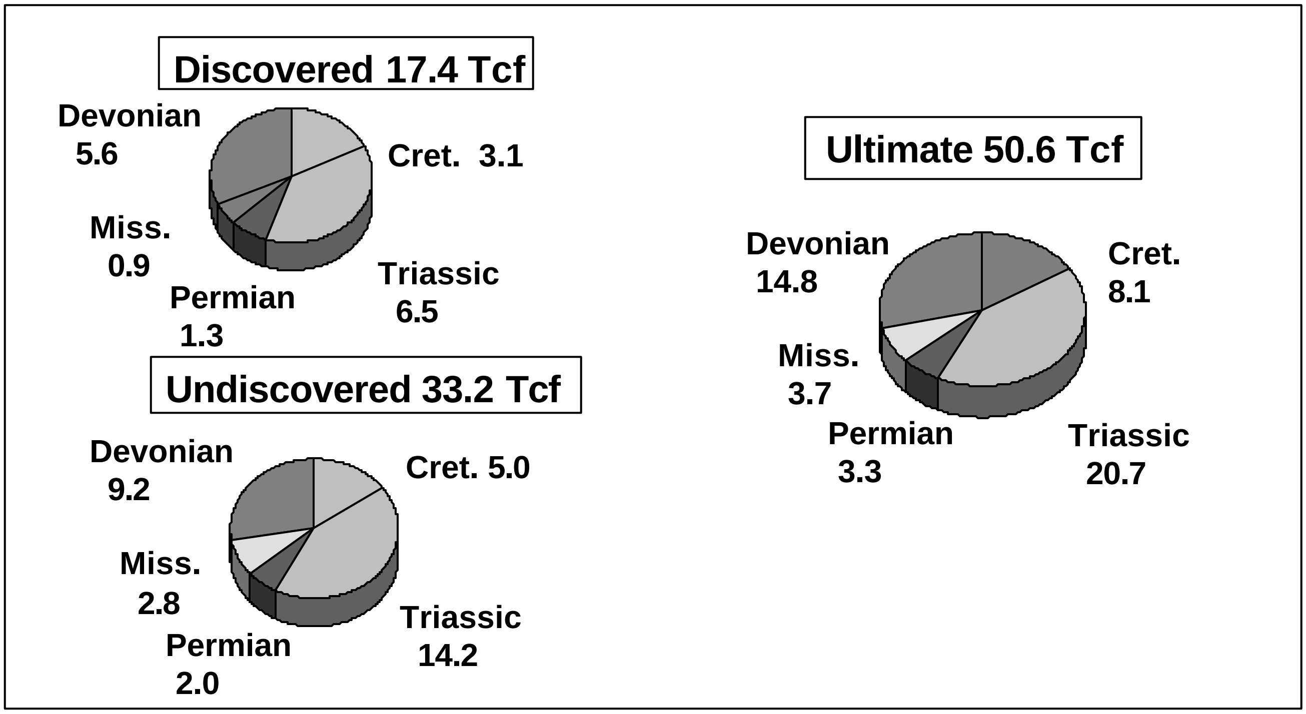

Figure 4. Distribution of gas resource volumes by geologic age

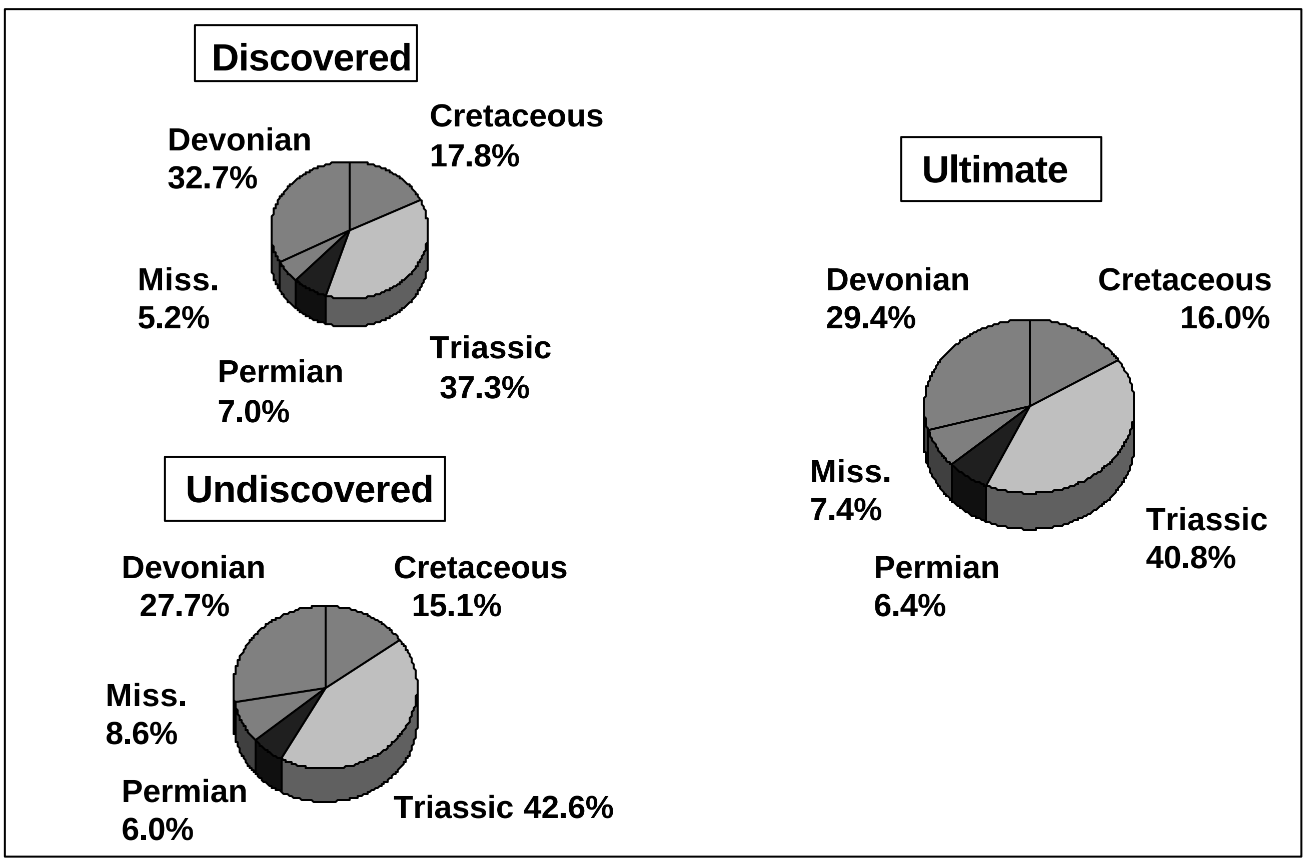

Figure 5. Percent share by geological age of gas resources

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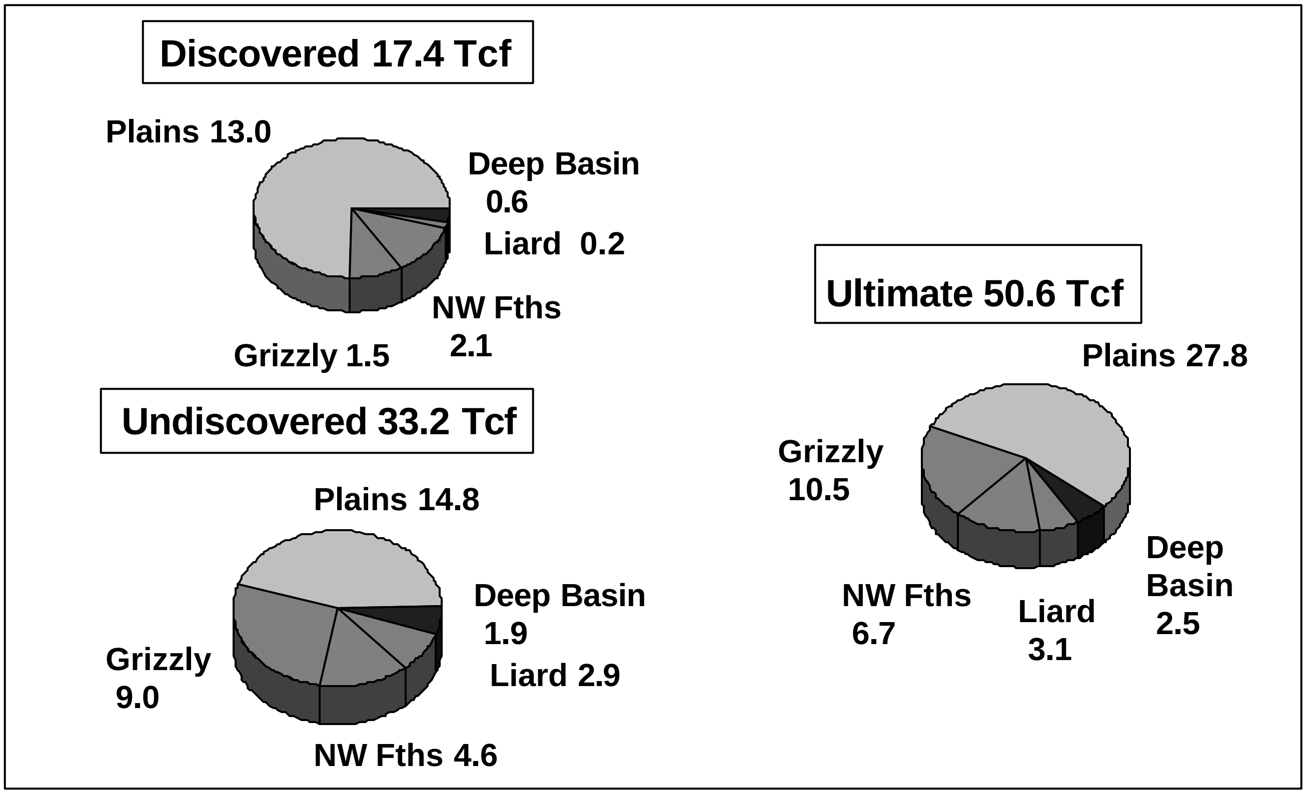

