

Cambridge University Press

978-1-107-19411-3 — Quantitative Analysis of Geopressure for Geoscientists and Engineers

Nader C. Dutta , Ran Bachrach , Tapan Mukerji

Index

[More Information](#)

Index

- abnormal pressure, 7
- acoustic tools, 313–319
 - Chapman method, 318–319
 - cycle skipping, 314
 - Eaton method, 317–318
 - HJ-method, 315–317
- amplitude inversion, 260
- amplitude versus offset, 262
- angle of internal friction, 38
- anisotropic tomography, 308
- anisotropy
 - correction, 287–289
 - elastic, 48
 - elliptical, 239
 - horizontal transverse, 237
 - orthorhombic, 54
 - seismic, 236
 - Thomsen’s parameters, 53, 237, 287
 - tilted transverse, 237
 - transverse isotropy, 51, 237, 282
 - vertical transverse, 237
 - weak approximation, 239
- anellipticity, 239
- Archie’s law, 324
- Arp’s empirical formula, 328
- aquathermal pressuring, 127–128
- attenuation coefficient, 276
- AVO *see* amplitude versus offset
- basin and petroleum system modeling, 368; *see also* basin modeling
 - one-dimensional, 379, 498
 - two-dimensional, 386
 - three-dimensional, 388
 - Bayesian framework, 471
 - calibrated, 364–366
 - governing equations, 369–370, 498
 - Gulf of Mexico, 386
 - Monte Carlo sampling, 471, 473
 - numerical solution, 498
 - turnaround time, 367
 - uncertainty, 471–478
 - velocity, 471, 475
- Bayes net, 469
- Biot’s coefficient, 57, 59, 69
 - anisotropic, 438
- Biot’s effective stress, 57
- borehole
 - failure modes, 426–427
 - Kirsch solution, 424
 - shear failure, 426
 - stability, 423
 - stress distribution, around, 424
 - tensile failure, 427
- Brown and Korringa, 61
- bulk modulus, 46
- buoyancy effect of hydrocarbon, 122–125
- capillary pressure, 28
- carbonates, pore pressure prediction, 175–180, 459
 - Biot model, 178
 - compressibility model, 176
 - inversion of seismic data, 179
 - wavelet transformation model, 178
- casing design, 18–19
 - safe mud window, 19, 187
- centroid effect, 453
- checkshot, 223
- CIP *see* common image point
- CIP tomography, 281
- Clausius–Duhem inequality, 44
- cohesion, 38
- common image point, 247
- compaction, 65, 87–90, 371–380
 - Athy’s model, 90–91
 - chalk, 94
 - comparison of Bowers’ and Dutta’s models, 173–175
 - differential, 65
 - disequilibrium (undercompaction), 1, 85–93
 - empirical law, 66
 - fluid flow, hydrological model, 94–96
 - Lagrangian coordinates, 376, 498
 - mechanical, 65, 87
 - mechanical compaction measurements, 87–89
 - nonsiliceous sediments, 93–94
 - numerical computation, 382–386, 498
 - sand-on-shale, 379
 - shales, 87–90
 - shale-on-shale, 372–379, 498
 - Terzaghi’s law, 90
- compressibility, 64, 65
 - conservation of angular momentum, 43
 - conservation of energy, 43
 - conservation of mass, 41
 - constrain the velocity, 283

