## Index

```
analogy estimates, reserve, 44
abandonment, well, 581, 585-586, 585 (table), 586 (figure), 591, 593
                                                                             ancient geothermal fields. See geothermal field evolution
above ground factors, offshore development cost, 613,
                                                                               simulation
                                                                             anionic surfactants, 278 (table)
  613 (figure)
                                                                             anisotropic (directional) permeability, 6, 10
aboveground storage tanks. See storage
                                                                             anisotropic geothermal field 3D dynamic simulation, 117-118, 118
absolute open flow (AOF), 401-404, 401 (table), 402 (figure), 403
                                                                                (figure)
   (figure), 403 (table)
                                                                             anisotropy, 88-89, 89 (figure)
absolute permeability, 11, 13-14
absolute porosity, 10, 55
                                                                             annular pressure risk, semisubmersible project, 618
accidents, 543, 553, 553 (figure), 706, 708. See also safety
                                                                             annular preventer, BOP stack, 204, 205 (figure)
accumulation history. See hydrocarbon migration and
                                                                             antiagglomerants (AAs), 438, 439
   accumulation history simulation
                                                                             anticlinal traps, 1
                                                                             antifreeze, preventing hydrate formation with, 241-242
acid rain, 538
                                                                             apatite fission track method (AFT), 121
acids, microbial, 470
                                                                             appended geothermal field, 116
acoustic logging, 17
                                                                             aqueous stability tests, 279
acoustic resonance technique (ART), 489
                                                                             aquifer activity, Messoyakha deposit, 454, 456, 456 (figure)
active solar energy, 684
                                                                             Arbuckle reservoir, polymer gel system in, 268, 270
actual models, numerical reservoir simulation, 191
additives
                                                                             Archie's equations, 60
     asphaltene deposition treatment, 498-499
                                                                             Arctic development, deepwater, 302, 343-344, 344 (figure),
     hydraulic fracturing, 325, 326 (table), 352, 365-366
                                                                                345 (table), 347
adsorption
                                                                             Arctic environments, methane hydrate accumulation in, 333, 334
     asphaltene, 493
                                                                               (figure)
     polymer, 260 (table)
                                                                             areal sweep efficiency, 256-258, 257 (figure), 257 (table)
                                                                             aromatics, 65, 485-486, 486 (figure)
     surfactant, 281-283, 282 (table)
                                                                             Arps decline forecasting, 367, 367 (table), 368–369, 368 (figure)
adsorption isotherms, capillary pressure by, 78-79, 78 (figure)
aerobic microorganisms, in oil reservoirs, 462, 467, 468. See also
                                                                             Arps equation, 60
                                                                             artificial intelligence. See artificial neural networks; oil field data mining
   microbial enhanced oil recovery
Africa, regulatory framework in, 536-537
                                                                             artificial islands, 225, 226 (figure), 227 (figure)
                                                                             artificial lift, 337, 681
air emissions. See emissions
                                                                             artificial neural networks
alarms, emergency, 561-562
                                                                                  Dongying Sag petroleum system example, 144-145, 144
Alberta Taciuk Process (ATP), 339-340, 339 (figure)
                                                                                    (figure), 145 (figure)
Albian's process, 317
                                                                                  hidden layers, 150, 150 (figure), 151
Alcaligenes strains, in MEOR, 473
                                                                                  input layer, 150, 150 (figure), 151
algorithms, decommissioning cost, 585-591
     conductor severance and removal, 586-587, 587 (figure)
                                                                                 mechanics of operation, 150-152, 150 (figure), 151 (figure)
                                                                                 output layer, 150, 150 (figure), 151
     fixed platform removal, 589-590, 590 (table)
                                                                                 overview, 149
     floating structure removal, 590-591, 590 (table)
                                                                                 petroleum migration and accumulation simulation, 123-124,
     overview, 584
     pipeline decommissioning, 587-588, 588 (table)
                                                                                    126-130, 126 (figure), 127 (figure), 131 (figure)
     umbilical, flowline, and riser removal, 588-589, 589 (figure)
                                                                                  production optimization
     well plugging and abandonment, 585-586, 586 (figure)
                                                                                       data availability and statistical analysis, 168-170, 169
alkaline flooding, 285
                                                                                          (table), 170 (table)
                                                                                       data-driven modeling, 170-173, 171 (figure), 172
alkaline-surfactant-polymer (ASP) flooding, 285-286
alkanes, 65
                                                                                       full-asset type curve analysis, 174, 175 (figure)
ambient conditions, asphaltene precipitation in, 486-488
                                                                                       single-well, single-parameter sensitivity analysis, 173,
American Petroleum Institute (API), 547
                                                                                          173 (figure)
American Petroleum Institute (API) gravity, 3, 36, 65, 302–303,
                                                                                       single-well, type curve analysis, 173, 174 (figure)
   302 (table), 508
                                                                                       single-well uncertainty analysis, 174–175, 175 (figure)
American Shale Oil, 386
                                                                                 reservoir characterization
Amott test, 72-73, 72 (figure)
                                                                                       synthetic model, 155 (figure), 155 (table), 156-159,
amphoteric surfactants, 278 (table)
anaerobic microorganisms, in oil reservoirs, 462-463. See also
                                                                                          156 (figure), 157 (figure), 158 (figure), 158 (table),
  microbial enhanced oil recovery
                                                                                          159-161 (figure), 161 (table)
```

Valley Field case study, 161–164, 162 (figure), 163	biodegradation, oil, 462, 466, 467
(figure), 164 (table), 165-168 (figure), 165 (table)	bioemulsifiers, 472
structure of, 149–150, 150 (figure)	biofilms, 470
training set, 151-152, 156-157, 157 (figure), 158 (figure), 158	biofuels, 33, 40, 40 (figure), 40 (table)
(table)	biological hazards, 547, 561
trap geological evaluation, 131-132	biological neural networks, 149, 150 (figure)
unit bodies, 126, 126 (figure), 129-130	biological stability of polymers, 261 (table)
verification data set, 151, 158 (figure), 158 (table)	biological treatment of wastewater, 556 (table)
weights on inputs, 151–152	biology. See microbiology of petroleum reservoirs
See also oil field data mining	biopolymers, 470, 471
Asia	bioremediation, oil, 466
associations pertaining to oil and gas industry, 547-548	biosurfactants, 286, 287, 466-467, 469-473
energy future, 707	Biot coefficient, 89–90
regulatory framework in, 534–535	bit hydraulics optimization, 210
asphaltene deposition, 483-499	bit-operating conditions, 197
case study, 497-498, 497 (figure), 498 (figure)	bits, drill, 205-207, 206 (figure), 207 (figure)
current research areas, 499	bit-side forces, 224, 224 (figure)
definition and classification of asphaltenes, 483-485, 484	bitumen
(figure), 485 (table)	classification of, 287 (table)
experimental determination of, 492-495	energy future, 37–39, 38 (figure), 38 (table)
impact on oil production, 483	oil sands mining
mitigation and remediation strategies, 498–499	bitumen extraction, 317
modeling methods to predict, 495-497, 496 (figure)	bitumen upgrading, 318–319, 320 (figure), 320 (table)
SARA analysis, 485–486, 486 (figure)	challenges of, 319, 320 (figure)
See also asphaltene precipitation	general discussion, 345–346
asphaltene deposition inhibitors, 498–499	oil sand tailings, 317–318, 318 (figure), 318 (table), 319
asphaltene onset pressures (AOPs), 488–489	(table)
asphaltene precipitation, 486–492	overview, 302, 316–317
case study, 492, 492 (figure)	overview, 9
experimental determination of, 486-490	physical properties of, 302–303, 302 (table)
modeling methods to predict, 490–492	production overview, 531
overview, 486, 607	worldwide distribution of, 303–304, 303 (figure), 304 (figure
associated gas, 377	See also specific recovery methods; thermal recovery methods
associations for health, safety, and environment, 547–548	black oil, 3, 68, 68 (figure), 68 (table)
Atlantis project, 653. See also semisubmersibles	black-oil formulation, numerical reservoir simulation, 179, 179
atmosphere flow, 125	(table), 180, 181
atmospheric effects	Blind Faith development, 654. See also semisubmersibles