Figure 6. Distribution of gas resources by area

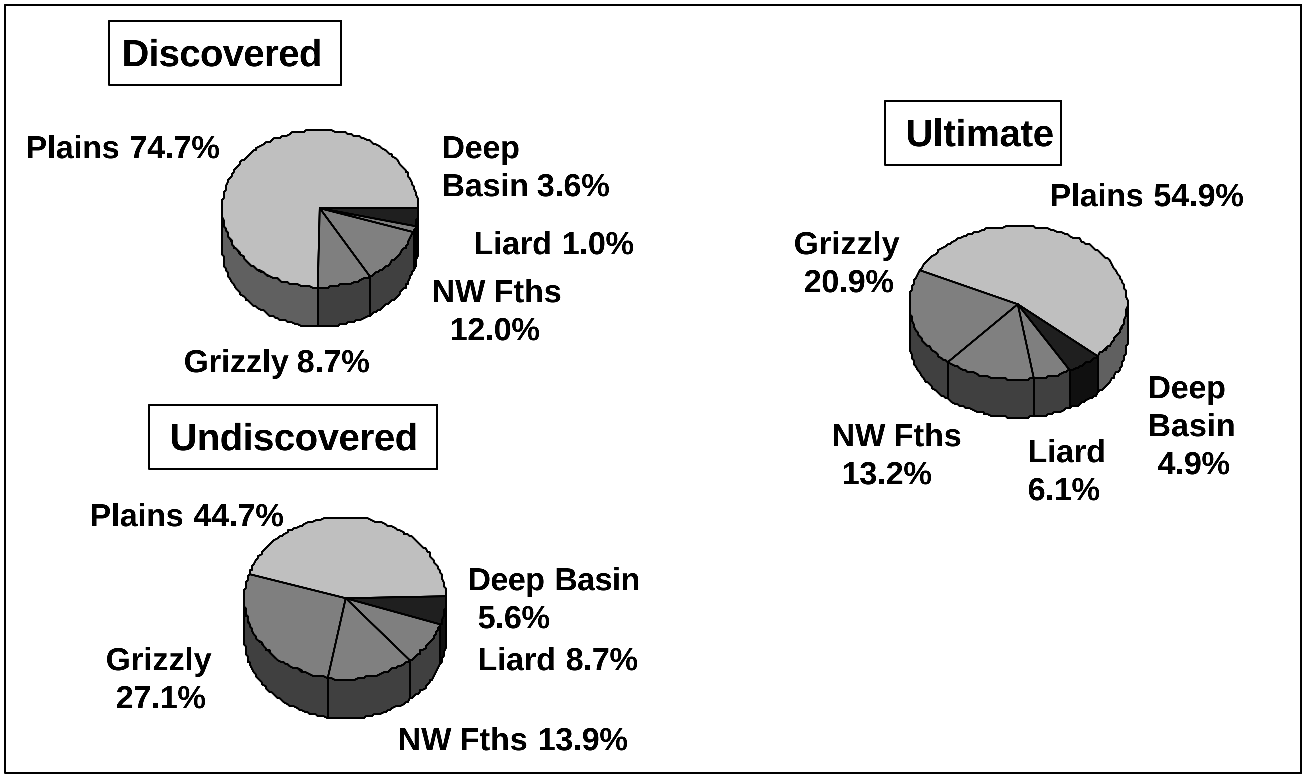

Figure 7. Percent share of gas resources by area

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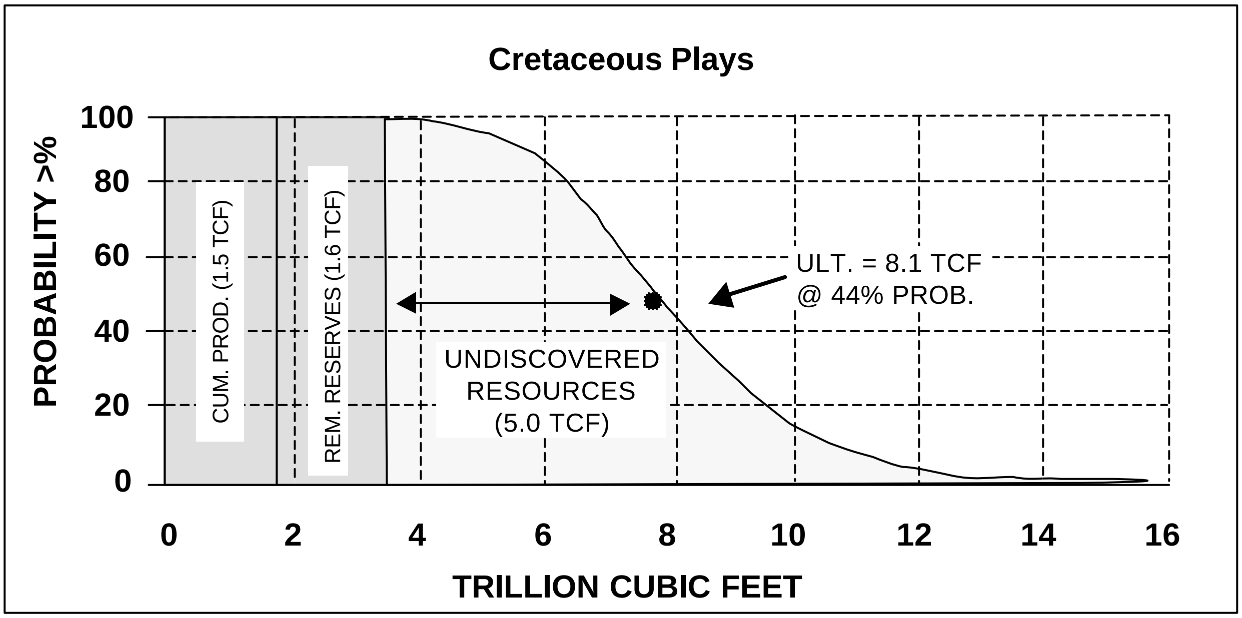

