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A Comparison of Analytic and Simulation Methods for Petroleum Play Analysis and Aggregation

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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CONTENTS

FIGURES

TABLES

A COMPARISON OF ANALYTIC AND SIMULATION METHODS FOR PETROLEUM PLAY ANALYSIS AND AGGREGATION

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INTRODUCTION

An analytic method using probability theory was developed as an alternative to an existing Monte Carlo simulation method for estimating the undiscovered oil and gas potential for a petroleum play and for an aggregation of plays. The objective was to duplicate the results of the simulation method by the analytic method, and increase the efficiency of the appraisal process. The resulting analytic method is a geo-stochastic system for petroleum resource appraisal of undiscovered oil and gas in an assessment area. Play analysis is a general term for various geologic models and probabilistic methods for analyzing a geologic play.

A geologic model for the quantity of undiscovered petroleum resources in a play involves uncertainty due to the incomplete or fragmentary geologic information generally available. The geologic model used in this study was developed by the U.S. Department of the Interior and applied by the U.S. Geological Survey in petroleum assessments of the National Petroleum Reserve in Alaska and the Arctic National Wildlife Refuge (U.S. Department of the Interior, 1979; White, 1979). The probabilistic methodology used in those two assessments was a Monte Carlo simulation method.

GEOLOGIC MODEL

In play analysis a petroleum assessment area is partitioned into geologic plays, and the individual plays are analyzed. A play consists of a collection of prospects having a relatively homogeneous geologic setting. A prospect is a potential hydrocarbon accumulation. A hydrocarbon accumulation is a discrete oil or gas deposit, which may consist of one or more pools depending upon the specific play concept. A prospect is modeled by separately considering the uncertainty as to the presence of a hydrocarbon accumulation, and its size if present. An accumulation of hydrocarbon is modeled as either crude oil with its dissolved gas or nonassociated gas. The amount of dissolved gas present in an accumulation of oil is calculated from a gas-oil ratio. Because gas refers to either nonassociated gas or dissolved gas, the amount of gas in a play is the sum of the two types of gas from the prospects. There are three sets of geologic attributes or random variables involved in this play-analysis approach; these are for the play, the prospect, and the hydrocarbon volume. The play and prospect attributes are concerned with the presence or absence of certain geologic characteristics at the play and prospect levels, respectively. The hydrocarbon-volume attributes are concerned with the size of the hydrocarbon accumulation.

The play attributes are (1) existence of a hydrocarbon source, (2) favorable timing for migration of hydrocarbons from source to trap, (3) potential migration paths, and (4) existence of potential reservoir facies. The presence of all four play attributes (in which case the play is said to be "favorable") is a necessary, but not sufficient, condition for the existence of oil or gas deposits in the play. Thus, if one or more of these attributes is not present, all the prospects within the play are dry. Subjective judgments are made by experts for estimating the probability of the presence of each play attribute. Assuming independence, the product of these four probabilities is the probability that the play is favorable for the existence of hydrocarbon accumulations and is called the marginal play probability.

The prospect attributes are (1) trapping mechanism, (2) effective porosity, and (3) hydrocarbon accumulation. Given a favorable play, the presence of all three prospect attributes is a necessary and sufficient condition for the existence of a hydrocarbon accumulation in the prospect. Subjective judgments are made by experts for estimating the probability of the presence of each prospect attribute. Assuming independence, the product of these three probabilities is the probability that a prospect is a hydrocarbon accumulation, given the play is favorable, and is called the conditional deposit probability.

The hydrocarbon-volume attributes are (1) area of closure, (2) thickness of reservoir rock, (3) effective porosity, (4) trap fill, (5) depth to reservoir, and (6) hydrocarbon saturation. The hydrocarbon-volume attributes jointly determine the volume of the hydrocarbon accumulation within the prospect. The following reservoir engineering equations are used to calculate the in-place volumes of oil and nonassociated gas, respectively:

Oil in place = $7,758*1,000*A*F*H*P*S_H/B_O$

Nonassociated gas in place = $1,537.8*1,000*A*F*H*P*S_H*(P_E/T)*(1/Z)$

where A = area of closure (1,000 acres)

F = trap fill (decimal fraction)

H = reservoir thickness (feet)

P = effective porosity (decimal fraction)

S_H = hydrocarbon saturation (decimal fraction)

B_O = oil formation volume factor

P_E = original reservoir pressure

T = reservoir temperature (degrees rankine)