- continuum mechanics, 41
- convolutional neural networks, 489
- coupling
 - density-velocity, 343
 - resistivity-velocity, 343
- critical pressure, 74
- cross-gradient, 344
- cuttings, density measurements on, 335
- Darcy's law, 62, 63
- d*-exponent, 353
 - example application, 354
 - workflow, 354–355
- deep neural networks, 489
- density measurements tools, 326–327
- diagenesis, 97–111
 - Arrhenius equation, 98
 - burial metamorphism of shale, 99–100
 - cation exchange capacity (CEC), 106
 - chemical, 97–111
 - chemical kinetics, 98–99
 - diagenetic function, 105
 - profiles of chemical diagenesis, 107–111
 - shale burial diagenesis, modeling, 102–107
 - shale diagenesis, importance of, 101
 - smectite-to-illite transformation, 99–100, 500
 - thermal transients, 107
 - type II process, 105
 - type I process, 105
- dilatation, 40
- dissipation function, 44
- Dix relation, 230
- drilling
 - dynamic kill drilling, 418
 - mud (drilling fluid), 311
 - parameters, 467
 - penetration rate, 467
 - safe mud window, 438
 - terminology, 497
- drilling methods to evaluate pore
 - pressure, 329–337
 - d*-exponent method, 330
 - dc*-exponent method, 331–333
 - penetration rate, 329
- Dutta's model, 325–326
- dynamic kill drilling, 418
- Eaton's method, 323
- effect of water depth, 208
- elasticity
 - elastic constants, 45
 - Hooke's law, 44
 - Poisson's ratio, 46, 51, 52
 - strain, 39
 - stress, 33
 - third-order, 448
 - Young's modulus, 45, 51, 53
- environmental corrections, 311
- equation of motion, 46
- equation of state, 43
- extended leak off test (XLOT), 75, 189
- effective stress, 9–12, 57, 90
- effective stress methods, 149
- Bowers' method, 166–171
- bulk density, diagenetic trend of, 163
- compaction models, 150–151
- critical porosity, 151
- Dutta's method, 154–160, 286
- Issler's equation, 152
- NCT-trend, 166
- porosity–velocity relations, 151
- relations between velocity and effective stress, 154
- shale classification scheme, 160
- smectite-to-illite, complete transition, 161–163
- smectitic and illitic shales, trends for, 160
- velocity versus effective stress, 158
- velocity–porosity–clay content relationships, 153
- effective vertical stress and Terzaghi's law, 9–12, 90
- Biot's consolidation coefficient, 11
- elastic waveform inversion (FWI), 408, 410
 - example, 409
- equivalent circulation density (ECD), 17
- first law of thermodynamics, 43
- flowline temperature, 335
- fluid properties, 491–495
 - brine, 380, 491
 - gas, 494
 - oil, 492
- fluid substitution, 60, 61
- formation pressure, 1, 12–15
 - geopressure characterization, 12
 - transition zone, 12
- formation temperature, 209
 - Horner method, 210–211
 - velocity method, 211–214
 - basin modeling method, 214
- fossil pressure, 126
 - datum change, 126
- fracture
 - hydraulic, 75
 - modes, 71
 - stability, 72
- fracture gradient measurement, 189–191
- fracture gradient of formation, 189
- fracture pressure, 17, 189–191
- fracture gradient prediction, 189–191
 - Daines' method, 193
 - Eaton's method, 192
 - Hubbert and Wills' method, 191
 - Matthews and Kelly's method, 192
- friction angle, 38
- full waveform inversion, 255, 256, 281, 484
- FWI *see* full waveform inversion
- gas hydrate, 414, 415
 - joint industry project (JIP), 416
- Gassmann, 60
- genetic algorithm (GA), 408
- geohazards, recommendation for detection
 - of, 419
- geopressure, 1, 29
- geohazard, 392–393
 - classification, 393
- geomechanics, 421
- geopressure mechanisms, 85–128

