

# Index

*Note:* Page numbers denoted in *italics* refer to figures and those in **bold** refer to tables.

- @ Risk 193, 199, 201
- acoustic impedance map 216
- analogue modelling 87
  - scale of 88
- anchoring 147, 148–149, 154, 158
- auto-ranked models 29–31, 30
- azimuth map 69, 72
  
- base case modelling 145–148, 146, 158, 166, 194, 195
- basement rooted faults 44, 44
- bedset surfaces 108–109, 108, 110, 118
- bootstrap method 65
- boundary conditions 135, 136, 140, 140
- Box-Behnken technique 155
  
- capillary entry pressure 22
- carbonate facies 39–49
  - diagenetic properties 39–49
  - fracture properties 39–49
- carbonate reservoirs 41
  - modelling 39
- cementation 46, 46
- clay content 12, 14, 15, 17, 18, 19, 20, 51
  - and threshold pressures 22, 23
- clay mixing algorithms 17
- clay smear 17–19
  - calculations 33
  - permeabilities 17
  - potential 17–19
  - value 19
- clay smear factor (CSF) 17
- clinoform 100, 118
  - barriers 99–121
  - effects on flow 99, 100, 102, 118
  - geometry 1, 99, 113
  - length scales 118
  - model hypotheses 113–115, 117
  - shale length 117–118
  - and water flood direction 118
- cloud transform process 89–92, 165–168, 166
  - point field 165–166
- coarse scale models 135, 137–140, 161, 170–172, 172, 183
  - flow simulation 143
- Cogollo Group 39, 42
  - conceptual model 42
  - facies model 43
- conceptual modelling 42, 69
- critical property relationships 33
- critical result traps 26–29, 27
  - input parameters 29, 29
  
- D-optimal technique 155
- data 1, 99, 205–206
  - collection methods 95, 102–103, 104, 118, 182–183
  - hard 1, 75
  - locally calibrated 36
  - processing 103
  - random sampling 138, 139
  - representativity of 127
  - sample population 60
  - sample variance 127
  - soft 1
  - types 6, 127
  - see also* digital data; gravity survey data; input data; magnetic survey data; seismic data
- Decision Analysis 161, 176–177, 178
- deep marine reservoir 51, 54, 64
  - impact index 63
- deepwater turbidite modelling 205–219
- deltaic outcrop analogues 99–121
- deltaic reservoir 99
  - highstand vs. lowstand 118–119
  - sedimentary sequence 99
- Depositional Elements scheme 209–210, 209, 211
- depositional environment 51, 55, 61, 63
  - sample population 52–53
- depositional facies 67, 163
  - model parameters 53, 54
  - modelling 67, 161, 163–165
  - realizations 164, 165
  - relationships 162
- depressurization 131
- Design of Experiments approach 2, 155–158, 156, 172–173, 174, 175, 175, 178, 202
  - advantages 157–158
  - methodology 161
  - parameters 173
  - see also* Box-Behnken technique; D-optimal technique; Plackett–Burman design
- deterministic analysis 173
- deterministic economic analysis 176
- deterministic facies model 194
- deterministic realizations 2
- diagenesis 39
  - burial 47
  - fault related 43–45
- diagenetic fluid pathways 44
- diagonal tensor method 212
- digital data 96
  - acquisition 88–90, 89–90
  - outcrop data for calibration 92–96, 93, 96
  - survey methods 88
- dipping grids 111, 113, 115, 117, 118
- discrete smoothed interpolation (DSI) 79, 81
- Dispersion Variance 128
- distribution function 196
- Dijkstra–Parsons coefficient 161, 172
- dynamic reservoir modelling 2, 145, 181
  
- effective shale gouge ratio (ESGR) 17, 19
- elastic rock properties 45
- estimation error 9–11, 10, 13
- Experimental Design analysis *see* Design of Experiments approach