Z = gas compressibility factor

Both equations consist of a product of factors that are functions of the hydrocarbon-volume attributes. The attributes are treated as continuous independent random variables, with the exception of effective porosity which is approximately perfectly positively correlated with hydrocarbon saturation. The probability distribution for an attribute is determined from subjective judgments made by experts, usually geologists, based either on actual geological and geophysical data, when available, or on the experience and knowledge of the experts using analog data and geologic extrapolations when data is unavailable. The probability distribution for each attribute is described by a complementary cumulative distribution function determined from seven estimated fractiles (100th, 95th, 75th, 50th, 25th, 5th, 0th). (The 5th fractile, for example, is an attribute value such that there is a 5% chance of at least that value.) In each play analyzed the seven fractiles are estimated for all of the hydrocarbon-volume attributes, except hydrocarbon saturation whose seven fractiles are one of two possible sets of fixed values depending upon the expected reservoir lithology, which is estimated by the geologists as either sandstone or carbonate. The experts also estimate the hydrocarbon-type probabilities which are the respective probabilities of a given accumulation being either oil or nonassociated gas; however, if the reservoir depth is greater than a specified depth, say for example 15,000 feet, the accumulation is always assumed to be nonassociated gas.

The number of drillable prospects in the play is treated as a discrete random variable, and seven fractiles are estimated.

Probability judgments concerning each of the three sets of attributes are developed by experts familiar with the geology of the area of interest. The experts first review all existing data relevant to the appraisal, identify the major plays within the assessment area (e.g., basin or province), and then assess each identified play. All of the geologic data required by this model for a play is entered on an oil and gas appraisal data form (Figure 1). Information from the data form is entered into computer data files as the input for a computer program based on a method of analysis.

Figure 1.--Oil and gas appraisal data form. (Modified from U.S. Department of Interior, 1979.)

Oil and Gas Appraisal Data Form

Evaluator : ______________________ Play Name ______________________

Date Evaluated: ______________________

	Attribute		Probability of Favorable or Present	Comments
Play Attributes	Hydrocarbon Source			
	Timing			
	Migration			
	Potential Reservoir Facies			
	Marginal Play Probability			
Prospect Attributes	Trapping Mechanism			
	Effective Porosity (>3%)			
	Hydrocarbon Accumulation			
	Conditional Deposit Probability			
Hydrocarbon Volume Parameters	Reservoir Lithology	Sand		
		Carbonate		
	Hydrocarbon	Gas		
		Oil		

	Attribute \ Fractiles	Probability of equal to or greater than 100	95	75	50	25	5	0	
Hydrocarbon Volume Parameters	Area of Closure ($x10^3$ Acres)								
	Reservoir Thickness/vertical closure (Ft)								
	Effective Porosity %								
	Trap Fill (%)								
	Reservoir Depth ($x10^3$ Ft)								
	No. of drillable prospects (a play characteristic)								
	Proved Reserves ($x10^6$ Bbl; TCF)								

SIMULATION METHOD

Given the geologic model, the Monte Carlo simulation method is one way of generating probability distributions for the quantity of undiscovered oil and gas resources in a play. The method uses the geologic model to simulate many possible values for the quantity of undiscovered oil and gas resources in the play and then uses these values to generate relative frequency distributions as well as various statistics. A computer is used to select a value for each of the geologic factors and calculate an estimate of the oil and of the gas for each repetition or pass of the model. Each pass consists of establishing the potential presence or absence of petroleum for the play, sampling the number of prospects if the play is simulated as favorable, determining the number and type of accumulations, and computing a volume for each accumulation. When the desired number of passes is completed, the resource estimates for the play are sorted, and described as approximate probability distributions, and various statistics are calculated.

The basic steps of the simulation method are:

1. Set the desired number of play passes n.

2. Select play of interest and begin the first pass.

3. Sample against the play's marginal probability to simulate the potential presence or absence of petroleum in the play, that is, whether the play is favorable or unfavorable (dry).

4. If the play is simulated as dry, zero resources are assigned to the play and the system moves on to the next pass (step 3). If the play is simulated as favorable, the system moves on to step 5.

5. Sample from the correponding number-of-drillable-prospects distribution to simulate the number of prospects in the play for this pass.

6. For each simulated prospect, sample against the play's conditional deposit probability to simulate the presence or absence of petroleum in the prospect.

7. For each prospect simulated as dry, zero resources are assigned to the prospect, and the system moves to the next prospect (step 6). For each prospect simulated as an accumulation, the system moves on to step 8.

8. For each simulated accumulation, sample from the reservoir depth distribution. If the simulated depth is greater than 15,000 feet, then the deposit is nonassociated gas; otherwise, sample against the play's hydrocarbon type probability to simulate the type of accumulation, oil or nonassociated gas.

9. For each simulated accumulation, sample from the hydrocarbon volume attribute distributions according to the estimation of sandstone or carbonate for reservoir lithology. Random numbers between 0 and 1 are drawn for each hydrocarbon volume attribute and matched to corresponding cumulative probability curves, linearly interpolating as necessary.

10. Compute the in-place oil or nonassociated gas volume of each simulated accumulation. If the accumulation is oil, the corresponding amount of associated-dissolved gas is also calculated.