- geopressure, methods to predict, 135–180
 - Eaton’s method, 145–146
 - Eaton’s method, misuse of, 146–147
 - Eberhart–Phillips method, 143–144
 - equivalent depth method, 147–148
 - Hottman and Johnson, 136–142
 - Hottman and Johnson’s data, 137
 - Pennebaker, 135–136
 - pressure calibration charts, 140
 - ratio method, 144
 - weaknesses of the methods, 142
- geostatistics, 470
- glossary, 31
- gravity
 - anomaly due to point mass, 339
 - inversion, 340
 - measurements, 340
 - Newton’s law of, 339
- Griffith, 72, 73
- guide for safe drilling practices, 21–23
 - economic basement, 23
 - exploration use, 23–26
 - lost circulation, 23
 - shallow water flow (SWF) sands, 26, 393–395
- gypsum to anhydrite transformation, 119
- head, 4–5
 - hydraulic head, 5
 - pressure head, 4
- Hooke’s law, 44
- horizontal stresses, 187
- hydraulic fracturing, 73, 74
- hydrocarbon accumulation (traps), 130–132
- hydrocarbon column height, 29
- hydrocarbon generation, 112
 - model, hydrocarbon generation, 112–119
- hydrostatic pressure, 3–4
 - dead oil, 4
 - live oil, 4
- importance of geopressure, 19–30
- integration of disciplines, 487
- internal friction angle, 434
- inversion
 - amplitude, 260
 - cooperative inversion, 343
 - EM, 342
 - full waveform, 255, 256, 281, 484
 - gravity, 340
 - joint, 343
 - poststack, 260
 - prestack, 261
 - simultaneous joint, 343, 344
- kick-margin, 187
- Kirsch solution, 424
- Lagrangian coordinates, 376, 498
- Lamé constants, 45, 59
- lateral stress (tectonic), 96–97
- shale diapirism, 97
- lateral transfer of fluids, 119–122, 303
- leak-off point, 74
- leak-off test (LOT), 74, 190
- link function, 344
- LOP *see* leak-off point
- lost circulation, 188
- LOT *see* leak-off test
- machine learning, 487–490
 - convolutional neural networks, 489
 - deep neural networks, 489
 - training data, 489
- magnetotellurics, 341
- manage nonuniqueness, 297
- Maxwell’s equations, 342
- MEM *see* mechanical earth model
- mechanical earth model, 428, 467
 - carbonate reservoir, 442
 - four-dimensional, 446
 - Gulf of Mexico, 444
 - life-of-the-field cycle, 430
 - one-dimensional, 429
 - probabilistic, 470
 - three-dimensional, 441
 - time-lapse, 446
- modulii
 - dynamic, 55, 56, 57
 - static, 55, 56
- Mohr circles, 37
- Mohr–Coulomb failure criteria, 38
- moveout
 - normal, 228
 - nonhyperbolic, 237
- moving boundary conditions, 376, 498
- MT *see* magnetotellurics
- mud logging, 334, 337
- mud-gas logging, 334
- mud window *see* safe mud window
- MWD and LWD, 313
- natural strain increment, 65, 67, 68
- normal compaction trend, 133, 166, 348
 - importance of temperature, 143
 - uncertainty analysis, 469
- osmosis, 128
- overpressure, 1, 7
- overburden stress (aka lithostatic stress), 7–9
 - See also* geopressure mechanisms, methods to predict geopressure
- See also* predicting and detecting geopressure, useful techniques for, 130–131
- overburden stress determination, 200–208
 - Amoco method, 202
 - Barker and Wood method, 204–206
 - compaction, depth-dependent model, 204
 - direct method, 201
 - Dutta method, 203
 - indirect methods, 202–208
 - methods that use velocity as input data, 204–206
 - Traugott method, 202
 - Zamora method, 203