- facies 39, 53, **54**, 55, **55**, 103–110
  - associations 105
  - correlation **187**
  - depocentre map 71, 71
  - scenarios 189
  - see also* carbonate facies; sedimentary facies
- facies belts 111, 112, 115
- facies conditioning 210, 210
- facies distribution 67, 110, 111, 150, 190, 210
  - multiple realizations 82–83
- facies distribution model (FDM) 67–74, 71, 73, 74
  - process 69–70
- facies modelling 41, **106**, 111–113, 125, **172**, 186–188, 206–207, 208–211
  - see also* depositional facies modelling
- facies permeability distributions 166, 166
- facies probability 76, 76
- facies probability cube 1, 67, 69–70, 71–73, 71, 74, 75, 76, 161, 164–165, 164, 165
- facies probability functions 209–210, 210
- facies proportion 76, 77
  - non stationary variations 69
- facies proportion cubes 80, 82, 82, 83, 83
- facies proportion curve 70, 76, 77–79, 79
- facies proportion map 80
- facies transition zones, uncertainty 77, 78
- fault modelling 47, 53–57, 94
- fault property modelling 51, 55–57, 56, 62, **62**
- fault seal 26–33
  - algorithm 51
  - mapping 5–38
  - parameters 54–55
  - single fixed relationships 33–34
- Fault Seal Toolbox 5
- fault throw 32–33, 51, 53
  - net offset 9–11, 10
  - standard deviation 7
- fault tips 44, 45
- fault transmissibility 11, 125
  - multipliers 11, 27, 27, 30, 33, 36, 53, 207, 218
- fault zone
  - complexity scale 6
  - physical properties 6
  - processes 16
  - structure 6
- fault-horizon intersection geometries 8–9
- fault-horizon projection distances 8, 9
- faults 39
  - classification 1, 7
  - compartmentalization 185
  - data 94
  - density 51, 52, 53
  - dipping reverse 129
  - displacement 11, 12, 13
    - and flow magnitude 1
  - geohistory 8–9
  - mislocation 9
  - patterns 51
  - permeability 19, 20, 51
  - principal slip surface 9, 10
    - and rock thickness 11, 12, 13
  - sealing nature 19, 22, 26–33
  - spacing 129
    - staircased 129
    - structural style 8–9
    - threshold pressures 22
    - Y-shaped 129
    - see also* basement rooted faults; growth faults; relay faults
- Ferron Member 99–121
  - bedset surfaces 108
  - data 103
- FFM2003 model, workflow 205–207
- fine scale models 135, 138, 170–172, 178, 211
- fixed volume grid 51
- flow barriers 215–216
  - strength 218
- flow equations 59
- flow properties
  - macroscopic 126
  - sedimentary structures 123
- flow simulation 51, 52, 57, 57, 99, 112, 113, **114**, 115, 116, **117**, 123, 161, 207
  - accuracy 130
  - coarse scale models 143
  - global approach 140
  - parameters **119**
  - single phase 140
  - software 103
  - uncertainty 161–179
    - and upscaling 135–144
- fluid contacts 185–186
- fluid pathways 1, 43, 44, 53
- fluvial reservoirs 51, **54**, 65
  - impact index 64
- folds
  - 3D geometry 95–96
  - development 95
  - strain accommodation 9
- forward flow modelling 30–31
- fractional flow curves 218
- fractures *see* faults
- framework modelling, fluid contact 185–186
- gas injection 131, 132
- gas–oil contacts 212–213
- geocellular grid 5, 8, 19, 206
  - incorporating uncertainty 22–26
  - parameter modifications 22–25
- geocellular modelling 8, 39
- geocellular stratigraphic grid 163
- geological modelling 1–3
  - 3D 1
    - calibration 92–96
    - case study 93–96
    - Glitne Field, North Sea **197**
    - realizations **52**, 211
    - uncertainty 161–179
    - validation 170
    - workflow 183
- geomechanical model 45, 435
- geometric coherency tool 7
- geometric parameters 22, 68–69, **68**
  - macro scale uncertainties 6–8, 7
  - relationships 6, 34
  - uncertainties 6–11