Figure 8. Distribution of ultimate marketable gas resources for the Cretaceous. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

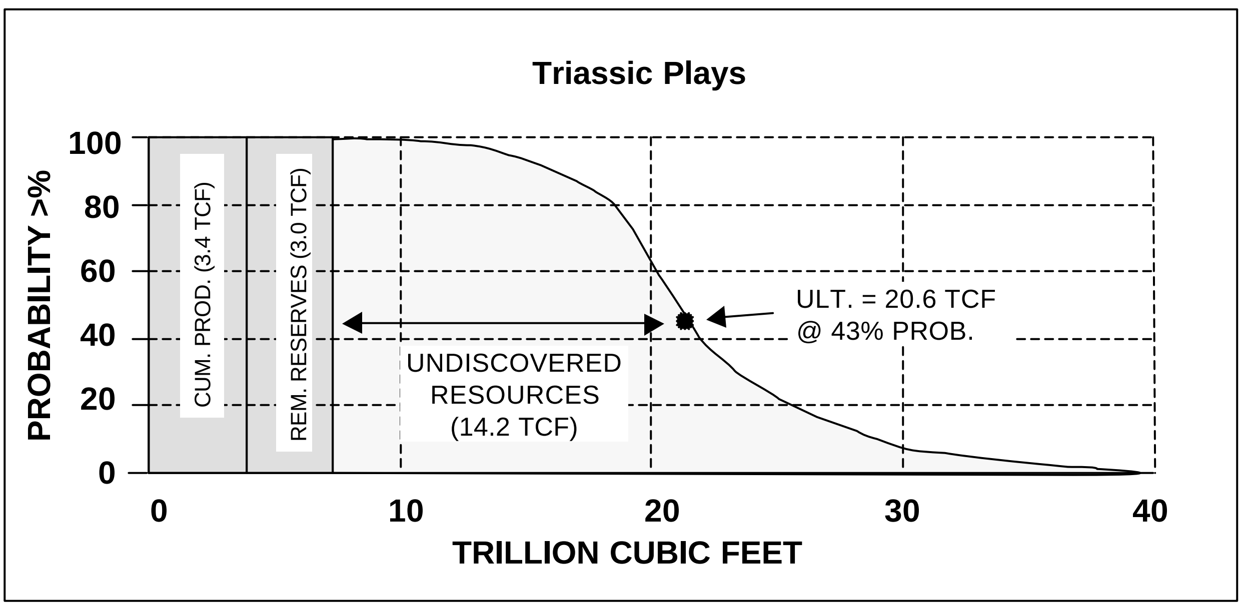

Figure 9. Distribution of ultimate marketable gas resources for the Triassic. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

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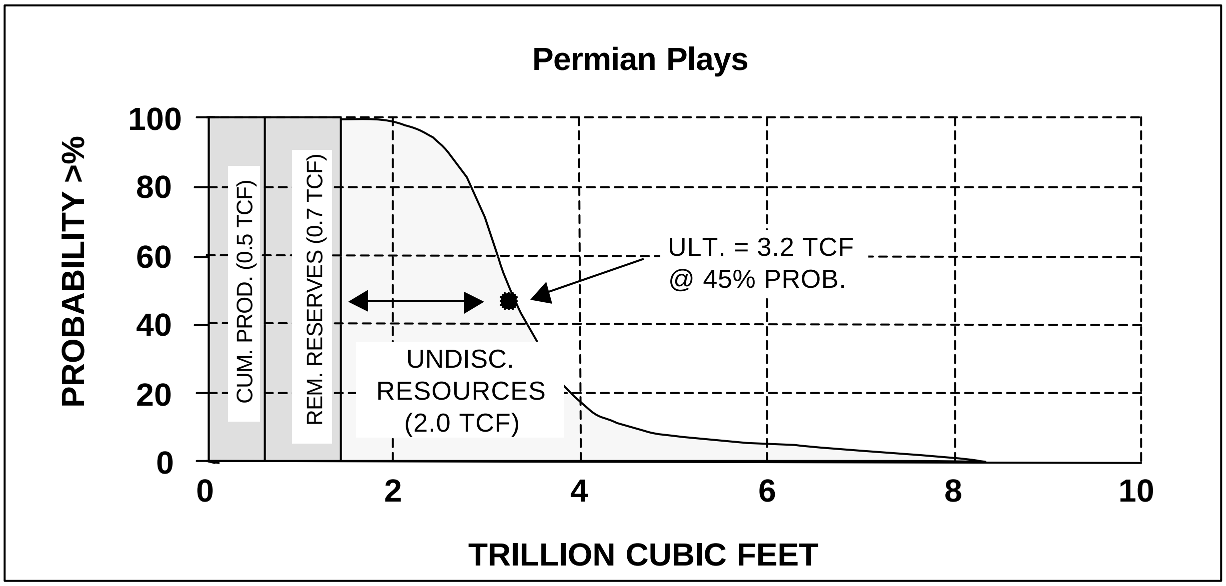

Figure 10. Distribution of ultimate marketable gas resources for the Permian. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

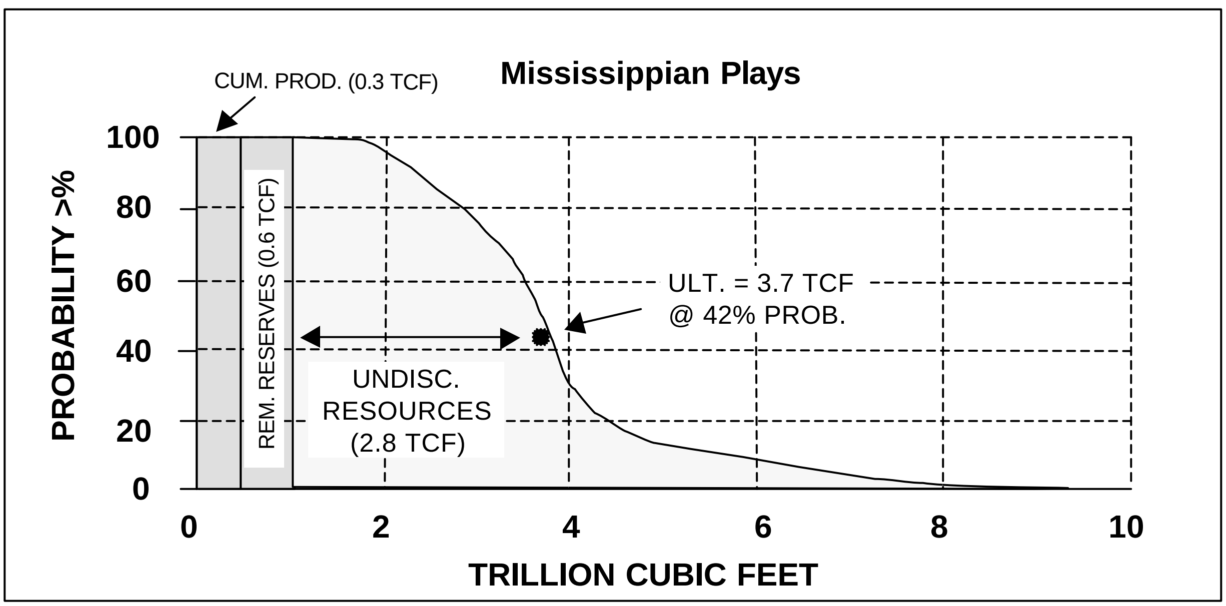

Figure 11. Distribution of ultimate marketable gas resources for the Mississippian. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