11. Save the individual amounts for accumulations of oil, nonassociated gas, and associated-dissolved gas from all of the simulated accumulations for use in determining the accumulation-size distributions.

12. The sum of the amounts of accumulations of all of the simulated prospects in the play pass is used to estimate the volumes of oil and gas in a favorable play. Since there are n play passes, there are n play resource estimates, including the zero resource estimates from plays simulated as unfavorable.

13. For each play, rank all play resource estimates resulting from passes in which the play was simulated to be favorable, and divide into fractiles to produce approximate conditional probability distributions for oil and gas that describe the conditional play potential, given a favorable play. Also for each play, rank all n play resource estimates and divide into fractiles to produce approximate probability distributions for oil and gas that describe the unconditional play potential. Calculate means and standard deviations.

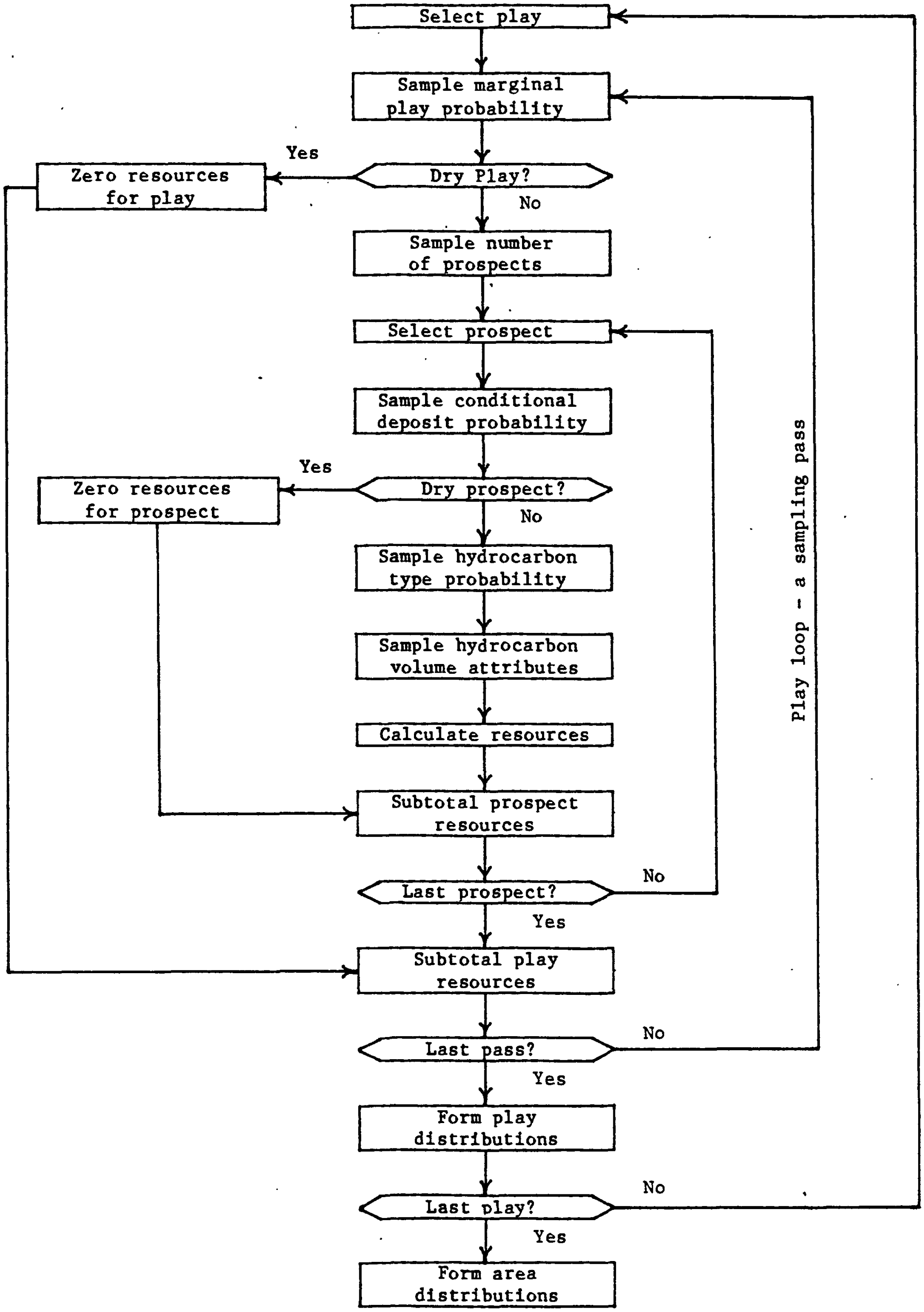
14. After all plays are completed, the sum of the resource estimates of all of the plays over corresponding play passes is used to estimate the total volumes of oil and gas in the assessment area. There are n aggregate resource estimates.