- geophysical data 87
- geospatial data, 3D models 91–92
- geostatistical simulation 148–149, 158
  - facies 82, 82
- gigascope scale 123
- Glitne Field, North Sea 193–203
  - base case model 195
  - geological parameters **197**
  - location 193–194, 194
  - reservoir map 199
  - well locations 195
- global single phase simulation 143–144
- global uncertainty 31, 32, 33, 36, 77
- Gocad software 68
- gravity survey data 87
- gridding algorithm 110
- gridding software 129
- grids 112
  - construction 129–131
  - design for structure mapping 207–208
  - manual editing 129–130
  - multimillion grid cells 135
  - resolution 110, 129, 187, 208
  - strategies 110–111, 118
  - unstructured 130
  - see also* dipping grids; fixed volume grid; geocellular grid; geocellular stratigraphic grid; regular grids; simulation grid; stratigraphic grid
- ground penetrating radar (GPR) 90
- growth faults, modelling 113
- High Impact Visualization Environment (HIVE) 90–91, 91
- history matching 47, 137–140, 137, 152, 153, 183, 189–191, 207, 211, 216, 217, 218
  - automatic 155
  - dataset 213
  - tools 152–153
  - see also* multiple history matching
- horizon, angular discordance 7, 9
- hybrid reference model 211
- hydrocarbon charge 39, 46
  - diagenesis 46–47
  - modelling charge history 46
- hydrocarbon column, cross fault 22
- hydrocarbon contact 181
- hydrocarbon probability distribution 169
- hydrocarbon production
  - fault factors 51, 57
  - forecast 75, 123, 152
  - tectonic parameters 51
  - variable 59–60, 64
  - see also* oil production
- hydrocarbon recovery 1–3, 161
  - estimating 135
  - role of modelling 2
  - see also* improved oil recovery (IOR); oil recovery
- hydrocarbon volume 157, 205
  - 3D 210
  - cumulative curve 168–169, 169
  - potential 194–196
  - prediction uncertainty 216–218
  - sensitivity 168–169, 168
  - uncertainty 193
- Icotea Formation 186–187
  - facies distribution 190
- impact index 62, 63
- improved oil recovery (IOR) 126
- indicator simulation 124
- input data 1, 87, 148–149, 193, 194
  - format 60
- IRAP RMS software 103, 110, 193, 196, 196–197, 199, **200**
- isochores, true vertical thickness 184
- juxtaposition analysis 26
- laser scan point cloud data 89–90, 90–91, 91
  - meshing 91, 91
  - picking 92, 92
  - see also* cloud transform process; terrestrial laser scanning (lidar)
- leaching zones 44, 44, 45, 46, 48
  - potential 45
- leak probability 20, 21
- log based electrofacies scheme 208–211
- magnetic survey data 87
- Maracaibo Basin, Venezuela 39, 40
- Misoa Formation 186
- model parameters
  - bulk values 55
  - clustering 31
  - dependence between 154
  - non stationarity 75
  - relationships 9
  - rules 6, 9
- modelling 44–45
  - assessing discrepancies 8
  - interpretation 60
  - results comparison 64
  - simulation time 72
  - see also* analogue modelling; base case modelling; conceptual modelling; depositional facies modelling; dynamic reservoir modelling; facies modelling; fault modelling; forward flow modelling; geocellular modelling; geological modelling; multiscale modelling; numerical based modelling; object based modelling; probabilistic simulation; scenario based modelling; static modelling; stochastic modelling; variogram based modelling
- modelling scale 88
- modelling software *see* software
- models
  - grid 112
  - resolution 19, 126
  - scale 1–2
  - tectonic parameters 1
  - testing with well data 212–213, 214
  - see also* coarse scale models; facies distribution model; FFM2003 model; fine scale models; flow simulation; geomechanical model; outcrop models; SPE 10 model