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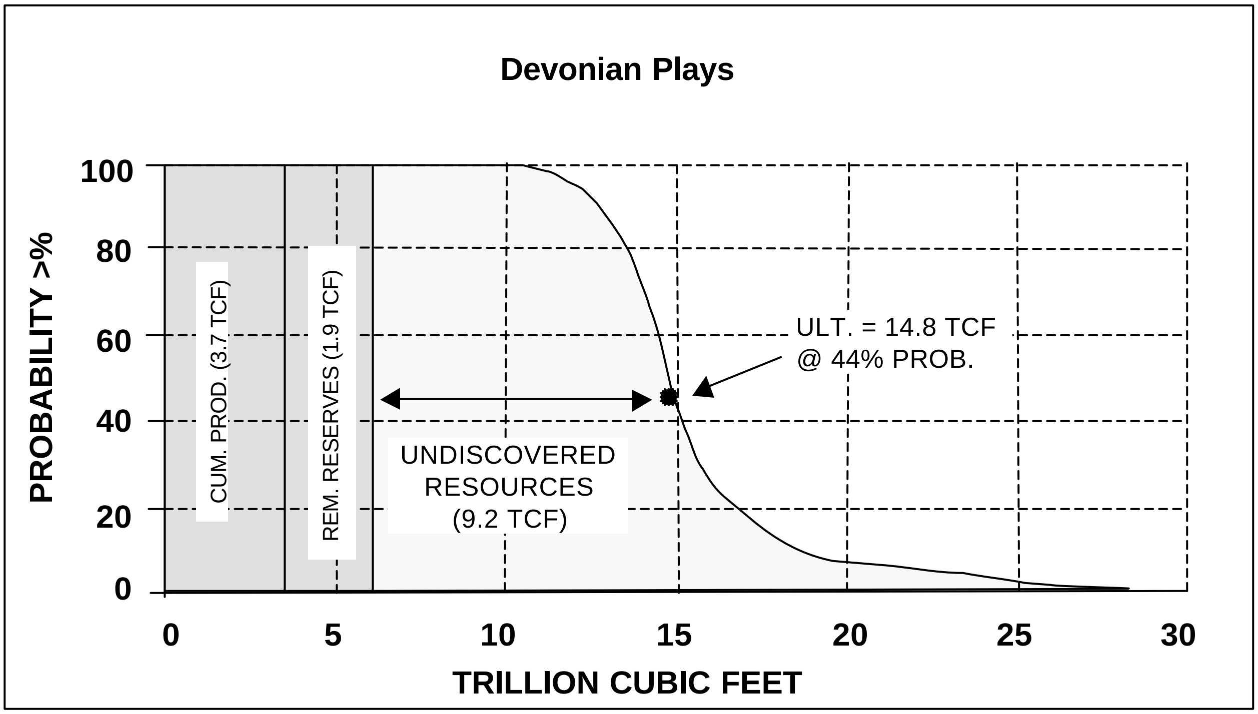

Figure 12. Distribution of ultimate marketable gas resources for the Devonian. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

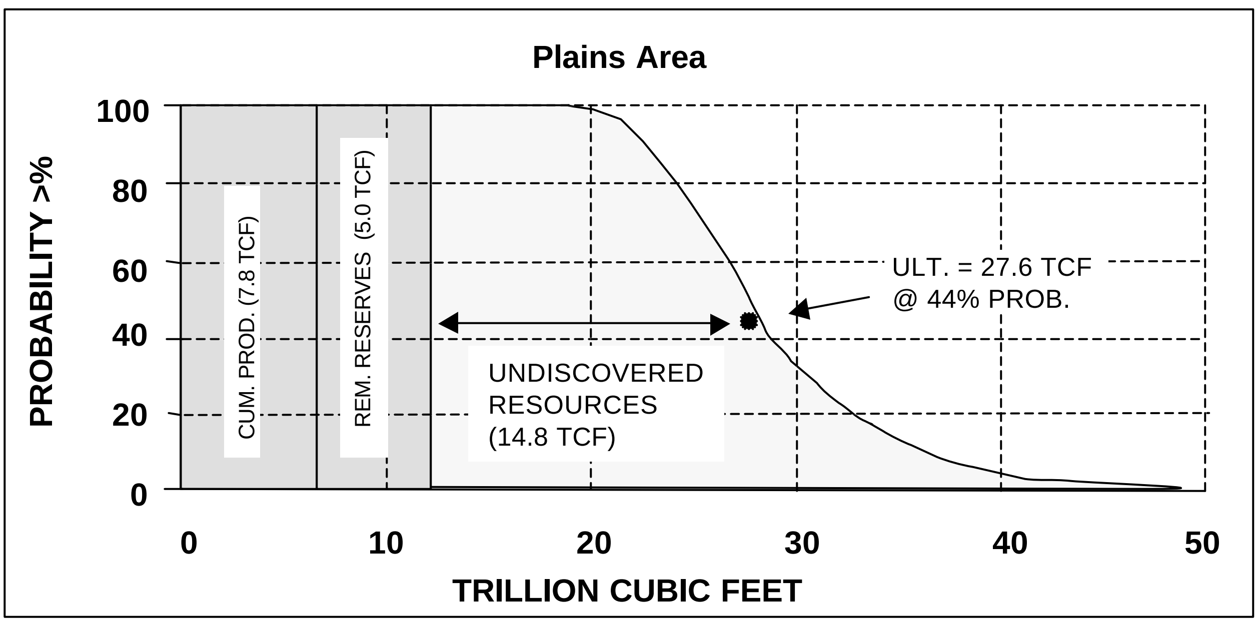

Figure 13. Distribution of ultimate marketable gas resources for the Plains area. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

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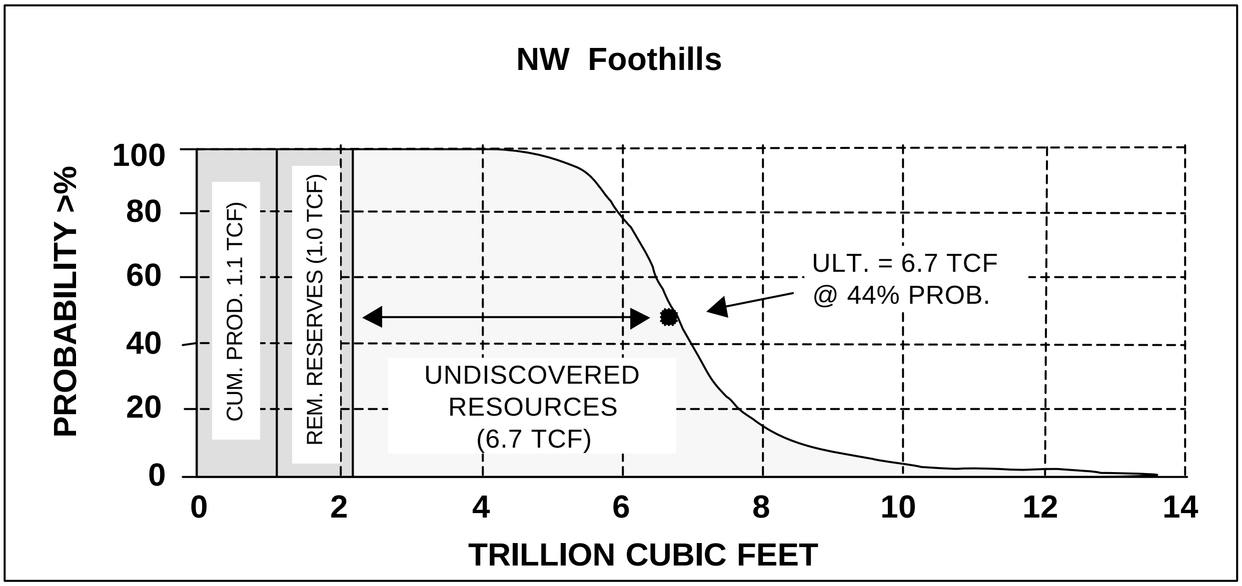

Figure 14. Distribution of ultimate marketable gas resources for the Northwest Foothills. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