environmental concerns, 537–538, 537 (figure), 538 (figure)	blind rams, 205, 205 (figure)
minimizing, 554	block-centered gridding, in numerical reservoir simulation, 185,
See also emissions	185 (figure)
Australia, regulatory framework in, 536	blocks and tackle, 199 (figure), 199 (table)
average angle method, 221–222, 222 (figure)	blowout preventer (BOP) stack, 204–205, 205 (figure), 226
average molecular weight. See molecular weight	blowouts, 546, 558, 558 (figure), 618
average temperature and compressibility method, 406	Bohai oil field, polymer flooding in, 263–264
axial coring, 61	booster stations, 510–511, 510 (figure), 511 (figure)
axial load distribution, drill string, 198–199, 201 (figure)	borate, 358–359, 358 (figure)
axially vibrating drilling tools, 225	bottom-founded systems, 225–226, 226 (figure), 227 (figure), 225
axially violating drilling tools, 225	(figure), 229 (figure)
В	bottomhole assembly (BHA), 198, 200 (figure), 224, 224 (figure)
Bacillus strains, in MEOR, 471–472, 473	bottomhole pressure (BHP), 406–407, 417
back-propagation algorithm, 152	bottom-up cost estimation, 582–583
backward-difference approximation, 183, 183 (figure)	bottom-up models, reserve depletion estimation, 47–48
**	boundary types, in numerical reservoir simulation, 185–187, 186
bacteria, in oil reservoirs, 462–463. See also microbial enhanced oil	
Palmain magnilatows from avanth in 524 525	(figure), 187 (figure)
Bahrain, regulatory framework in, 534–535	boundary-dominated flow (BDF), 399, 400, 416, 419
Barnett Shales play, 322, 322 (figure), 328	bow-tie analysis, 551, 551 (figure)
basin simulation. See 3D dynamic simulation of pool-forming	Boyle's law, 13, 55
Beggs and Brill correlation for multiphase flow, 409–411, 409 (table)	Brazil, regulatory framework in, 535
below ground factors, offshore development cost, 612–613, 613	Brazilian Indirect Tensile Strength Test, 98, 98 (figure)
(figure)	breaker-free fracturing fluids, 363, 364 (figure)
bending force, 224, 224 (figure)	breakers for fracturing fluids, 359–360, 361 (figure), 362
benthic ecosystems, environmental concerns in, 542-543	Bright Water™ microgels, 267

bubble-point pressure, 3, 66–67, 67 (figure) Buckley-Leverett equation, 75	channel system evaluation model, 127–130 check valves, 511, 512 (figure)
Buffalo Valley Field. See synthetic model, reservoir	chemical flooding, 276–286
characterization; Valley Field reservoir characterization	alkaline flooding, 285
build-up production period, gas field, 421–422, 421 (figure)	alkaline-surfactant-polymer flooding, 285–286
bulk modulus, 88, 88 (figure), 95	overview, 276–277, 276 (figure), 277 (figure), 468
	surfactant flooding, 277–285, 277 (figure), 278 (table), 279
bulk-foam systems, 265	e e
Bullwinkle platform, 573, 574 (figure), 576 (figure), 591	(figure), 280 (figure), 282 (table), 284 (table), 285 (figure)
	Chemical Hazard Analysis, 551
C	chemical stability of polymers, 261 (table)
calibration	chemical surfactants, 469–470. See also chemical flooding
data set for, artificial neural networks, 151, 158 (figure), 158 (table)	chemicals asphaltene deposition treatment with, 498–499
of models to actual field data, 102	characteristics of fracturing fluid, 365–366
in numerical reservoir simulation, 193	control of gas hydrates with, 437–439, 438 (figure), 440
Canada, regulatory framework in, 533	degradation of guar-based solutions, 359–360
capacity	in produced water, 238, 238 (table)
pipeline, 510–511	used in hydraulic fracturing, 388, 540, 540 (figure)
semisubmersible production, 631, 636 (table)	in wastewater discharge, 538–540, 538 (figure), 539 (figure)
capacity-reserves relations, 635, 636, 637 (figure), 638 (figure)	wastewater treatment with, 556 (table)
capillary hysteresis, 70–71, 71 (figure)	workplace hazards, 543, 546, 559
capillary number, 71, 71 (figure), 276–277, 276 (figure)	Chen's formula, 405
capillary pressure, 69–73	China. See Dongying Sag petroleum system simulation
capillary hysteresis and saturation history, 70–71, 71 (figure)	chlorine (Cl.,) hydrates, 432, 433, 434 (figure)
core analysis, 14	choke, flow control, 237, 241
and corresponding height above free water level, 70 (figure)	choke line, BOP stack, 205
dilute surfactant flooding, 283, 285 (figure)	chokepoints, world oil transit, 518, 518 (figure), 518 (table)
effect of IFT on oil recovery, 277, 277 (figure)	chromatographic methods, SARA analysis, 485, 486
	clastic rocks, 2, 5–6, 11, 55. <i>See also</i> reservoir rock
interfacial tension and contact angle, 69	
by isotherms, 78–79, 78 (figure)	clathrates. See gas hydrate deposits; natural gas hydrates
Leverett J-function, 70, 71 (figure)	clay-dominated disseminated methane hydrate deposits, 334
nonwetting phase trapping and capillary number, 71, 71 (figure)	clay-dominated fracture reservoirs, methane hydrates in, 334
numerical reservoir simulation, 181–182	clays, formation damage and, 75
trapping residual oil, 272, 272 (figure)	cleats, coal, 7–8
unconventional reservoirs, 78–79, 78 (figure)	climate change, 708. See also environmental concerns
Young-Laplace equation, 69–70, 70 (figure)	coal, 34–35, 34 (figure), 657, 658 (figure)
capillary resistance, 125	coal rank, 7, 329, 330 (figure)
capillary viscosimetry method, 487–488	coalbed methane (CBM), 329–332
capillary-gravity-pressure equilibrium, 187, 187 (figure)	defined, 321
capital spending, semisubmersible project, 616, 616 (figure)	energy future, 40–41, 41 (figure), 42 (table)
caprock, 1	field development, 332, 333 (figure)
carbon capture, utilization, and storage (CCUS), 706	gas composition in reservoirs, 329
carbon dioxide (CO <sub>2</sub> ) emissions, 658–659, 659 (figure), 659 (table),	general discussion, 346
681–683, 681 (figure), 682 (table), 683 (figure), 683 (table)	overview, 7–8, 8 (figure), 302, 329, 329 (figure)
carbon dioxide (CO <sub>2</sub> ) flooding, 8, 274–276, 294, 294 (figure)	production techniques, 331–332, 331 (figure), 332 (figure)
carbon dioxide (CO <sub>2</sub> ) foam, 363	properties of, 330–331
carbon dioxide (CO <sub>2</sub> )-enhanced CBM production, 332, 332 (figure)	coal-to-liquids (CTLs), 39, 40 (figure), 40 (table)
carbonate rocks, 2, 6, 10–11, 55, 58. See also reservoir rock	coating, pipeline and tank, 523–524
cased-hole logging, 16	Cognac platform removal cost estimate, 590
casing installation, 211, 213, 213 (figure), 680–681	Colebrook formula, 405
casing schedules, 210–211, 212 (figure)	collection platforms (CPs), 679
casing whipstocks, 219, 220 (figure)	colloidal models of asphaltenes, 483, 485, 490, 491–492
catalytic upgrading process in situ (CAPRI), 315, 315 (figure), 345	colloidal-dispersion gels (CDGs), 267
catenary moorings, 601–602, 601 (figure). See also mooring	combination drive, 5, 250 (table)
systems, floating platforms	compaction correction for stratum thickness, 115–116, 115 (figure)
cathodic protection, 524, 524 (figure), 687–688, 688 (figure)	compaction failure, 94
cationic surfactants, 278 (table)	compaction flow, 125
Cause and Effect Diagram, 551	compaction yielding, 91
cell-based models, hydraulic fracturing, 355, 356 (figure)	completion
cement, for in situ permeability reduction, 267 (table)	as phase of production, 530
central flooding, 251, 252 (figure)	smart, 609
central-difference approximation, 182–183, 183 (figure), 184	well, 680-681

```
compliant towers, 600 (figure)
                                                                                  porosity measurement, 13
     decommissioning cost, 591–593, 591–592 (table), 593, 595,
                                                                                  routine, 13
       595 (figure)
                                                                                  special, 14-16
     decommissioning stages, 581-582
                                                                            core tests, geomechanical, 96–101, 96 (figure), 97 (figure), 98 (figure),
     deepwater inventory, 573, 574-575 (table), 576 (figure), 576-577
                                                                               99 (figure), 100 (figure)
comprehensive evaluation of trap, 133, 146, 146 (table)
                                                                             core-flood experiments
                                                                                  asphaltene deposition studies, 494
compressibility
     average temperature and compressibility method, 406
                                                                                  to determine surfactant retention, 283
     formation, 61
                                                                                  MEOR, 470-473
     ideal gas, 62
                                                                                  relative permeability, 74, 74 (figure)
     oil, 66
                                                                             Corey model, 75
     petroleum product, 508-509
                                                                            coring, 11, 12, 61. See also core analysis
     pore, 61, 61 (figure)
                                                                            coriolis meters, 246-247, 246 (figure)
     pore volume, 97-98
                                                                             corner-point grid model
     real gas, 63
                                                                                  Dongying Sag petroleum system simulation, 137, 137 (figure)
                                                                                  fault displacement elimination and recovery, 112-113, 112
     reservoir rock, 60-61, 61 (figure)
compression, gas, 242-244, 243 (figure), 244 (figure)
                                                                                    (figure), 113 (figure)
compressors, for pipelines, 511, 512 (figure)
                                                                                  overview, 110-112, 111 (figure)
computational fluid dynamics (CFD), 496
                                                                                  structural deformation recovery, 113-116, 113 (figure), 114
conceptual models, numerical reservoir simulation, 191
                                                                                    (figure), 115 (figure)
condensate reservoirs, 3-4, 68, 68 (figure), 68 (table)
                                                                             corrosion
condensing-gas process, MCM, 273
                                                                                  by gas hydrates, 439, 440, 441, 441 (figure)
condensing-vaporizing-gas process, MCM, 274
                                                                                  tank and pipeline, 523-524, 524 (figure)
conductivity method, asphaltene precipitation studies, 487
                                                                             costs, semisubmersible project
conductor severance and removal