15. For the entire assessment area, rank all n aggregate resource estimates and divide into fractiles to produce approximate probability distributions for oil and gas that describe the unconditional aggregate potential. Calculate means and standard deviations.

A simplified flow chart of the simulation method for play analysis is presented in Figure 2.

A computer program entitled Resource Appraisal Simulation for Petroleum (RASP) was developed by L. P. White of the U.S. Department of the Interior (written communication, 1983) and was based on a simulation method similar to the one described above. RASP was designed for 500 to 3,000 play passes; the larger the number of repetitions, the greater the statistical reliability, but also the greater the computer cost. RASP was used by the U.S. Geological Survey in the assessments of the National Petroleum Reserve in Alaska and the Arctic National Wildlife Refuge (U.S. Department of the Interior, 1979; White, 1979).

Figure 2.--Flow Chart of Simulation Method for Play Analysis



ANALYTIC METHOD

An analytic method using probability theory is proposed as a more efficient alternative to the costly and time-consuming Monte Carlo simulation method for petroleum play analysis. The analytic method is based upon the same geologic model, same type data, and same probability assumptions as the simulation method.

The analytic method was developed by the application of many laws of expectation and variance in probability theory. The analytic method systematically tracks through the geologic model, computes all of the means and variances of the appropriate random variables, and calculates all of the probabilities of occurrence. The lognormal distribution is used as a model for various unknown distributions in order to arrive at probability fractiles. Oil, nonassociated gas, dissolved gas, and gas resources are each assessed in turn. Separate methodologies have been developed for analyzing individual plays and for aggregating the plays.

The basic steps of the analytic method of play analysis are:

1. Select the play.

2. Select oil as the first resource to be assessed.

3. Compute the mean and variance of each of the following hydrocarbon-volume attributes: (1) area of closure, (2) thickness of reservoir rock, (3) effective porosity, (4) trap fill, (5) depth to reservoir, and (6) hydrocarbon saturation. Determine the mean and variance from the estimated seven fractiles, assuming a uniform distribution between fractiles, that is, a piecewise uniform probability density function (as was done in the case of the simulation method). Recall that the hydrocarbon saturation distribution depends on whether the estimated reservoir lithology is sandstone or carbonate. Calculate the mean and variance of the product of effective porosity and hydrocarbon saturation, assuming they are approximately perfectly positively correlated. Also compute the mean and variance for the reciprocal of the oil formation volume factor, which is a function of reservoir depth through a series of formulas.

4. Compute the mean and variance of the accumulation size of oil in place using a reservoir engineering equation. The equation involves the product of a constant, area of closure, reservoir thickness, trap fill, effective porosity, hydrocarbon saturation, and the reciprocal of the oil formation volume factor. Various laws of expectation and variance are involved in the calculations.

5. Model the accumulation-size distribution by the lognormal probability distribution with mean and variance from step 4. Calculate various lognormal fractiles of the accumulation size for oil.

6. Compute the probability that a prospect has an oil accumulation, given the play is favorable. This is called the conditional prospect probability of oil. This probability is the product of the conditional deposit probability, the probability that the reservoir depth is less than 15,000 feet, and the hydrocarbon-type probability of oil.

7. Compute the mean and variance of the conditional prospect potential for oil, which is the quantity of oil in a prospect, given the play is favorable. They are arrived at by applying the conditional prospect probability of oil to the mean and variance of the accumulation size of oil.

8. Compute various fractiles of the conditional prospect potential for oil by a transformation to appropriate lognormal fractiles of the accumulation size of oil using the conditional prospect probability of oil.

9. Compute the mean and variance of the number of prospects from the estimated seven fractiles, assuming a uniform distribution between fractiles (as is also the case in the simulation method).

10. Compute the mean and variance of the number of oil accumulations, given the play is favorable. They are arrived at by applying the conditional prospect probability of oil to the mean and variance of the number of prospects.

11. Compute the mean and variance of the conditional (A) play potential for oil, which is the quantity of oil in the play, given the play is favorable. They are determined from the probability theory of the expectation and variance of a random number (number of prospects) of random variables (conditional prospect potential).

12. Compute the conditional play probability of oil, which is the probability that a favorable play has at least one oil accumulation, and is a function of the conditional prospect probability of oil and the number-of-prospects distribution.

13. Compute the mean and variance of the conditional (B) play potential for oil, which is the quantity of oil in the play, given the play is favorable and there is at least one oil accumulation within the play. They are arrived at by applying the conditional play probability of oil to the mean and variance of the conditional (A) play potential for oil.

14. Compute the unconditional play probability of oil, which is the probability that the play has at least one oil accumulation, and is the product of the conditional play probability of oil and the marginal play probability.