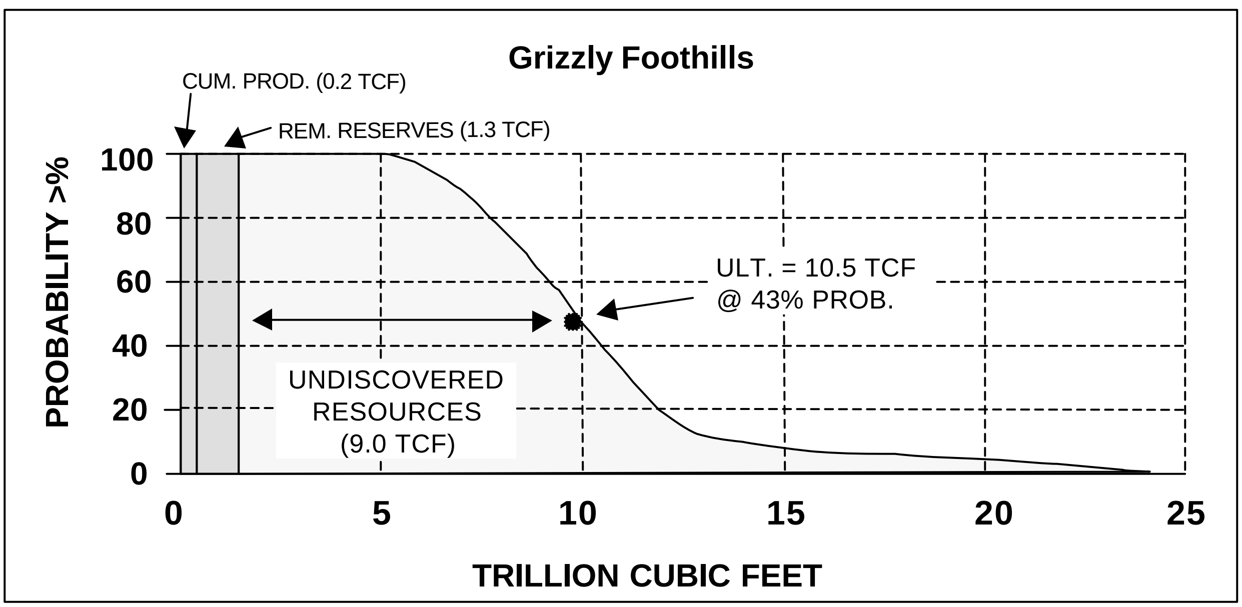

Figure 15. Distribution of ultimate marketable gas resources for the Grizzly Foothills. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

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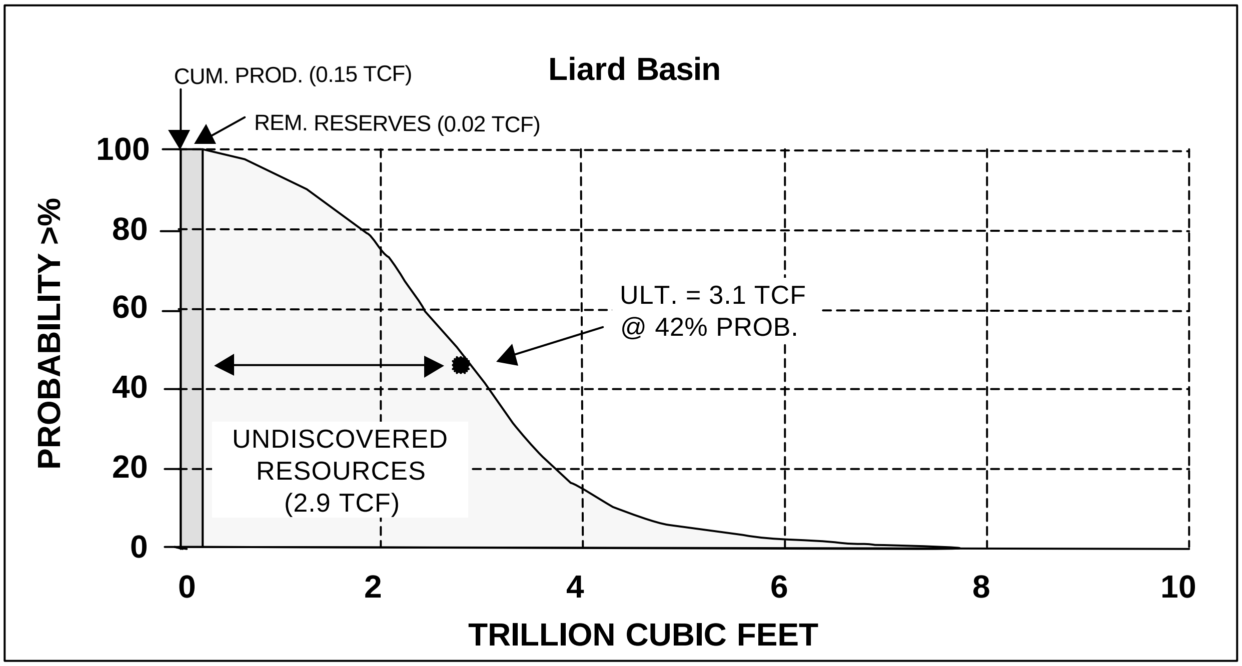

Figure 16. Distribution of ultimate marketable gas resources for the Liard Basin. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

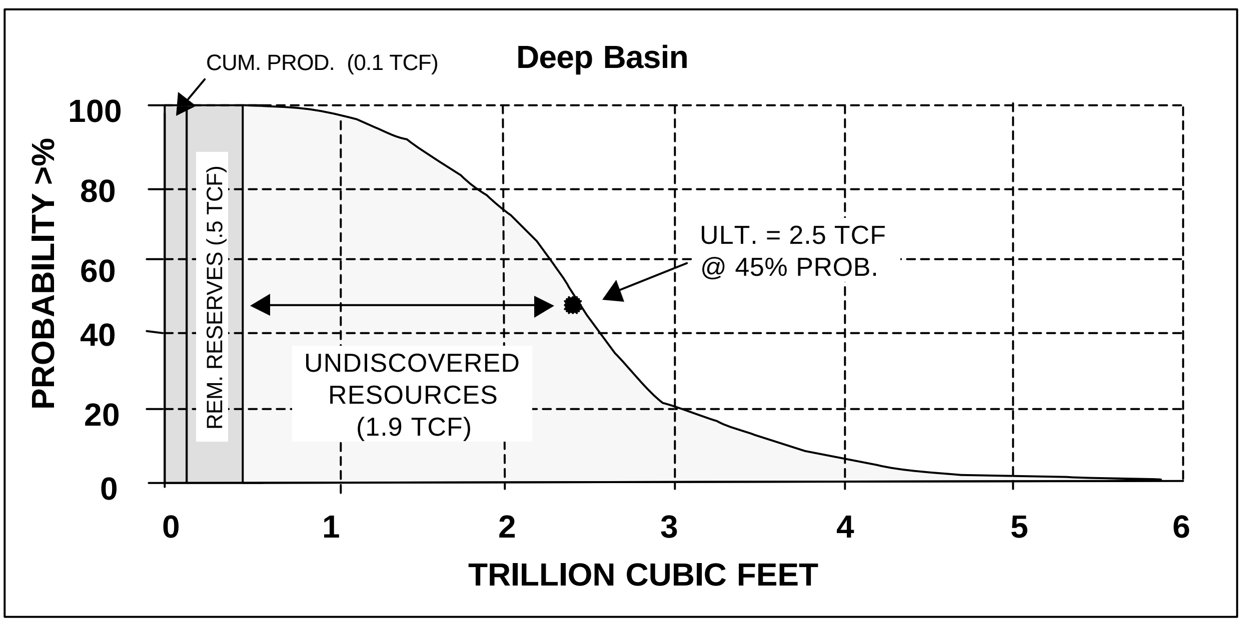

Figure 17. Distribution of ultimate marketable gas resources for the Deep Basin. Cumulative production and reserves to Dec. 31, 1992 (BCEMPR).