                                                                                  cost relations, 627-628, 628 (figure), 629 (figure), 629 (table),
     decommissioning cost, 585 (table), 586-587, 587 (figure), 592
                                                                                    630 (figure)
                                                                                  decommissioning, 626-627, 627 (table)
     overview, 582
confined spaces, workplace hazards in, 546, 560
                                                                                  development, 625-626, 627 (table)
connectivity factor, polymer flooding, 262-263
                                                                                  leases, 623-624, 625 (table)
                                                                                  revenue-cost relation, 638, 640 (figure), 641 (figure)
constant bottomhole pressure (CBHP), 214, 215 (figure)
                                                                                  well, 624-625, 626 (table), 627 (table)
consumption
     energy future, 31-35, 31 (figure), 32 (figure), 33 (figure),
                                                                                  See also decommissioning cost estimation in deepwater GOM
       34 (figure)
                                                                             Couette device, 493
     natural gas, 26 (figure), 29-31, 29 (figure), 30 (table), 669, 671
                                                                             coupling equation, heat conduction and convection, 117
       (figure)
                                                                            creep, 92, 92 (figure)
     oil, 22 (figure), 24-26, 25 (figure), 26 (table), 666, 667 (figure)
                                                                            cricondenbar, 3, 67
     prospective outlook on, 21
                                                                             cricondentherm, 3, 67
contact angle, 69, 69 (figure), 73
                                                                            critical micelle concentration (CMC), 278, 279 (figure)
contact injuries, 543, 560
                                                                            critical point, reservoir fluid phase behavior, 3, 3 (figure), 66, 67,
contamination. See environmental concerns
                                                                                67 (figure)
continuity equation, numerical reservoir simulation, 180, 181
                                                                             critical stress intensity factor. See fracture toughness
continuous gas injection, 270, 270 (figure), 271 (figure)
                                                                            crosslinked polymer, for conformance control, 266 (figure),
continuous materials
                                                                                266-270, 267 (figure), 267 (table), 268 (table), 269 (table)
     assumption of continuity, 83, 84 (figure)
                                                                             cross-linked-gel fracturing, 325
     basic geomechanical parameters for, 95-96
                                                                             cross-linking of guar, 358-359
continuum approach, flow equations, 180
                                                                            cross-well seismic data, 154
contracts, offshore development, 614, 615
                                                                            crude oil
control systems, pipeline, 512-513, 514, 515 (figure)
                                                                                  asphaltene deposition, effect on production, 483
convection, thermal, 117
                                                                                  classification of, 3
conventional reservoirs, 6, 319, 321
                                                                                  composition of, 64 (table)
conventional triaxial compression (CTC) test, 93 (figure), 96-97,
                                                                                  dehydration of, at topsides facilities, 610-611
  96 (figure), 97 (figure)
                                                                                  energy future, 31-33
conversion processes, crude oil refining, 531
                                                                                  GHG emissions related to type of, 683 (table)
cooling water environmental concerns, 540
                                                                                  history of, 529
coordinates, directional well trajectory, 221-222, 221 (figure),
                                                                                  major producers of, 529
  222 (figure)
                                                                                  overview, 461-462
Corbett method, SARA analysis, 485
                                                                                  pipelines for, 513, 513 (figure)
core analysis
                                                                                  production process overview, 529-531, 530 (figure)
     fluid saturations measurement, 14
                                                                                  production stages, 249-255, 250 (figure), 252 (figure), 253 (figure),
     limitations of, 15-16
                                                                                    254 (figure)
     overview, 11, 12, 61-62
                                                                                  refining, 531
     permeability measurement, 13-14
                                                                                  as reservoir fluid, 65-66, 66 (figure)
```

715

```
reservoir rock wettability, 71-72, 71 (figure)
                                                                                       top-down versus bottom-up, 582-583
     SARA analysis, 485-486, 486 (figure)
                                                                                       total exposure, 593, 595, 595 (figure), 596 (figure), 597
     See also microbiology of petroleum reservoirs; petroleum
                                                                                       uncertainty range, 583
       geomechanics; specific entries under "hydrocarbon"; specific
                                                                                       work breakdown structures, 583
       oil types; specific production and recovery processes; upstream
                                                                                  decommissioned structures, 571, 573 (table)
       oil supply chain
                                                                                  decommissioning requirements, 572 (table)
crude oil tankers, 517–518, 517 (figure), 517 (table)
                                                                                  decommissioning stages, 581-582
crust thermal structure analysis, 118-120, 119 (table), 120 (table)
                                                                                  deepwater inventory
cryogenic tanks, 522-523, 523 (figure)
                                                                                       compliant towers, 573, 574-575 (table), 576 (figure),
crystalline silicon PV (CSP) technology, 684, 684 (figure),
                                                                                          576-577
   685 (figure), 686
                                                                                       data source, 573
crystals, gas hydrate, 429, 444, 444-445 (figure), 445
                                                                                       fixed platforms, 573, 574-575 (table), 574 (figure),
cubic EOS, 67
                                                                                          576 (figure)
cubic equations of state, solubility models, 491
                                                                                       floaters, 577-578, 577 (figure), 578 (figure), 579-580
cubic-plus-association (CPA) model, 491
                                                                                          (table), 579 (figure), 580-581, 580 (figure),
Cullender and Smith method, 406-410, 409 (table)
                                                                                          581 (figure)
culture-dependent microbiology techniques, 463-464, 465
                                                                                  overview, 571-573, 572 (figure), 572 (table), 573 (table)
culture-independent microbiology techniques. See metagenomics
                                                                             decompaction correction for stratum thickness, 115-116,
                                                                                115 (figure)
cumulative production function, 418
curve-fitting models, reserve depletion estimation, 46
                                                                             deepwater development
cyclic MEOR, 286
                                                                                  Arctic, 302, 343-344, 344 (figure), 345 (table), 347
cyclic steam stimulation (CSS)
                                                                                  deepwater geology, 603, 605-606, 607 (figure)
     field applications, 307
                                                                                  deepwater systems, 606-607, 608 (figure)
     general discussion, 287-288, 288 (figure)
                                                                                  energy future, 35-36, 36 (figure)
     oil recovery mechanisms, 305 (table)
                                                                                  offshore components, 607-611, 609 (figure), 611 (figure),
     overview, 9, 344
                                                                                    612 (figure), 612 (table)
     process characteristics, 304, 306 (table), 306-307
                                                                                  overview, 599-600
     reservoir selection, 304, 305 (table)
                                                                                  structure types used in, 599, 600 (figure)
     SAGD/CSS Hybrid, 311
                                                                                  See also decommissioning cost estimation in deepwater GOM;
     stages of, 304, 304 (figure)
                                                                                    floating systems; semisubmersibles
cycloalkanes (naphthenes), 65
                                                                             deepwater offshore reservoirs, 302, 341-342, 341 (figure), 342
                                                                                (table), 343 (figure), 344 (figure), 346-347