15. Compute the mean and variance of the unconditional play potential for oil, which is the quantity of oil in the play. They are arrived at by applying the unconditional play probability of oil to the mean and variance of the conditional (B) play potential for oil.

16. Model the probability distribution of the conditional (B) play potential for oil by the lognormal distribution with mean and variance from step 13. Calculate various lognormal fractiles.

17. Compute various fractiles of the conditional (A) play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the conditional play probability of oil.

18. Compute various fractiles of the unconditional play potential for oil by a transformation to appropriate lognormal fractiles of the conditional (B) play potential for oil using the unconditional play probability of oil.

19. Select nonassociated gas as the second resource to be assessed. Repeat steps 3 through 18, substituting nonassociated gas for oil, with two basic modifications as follows. A reservoir engineering equation is used to calculate the accumulation size of nonassociated gas in place. The conditional prospect probability of nonassociated gas is equal to the conditional deposit probability minus the conditional prospect probability of oil.

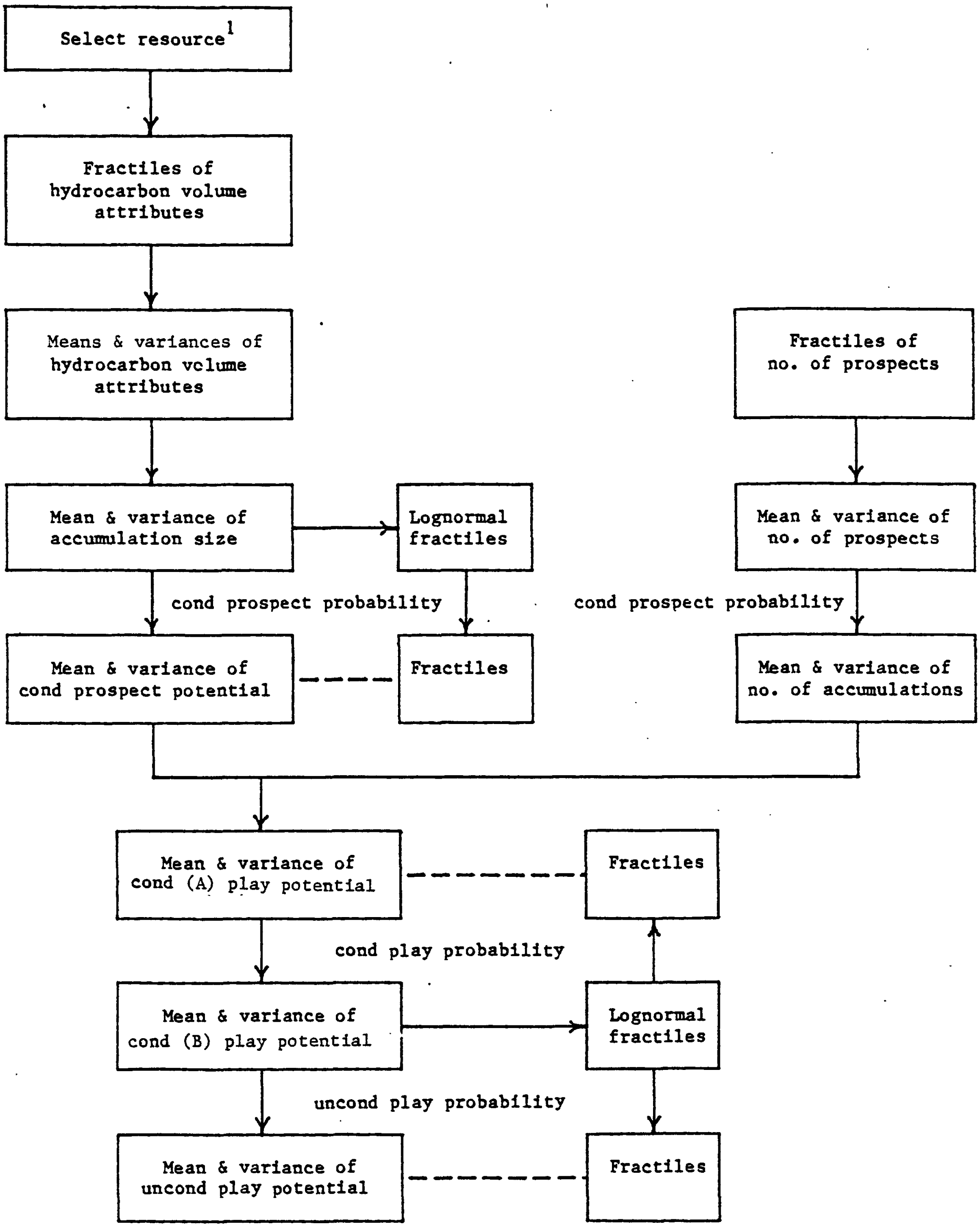
20. Select dissolved gas as the third resource to be assessed. Repeat steps 3 through 18, substituting dissolved gas for oil, with two basic modifications as follows. The reservoir engineering equation for the accumulation size of oil in-place is multiplied by a gas-oil ratio which is a function of reservoir depth. The conditional prospect probability of dissolved gas is the same as the conditional prospect probability of oil.

