

STATISTICAL METHODS FOR ESTIMATING PETROLEUM RESOURCES

P. J. Lee

OXFORD
UNIVERSITY PRESS
2008

Contents

Foreword to the Series	vii
Foreword	ix
1 Introduction	3
Background	3
Objectives	4
An Outline of the Evaluation Procedure	5
Scope	5
2 Evaluation Models	7
Geological Models and Play Definitions	7
Statistical Models	11
Concepts Used	14
The Nature of Geological Populations	18
<i>The Beaverhill Lake Play</i>	18
<i>Outliers</i>	21
<i>Correlation between Random Variables</i>	22
<i>Mixed Populations</i>	25
3 Estimating Mature Plays	26
The Superpopulation Model	27
<i>Lognormal Discovery Process Model</i>	27
<i>Nonparametric Discovery Process Model</i>	33
<i>Estimating Pool-Size Distribution for the Beaverhill Lake Play</i>	34
<i>Lognormal/Nonparametric–Poisson Discovery Process Model</i>	36
Previous Work	36
The BDSCV Model	38
The Keg River Shelf	39
Remarks	39
<i>Multivariate Discovery Process Model</i>	40
Bivariate Lognormal Distribution for Oil and Gas Pools	43

- Estimating the Covariance Matrix
- Remarks*
- Pool-Size-by-Rank by Order Statistics
- Interpretations*
- The Matching Process: Operation*
- The Beaverhill Lake Play*
- Pool Sizes Conditional on Pool Rank*
- Distribution of the Ratio of Two Pools*
- Play Resource and Potential Distribution
- Play Resource Distribution*
- Play Potential Distribution*
- Expected Play Potential
- Probable Play Potential Distribution
- The Beaverhill Lake Play

- 4 More about Discovery Process Models**
- Validation Study by Simulation
- Validation Procedure*
- Estimates for the N Value*
- Lognormal Population
- Weibull Population
- Pareto Population
- Mixed Population of Two Lognormal Populations
- Mixed Population of Lognormal, Weibull,
and Pareto Populations
- Estimation of Exploration Efficiency*
- Pool-Size-by-Rank*
- Play Resource Distribution*
- Reduction of Uncertainty*
- Validation by Retrospective Study
- Jumping Pound Rundle Gas Play*
- Swan Hills Shelf Margin Gas and Leduc Isolated
Reef Oil Plays*
- Remarks*
- Impact of Nonproductive and Noncommercial Pools
- Impact of a Nonproductive Trap*
- Impact of Missing Pools*
- Testing the Adequacy of Probability Distributions
- The Procedure*

<i>Interpretation</i>	89
Outliers	89
Long or Short Tails at Both Ends	90
Symmetry	90
Plateaus	90
<i>The Beaverhill Lake Play</i>	91
<i>Plays from Worldwide Basins</i>	91
Pool-Size Distribution of a Basin	100
Justifications for Using a Lognormal Distribution	102
<i>Evidence from the Q-Q Plots</i>	102
<i>Approximation of a Lognormal Distribution to Geological Random Variables</i>	102
<i>Advantages of Using a Lognormal Distribution</i>	103
<i>Estimation Error Resulting from Lognormal Distribution Approximation</i>	105
5 Evaluating Conceptual Plays	106
Geological Factors	106
<i>Exploration Risk</i>	106
<i>Methods for Estimating Marginal Probability</i>	107
Play-Level Geological Factor	108
Prospect-Level Geological Factor	111
Marginal Probability Distribution	112
<i>Dependence in Prospect-Level Geological Factors</i>	114
<i>The East Coast Play</i>	115
Pool-Size Distribution	116
<i>The Monte Carlo Method</i>	116
<i>The Lognormal Approximation</i>	119
<i>Examples</i>	120
The Beaverhill Lake Play	120
The East Coast Play	124
Estimating Resources	127
<i>Number-of-Prospects Distribution</i>	127
<i>Number-of-Pools Distribution</i>	127
<i>Play Resource Distribution</i>	131
<i>Pool-Size-by-Rank</i>	133
<i>Generation of Reservoir Parameters</i>	135
Constructing Probability Distributions	136

6 Estimation Update and Feedback Procedures

Procedure for Estimating Mature Plays

Step 1: Formulating a Play Definition and Its Geographic Boundary

Step 2: Compiling Play Data

Step 3: Validating Mixed Populations or Lognormal Assumptions

Step 4: Estimating Pool-Size Distribution

Step 5: Determining an Appropriate Probability Distribution

Step 6: Estimating Pool-Size-by-Rank

Step 7: Estimating Expected and Probable Play Potential

Step 8: Computing Play Resource Distribution

Procedure for Estimating Conceptual Plays

Conceptual Plays from a Mature Basin

Conceptual Plays from a Frontier Basin

Step 1: Formulating Play Definitions

Step 2: Estimating Pool-Size Distribution

Step 3: Estimating Number-of-Pools Distribution

Step 4: Estimating Individual Pool-Size Distribution

Step 5: Estimating Play Resource Distribution

Step 6: Estimating Other Reservoir Parameters

Update Procedure

Feedback Procedure

Can We Predict the Current Situation?

Has the Largest Pool Been Discovered?

Pool Size Conditional on Play Resource

7 Other Assessment Methods—An Overview

Geological Approach

Volumetric Yield by Analogous Basin Method

Basin Classification Method

Geochemical Approaches

Petroleum System or Geochemical Mass Balance Method

Burial and Thermal History Modeling

Statistical Approaches

Finite Population Methods

The Arps and Roberts Method

Bickel, Nair, and Wang's Method

Kaufman's Anchored Method	164
Chen and Sinding-Larsen's Geo-Anchored Method	166
<i>Superpopulation Methods</i>	166
USGS Log-Geometric Method	166
The Creaming Method	169
The Long Method	170
<i>The Regression Method</i>	170
<i>The Fractal Method</i>	171
8 Concluding Remarks	174
Appendix A: Estimation of Superpopulation Parameters from a Successively Sampled Finite Population	176
The Likelihood Function	178
Maximum-Likelihood Estimation	183
Inference for θ and N	192
Inference for the Weight Function	197
Appendix B: Nonparametric Procedure for Estimating Distributions	200
Appendix C: The Largest Pool Size and Its Distribution	203
The r th Largest Pool-Size Distribution	203
Generation of Reservoir Parameters for a Given Pool Size	205
Appendix D: Pool Size Conditional on Pool Ranks	208
Theorem 1	208
<i>Corollary</i>	209
Theorem 2	210
References	213
Index	221