D
                                                                             deflection tools, 219, 220 (figure)
daisy chain looped system, subsea wells, 610, 611 (figure)
                                                                             deformation
Daqing oil field, polymer flooding in, 262 (table), 263
                                                                                  monitoring, 102
Darcy units, 2
                                                                                  overview, 83-85, 84 (figure), 85 (figure)
Darcy's law, 13-14, 56-57, 71, 73, 181, 398-400
                                                                                  parameters for, 95-96
data acquisition system, drill rig, 205
                                                                                  recovery of structural, 113-116, 113 (figure), 114 (figure),
data mining. See oil field data mining
                                                                                    115 (figure)
data-driven modeling for production optimization, 170-173, 171
                                                                             degradation
                                                                                  of guar-based solutions, 359-360, 361 (figure)
   (figure), 172 (figure)
Davy, Sir Humphry, 432
                                                                                  oil, 462, 466, 467
decks, floating platforms, 577, 578 (figure), 582, 590, 601, 601 (figure)
                                                                             dehydration
decline curve analysis (DCA)
                                                                                  of gas hydrates, 437
     hydraulic fracturing, 366-369, 367 (table), 368 (figure), 368
                                                                                  natural gas, 244-245, 244 (figure)
                                                                                  in topsides facilities, 610-611
        (table), 369 (figure)
     natural gas reserves, 415, 416-419
                                                                             deliverability and inflow performance analysis, 398-404, 401
                                                                                (table), 402 (figure), 403 (figure), 403 (table), 404 (figure)
     reserve estimation, 45
                                                                             deliverability testing, gas well, 401
decline production period, gas field, 421 (figure), 422-423
decommissioning
                                                                             Delta House project, 655. See also semisubmersibles
     life-cycle stages, 652
     options for, 557, 557 (figure)
                                                                                  crude oil, 65, 66, 66 (figure)
     risk involved, 617 (figure)
                                                                                  ideal gas, 62
     semisubmersible projects, cost of, 626-627, 627 (table)
                                                                                  petroleum product, 508
decommissioning cost estimation in deepwater GOM, 571-597
                                                                                  real gas, 63
     cost estimation
                                                                                  stock tank oil, 65
          algorithms for, 584, 585-591, 586 (figure), 587 (figure),
                                                                             density diffusivity equation, 398
             588 (table), 589 (figure), 590 (table)
                                                                             density-based PDA method, 418-420, 419 (figure), 420 (figure)
          challenges, 583-584
                                                                             denudation volume estimation, 115, 115 (figure)
          fixed platforms, 591-593, 591-592 (table)
                                                                             depletion drive, 4, 4 (figure), 250 (table)
          floaters, 593, 594 (table)
                                                                             deposition, asphaltene. See asphaltene deposition
                                                                             depositional environments, reservoirs, 5-6
          methodology, 584, 584 (table), 585 (table), 586 (table)
```

```
depressurization
                                                                                  geothermal field evolution simulation, 138–140, 139 (table),
     in hydrate control, 437, 439-440
                                                                                     140 (table), 141 (figure)
     reservoir, for methane hydrate production, 334-335
                                                                                  hydrocarbon expulsion history, 142-144, 143 (figure),
                                                                                     143 (table)
depth, reservoir, 1, 2 (figure)
derrick, 199 (figure), 199 (table)
                                                                                  hydrocarbon generation history, 140–142, 142 (figure),
desalination, 366
                                                                                     142 (table)
desorption, coalbed methane, 8
                                                                                   structure-stratum framework evolution, 136-138, 136 (figure),
desorption isotherms, capillary pressure by, 78-79, 78 (figure)
                                                                                     137 (figure), 138 (figure), 139 (figure)
deterministic methods, reserve estimation, 44
                                                                                  trap evaluation example, 145-146, 145 (figure), 146 (table)
development
                                                                              downhole rotary systems, 200–201, 203 (figure), 204 (figure)
     as life-cycle stage, 652
                                                                             downhole sensors, 702-703, 703 (figure)
     natural gas field, plan for, 420-425, 421 (figure), 422 (figure),
                                                                             downstream oil production processes, 679
       424 (figure), 425 (figure), 425 (table)
                                                                             drag, in directional drilling, 224-225, 225 (figure)
     semisubmersible project
                                                                             drag bits, 205-206
          cost of, 612-616, 613 (figure), 614 (figure), 615 (figure),
                                                                             drag coefficient, 233
             625-626, 627 (table), 643
                                                                             drainage conditions, poroelasticity, 90
          development wells, 619, 620-621 (figure)
                                                                             draw works, 199 (figure), 199 (table)
                                                                             drill bits, 205-207, 206 (figure), 207 (figure)
          drilling schedule, 619, 622, 622 (figure), 622 (table)
          flowline, umbilical, export pipeline, 623, 624 (table),
                                                                             drill rig systems, 197-205
             625 (figure)
                                                                                  hoisting system and drill strings, 198-199, 199 (figure), 199
          risk involved, 617 (figure)
                                                                                     (table), 200 (figure), 201 (figure)
          well counts and footage drilled, 622, 623 (figure)
                                                                                  mud circulation system, 201–202, 202 (table), 204 (figure)
                                                                                  overview, 197-198, 198 (figure)
          well type, 623, 624 (table)
deviation, well trajectory, 223-224, 224 (figure)
                                                                                  power system, 198
Devonian period, 378, 378 (figure)
                                                                                  rotary systems, 199-201, 202 (figure), 203 (figure), 204 (figure)
                                                                                  well control system, 202, 204-205, 205 (figure)
dew-point pressure, 3, 66-67, 67 (figure)
Diadema oil field, polymer flooding in, 264-265
                                                                                   well monitoring system, 205
diamond drag bits, 205-206, 207 (figure)
                                                                             drill ships, 227-228, 230, 230 (figure)
Dietz shape factors, 399, 400
                                                                             drill strings, 198-199, 199 (figure), 200 (figure), 201 (figure)
dilute surfactant flooding, 283, 285 (figure)
                                                                             drilling
dimensionality, numerical reservoir simulation model, 191
                                                                                   as phase of production, 530
direct in situ deformation monitoring, 102
                                                                                  in USOSC, 680-681
direct solution methods, numerical reservoir simulation, 188-189,
                                                                                  waste from, 538-539, 539 (figure), 542, 555, 555 (figure)
                                                                                   See also drilling technology methods; specific drilling
   188 (figure)
directional drilling, 215-225
                                                                                     techniques
     deviation, wander, and BHA design, 223-224, 224 (figure)
                                                                             drilling barges, 227, 230 (figure)
     directional well trajectory coordinates, 221-222, 221 (figure),
                                                                             drilling efficiency, 208-209
       222 (figure)
                                                                             drilling fluids, 207-208, 208 (figure)
     measuring well trajectories, 219
                                                                             drilling optimization, 208-210, 209 (figure)
                                                                             drilling schedule, semisubmersible projects, 619, 622, 622 (figure),