- permeability, 30–31
 - absolute permeability, 30
 - effective permeability, 31
 - flow equation, 30
 - Kozeny–Carman equation, 31
 - relative permeability, 30
 - shale, 380–381
- Poisson's ratio, 46, 51, 52
- pore pressure, 320
 - pressure analysis, tools for, 310
 - pore pressure domain, angle gathers, 289–291
 - pore pressure from log-derived shale values, 313–329
 - pore pressure gradient scan, 290
 - pore pressure, subsalt, 197
 - pore pressure gradient, 5–7
 - conceptual display, 313
 - equivalent mud weight (EMW), 5–6
 - pore pressure, measurement of, 180–182
 - DST tool, 181, 352
 - MDT tools, 181
 - Repeat Formation Tester (RFT), 180, 352
- poroelasticity
 - consolidation, 63
 - linear stress–strain relation, 60
 - Skempton's coefficient, 61
 - static, 59
- poststack inversion, 260
- potential field, 338
- predicting and detecting geopressure, useful techniques for, 130
- pressure pulse transient analysis, 182
- pressure transition zone, 134–135
- prestack inversion, 261
- Q *see* quality factor
- quality factor, 274
- ray tracing, 247, 248
- real-time pressure prediction, 348–352, 486
 - how often?, 349
 - process, 349–351
 - meaning of real-time, 348
 - when is this needed?, 348
- reflection tomography, 246
- residual migration, 248
- residual moveout, 247
- resistivity logging, 320–326
- revolution seismic survey, 464
- RMO *see* residual moveout
- rock physics guided workflow, 282–285
 - basic concept, 284–285
 - Dutta model, 286
 - input parameters, 285
 - rock physics model, 286–287
 - rock physics template (RPT), 287
 - RPGVM, 287, 308
- Thomsen's parameters, 287
- example applications, 291–306
 - full waveform inversion (FWI), 306–308
 - Green Canyon Area, 301
 - Gulf of Mexico, USA, 295
 - Indonesia, Makassar Straits, 291
 - offshore India, 294
- safe casing program, 187
- safe mud window, 187, 438
- seals, seal capacity and pore pressure, 27
- seal capacity, 28
- seal capacities of rocks, 29
- second law of thermodynamics, 43
- seismic inversion, 399
 - traffic light map, 404, 407
 - workflow, 399–407
- seismic while drilling (SWD), 356–364
 - drill-bit SWD, 356–364
 - overpressured zones, prediction, 358
 - shale formation factor, F, 323–325
 - shallow gas, 411
 - ocean bottom nodes, 413
 - shallow hazard, 392
 - shallow-water-flow (SWF) sands, 393–395
 - BOEM notices to the leaseholders (NTLs), 395
 - environment, 393, 396
 - identification, geophysical techniques for, 398
 - rock properties, 398
 - Shell's Ursa (MC 810) disaster, 395
 - shear wave velocity *see* velocity, S-wave
 - simultaneous joint inversion (SJI), 343, 344
 - Skempton's coefficient, 61
 - smectite-to-illite transformation, 99–100, 500
 - strain
 - elastic, 65
 - extensional, 40
 - infinitesimal, 39
 - plastic, 55, 65
 - shear, 41
 - total, 65
 - volumetric, 65
 - stress
 - Cauchy, 33
 - effective, 57, 58, 60
 - path, 54
 - plane, 39
 - principal, 36
 - regimes, 454
 - shear, 37
 - symmetry, 36
 - subsalt wells, fracture pressure modeling, 197
 - technology
 - adapting, 490
 - disruptive, 481
 - tensor
 - definition, 33
 - transformation, 33, 36
 - Terzaghi's effective stress, 57
 - third-order elasticity, 448
 - Thomsen's parameters, 53, 237, 287
 - TI *see* anisotropy, transverse isotropy
 - time domain velocity analysis, 232
 - TOE *see* third order elasticity

- tomography, 246–254
 limitations, 253
 pore pressure prediction, 250
 ray tracing, 247, 248
 reflection, 246
 well-constrained, 249
 workflow, 249
torque and drag parameters, 334
traction, 34
transverse isotropy, *see* anisotropy, transverse isotropy
trip margin, 187
TTI *see* anisotropy, tilted transverse isotropy
UCS *see* unconfined compressive strength
uncertainty analysis, 468–478
 basin modeling, 471–478
 Bayesian Monte Carlo, 469
 Bayes net, 469
 geostatistics, 470
 Gulf of Mexico, 472
 normal trends, 469
 posterior distributions, 469, 470, 472, 477
 prior distributions, 468, 471, 477
 spatial uncertainty, 470
unconfined compressive strength, 433
unconventional reservoirs, 485, 489
underpressures or subpressures, 1, 15–17
units and dimensions, 2–5
velocity
 analysis, time-domain, 232
 analysis tools, 461–464
 basin modeling, 471, 475
 geologically complex areas, 463
 group velocity, 238
 horizontal, 238
 NMO velocity, 229, 238
 P-wave, 48, 221
 RMS velocity, 229
 rock physics guided, 287, 308, 463, 464, 483
 road ahead, 482
 S-wave velocity, 48, 221, 271, 273
 sonic velocity, 225
vertical seismic profiling, 224
viscosity, 380
void ratio, 67
Voigt notation, 48
 V_P/V_S ratio, 222, 271, 273
VSP *see* vertical seismic profiling
VSP-WD, 356, 360
 clarifications, 363
 example, 362
 Saudi Aramco's version, 364
water viscosity, 380
wave equation, 47
weak anisotropy approximation, 239
well-constrained tomography, 249
well logs, 311–313, 466
 recommendations, 327–329
XLOT *see* extended leak off test
Young's modulus, 45, 51, 53