

Seismic Petrophysics in Quantitative Interpretation

Investigations in Geophysics Series No. 18

Lev Vernik

Rebecca Latimer, managing editor
Tad Smith, volume editor



SOCIETY OF EXPLORATION
— GEOPHYSICISTS —

Contents

About the Author	vii
Preface	ix
Acknowledgments	xi
Chapter 1: Petrophysics of Siliciclastic Rocks	1
Petrophysical classification of siliciclastics	1
Petrographic data and petrophysical classification	1
Application to the core/log database	4
Petrophysical model building	8
Lithologic parameters V_{cl} and V_{sh}	8
Total porosity	11
Permeability prediction in siliciclastics	13
Seismic petrophysics.....	17
Log editing	20
Sonic log	20
Density log	20
Anisotropic correction of sonic logs	23
Chapter 2: Pore Pressure and Stress State	29
Shale-compaction model.....	29
Porosity reduction.....	29
Density model for stress computation.....	31
Vertical effective stress	32
Pore-pressure prediction from shale velocity	34
Sonic velocity versus effective stress in shales	34
Pore-pressure prediction	36
The effective-stress tensor and the S_{hmin} gradient	40
Chapter 3: Seismic Rock Properties and Rock Physics	43
Theoretical models in rock physics.....	43
Fluid-saturation effect.....	43
Drained rock-frame moduli.....	45
Cracks in dry and fluid-saturated rocks: The effect of aspect ratios	46
Drained rock-frame moduli: A mixture of cracks and pores	47
Effects of pore/crack interactions	49
Contact models	51

Drained frame moduli and effective stress	52
Rock-physics modeling in sand/shale sequences	56
Pore shapes and porosity thresholds in sands	56
Consolidated sandstones	58
Unconsolidated and poorly consolidated sands	61
Sandstone diagenesis models	64
Conventional shales	66
Rock-physics templates in siliciclastic sequences	69
V_P - V_S and AI - SI relationships in siliciclastics	72
The V_P - V_S relationship	72
The AI - SI relationship	76
Fluid substitution and the AI - SI template	78
4D modeling of sands and sandstones	80
Chapter 4: AVO Analysis: Rock-physics Basis	87
Linearized AVO equations and their features	87
AVO classification in AI - SI space	89
From the AI - SI template to synthetic-gather models	91
AVO Class III and the zero-gradient case	91
AVO Class IV	93
AVO Classes I and II	95
VTI anisotropy effect	97
The fluid factor in prospect risk mitigation	100
Tuning effects in AVO synthetic modeling	101
Chapter 5: Simultaneous AI-SI Inversion and N/G Computation	105
Log editing and the AI - SI template	105
Anisotropy correction of sonic velocities	106
Additional log editing	107
AI - SI crossplot	107
Modeling N/G	109
Seismic N/G computation from simultaneous inversion	111
AI - SI inversion	111
Sand volume computation and net/gross mapping	114
Effects of lithology and fluid on prestack attributes	118
Chapter 6: Seismic Petrophysics of Unconventional Reservoirs	121
Petrologic data in unconventional shales	121
Rock composition	121
Organic richness and thermal maturity	122
Rock texture	126
Log model for unconventional shales	129
Microstructural observations	129
Kerogen-fraction log	131
Total porosity and kerogen porosity	131
Water saturation	133
Model applications	134
Rock physics of unconventional shales	137
Core measurements of velocity and anisotropy	137
Phase velocity versus group velocity	139
Intrinsic velocity and anisotropy	141
Effect of kerogen on velocities and anisotropy	144

Stress dependence of velocity and anisotropy	153
Modeling stress dependence	155
Rock-physics model	158
V_P - V_S and AI - SI relationships	162
Chapter 7: Geomechanics of Organic Shales	167
Elastic-property relationships in TI shales	167
Can brittleness be estimated from elastic properties?	168
Static and dynamic elastic parameters in anisotropic mudrocks	169
Elasticity-based brittleness of organic mudrocks: A controversial notion	171
S_{hmin} stress-gradient estimation	173
Uniaxial-strain-based approach	173
Anisotropy prediction in organic and conventional shales	174
Stress profiling from log data	175
Geomechanics of maturation-induced microcracking	176
Chapter 8: Seismic Analysis in Unconventional Shales	183
Reservoir-scale anisotropy estimation	183
Seismic ties	184
TOC estimation from an AI - SI template	186
AI - SI Inversion of Prestack Seismic Data	191
TOC mapping	191
S_{hmin} stress-gradient mapping	194
References	199
Index	209