     overview, 215-216, 216 (figure)
     planning trajectory changes, 223, 223 (figure)
                                                                                622 (table)
     shale- and mudstone-hosted oil and gas, 373
                                                                             drilling specific energy (DSE), 209, 209 (figure)
     subsurface steering tools, 219-221, 220 (figure), 221 (figure)
                                                                             drilling technology methods, 197-230
     for tight gas, 322-323, 324 (figure)
                                                                                  directional drilling
     torque and drag, 224-225, 225 (figure)
                                                                                       deviation, wander, and BHA design, 223-224, 224
     well trajectory terminology, 216-217, 217 (figure), 218 (figure),
                                                                                          (figure)
       219 (figure)
                                                                                        directional well trajectory coordinates, 221-222, 221
directional permeability, 6, 10
                                                                                          (figure), 222 (figure)
Dirichlet-type boundary condition, 186, 186 (figure)
                                                                                       measuring well trajectories, 219
disasters, 706, 708. See also safety
                                                                                       overview, 215-216, 216 (figure)
discharging practice, safe, 526, 526 (figure)
                                                                                       planning trajectory changes, 223, 223 (figure)
                                                                                        subsurface steering tools, 219-221, 220 (figure), 221
discretized form of flow equations, 182-185, 182 (figure), 183
   (figure), 185 (figure)
disproportionate permeability reduction (DPR), 268
                                                                                        torque and drag, 224-225, 225 (figure)
dissipative QCM, 493
                                                                                        well trajectory terminology, 216-217, 217 (figure), 218
dissolved-gas drive, 4, 4 (figure)
                                                                                          (figure), 219 (figure)
documentation, numerical reservoir simulation, 193-194
                                                                                  drill bits, 205-207, 206 (figure), 207 (figure)
Dongying Sag petroleum system simulation, 134-146
                                                                                  drilling fluids, 207-208, 208 (figure)
     analysis on petroleum system, 134-136, 134 (figure), 135
                                                                                  drilling optimization, 208-210, 209 (figure)
        (figure), 135 (table)
                                                                                  fundamental drilling systems, 197, 197 (figure)
     artificial neural network simulation, 144-145, 144 (figure),
                                                                                  offshore drilling, 225-228, 226 (figure), 227 (figure), 228
        145 (figure)
                                                                                     (figure), 229 (figure), 230, 230 (figure)
```

well control	employee training, in health and safety management systems, 552
casing installation, 211, 213, 213 (figure)	emulsifiers, 438, 439
kick detection and shut-in procedures, 213-214	emulsions, treating, 235–236, 236 (figure)
managed pressure drilling, 214-215, 214 (figure),	end-to-end flooding, 251, 252 (figure)
215 (figure)	energized fracturing fluids, 362–363
mud pressure bounds and casing schedules, 210-211,	energy conservation for flow, 510
210 (figure), 211 (figure), 212 (figure)	energy consumption
See also drill rig systems	reducing, 555
drill-off tests (DOTs), 209, 209 (figure)	in USOSC, 679, 681
drive mechanisms	energy control techniques, 560
natural, 249, 250 (table)	energy dissipation and supply, pipelines, 513, 513 (figure)
petroleum migration, 125	energy flow optimization model (EFOM), 49 (table)
reservoir classification based on, 4–5	energy future, 31–41, 693–709
dry gas, 3, 68, 68 (figure), 68 (table), 378	deep-water oil and gas outlook, 35–36, 36 (figure)
dry-gas well performance analysis, 411, 412–413, 413 (figure)	enhanced oil recovery, 698–701, 700 (figure), 701 (figure)
dry-tree wells	fuel production and consumption, 31–35, 32 (figure),
decommissioning cost, 585, 585 (table), 586 (figure), 591	33 (figure), 34 (figure)
overview, 606, 607–608, 608 (figure), 609 (figure)	geopolitics and environment, 706–708, 707 (figure)
semisubmersible projects, 623, 624 (table)	overview, 693
dual-gradient drilling (DGD), 215, 215 (figure), 216 (figure)	technological advancements and innovation, 704–706, 704
dual-porosity systems, 11, 17	(figure), 705 (figure)
Duong decline forecasting, 367, 368–369, 368 (figure), 368 (table),	total world energy consumption, 31 (figure)
369 (figure)	unconventional resources
dynamic parameters, geomechanical, 96, 99, 99 (figure)	gas, 40–41, 41 (figure), 42 (table)
dynamic simulation of pool-forming. See 3D dynamic simulation	general discussion, 697, 697 (figure), 698 (figure), 699 (figure)
of pool-forming	oil, 36–40, 37 (figure), 38 (figure), 38 (table), 39 (figure),
or poor-forming	
E	39 (table), 40 (figure), 40 (table)
Eagle Ford Shale, 337, 346	upstream resources and reserves, 693–694, 694 (figure), 695
ecological effects, 541–543, 555–557, 557 (figure). See also	(figure), 696, 696 (figure)
environmental concerns	well, reservoir, and facility management, 701–704, 702 (figure),
	703 (figure)
economic evaluation of trap, 132–133, 146, 146 (table)	energy market, global, 657, 658 (figure). See also specific energy
economic models, reserve depletion estimation, 48	sources
economically recoverable resources (ERR), 352	energy studies on natural gas hydrates, 434–435
economics of semisubmersible developments. See	energy systems models
semisubmersibles	electricity system models, 52
economies of scale, semisubmersible projects, 628, 629 (table), 630	examples of, 49–50 (table)
(figure)	hybrid models, 51, 52 (figure)
effective permeability, 11, 73, 74	optimization models, 50–51, 50 (figure)
effective porosity, 10, 55	overview, 48
effective stress, 8, 89–90, 93–94	simulation models, 51, 51 (figure)
elasticity, 87–89, 88 (figure), 89 (figure), 101	Enform, 547
electric logging, 16	engineering studies on natural gas hydrates, 434
electrical energy storage, 686	enhanced microbial water floods, 286
electrical hazards, 543	enhanced oil recovery (EOR), 249–294
Electrical HAZOP (EHAZOP) study, 551	energy future, 698–701, 700 (figure), 701 (figure)
electrical properties, reservoir rock and fluid, 15, 59-60, 60 (figure)	foam flooding, 265–266, 265 (figure)
electricity system modeling platforms, 50 (table), 52	global status of, 294, 294 (figure)
electricity-generation expansion analysis system (EGEAS), 50 (table)	immiscible gas displacement processes, 276
electromagnetic telemetry (EMT), 219	implementation of processes, 293–294, 293 (table)
electron donors and acceptors, 462	low-salinity water flooding, 291–292
electrostatic emulsion treaters, 235-236, 236 (figure)	miscible displacement processes, 271–275, 272 (table), 273
electro-thermal dynamic stripping (ET-DSP), 315	(figure), 275 (figure), 276 (figure)
emergency evacuation, 561–562, 563 (figure)	mobility-control processes, 256
emergency shutdown, 562	overview, 255–256, 461
emergency venting valves, 521	performance of, 256, 256 (figure)
emissions	in situ conversion processes, 292, 293 (figure), 340
environmental concerns, 537–538, 537 (figure), 538 (figure)	in situ permeability modification processes, 266 (figure),
gravity separator, 238	266–270, 267 (figure), 267 (table), 268 (table), 269 (table)
minimizing, 554	solar energy in, 688–689, 688 (figure), 690 (figure)
storage tank, 521–522, 522 (figure)	stages of crude oil production, 249–255, 250 (figure),
See also greenhouse gases	252 (figure), 253 (figure), 254 (figure)
out the greening gases	252 (liguic), 255 (liguic), 254 (liguic)

```
techniques for, 468, 469 (table)
                                                                             extended-reach drilling (ERD) wells, 217, 219 (figure)
     water-alternating gas process, 270–271, 270 (figure), 271 (figure)
                                                                             external floating roof (EFR) tanks, 519, 520 (figure), 522
     See also chemical flooding; microbial enhanced oil recovery;
                                                                             extinguishing fires, 525
       polymer flooding; thermal recovery methods
                                                                             extraction
enriched-gas process, MCM, 273
                                                                                  atmospheric effects and emissions from, 537
Enterobacter cloacae in MEOR, 473
                                                                                  bitumen, 317
environmental concerns, 537-543
                                                                                  metagenomics, 465-466
                                                                                  shale- and mudstone-hosted oil and gas, 383-387, 385 (figure)
     associations for, 547-548
     atmospheric effects and emissions, 537-538, 537 (figure),
                                                                                  See also specific extraction methods
                                                                             extra-heavy oil
       538 (figure)
     ecological effects, 541-543
                                                                                  classification of, 3, 287 (table)
     and energy future, 708
                                                                                  energy future, 37-39, 38 (figure), 38 (table)
     fracturing fluids, 365-366
                                                                                  overview, 9, 287
     gas hydrates, 435-436
                                                                                  physical properties of, 302, 302 (table)
     groundwater contamination, 540, 540 (figure)
                                                                                  See also bitumen
     hydrate control, 440
                                                                             ExxonMobil in situ retorting, 386
     hydraulic fracturing, 388-389, 673, 675
     land and soil effects, 540-541, 541 (table)
