

CONTENTS

Chapter 1	INTRODUCTION	
1.1	Definition of Inversion	3
1.2	Geophysical Models	10
1.3	Model Parameters	16
1.4	Fitting Model Fields to Data	17
1.5	Factors Affecting Inversion	18
1.6	Computational Aspects	25
1.7	Psychological Aspects of Inversion	29
1.8	What then is Pragmatic Inversion?	31
	References	32
Chapter 2	INTERPRETATION USING NOMOGRAMS	
2.1	Characteristic Points	35
2.2	Nomograms and Their Use	38
2.2.1	Gravity Nomograms	38
2.2.2	Nomogram for Interpretation of VLF Resistivity Data	41
2.2.3	Nomograms for Magnetic Dipole (Slingram) Profiling	42
2.3	Computerized "Nomograms"	44
2.4	On the Accuracy of Characteristic Point Inversion	46
	References	46
Chapter 3	LINEAR PARAMETERS	
3.1	Defining the Linear Problem	51
3.1.1	Genuine Linear Problems	51
3.1.2	Discretization of the Linear Model	52
3.1.3	Linearization	53
3.1.4	Iterative Approaches	55
3.2	Fitting Linear Models to Data	57
3.2.1	Systems of Linear Equations	57
3.2.2	Exact Fit	60
3.2.3	Least Squares (LSQ)	60
3.3	Iterative Solutions: The Method of Gauss-Seidel	61
3.4	Generalized Inversion	63
3.4.1	Singular Value Decomposition (SVD)	64
3.4.1.1	Zero Eigenvalues	66
3.4.1.2	Zero Eigenvalues, a Least-Squares Approach	67
3.4.1.3	Why are Small Eigenvalues Dangerous?	69
3.4.2	SVD of a Rectangular Matrix	72
3.4.3	Geophysical Examples of the Use of SVD	73
3.4.3.1	Gravity	73
3.4.3.2	Earth Density Model	78
3.4.3.3	Magnetometry	81
3.4.3.4	Magnetometry, Theoretical Plate Models	82
3.4.3.5	Electromagnetism	90
3.4.3.6	Seismology	94

	3.4.3.7 Oceanography	96
	3.4.3.8 Joint Inversion	97
	3.4.4 Ridge Regression	100
3.5	The Backus-Gilbert Approach	101
	3.5.1 Definitions	101
	3.5.2 Parameter Trade-Off	103
3.6	Geophysical Tomography	104
	3.6.1 Seismic Tomography	105
	3.6.2 Tomography and the Radon Transform	107
	3.6.3 Example on Seismic Regional Tomography	110
	References	112
Chapter 4	NON-LINEAR PARAMETERS	
4.1	Definitions	117
	4.1.1 Objective Functions and Norms	118
	4.1.1.1 Exact Fit	118
	4.1.1.2 Least Squares	118
	4.1.1.3 Robust Methods. The Minimax Solution	119
	4.1.1.4 Weighted Objective Functions	119
	4.1.2 Properties of Objective Functions	121
	4.1.3 Constrained Optimization	127
	4.1.3.1 Penalty Functions	127
	4.1.3.2 Lagrangian Multipliers	128
	4.1.4 Stopping Criteria in Iterative Optimization	129
4.2	One-Dimensional Optimization	131
	4.2.1 Golden Cut	132
	4.2.2 Fibonacci Search	133
	4.2.3 Speedup by Parabolic Fit	134
	4.2.4 The Secant Method	136
	4.2.5 The Gradient Method	136
	4.2.5.1 On the Instability of the Newton Iteration	137
4.3	Multidimensional Search	138
	4.3.1 Direct Search	142
	4.3.1.1 Sequential Search (Search by Parameters)	142
	4.3.1.2 Hyperparabolic Fit	142
	4.3.1.3 Pattern Search	144
	4.3.2 Multivariate Search	147
	4.3.2.1 The Simplex Method	147
	4.3.2.2 Steepest Descent Methods: the Gradient Method	149
	4.3.2.3 Steepest Descent Methods: the Method of Conjugate Directions	150
	4.3.2.4 The Levenberg-Morrison-Marquardt Algorithm	152
	4.3.3 Random Search Methods	153
4.4	Examples	155
	4.4.1 Magnetic 2D Profiling	156
	4.4.2 Gravity Inversion	165
	4.4.3 Seismic Refraction	166
	4.4.4 Magnetotellurics	167
	References	171

Chapter 5	MAXIMUM LIKELIHOOD AND MAXIMUM ENTROPY	
5.1	Introduction and Definitions	177
5.1.1	Probability Density	177
5.1.2	Measure of Information	179
5.2	Probabilistic Formulations of the Inversion Problem	181
5.2.1	The Principle of Maximum Likelihood	181
5.2.2	The Maximum Entropy Method	184
5.2.3	Bayesian Estimation	186
5.2.4	Some Useful Expressions for the Probabilistic Approach of Inversion	187
5.2.4.1	Normal Distribution	187
5.2.4.2	Smoothness	188
5.2.4.3	Weighted Least Squares	189
5.2.4.4	Parameter Boundaries	189
5.2.4.5	More on a Priori Information	190
	References	192
Chapter 6	ANALYTIC INVERSION	
6.1	General Principles	197
6.1.1	Combination of Components	197
6.2	Examples of Analytic Inversion	200
6.2.1	Magnetometry	200
6.2.2	EM Magnetic Dipole and an Infinitely Well Conducting Half-Plane	207
	References	211
Chapter 7	ADVANCED INVERSION METHODS	
7.1	Functional Analytical Methods	215
7.1.1	Methods of Singular Points	216
7.1.2	Method of Tightening Contours	216
7.1.3	Method of Finite Functions	219
7.2	Continuation of Fields	222
7.3	Migration	226
	References	226
Chapter 8	ERROR ANALYSIS	
8.1	Introduction	231
8.2	On Linearized Errors	232
8.3	Minimal Error in Least-Squares Inversion	233
8.4	Correlation Between Parameters	234
8.5	Advanced Concepts of Error Analysis	240
	References	243
Chapter 9	PARALLEL COMPUTATION IN MODELLING AND INVERSION	
9.1	Parallelism in Geophysical Problems	248
9.2	Forward Problems	249
9.3	Inversion by Optimization	250
9.4	Large Systems of Equations	253
	References	254
	SUBJECT INDEX	257