21. Select gas as the fourth resource to be assessed. Repeat steps 4 through 18, substituting gas for oil, with two basic modifications as follows. Replace step 4 to compute the mean and variance of the accumulation size of gas in-place by using conditional probability theory and conditioning on the type of gas. The conditional prospect probability of gas is the same as the conditional deposit probability.

A simplified flow chart of the analytic method of play analysis is presented in Figure 3.

On the basis of the analytic method, a computer program was designed and called the Fast Appraisal System for Petroleum (FASP). Because both cost and running time are negligible, FASP allows for quick feedback evaluation of geologic input data. FASP can be easily adapted to most mainframe computers and microcomputers.

Figure 3.--Flow Chart of Analytic Method of Play Analysis



[1] Oil, nonassociated gas, dissolved gas, and gas resources are each assessed in turn.

A separate methodology was developed for estimating the aggregaton of a set of plays. In this method the resource estimates of the individual plays from the analytic method of play analysis using the FASP program are aggregated by means of probability theory. Oil, nonassociated gas, dissolved gas, and gas resources are each aggregated in turn.

The basic steps of the analytic method of play aggregation are:

1. Select plays to aggregate.

2. Select oil as the first resource to be aggregated.

3. Compute the mean and variance of the unconditional aggregate potential for oil, which is the quantity of oil in the assessment area. They are determined by adding all of the individual play means and variances of the unconditional play potential for oil, respectively, assuming independence among the plays.

4. Compute the unconditional aggregate probability of oil, which is the probability that the assessment area has at least one play with oil, and is a function of the individual unconditional play probabilities of oil.

5. Compute the mean and variance of the conditional aggregate potential for oil, which is the quantity of oil in the assessment area, given the assessment area has at least one play with oil. These are arrived at by applying the unconditional aggregate probability of oil to the mean and variance of the unconditional aggregate potential for oil.

6. Model the probability distribution of the conditional aggregate potential for oil by the lognormal distribution with mean and variance from step 5. Calculate various lognormal fractiles.

7. Compute various fractiles of the unconditional aggregate potential for oil by a transformation to appropriate lognormal fractiles of the conditional aggregate potential for oil using the unconditional aggregate probability of oil.

8. Select nonassociated gas as the second resource to be aggregated. Repeat steps 3 through 7 using play analysis estimates of nonassociated gas, namely the individual play means and variances of the unconditional play potential for nonassociated gas, along with the individual unconditional play probabilities of nonassociated gas.

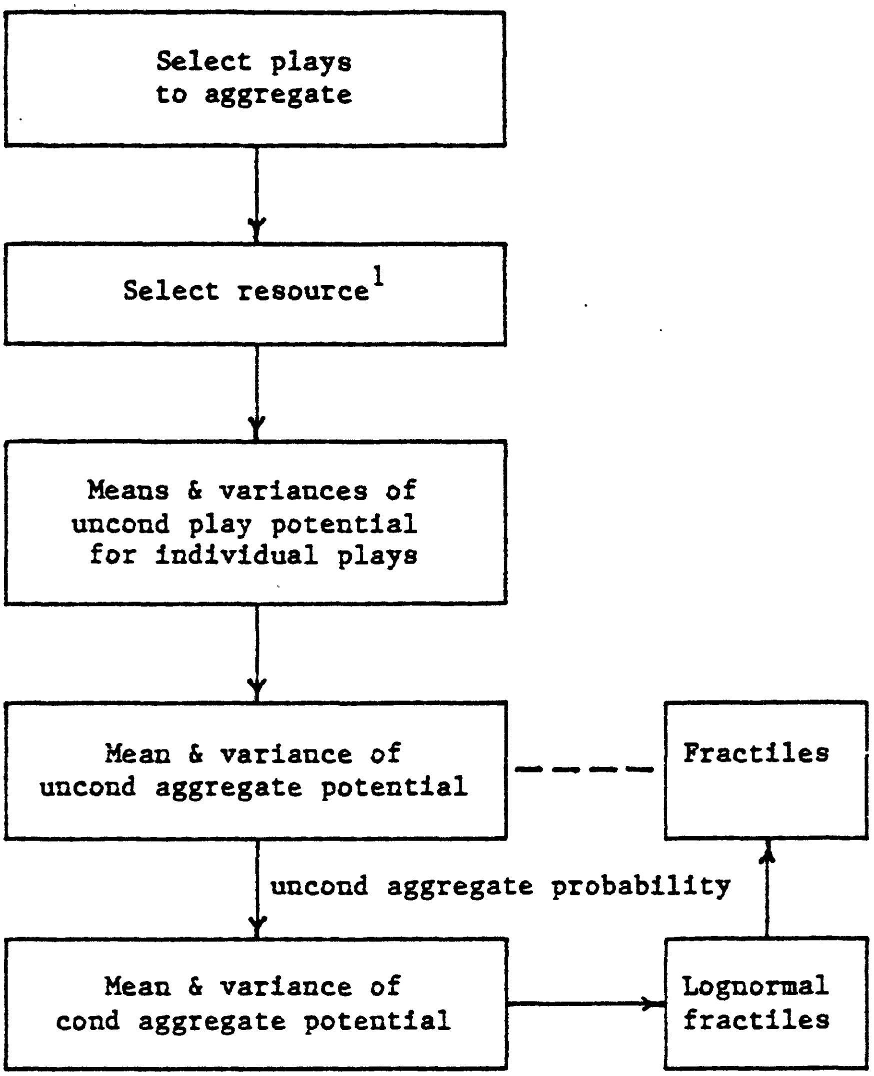
9. Select dissolved gas as the third resource to be aggregated. Repeat steps 3 through 7 using play analysis estimates of dissolved gas, namely the individual play means and variances of the unconditional play potential for dissolved gas, along with the individual unconditional play probabilities of dissolved gas.