     minimizing environmental impact, 553-557, 555 (figure),
                                                                             facility management, 701-704, 702 (figure), 703 (figure)
        556 (table), 557 (figure)
                                                                             failure, in petroleum geomechanics, 92-95, 93 (figure), 94 (figure),
     oil shale retorting, 386-387
                                                                               95 (figure)
                                                                             failure mode and effects analysis, 551
     shale gas, 675
     wastewater discharge, 538-540, 538 (figure), 539 (figure),
                                                                             falls, as workplace hazard, 543
        539 (table)
                                                                             Faraday, Michael, 432
     water consumption, 540
                                                                             Fast-SAGD, 311
environmental management, 548-549, 549 (figure), 553-557, 555
                                                                             fatalities, workplace, 544-546 (table), 553, 553 (figure). See also
   (figure), 556 (table), 557 (figure)
environmental regulations, 532-537
                                                                             fault displacement, elimination and recovery of, 112-113, 112
enzymes, as breakers for fracturing fluids, 359, 360
                                                                               (figure), 113 (figure)
episodic hydrocarbon expulsion model, 122-123
                                                                             fault evaluation submodel, artificial neural networks, 127-128
equation of state (EOS)
                                                                             fault tree analysis, 551
     for reservoir fluid, 67-69
                                                                             faults, in 3D static geological modeling, 111-112, 111 (figure)
     solubility models, 490-491
                                                                             fermentative bacteria, 463
Equatorial Guinea, regulatory framework in, 536-537
                                                                             field development plan, for natural gas, 420-425, 421 (figure),
ergonomic hazards, 543
                                                                               422 (figure), 424 (figure), 425 (figure), 425 (table)
erosion, hydrate control and, 441
                                                                             field scale, upscaling measurements to, 101-102, 102 (figure)
Europe
                                                                             field surveillance, petroleum geomechanics, 102-103
     associations pertaining to oil and gas industry, 547
                                                                             field testing, methane hydrate production, 335
     energy future, 706-707
                                                                             filling practice, safe, 526, 526 (figure)
     regulatory framework in, 533-534
                                                                             filtration method
evacuation, emergency, 561–562, 563 (figure)
                                                                                  asphaltene precipitation studies, 487
evaluation model, artificial neural network simulation, 127-130
                                                                                  HPHT, 489
                                                                             filtration units, removing trace oil with, 240-241
event trees, 551
expanding solvent steam-assisted gravity drainage (ES-SAGD),
                                                                             finite-difference approximation, 182-184, 183 (figure)
   289, 290 (figure), 311
                                                                             fire flooding. See in situ combustion
expansion, thermal, 90, 96
                                                                             fire hazards, 546, 557-558
expected ultimate recoveries (EUR), semisubmersible projects,
                                                                             fire prevention and extinguishing, 525
  628, 628 (figure), 629 (table), 640-641, 642 (figure), 643 (table),
                                                                             first contact miscible (FCM), 271-273, 272 (figure), 272 (table),
  644 (table), 645 (figure), 646 (figure)
                                                                               273 (figure)
explicit-scheme formulation, flow equations, 184, 185 (figure)
                                                                             fission track, 121
exploration
                                                                             fissure zone evaluation, 128-129
     overview, 530, 652
                                                                             fixed platforms, 600 (figure)
     risk involved, 616, 617 (figure)
                                                                                  decommissioning cost, 585 (table), 589-590, 590 (table),
     semisubmersible projects, 618-619, 619 (table)
                                                                                    591-593, 591-592 (table), 595, 595 (figure)
     in USOSC, 680-681
                                                                                  decommissioning stages, 581-582
explosions, 546, 557-558
                                                                                  deepwater inventory, 573, 574-575 (table), 574 (figure),
exponential curve-fitting models, 46
                                                                                    576 (figure)
exponential decline, 367, 367 (table), 416
                                                                             fixed roofs, storage tank, 521, 521 (figure)
export pipelines
                                                                             flaring, 557, 559, 559 (figure)
     deepwater systems, 607, 608 (figure), 611
                                                                             flexible piping system, storage tank, 520
     semisubmersible projects, 623, 624 (table), 625 (figure)
                                                                             flexible wiper seals, 520
expulsion history, 3D dynamic simulation of, 122-123, 122 (figure)
                                                                             flexural-slip mechanism recovery method, 113-114, 113 (figure)
```

719

```
floating force, 125
                                                                                       guar-based, 358-360, 358 (figure), 361 (figure)
                                                                                       overview, 351–352
floating production, storage, and offloading (FPSO) vessels,
  600 (figure)
                                                                                       potential for technology improvement, 390
                                                                                       rheological properties of, 363
     deep offshore reservoirs, 341–342, 343 (figure), 344 (figure)
                                                                                       slickwater, 360-361, 362 (figure)
     deepwater inventory, 578, 579 (figure)
     overview, 577, 577 (figure)
                                                                                       for tight gas production, 325-328, 326 (table), 327
                                                                                          (table), 336
floating roofs, storage tank, 519
floating systems (floaters)
                                                                                       viscoelastic surfactant-based, 361-362, 362 (figure)
     decommissioned, 571, 573 (table)
                                                                                  natural gas, separation of, 531
     decommissioning cost, 585 (table), 590-591, 590 (table), 593,
                                                                                  in well performance analysis, 412, 412 (figure)
       594 (table), 595, 596 (figure)
                                                                                  See also reservoir fluids
     decommissioning stages, 581-582
                                                                             foam flooding, 265-266, 265 (figure)
     deepwater inventory, 577-578, 577 (figure), 578 (figure),
                                                                             foam systems, as fracturing fluids, 362-363
       579-580 (table), 579 (figure), 580-581, 580 (figure),
                                                                             foam-assisted WAG (FAWAG) process, 271, 271 (figure)
       580 (table), 581 (figure)
                                                                             footage drilled, semisubmersible projects, 620-621 (figure),
     offshore drilling, 226-228, 229 (figure), 230, 230 (figure)
                                                                                622, 623 (figure)
     overview, 600 (figure), 600-602
                                                                             Forchheimer's equation, 398, 400
     structural components, 601-602, 601 (figure), 602 (figure)
                                                                             forecasting, field production
     See also semisubmersibles
                                                                                  build-up production period, 421–422, 421 (figure)
floats, liquid-level control, 238, 238 (figure)
                                                                                  decline production period, 422-423, 422 (figure)
flooding processes. See specific processes
                                                                                  example of, 423-425, 424 (figure), 425 (figure), 425 (table)
Flory-Huggins regular-solution-based models, 490
                                                                                  plateau production period, 422
                                                                             formation damage, 75
flow
     in deliverability and inflow analysis, 398-404
                                                                             formation fluid, separation of, 530
     wellbore and outflow performance analysis, 404-411
                                                                             formation pore fluid pressure, 210-211
flow assurance, for gas production from hydrates, 437
                                                                             formation volume factor, 65-66, 66 (figure)