- Monte Carlo simulation 157, 196, 199–202
- multimillion grid cells 135
- multiple deterministic scenarios 145, 145–146, 146, 148, 151
  - see also* scenario based modelling
- multiple history matching 145, 158
- multiple model handling 154–155, 154
- multiple point geostatistical simulation 124, 161, 163–165
  - training image 162
- multiple point statistics (MPS) 67–74
  - advantages 72
  - constraints 69–72, 72–73
  - tidal reservoir 73, 73
- multiple probabilistic models 158
- multiple stochastic modelling 2, 145–146, 146, 147, 149, 158, 196
- multiscale modelling
  - factors 131, **131**
  - million cell model 126
  - sedimentary structures 123
- nearest neighbour resampling algorithm 111
- Neighbourhood Approximation algorithm 137–138
- net sandbody connectivity 181
- net to gross multiplier map 216
- net to gross ratio 165
  - permeability 217–218
  - porosity 184
- numerical based modelling 87
  - scale of 88
- object based modelling 1, 67, 83, 83, 99, 112, 112, 124, 164, 205, 206–207, 209
- oil production 138, 143
- oil recovery 138
- oil water contacts 185, 189, 189, 191
- oil-in-place 181, 191
  - uncertainty 217
- outcrop analogues 87–98
- outcrop data 88–90, 100
  - digital visualization 90–91
- outcrop models 110
  - quantitative 92, 93
  - visualization 96
- outcrop studies 87–88
  - quantitative data 88–90
- Panther Tongue Member 99–121
  - bedset surfaces 109
  - data 103
  - flow simulations 115
- pattern recognition methods 124
- permeability 11, 12, 53, 54, 55, **55**, **57**, 67, 127, 161, 165, 188–189, 188
  - coarse scale 137–140
  - curves 141, 142
  - cut-off 168
  - data 128, **129**
  - distribution 137, 215
  - net to gross ratio 190, 217–218
  - relative 217
  - transform 212–213
  - transmissibility multiplier 34
    - uncertainty 166, 167
    - upscaling 211–213
- petrophysical properties **106**, 110, 112
- phased development strategy 177–178, 178
- photo logs 99
  - calibrated 103, 104, 118
- photomontage 103
- pilot point approach 137–138
- Pinda Formation, geology 162
- pixel-based approach 1
- Plackett–Burman design 155–157, **157**, 172–173, **173**
- pore scale modelling, flow properties 123–124
- Pore Volume Weighted (PVW) method 141–142
- pores
  - geochemical signature 43
  - microscopic scale 123
  - secondary volume 39, 43
  - space 125
  - structure 41
  - systems 39
  - types 39
- porosity 47, 53, 55, **55**, 67, 161, 188, 188, 211
  - distribution 46, 136
  - economic 41
  - net to gross ratio 184, 206
  - profiles 42
  - realizations 190
  - uncertainty 166–168, 167
  - upscaling 211–213
- porosity–permeability transform 189, 211, 212, 214
- prediction accuracy 5, 32, 36
- pressure solution methods 135, 136, 140, 142
- probabilistic distribution curve 157
- probabilistic economic analysis 177, 177
- probabilistic simulation 161
  - forecasts 175–176
  - see also* multiple probabilistic models
- probability 26, 27–28, 27, 169
- probability density function 138, 139, 149–150, 208
- process based modelling 124
- property models 207, 211
  - parameters 11–22
- property uncertainties, fault seal analysis 11
- prospect analysis, probability 28, 29
- rationalist approach *see* base case modelling
- Real Time Kinematic GPS 87, 89–90, 90, 95, 96
- realizations 2, 25–26, **52**, 82–83, 112, 140, 164, 165, 211
  - and auto ranking 29–30
  - multiple 2, 35, 183
  - multiple stochastic 196
- recovery factor (RF) 115, 116, 117
- regular grids 111, 113, 115, 117, 118
- relay faults, displacement patterns 93–95
- Representative Elementary Volume (REV) 126, 127
  - lithofacies scale 127
  - permeability 127
- reservoir analogues, quantitative 88–92
- reservoir connectivity 186–188
- reservoir development alternatives 173–175, 176, 178
- reservoir modelling 169–173, 169, 173–178
  - calibration of 87–98
  - comparison 73–74
  - construction 110–113

