

Contents

1	Introduction	1
1.1	The Shale Revolution	2
1.2	Traditional Modeling	4
1.3	A Paradigm Shift	4
2	Modeling Production from Shale	7
2.1	Reservoir Modeling of Shale	9
2.2	System of Natural Fracture Networks	10
2.3	System of Natural Fracture Networks in Shale	13
2.4	A New Hypothesis on Natural Fractures in Shale	14
2.5	Consequences of Shale SNFN	16
2.6	“Hard Data” Versus “Soft Data”	18
2.7	Current State of Reservoir Simulation and Modeling of Shale	19
2.7.1	Decline Curve Analysis	20
2.7.2	Rate Transient Analysis	21
2.8	Explicit Hydraulic Fracture Modeling	22
2.9	Stimulated Reservoir Volume	24
2.10	Microseismic	27
3	Shale Analytics	29
3.1	Artificial Intelligence	33
3.2	Data Mining	33
3.2.1	Steps Involved in Data Mining	34
3.3	Artificial Neural Networks	35
3.3.1	Structure of a Neural Network	36
3.3.2	Mechanics of Neural Networks Operation	38
3.3.3	Practical Considerations During the Training of a Neural Network	41

3.4	Fuzzy Logic	55
3.4.1	Fuzzy Set Theory	57
3.4.2	Approximate Reasoning.	59
3.4.3	Fuzzy Inference.	60
3.5	Evolutionary Optimization	62
3.5.1	Genetic Algorithms	63
3.5.2	Mechanism of a Genetic Algorithm.	64
3.6	Cluster Analysis	66
3.7	Fuzzy Cluster Analysis.	68
3.8	Supervised Fuzzy Cluster Analysis.	70
3.8.1	Well Quality Analysis (WQA).	71
3.8.2	Fuzzy Pattern Recognition.	74
4	Practical Considerations	83
4.1	Role of Physics and Geology	84
4.2	Correlation is not the Same as Causation	84
4.3	Quality Control and Quality Assurance of the Data	86
5	Which Parameters Control Production from Shale	91
5.1	Conventional Wisdom	92
5.2	Shale Formation Quality.	93
5.3	Granularity	98
5.4	Impact of Completion and Formation Parameters	98
5.4.1	Results of Pattern Recognition Analysis	99
5.4.2	Influence of Completion Parameters	102
5.4.3	Important Notes on the Results and Discussion.	106
5.5	Chapter Conclusion and Closing Remarks	106
6	Synthetic Geomechanical Logs	109
6.1	Geomechanical Properties of Rocks	109
6.1.1	Minimum Horizontal Stress.	110
6.1.2	Shear Modulus	110
6.1.3	Bulk Modulus	110
6.1.4	Young's Modulus	111
6.1.5	Poisson's Ratio	112
6.2	Geomechanical Well Logs	112
6.3	Synthetic Model Development	113
6.3.1	Synthetic Log Development Strategy.	115
6.3.2	Results of the Synthetic Logs	116
6.4	Post-Modeling Analysis	124
7	Extending the Utility of Decline Curve Analysis	127
7.1	Decline Curve Analysis and Its Use in Shale.	127
7.1.1	Power Law Exponential Decline	129
7.1.2	Stretched Exponential Decline.	130

- 7.1.3 Doung’s Decline 130
- 7.1.4 Tail-End Exponential Decline (TED). 132
- 7.2 Comparing Different DCA Techniques. 134
 - 7.2.1 Is One DCA Technique Better Than the Other? 136
- 7.3 Extending the Utility of Decline Curve Analysis in Shale 140
 - 7.3.1 Impact of Different Parameters on DCA Technique 140
 - 7.3.2 Conventional Statistical Analysis Versus Shale Analytics 142
 - 7.3.3 More Results of Shale Analytics 144
- 7.4 Shale Analytics and Decline Curve Analysis 151
- 8 Shale Production Optimization Technology (SPOT) 153**
 - 8.1 Dataset 153
 - 8.1.1 Production Data. 153
 - 8.1.2 Hydraulic Fracturing Data 154
 - 8.1.3 Reservoir Characteristics Data 154
 - 8.2 Complexity of Well/Frac Behavior 155
 - 8.3 Well Quality Analysis (WQA) 164
 - 8.4 Fuzzy Pattern Recognition 175
 - 8.5 Key Performance Indicators (KPIs). 183
 - 8.6 Predictive Modeling 197
 - 8.6.1 Training, Calibration, and Validation of the Model 197
 - 8.7 Sensitivity Analysis 201
 - 8.7.1 Single-Parameter Sensitivity Analysis 202
 - 8.7.2 Combinatorial Sensitivity Analysis 208
 - 8.8 Generating Type Curves 211
 - 8.9 Look-Back Analysis 220
 - 8.10 Evaluating Service Companies’ Performance 224
- 9 Shale Numerical Simulation and Smart Proxy 229**
 - 9.1 Numerical Simulation of Production from Shale Wells. 229
 - 9.1.1 Discrete Natural Fracture Modeling. 230
 - 9.1.2 Modeling the Induced Fractures 231
 - 9.2 Case Study: Marcellus Shale 233
 - 9.2.1 Geological (Static) Model 233
 - 9.2.2 Dynamic Model. 234
 - 9.2.3 History Matching. 235
 - 9.3 Smart Proxy Modeling 237
 - 9.3.1 A Short Introduction to Smart Proxy. 237
 - 9.3.2 Cluster Level Proxy Modeling. 238
 - 9.3.3 Model Development (Training and Calibration) 240
 - 9.3.4 Model Validation (Blind Runs) 247
- 10 Shale Full Field Reservoir Modeling 251**
 - 10.1 Introduction to Data-Driven Reservoir Modeling (Top-Down Modeling) 253

- 10.2 Data from Marcellus Shale 255
 - 10.2.1 Well Construction Data 255
 - 10.2.2 Reservoir Characteristics Data 256
 - 10.2.3 Completion and Stimulation Data 258
 - 10.2.4 Production Data 258
- 10.3 Pre-modeling Data Mining 259
- 10.4 TDM Model Development 260
 - 10.4.1 Training and Calibration (History Matching) 260
 - 10.4.2 Model Validation 262
- 11 Restimulation (Re-frac) of Shale Wells 267**
 - 11.1 Re-frac Candidate Selection 268
 - 11.2 Re-frac Design 272
- Bibliography 279**



<http://www.springer.com/978-3-319-48751-9>

Shale Analytics

Data-Driven Analytics in Unconventional Resources

Mohaghegh, S.D.

2017, XIV, 287 p. 243 illus., 235 illus. in color.,

Hardcover

ISBN: 978-3-319-48751-9