flow control, gravity separator, 237-238, 237 (figure), 238 (figure)
                                                                             formation water, 62, 69, 456. See also reservoir fluids
flow equations, in numerical reservoir simulation
                                                                             forward ISC, 314
     discretized form of, 182-185, 182 (figure), 183 (figure),
                                                                             forward-difference approximation, 183, 183 (figure)
        185 (figure)
                                                                             fossil fuels
     numerical solution of linear systems of equations, 188-189,
                                                                                  comparative analysis between renewables and, 657-660, 659
       188 (figure), 189 (figure), 189 (table)
                                                                                    (figure), 659 (table), 660 (table)
                                                                                  role in world energy production, 301, 657, 658 (figure)
     overview, 180
     in rectangular coordinates, 180-182, 180 (figure)
                                                                                  See also specific fossil fuels
flow patterns/flow regimes, 408
                                                                             foundation, storage tank, 522
flow rate
                                                                             four-dimensional (4D) seismic monitoring, 703 (figure), 703-704
     calculating achievable, 412-413
                                                                             fracture pressure, 210-211, 211 (figure), 212 (figure)
     pipelines, 510-511
                                                                             fracture toughness, 95, 96, 98, 357
flow test, permeability measurement through, 13
                                                                             fractured reservoirs, 11, 17-18, 58, 58 (figure)
flowback of fracturing fluid, 327-328
                                                                             fractures
flowing material balance (FMB) methodology, 418, 420, 420 (figure)
                                                                                  as form of failure, 94-95, 95 (figure)
flowlines
                                                                                  polymer flooding as causing, 260-261
     decommissioning cost, 582, 585 (table), 589 (figure), 593
                                                                                  and stress determination in subsurface, 100 (figure), 100-101
     deepwater systems, 610
                                                                                  See also hydraulic fracturing
     semisubmersible projects, 623
                                                                             fracturing-fluid flowback, 327-328
flue gas, 272, 276
                                                                             framework modeling, 110. See also structure-stratum framework
fluid electric properties, reservoir rock and, 59-60, 60 (figure)
                                                                                simulation
fluid inclusion, 121
                                                                             free gas, in GHDs, 450-451
fluid potential, 125
                                                                             free water knockouts, 235, 236 (table)
fluid saturation, 14, 55-56, 181-182
                                                                             freeze wall, 292, 293 (figure)
fluid separation. See gravity separation
                                                                             friction factors, 405, 409, 410
fluids
                                                                             Front Runner umbilical, flowline, and riser removal cost, 588-589
     drilling, 207-208, 208 (figure)
                                                                             froth treatment, bitumen extraction process, 317
     hydraulic fracturing
                                                                             Fuel-to-Liquid energy future, 39-40
          breaker-free, 363, 364 (figure)
                                                                             fugitive emissions, 537-538, 554, 682
          chemicals found in, 540, 540 (figure)
                                                                             full-asset type curve analysis, 174, 175 (figure)
          cleanup, 354, 359-360
                                                                             full-field models, numerical reservoir simulation, 191
          composition example, 364-365, 364 (table), 365 (table)
                                                                             fully 3D models, hydraulic fracturing, 356, 357 (table)
                                                                             function-based approach, metagenomics, 465, 466-467
          energized, 362-363
          environmental aspects of, 365-366
                                                                             future economics, semisubmersible projects, 645, 647 (table)
          flowback, 327-328
                                                                             future of energy industry. See energy future
          guar alternatives, 363
                                                                             fuzzy comprehensive evaluation of trap, 132
```

721

```
heat control, gas hydrates, 437, 441
                                                                                      cleanup, 354, 359-360
heat flow, in geothermal field evolution simulation
                                                                                      composition example, 364-365, 364 (table), 365 (table)
     calculating value of, 118-120, 119 (table), 120 (table)
                                                                                      energized, 362-363
     status of, 116-117
                                                                                      environmental aspects of, 365-366
                                                                                      flowback, 327-328
heat requirements, emulsion treater, 236
heavy oil, 302-316
                                                                                      guar alternatives, 363
     classification of, 3, 287 (table)
                                                                                      guar-based, 358-360, 358 (figure), 361 (figure)
     overview, 9, 287
                                                                                      overview, 351-352
     physical properties of, 302-303, 302 (table)
                                                                                      potential for technology improvement, 390
     worldwide distribution of, 303-304, 303 (figure), 304 (figure)
                                                                                      rheological properties of, 363
     See also thermal recovery methods
                                                                                      slickwater, 360-361, 362 (figure)
Herschel-Buckley (HB) rheological behaviors, 363
                                                                                      for tight gas production, 325-328, 326 (table), 327
heterogeneous reservoirs, 11, 16, 17-18
                                                                                         (table), 336
high-performance liquid chromatography (HPLC), 485
                                                                                      viscoelastic surfactant-based, 361-362, 362 (figure)
high-pressure air injection (HPAI), 314
                                                                                 groundwater contamination, 540, 540 (figure)
                                                                                 modeling, 101, 101 (figure)
high-pressure gas drive, MCM, 273
high-pressure high-temperature (HPHT) conditions, asphaltene
                                                                                 monitoring, 103
   precipitation in, 488-489
                                                                                 multistage, 388
high-pressure microscopy (HPM), 489
                                                                                 overview, 323, 325, 325 (figure), 351–352, 352 (figure)
high-temperature high-pressure (HTHP) drilling fluids, 207-208
                                                                                 potential for technology improvement, 390
historic economic evaluations, semisubmersible projects, 645, 647
                                                                                 production of shale oil and tight oil, 336, 337
                                                                                 proppants, 325-327, 326 (table), 327 (table), 336
history matching, in numerical reservoir simulation, 192 (table),
                                                                                 propped, 354-358, 355 (figure), 356 (figure), 357 (table)
   192-193
                                                                                 reuse of produced water for treatments, 366, 366 (table)
hoisting systems, drill rig, 198-199, 199 (figure), 199 (table), 200
                                                                                 seismic activity caused by, 329, 388, 541
   (figure), 201 (figure)
                                                                                 shale- and mudstone-hosted oil and gas, 373, 374, 383-384,
                                                                                    387-389
horizontal drilling/wells
     for CO<sub>2</sub> flooding, 275
                                                                                 shale gas, 8-9
     cyclic steam stimulation using, 288, 288 (figure)
                                                                                 shale gas production, 531, 532 (figure)
     in FCM, 272-273, 273 (figure)
                                                                                 tight-gas sands, 7
     overview, 217, 218 (figure)
                                                                                 water from primary production facilities, 241
     production of shale oil and tight oil, 336
                                                                                 water use in, 241, 326-327
     shale- and mudstone-hosted oil and gas, 373, 374, 387
                                                                            hydrocarbon accumulations in unconventional locations, 301.