Chapter 2: Resource Estimation Using @RISK With EXCEL

2.1 Description

For resource estimation, the National Energy Board has developed a series of templates created in Excel 4.0, using the @Risk add-in. The probabilistic methodology used in the templates has been adapted from Roadifer, 1979. The methodology requires a set of input variables, which are then sampled using a random sampling method such as Monte Carlo. The Monte Carlo simulation uses a range of input parameters to give a distribution of results. A probabilistic estimate of resources can be achieved by multiplying computer generated numbers for volume, yield and risk (probability of success). The variable input parameters for the National Energy Board undiscovered resource methodology is summarized as follows:

Hydrocarbon Volume	Untested Play Area Fraction of Untested Play Area in Trap Areal Fill of Traps Average Net Pay
Yield	Porosity Hydrocarbon Saturation Recovery Factor
Risk	Probability of Hydrocarbons

Hydrocarbon Volume *x* Yield *x* Risk = Undiscovered Resource

2.2 Input Parameters

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 retrieving and mapping all wells that penetrated the play and assigning a tested area to each well. The area assigned was judgmental based on reservoir type and structural style. In many cases, a well was considered to have tested one section (640 acres).

Fraction of Play Area in Trap

The fraction of play area in trap is the fraction of the untested play area that is expected to have structural and/or stratigraphic closure. It is a consideration of trap density generally based on analogy to plays with similar structural style. As the National Energy Board does not have seismic maps or detailed play maps, it was necessary to make a judgment of this factor based on the experience and knowledge of the assessment team.

Areal Fill of Traps

This is an estimate of the fraction of the closure, on an areal basis, that is expected to be occupied by hydrocarbons. The estimate is based on analogy and experience and is dependent on a considerable extent on the type and geometry of the trap. In general, stratigraphic traps will be close to full; pinnacle reefs can have only a small vertical fill but on an areal basis will be high while low relief structures will generally have a low areal fill.

Average Net Pay

The average net pay, as with other reservoir parameters, is the overall average for all pools expected to be discovered. The input parameters such as net pay, porosity, hydrocarbon saturation, GOR, gas compressibility are generally taken from the descriptive statistics for discovered pools. A judgment is made as to whether these means are a true representative sample of future discoveries. In some cases, adjustments have been made based on the assessor's knowledge of the play. For those plays with no discoveries, the estimates are based on analogy.

Recovery Factor

The recovery factors for raw recoverable and marketable gas are taken from the averages calculated from the initial established reserves of the discovered pools. Again, a judgment is made as to whether this truly represents future discoveries.

Probability of Hydrocarbons

This is the probability that a trap will contain hydrocarbons and is generally the exploration success factor. Well retrievals from the Geowell database, by formation, were done to establish historical success rates for each play. These were used as a guide in establishing the value for probability of hydrocarbons. For plays with no exploration history, a consideration of the various factors needed for hydrocarbon accumulation (i.e. presence of reservoir rock, source and seals) will give an estimate of the probability of encountering hydrocarbons.

2.3 @RISK

The @RISK program is an add-in program which adds simulation analysis capabilities to the Excel spreadsheet. @RISK allows the user to define uncertain cell values as probability distribution functions in Excel. There are a total of 24 distribution functions including triangular, lognormal, beta, weibel, discrete, cumulative, etc. The functions are entered for all variables such as net pay, porosity, area, recovery factor, that enter into the gas equation. The gas equation multiplying all the various variables is entered into a cell which is then designated as the output for @RISK. The program will then execute a Monte Carlo or Latin Hypercube simulation for a specified number of iterations, i.e. 3000, and generate a cumulative frequency distribution with a range of probabilities for resource estimates. The program utilizes the graphics capabilities of Excel to generate graphical output for the results.

@RISK has two sampling methods - Monte Carlo and Latin Hypercube. The Monte Carlo method of sampling is entirely random, whereas the Latin Hypercube is a stratified sampling technique. This technique has the overall range separated into several ranges and equal samples are taken from each range. This ensures that the overall range is sampled more evenly. It also runs a little faster on the computer and converges on the mean quicker with a lower number of iterations needed. In general, the National Energy Board has been using the Latin Hypercube in resource estimations.

2.4 @RISK Excel Templates

RSK_TPL.XLS — A template created in Excel 4.0 for estimation of undiscovered resources using triangular distributions for the input parameters. The template also includes dependent equations between porosity and water saturation and sour gases. The template should be opened by using the @RISK menu to open the simulation RSK_TPL.SIM which will retrieve the template with all the necessary settings.

The input template requires minimum, maximum and most likely estimates for each of the parameters. An example input template and explanatory notes are attached.

EX_OUT.XLS	This is an output file made from executing the above template. After execution of the input template, the mean values are copied to the value #1 line. From the @RISK menu, select Targets, to get the probabilities for each of the means. The output from @RISK gives 5 percentile values. In order to smooth the tails of the curve in an Excel chart, it is necessary to get the 1, 2, 3, 4, 96, 97, 98 and 99 percentile values. These probabilities can be entered in the probability lines #1 to #9 as the running targets to get the values. A macro, ATRISK.XLM, has been written to enter the mean values and additional percentiles in the appropriate cells. The procedure is to execute the macro and then targets from the @RISK menu. The output file is saved, with a new name, and linked to a results Excel file - RSK_MG.XLS.
RESULTS	RSK_MG.XLS Marketable gas RSK_OIL.XLS Recoverable oil The above two templates have been prepared to create a cumulative probability curve for the various hydrocarbon components. These templates are kinked to data in the input template (RSK_TPL.XLS) and the output template (EX_OUT.XLS). After execution, these files should be renamed and linked to the results template which then can be saved under new file names. The graphic output is shown as a "greater than" cumulative probability curve. That means values shown have a certain probability of being equal to or greater than the indicated value.

2.5 Probability Distribution Functions

Any number of distribution functions can be used for the various variables used in the template. The authors have chosen to use the triangular distribution as it is the easiest to understand to develop input from historical data. The triangular distribution requires estimates of minimum, maximum and most likely for each of the parameters.

2.6 Dependent Variables

@RISK allows dependency equations to be used where one variable is dependent on another variable. The template includes dependency equations between porosity and water saturation and sour gases. The dependency co-efficients can be derived from a linear regression of historical pool data or utilizing the correlation function in the analysis toolpack add-in for Excel.

2.7 Gas Equation

The gas equation used in the template is as follows:

Gas-in-place = 43,560 *x* Area *x* Net Pay *x* Porosity *x* Gas Saturation *x* GVF

GVF = 520/(460 + Temp (F)) *x* Pressure (psi)/14.65 *x* 1/Z

Temperature and Pressure can be entered or use the template default which is derived from average temperature and pressure gradients and the average depth. The gas compressibility factor "Z" can be obtained from the discovered pool statistics or by analogy.

2.8 Procedure

The following is a step-by-step procedure for the running of a resource estimate using the National Energy Board template:

1) Load Excel 4.0 and open RISK.XLM (to add the @RISK add-in).

2) From the @RISK menu, open RSK_TPL.SIM that opens RSK_TPL.XLS.

3) Enter all the appropriate information and input parameters. Check and set calculation to automatic. Save as a new filename. Select ‘Execute” from the @RISK menu.

4) Open ATRISK.XLM. Go to the @RISK output which will be named sheet?.xls. Run the macro named “Targets” and save as with a new filename.

5) Open the results template (RSK_MG.XLS or RSK_OIL.XLS). Change the links to the filenames of the new input file from step 2 and the output file from step 4. Calculate the document and all information should be updated showing the results of the estimation. Save as a new file.

The above is the procedure which has been used by the National Energy Board in estimating the Resource Assessment for Northeast British Columbia. The user can, however, modify the templates and procedures to suit their own situation. The @RISK add-in also has many more features which are beyond the scope of this short document.