- full field 205
- methodology 161–162
- multiscale 123–134
- properties 165–168
- resolution 51–52
- scale transitions 124–125
- scales 75–85, 123, 124–126
- scenario models 172–173
- simulation grid 125
- single realization 146
- software 5, 39–49, 52, 68
- strategy 118
- validation of 87–98
- workflow 112, 118, 176
- see also* modelling
- reservoir performance 117, 118, 131, **131**
- structural controls 51–66
- reservoir potential, mature field 181–192
- reservoirs
  - assessing targets 193–203
  - economic feasibility 193
  - effective properties 211
  - field development planning 123
  - heterogeneity 135–144, 186–188
  - management 1
  - productivity 181, 191
  - property extrapolation 39
  - subdivision scheme 184
  - see also* carbonate reservoirs; deep marine reservoir; deltaic reservoir; shallow marine reservoir; tidal reservoir
- response data 157
- response variable calculation 196–197
- Restricted Maximum Likelihood Method (REML) 57
- RMS finite difference black oil simulator 113
- Roxar RMS software *see* IRAP RMS software
- sand
  - net to gross values 21–22
  - sand–sand windows 33, 34, 35
- saturation distributions 142, 142
- scenario based modelling 135, 145–159, 148, 158
  - application of 150–153
  - benefits 153–154
  - issues 154
- scenario building 196–197
  - parameter clustering 31
- Schiehallion Field 205–219
  - location 206
  - model workflow 208
  - principle reservoirs 207
  - stratigraphy 205
  - structural control 205
  - well locations 213
- sedimentary facies 51, 103–110
  - 3D modelling 75–85
  - cross section 75, 76–79, 78
  - interpretation 76–77, 78
  - parameters 60
- sedimentary logs 99, 103, 104
- sedimentary structures
  - flow properties 123
  - scale 123
  - scale transitions 125
- seismic coherency, data derived barriers 215–216, 216
- seismic data 6–7, 8, 53, 69, 87
  - resolution 9
  - seismic lines 163
- seismic volume 7–8
- seismic weighting factor (SWF) 210
- semivariograms 137
- sensitivity index 62–63, 63
- Sequential Gaussian Simulation (SGS) 124, 137, 165–166, 188, 190
- Sequential Indicator Simulation (SIS) 72, 73, 82, 188, 189
- shale gouge ratio (SGR) 14–17, 51, 52, 53, 54–55, **57**
  - percentage errors 14–17, 16
  - sealing 19–22, 21
  - trap sealing nature 19
  - see also* effective shale gouge ratio (ESGR)
- shale smear factor 51, 52, 53, 54–55
- uncertainties 19
- shale volume fraction *see* VShale
- shallow marine reservoir 51, **54**, 64
  - impact index 63
- simulation grid 130, 206, 207, 218
  - automated construction 123
  - construction 129–131
- single normal equation simulation (snesim) 72
- software 1, 5, 39–49, 52, 68, 96
  - see also* IRAP RMS software
- SPE 10 model 135, 136, 136, 141, 143
- static modelling 2, 145, 163–168, 181, 183, 211
  - assurance tests 213–215, 215
  - grid 5, 206, 208
  - uncertainties 183–185
- statistical analysis 57–60, 58–59, 199–202
  - methods 124
- stereoscopic image 90–91, 91
- stochastic modelling 5, 75
  - advantages 75
  - multiple realizations 5
  - techniques 35
  - see also* multiple stochastic modelling
- Stock Tank Oil Initially In Place (STOIIIP) 193, 196, 207
  - numbers 201
  - uncertainty range 199, 201
- strain partitioning 9–11
- stratigraphic framework, influence of 79–82, 81
- stratigraphic grid 70
- stratigraphy 41
  - cross section 101
  - settings 51–66
  - studies 99–100
  - variation 12–14
- stress ratio 45
- stress values 44, 45
- structural modelling 1, 130
  - feature category 130
  - parameters 60
- structure mapping, grid design 207–208
- surface stability index 7, 7, 9
- tectonic evolution 39
  - controlled facies 47
- terrestrial laser scanning (lidar) 87, 89–90