10. Select gas as the fourth resource to be aggregated. Repeat steps 3 through 7 using play-analysis estimates of gas, namely the individual play means and variances of the unconditional play potential for gas, along with the individual unconditional play probabilities of gas.

A simplified flow chart of the analytic method of play aggregation is presented in Figure 4.

A computer program was designed on the basis of the analytic method for the aggregation of plays and called the Fast Appraisal System for Petroleum Aggregation (FASPA). FASPA interfaces with FASP as follows. FASP not only generates a file of resource estimates for an individual play, but also outputs a second file of results which consists of the mean and standard deviation of the unconditional play potential for each of the four resources, along with the corresponding unconditional play probabilities. The second file is needed for an aggregation of plays and forms an input file for FASPA. Therefore, after FASP is run on each play in a set of plays, any subset of plays can be aggregated by running FASPA on the corresponding subset of aggregation input files. FASPA not only generates a file of resource estimates for an aggregation of plays, but also outputs a second file of results needed for an aggregation of aggregations, which forms yet another input file for FASPA. Hence, after FASPA is run on each aggregation in a set of aggregations, any subset of aggregations can be aggregated at once. Compared to the simulation method, the application of FASPA can result in tremendous savings of time and cost, especially when analyzing many aggregations involving hundreds of plays. FASPA also possesses the capacity of aggregating a set of plays under a dependency assumption. In which case, all of the individual play standard deviations (instead of the variances) of the unconditional play potential for a resource are added together.

Figure 4.--Flow Chart of Analytic Method of Play Aggregation



[1] Oil, nonassociated gas, dissolved gas, and gas resources are each aggregated in turn.

COMPARATIVE EXAMPLES

A comparison of the results from both the simulation and analytic methods of play analysis is illustrated using an actual resource assessment of an individual play, Sag River. The play is from a U.S. Geological Survey assessment of an area in Alaska (U.S. Department of the Interior, 1979). The completed oil and gas appraisal data form used in that study is given in Figure 5. The form was filled out by a USGS resource appraisal team of experts, and the data analyzed by the simulation method using the computer program RASP with 3,000 play passes. The same data was also analyzed by the analytic method using the computer program FASP. A comparison of results from both methods is presented in Table 1 and shows excellent agreement between the two methods of analysis, especially between the means and standard deviations.

A comparison was also made of the results from both the simulation and analytic methods applied to a U.S. Geological Survey resource assessment of an aggregation of plays. The data is from an assessment of an area in Alaska (Mast, R. F., and others, 1980). The assessment area had been partitioned into ten geologic plays. An oil and gas appraisal data form (Figure 1) had been filled out for each of the ten plays by USGS resource appraisal experts (U.S. Department of Interior, 1980, written commun.). The data for the aggregation had been analyzed by the simulation method using the computer program RASP with 3,000 play passes. The same data was now analyzed by the analytic method of play analysis using the computer program FASP for the ten individual plays, and then FASPA for their aggregation. Results from RASP and FASPA for the aggregation of the ten plays are presented in Table 2. The estimates in Table 2 again show excellent agreement between the two methods of analysis.

Figure 5.--Data used in appraisal of Sag River play, Alaska, developed during U.S. Department of Interior Study, 1979.