2.9 Reference

Roadifer, R.E., 1979, A probability approach to estimate volumes of undiscovered oil and gas in M. Grenon, ed., Proceedings of the first IIASA Conference on Energy Resources, Laxenburg, Austria: Oxford, Pergamon Press, p. 268-278.

Table 3

INPUT TEMPLATE - ESTIMATION OF UNDISCOVERED RESOURCES

AREA/REGION	NE BRITISH COLUMBIA				
PLAY NAME	EXAMPLE PLAY				
ESTIMATOR NAME					
OIL DEPTH	4837	GAS	4404	(FEET)	
GAS: RESERVOIR	114.87	PRES	1820	(PSI)	

		MIN	MOST	MAX	MEAN	
A	TOTAL PLAY AREA -MM ACRES	7.7	7.968	8.1	7.923	
A’	TESTED PLAY AREA -MM ACRES	2.865	2.868	2.871	2.868	
B	UNTESTED PLAY AREA	4.835	5.1	5.229	5.055	
C	FRACTION OF B IN TRAP	0.15	0.24	0.35	0.247	
D	FRACTION OF C FILLED AREALLY	0.75	0.8	0.85	0.8	
E	POTENTIAL HC AREA -MM ACRES				0.997	
F	POROSITY	0.05	0.13	0.27	0.15	
G	HC SATURATION	0.75	0.8	0.85	0.8	
H	OIL RECOVERY FACTOR	0.16	0.2	0.25	0.203	
I	GAS RECOVERY FACTOR	0.76	0.82	0.88	0.82	
J	AVERAGE NET PAY (FEET)	4	6	10	6.7	
K	PROB. OF HYDROCARBONS	0.15	0.2	0.25	0.2	
L	FRAC OF PORE VOL OIL BEARING	0.3	0.38	0.45	0.377	
M	POTENTIAL OIL AREA -MM ACRES				0.075	
N	POTENTIAL GAS AREA -MM ACRES				0.124	
O	GOR (MCF/BBL)	0.541	0.569	0.597	0.569	
P	FVF	1.308	1.324	1.341	1.324	
Q	GAS COMPRESSIBILITY ‘Z’	0.796	0.812	0.828	0.812	
R	GVF				0.138	
S	OIL IN PLACE (BBLS/ACRE-FOOT)				703	
T	OIL RECOVERY (BBLS/ACRE-FOOT)				142.9	
U	GAS IN PLACE (MCF/ACRE-FOOT)				723.5	
V	RAW GAS REC. (MCF/ACRE-FT)				593.3	
W	MARKETABLE GAS REC.				566	
X	LIQUIDS YIELD (BBLS/MMCF)	30	36.8	42	36.3	
Y	H2S CONTENT (FRAC.)	0.01	0.03	0.035	0.023	
Z	CO2 CONTENT (FRAC.)	0.001	0	0.006	0.004	
	GAS TO BOE FACTOR		6			
	SURFACE LOSS (FUEL GAS, ETC)		0.08			
	MARKETABLE GAS -FRAC. OF RAW		0.954			

TOTAL FOR PLAY

	Oil	**Soln Gas**	**N.A. Gas**	**Total Gas**	**Liquids**	**BOE**	**MKT Gas**
	MMBBL	BCF	BCF	BCF	MMBBL	MMBOE	BCF
IN PLACE	352.15		599.8	599.8		452.11	
RECOVERABLE	71.6	40.74	491.83	532.6	17.84	178.2	510
SULPHUR (MMLT)		0.43					

2.10 Input Template Notes

1) The template is used to calculate the potential resources in an area or a prospect based on the input variables. The only input required is the minimum, most likely and maximum values for the input parameters. Means are calculated based on triangular distributions of the input variables.

   The template calculates the estimated undiscovered potential for the play by using the various hydrocarbon components for in-place and recoverable resources. A risked potential is calculated by multiplying the recoverable resource by the probability of encountering hydrocarbons. For mature plays, the estimates will be the same as the recoverable resources.

2) *Reservoir Temperature and Pressure:*
   The reservoir temperature and pressure are determined using the temperature and pressure gradients entered above and the depth entered for gas.

3) Means, in this template, are all calculated based on a triangular distribution.

4) *Potential Hydrocarbon Area:*
   This is the total area, in millions of acres, which could be hydrocarbon-bearing and is calculated by multiplying lines A, B, C, and D.

5) *Probability of Hydrocarbons:*
   This is the probability of a successful well being drilled in the play area. In many areas, it can be based on historical drilling statistics. In general, there is no associated size connotation.

6) *Fraction of Pore Volume Oil Bearing:*
   This is an estimate of the fraction of the pore space that is expected to contain oil. For a completely oil-prone area, enter a maximum of 1.0, most likely of 0.999 and a minimum of 0.998. Values cannot be zero.

7) *GOR:*
   A default estimate is entered based on the oil depth entered and calculated at 1 MCF/BBL per 10,000 feet. This value can be overwritten if needed.

8) *BOE conversion factor:*
   Enter the value to be used for conversion of gas to “barrels of oil equivalent” (BOE). A default value of 6.0 has been entered.

9) *Marketable Gas (Fraction of Raw):*
   The fraction of raw gas that is marketable gas is calculated by discounting for extracted liquids, sour gases, plant and fuel losses. This value can be overwritten if needed.

Table 4. Formulas used in template estimation

	A	B	C	D		F		H	I
1			Avg. Surface Temp. (degrees F)		40	Pressure Gradient		0.41	
2						Temp. Gradient		1.7	
3						Gas Gravity		=0.59+0.0021*H39+0.62*H40+0.97*H41	
4									
5					**ESTIMATION OF UNDISCOVERED RESOURCES**				
6									
7				Area/Region		NE British Columbia			
8				Play Name		Example			
9				Estimator Name					
10				Oil Depth (feet)		*4160*	Gas Depth (feet)	*4494*	
11				Gas: Reservoir Temp. (F)		=E1+H2*G10/100	Pressure	=14.65+H1*G10	
12									
13									Dependency
14					Minimum	Most Likely	Maximum	Mean	Co-eff.
15	A	Total Play Area (MM acres)			7.7	7.968	8.1	=RiskTriang(E15,F15,G15)	
16	A'	Tested Play Area (MM acres)			=F16*0.999	2.868	=F16*1.001	=RiskTriang(E16,F16,G16)	
17	B	Untested Play Area (MM acres)			=E15-E16	=F15-F16	=G15-G16	=RiskTriang(E17,F17,G17)	
18	C	Fraction of B in Trap			0.15	0.24	0.04	=RiskTriang(E18,F18,G18)	
19	D	Fraction of C Filled (areally)			0.75	0.80	0.85	=RiskTriang(E19,F19,G19)	
20	E	Potential HC Area (MM acres)						=H17*H18*H19	
21	F	Porosity			0.05	0.13	0.27	=RiskIndepC("POR")+RiskTriang(E21,F21,G21)	
22	G	HC Saturation			0.75	0.80	0.85	=RiskDepC("POR",I22) +RiskTriang(E22,F22,G22)	0.70
23	H	Oil Recovery Factor			0.16	0.20	0.25	=RiskTriang(E23,F23,G23)	
24	I	Gas Recovery Factor			0.76	0.82	0.88	=RiskTriang(E24,F24,G24)	
25	J	Average Net Pay (feet)			4.00	6.00	10.00	=RiskTriang(E25,F25,G25)	
26	K	Prob. of Hydrocarbons			0.15	0.20	0.25	=RiskTriang(E26,F26,G26)	
27	L	Frac. of Pore Vol - Oil Bearing			0.30	0.38	0.45	=RiskTriang(E27,F27,G27)	
28	M	Potential Oil Area (MM acres)						=H20*H26*H27	
29	N	Potential Gas Area (MM acres)						=(1-H27)*H20*H26	
30	O	GOR (Mcf/Bbl)			=F30*0.95	=E10*0.0001	=F30*1.05	=RiskTriang(E30,F30,G30)	
31	P	FVF			=1+0.57*E30	=1+0.57*F30	=1+0.57*G30	=RiskTriang(E31,F31,G31)	
32	Q	Gas Compressibility ("Z")			=F32*0.98	0.812	=F32*1.02	=RiskTriang(E32,F32,G32)	
33	R	GVF						=0.001*520/(460+E11)*G11/14.65/H32	
34	S	Oil In Place (Bbls/acres-ft)						=7758*H21*H22/H31	
35	T	Oil Recovery (Bbls/acre-ft)						=H34*H23	
36	U	Gas In Place (Mcf/acre-ft)						=43560*H21*H22*H33	
37	V	Raw Gas Recovery (Mcf/acre-ft)						=H24*H36	
38	W	Marketable Gas Rec. (Mcf/acre-ft)						=H37*F44	
39	X	Liquids Yield (Bbls/Mmcf)			30	36.8	42	=RiskTriang(E39,F39,G39)	
40	Y	H2S Content (Frac.)			0.010	0.025	0.035	=RiskIndepC("sour")+RiskTriang(E40,F40,G40)	
41	Z	CO2 Content (Frac.)			0.001	0.004	0.006	=RiskDepC("sour",I41)+RiskTriang(E41,F41,G41)	0.91
42		Gas to BOE Conversion Factor (Mcf/BOE)				6.0			
43		Surface Loss (Fuel Gas, etc)				0.08			
44		Marketable Gas (Frac. of Raw)				=(1-F43)-F40-F41			
45									
46		**Total for Play**							
47			Oil	Soln Gas	N.A. Gas	Total Gas	Liquids	BOE	Mkt Gas
48			(MMBbls)	(Bcf)	(Bcf)	(Bcf)	(MmBbls)	(MMBOE)	(Bcf)
49		In Place	=H25*H28*H34		=H25*H29*H36	=E49		=C49+G49+F49/F42	
50		Recoverable	=H25*H28*H35	=C50*H30	=H25*H29*H37	=D50+E50	=E50*H39/1000	=C50+G50+F50/F42	=E50*F44+D50
51									
52		Sulphur (MMLT)	=0.03715*H40*E50						