- tidal reservoir 51, **54**, 64–65, 68–69, 70, 70, 71  
 impact index 64  
 multiple point statistics (MPS) 73, 73
- top down approach 135
- training image 68–69, 69, 72, 74, 161, 162, 163–165
- transmissibility barriers 216, 216
- transmissibility multipliers 11, 27, 27, 30, 33, 53,  
 207, 218  
 auto-ranked 30  
 predictions 32  
 zero uncertainty 36
- Truncated Gaussian Simulations (TGS) 82, 82, 99, 111
- uncertainty 5–38, 23, 65, 76, 135, 139–140, **157**, 178,  
 181–192  
 absolute value shifts 22  
 analysis 161  
 assessment 82–83  
 bias 25–26  
 distribution profiles 25  
 fault seal analysis 6, **24**  
 geometric properties 5–38, 6–11  
 handling 146–150, 146, 158  
 impact 31–32  
 incorporation techniques 5, 161–179  
 juxtaposition 9, 11  
 key parameters 172–173, **175**, 184–185, 201–202  
 lists 149–150, 150, 151, 152, 152, 153,  
 154, 155–157  
 management 2  
 modelling 10–11, 207  
 and net to gross 188–189  
 parameters 168, 200  
 percentage shifts 22  
 principle 151  
 property parameters 11–22  
 quantifying 193–203  
 range 185–189  
 ranking 77, 149–150, 150, 157, 181, 191  
 shift application 25  
 single parameter 36  
 specific risks 32–33  
 static modelling 183–185, **197**  
 volumetric 193  
 workflow method 194–202, 196, 198  
*see also* global uncertainty
- upscaling 92, 124, 129, 135–136, 136, 161, 170–171,  
 170, 207, 211  
 dynamic 141, 171–172  
 errors 2  
 factor 139, 140  
 global 140  
 methods 123, 125, 126, 135, 138, 139,  
 140–142, 170  
 multiphase 126  
 single phase 126, 135, 140, 141, 170  
 transmissibilities 140, 141  
 two phase 135, 141, 171–172
- Urdaneta West Field, Venezuela 39, 181–192  
 basement rooted faults 44  
 dataset 40  
 diagenetic fluid pathways 44  
 facies and thickness 40–43  
 geological setting 39, 181–182  
 location 182  
 modelling 41–43, 44–45  
 porosity distribution pattern 47  
 stratigraphy 183  
 structural cross section 189  
 structural history 44  
 well correlation 185, 187–188, 190  
 wells 182–183
- variance adjustment factor 128  
 variance analysis 123, 127–129, **129**  
 variance components 57, 58–59, 59–60, 60–62,  
 61, 65
- variogram based modelling 67  
*see also* semivariograms
- VClay data 14–17, 15, 22
- volume calculation output 197
- VShale distribution 14, 15, 22, 53, **54**, 55, **55**
- water alternating gas injection (WAG) 131
- water injection 152–153
- water saturation 161, 165  
 initial 214, 215
- water-wet faults 22
- waterflooding 171, 171
- well drive boundary conditions 140
- Well Drive Upscaling (WDU) method 140–142
- well log data 69, 87  
 averaging 126  
 model testing 212–213, 214
- West Africa, offshore 161–179
- Western Interior Basin, USA 99–121  
 claystone and siltstone 106  
 cross section 101  
 delta front sandstones 106  
 delta front siltstones 106–107  
 delta lobes 107–110  
 distributary channel facies 107  
 geological setting 102  
 location 101