Oil and Gas Appraisal Data Form

Evaluator : Resource Appraisal Team Play Name Sag River

Date Evaluated: 5/21/79

	Attribute		Probability of Favorable or Present	Comments
Play Attributes	Hydrocarbon Source		1.0	Oil shows in Barrow 12, 17, and 19
	Timing		1.0	
	Migration		1.0	
	Potential Reservoir Facies		.7	New core data shows low perm.
	Merginal Play Probability		.7	
Prospect Attributes	Trapping Mechanism		.3	
	Effective Porosity (>3%)		.9	
	Hydrocarbon Accumulation		.9	
	Conditional Deposit Probability		.243	
Hydrocarbon Volume Parameters	Reservoir Lithology	Sand	1.0	
		Carbonate	0	
	Hydrocarbon	Gas	.2	
		Oil	.8	

Attribute \ Fractiles (Probability of equal to or greater than)	100	95	75	50	25	5	0	Comments
Area of Closure ($x10^3$ Acres)	.6	1	3	6	8	10	25	Lease prospect is potentially large stratigraphic trap
Reservoir Thick-ness/vertical closure (Ft)	5	30	60	90	120	140	170	
Effective Porosity %	3	8	10	12	15	20	25	glauconitic ss: standard porosity vs. permeability Relations may not hold
Trap Fill (%)	1	15	30	45	55	70	95	
Reservoir Depth ($x10^3$ Ft)	2	5	8	9	10	11	13	
No. of drillable prospects (a play characteristic)	4	5	6	8	12	15	20	
Proved Reserves ($x10^6$ Bbl; TCF)							0	

Table 1.--Comparison of results of RASP and FASP for one play.

	RASP[1]	FASP
Mean no. of pools	2.1	2.1
Oil (Millions of BBLS)		
Conditional play potential		
Mean	190	192
Standard deviation	230	236
F_{95}	0	0
F_5	638	612
Unconditional play potential		
Mean	133	134
F_{95}	0	0
F_5	554	522
Gas (Billions of Cu Ft)		
Conditional play potential		
Mean	242	246
Standard deviation	289	294
F_{95}	0	0
F_5	800	763
Unconditional play potential		
Mean	169	172
F_{95}	0	0
F_5	669	649

[1] Data from U.S. Department of the Interior (1979), Sag River play using 3,000 play passes.

Table 2.--Comparison of results of RASP and FASPA for the aggregation of ten plays.

	RASP[1]	FASPA
Oil (Billions of BBLS)		
Unconditional aggregate potential		
Mean	4.85	4.88
Standard deviation	6.60	6.44
F_{95}	0.16	0.51
F_{75}	1.12	1.49
F_{50}	2.71	2.96
F_{25}	5.87	5.84
F_{5}	17.03	15.46
Gas (Trillions of Cu Ft)		
Unconditional aggregate potential		
Mean	11.90	12.24
Standard deviation	11.86	12.57
F_{95}	1.44	2.11
F_{75}	4.33	4.82
F_{50}	8.41	8.54
F_{25}	15.14	15.16
F_{5}	33.93	34.58

[1] Data from Mast, R. F., and others (1980), using 3,000 play passes.

CONCLUSIONS

The analytic method using probability theory is a practical alternative to the simulation method for petroleum play analysis. The two comparative examples demonstrate excellent agreement between the two methods of analysis. The computer program FASP based on the analytic method operates thousands of times faster than the computer program RASP based on the simulation method. Because the cost and running time are negligible, FASP allows for quick feedback evaluation of the estimated geologic data, a feature which is invaluable during actual resource assessment meetings. Moreover, FASP and FASPA can be adapted to most microcomputers; they need no system-dependent subroutines or unusual library functions.

A tremendous savings of time and cost can result using FASP, especially when analyzing hundreds of individual plays. However, the greater advantage of the analytic method might lie in the aggregation of a set of plays, especially if the set is large and there are many combinations of aggregations required. The computer program FASPA based on the analytic method can aggregate any subset of plays virtually instantly, and can aggregate aggregations. FASPA has considerably more flexibility than RASP, even aggregating under a dependency assumption.

The analytic and simulation methods are very different approaches to petroleum play analysis. Not only are the technical tools used to solve the problem different, but also the problem is viewed differently under the two methods. The analytic method involves the hydrocarbon-volume attributes at the beginning of the analysis and the marginal play probability at the end. The simulation method reverses the order of development of the analysis, the marginal play probability first and the hydrocarbon-volume attributes last. Oil, nonassociated gas, associated-dissolved gas, and gas resources are each in turn separately assessed by the analytic method. In the simulation method all of the resources are recorded at the same time. The analytic method produces not only numerical estimates of petroleum resources, but also mathematical equations of probabilistic relationships involving these resources; whereas the simulation method produces no such equations.

ACKNOWLEDGMENT

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