Table 5. Sample of output table used in simulations

Simulation Statistics												
Date: 11/24/93			Example Output									
Iterations: 3000												
Simulations: 1												
Worksheet:	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS	EX_TP L.XLS
Output Range:	OIL IN PLAC	RECOVERABLE	SOLUTION GAS (	NON-ASSOC GI	PREC NON-ASSO	TOTAL GAS IN P	TOTAL REC GA	CONDENSATE (	BOE IN PLACE (	BOE RECOVERAB	MARKETABLE G	SULPHUR (MMLT)
Cell:	C49	C50	D50	E49	E50	F49	F50	G50	H49	H50	I50	D52
Minimum=	61.29	13.02	7.75	132.04	101.53	132.04	111.79	3.55	84.06	36.65	107.12	0.07
Maximum=	1225.54	272.32	160.38	2001.70	1639.72	2001.70	1783.47	60.11	1549.51	612.07	1708.04	1.58
Mean=	353.29	71.78	40.84	601.08	492.75	601.08	533.59	17.88	453.47	178.59	510.92	0.43
Std Deviation=	155.16	32.14	18.33	259.72	213.05	259.72	230.04	7.82	196.60	76.90	220.24	0.21
Variance=	24075.88	1032.71	335.81	67454.46	45389.36	67454.46	52916.32	61.23	38650.33	5914.19	48505.75	0.04
Skewness=	1.06	1.10	1.12	1.06	1.06	1.06	1.05	1.05	1.04	1.03	1.05	1.19
Kurtosis=	4.54	4.75	4.90	4.54	4.55	4.54	4.50	4.48	4.43	4.40	4.50	5.14
Percentile Values												
5Perc=	152.48	30.57	17.40	262.80	215.93	262.80	235.977	7.79	197.87	78.17	225.99	0.17
10Perc=	181.21	36.63	20.74	317.28	258.43	317.28	280.47	9.28	237.36	94.21	268.85	0.20
15Perc=	204.32	40.83	23.23	350.62	286.71	350.62	311.13	10.34	264.53	104.56	297.95	0.23
20Perc=	222.09	44.83	25.45	383.66	314.15	383.66	340.98	11.25	287.43	113.62	326.36	0.25
25Perc=	239.05	48.29	27.45	409.27	337.70	409.27	366.36	12.08	307.41	122.07	350.83	0.28
30Perc=	256.63	51.55	29.25	439.85	360.31	439.85	390.52	13.05	331.51	131.03	373.69	0.30
35Perc=	271.44	54.98	31.31	468.21	381.18	468.21	413.91	13.88	351.76	139.15	396.26	0.32
40Perc=	289.82	58.69	33.30	494.41	407.04	494.41	440.83	14.66	372.70	146.76	421.83	0.34
45Perc=	306.33	62.23	35.50	524.27	430.46	524.27	465.73	15.48	393.97	155.66	445.94	0.36
50Perc=	326.6	66.27	37.67	555.62	453.74	555.62	491.84	16.46	419.42	164.53	471.08	0.39
55Perc=	347.28	69.99	39.84	584.11	480.29	584.11	519.64	17.38	444.48	174.56	497.34	0.41
60Perc=	367.08	74.35	42.19	617.25	507.20	617.25	549.93	18.32	469.75	185.28	526.76	0.44
65Perc=	385.97	78.35	44.59	652.38	536.27	652.36	582.91	19.49	495.32	194.96	558.18	0.47
70Perc=	409.01	82.98	46.98	695.81	571.48	695.81	619.73	20.84	524.27	208.14	593.39	0.50
75Perc=	435.69	88.93	50.70	743.99	609.37	743.99	661.80	22.28	560.47	221.09	634.04	0.54
80Perc=	467.14	95.58	54.49	794.99	652.53	794.99	705.66	23.79	599.35	235.11	675.42	0.58
85Perc=	509.89	103.24	58.71	862.64	708.07	862.64	763.18	25.68	647.95	254.47	730.29	0.63
90Perc=	559.42	114.71	64.98	938.39	771.65	938.39	835.49	28.24	712.26	280.75	799.83	0.70
95Perc=	650.27	134.90	76.50	1082.39	891.28	1082.39	968.13	32.60	837.54	324.94	927.61	0.82
Target Values:												
Value#1=	353.29	71.78	40.84	601.08	492.75	601.08	533.59	17.88	453.47	178.59	510.92	0.43
Prob#1=	0.57	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.58
Value#2=	826.98	168.85	96.59	1417.01	1167.74	1417.01	1260.87	42.88	1063.48	411.81	1207.55	1.09
Prob#2=	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Value#3=	761.38	155.97	88.47	1308.81	1069.38	1308.81	1154.54	38.27	969.87	381.04	1105.87	0.98
Prob#3=	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
Value#4=	716.57	147.57	83.87	1209.57	985.20	1209.57	1070.07	35.98	915.40	362.15	1024.44	0.91
Prob#4=	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Value#5=	676.95	140.34	79.89	1145.69	939.87	1145.69	1013.36	34.08	862.17	339.56	696.82	0.86
Prob#5=	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
Value#6=	146.65	28.87	16.44	254.08	207.56	254.08	224.37	7.45	190.32	75.13	214.87	0.15
Prob#6=	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Value#7=	140.82	27.46	15.73	239.54	196.24	239.54	212.67	6.98	181.40	71.67	203.90	0.15
Prob#7=	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Value#8=	130.89	26.42	14.78	222.48	182.14	222.48	198.54	6.45	169.96	66.01	190.30	0.13
Prob#8=	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Value#9=	114.62	22.44	12.92	199.01	164.12	199.01	178.48	5.78	150.37	58.67	170.80	0.11
Prob#9=	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01