     for tight gas, 322-323, 324 (figure)
                                                                               See also deepwater development; deepwater offshore reservoirs
     for water flooding, 253, 254 (figure)
                                                                            hydrocarbon expulsion history
     See also hydraulic fracturing
                                                                                 Dongying Sag petroleum system simulation, 142-144, 143
horizontal permeability, 10-11, 14
                                                                                    (figure), 143 (table)
horsepower per square inch (HSI), 210
                                                                                 3D dynamic simulation of, 122-123, 122 (figure)
hot tanks, 522
                                                                            hydrocarbon gases, 62. See also gas; natural gas; specific gases
Houpeurt analysis, 400, 402-403, 402 (figure), 403 (figure), 403 (table)
                                                                            hydrocarbon generation history
Hubbert's logistic model, 46
                                                                                 Dongying Sag petroleum system simulation, 140, 142, 142
"Huff and Puff" MEOR, 286. See also cyclic steam stimulation
                                                                                    (figure), 142 (table)
hull, floating platforms, 577, 578 (figure), 582, 591, 601, 601 (figure)
                                                                                 generation from source rocks, 377-378, 378 (figure), 379
hurricane risk, semisubmersible projects, 618
                                                                                    (figure), 380 (figure)
hybrid energy systems modeling platforms, 49-50 (table), 51, 52
                                                                                 3D dynamic simulation of, 121-122
  (figure)
                                                                            hydrocarbon migration and accumulation history simulation,
hybrid PV-diesel systems, 687
                                                                               123-130
hybrid steam-solvent processes, 316, 317 (figure)
                                                                                 artificial intelligence model, 126-130, 126 (figure), 127 (figure)
hydrate formation zones (HFZs), 446-447, 448 (figure), 449
                                                                                 concept model, 123-124
   (figure). See also natural gas hydrates
                                                                                 driving mechanism and mathematic model, 125
hydrated gas. See gas hydrate deposits; natural gas hydrates
                                                                                 phase judgment submodel, 124-125
hydraulic fracturing (hydrofracturing/fracking), 351–369
                                                                            hydrocarbon reservoirs. See numerical reservoir simulation;
     of CBM reservoirs, 331
                                                                               reservoir fluids; reservoir rock; reservoirs
     decline curve analysis, 366-369, 367 (table), 368 (figure), 368
                                                                            hydrocarbon resource distribution, 301, 302 (figure). See also
        (table), 369 (figure)
                                                                               specific hydrocarbon resources
     defined, 672
                                                                            hydrocarbon source rock. See reservoir rock; shale- and mudstone-
     economics of, 352-354, 353 (figure), 354 (figure)
                                                                               hosted oil and gas; source rock
     energy future, 697
                                                                            hydrocarbon transmission ratio, 129-130
     environmental concerns, 673, 675
                                                                            hydrocyclones, removing trace oil with, 239
     fluids
                                                                            hydrodynamic retention, polymer, 260 (table)
          breaker-free, 363, 364 (figure)
                                                                            hydropower, 35
          chemicals found in, 540, 540 (figure)
                                                                            hydrostatic weighing, 13
```

hyperbolic decline, 367, 367 (table), 416-417	solubilization ratio and, 280
hysteresis	surfactant phase behavior and, 278-281, 280 (figure)
capillary, 70–71, 71 (figure)	intergranular-intercrystalline porosity systems, 6
contact angle, 69, 69 (figure)	internal floating roof (IFR) tanks, 519, 520 (figure), 522
relative permeability, 73	internal-gas drive, 4, 4 (figure)
•	International Association of Drilling Contractors (IADC) bit
I	classification system, 206, 206 (figure), 207 (figure)
Iatroscan method, SARA analysis, 485, 486	international associations for health, safety, and environment,
ideal gas law, 62–63	547-548
ignition sources, 525, 557	International Energy Agency (IEA), 547
immiscible gas displacement processes, 276	International Organization for Standardization (ISO), 549, 553
implicit-pressure, explicit-saturation (IMPES) formulation, flow	International Petroleum Industry Environmental Conservation
equations, 184–185	Association (IPIECA), 547
implicit-scheme formulation, flow equations, 184, 185 (figure)	interporosity flow coefficient, 11, 17
impreg bits, 206, 206 (figure)	interstice, reservoirs, 9–10
improved oil recovery (IOR) processes, 255	investment risk matrix, 617–618, 618 (figure)
in situ combustion (ISC), 290–291, 291 (table), 292 (figure),	ionic surfactants, 278 (table), 282
313–315, 314 (figure), 315 (figure)	islands, artificial, 225, 226 (figure), 227 (figure)
in situ conversion processes (ICPs), 292, 293 (figure), 340	isothermal compressibility, 60–61, 62, 66
in situ deformation monitoring, 102	isothermal pressure versus specific volume ( <i>p-V</i> ) diagram, 67, 67
in situ permeability modification processes, 266–270, 266 (figure),	(figure)
267 (figure), 267 (table), 268 (table), 269 (table)	isotherms, capillary pressure by, 78 (figure), 78–79
in situ reactive gel system, 266–267	isotropic elasticity, 87, 88
in situ retorting, 384–386, 385 (figure)	iterative solution methods, numerical reservoir simulation,
in situ stress, 87, 99–101	188–189, 188 (figure)
	100–109, 100 (ligure)
in-capsule retorting, 386 incident indicators, 552, 552 (figure)	J
	Jack project, 655. See also semisubmersibles
incident management, 552	jacket removal, 582
incidents, major, 544–546 (table), 561–562, 563 (figure)	jackups, 225–226, 228 (figure)
inclination, well trajectory, 216	J-function (JF), Leverett, 70, 71 (figure)
incremental oil recovery factor, 256, 256 (figure)	Johnson-Bossler-Naumann (JBN) method, 75
Independence project, 653–654. <i>See also</i> semisubmersibles	J-shaped well configuration, SAGD, 311
indirect deformation monitoring, 102	9 ,
indirect method, asphaltene precipitation studies, 488	K
induction tools, 16	kelly pipes, 199–200
inelasticity, 91–92, 91 (figure), 92 (figure)	Kelvin's equation, 78
inference rules, artificial neural networks, 126	kerogen, 337–341
infinitesimal deformations, 84	commercial development, 341
inflow performance analysis, gas reservoirs, 398–404, 401 (table),	composition of, 338–339, 338 (table), 339 (figure)
402 (figure), 403 (figure), 403 (table), 404 (figure)	defined, 375
inflow performance relationships (IPRs)	general discussion, 346
deliverability and inflow analysis, 399–404, 401 (table), 402	operational challenges, 340-341
(figure), 403 (figure), 403 (table)	overview, 302, 337–338
well performance analysis, 411–414, 411 (figure)	production processes, 339 (figure), 339-340
infrared (IR), SARA analysis with, 485	resource estimate, 339
inherently safe design, 561, 561 (figure), 562 (figure)	See also oil shale; shale oil
initial conditions, numerical reservoir simulation, 187, 187 (figure),	Kerrobert Pilot, THAI process, 315
192	Khristianovic, Geertsma, and de Klerk (KGD) model, 355, 355
initial production rates, semisubmersible projects, 630, 635 (table),	(figure), 357 (table)
636 (figure)	kick detection, 213–214
injection processes. See specific flooding processes	kill line, BOP stack, 205
injection wells, 251	kinetic hydrate inhibitors (KHI), 437–438, 439
injuries. See safety	kinetics of asphaltene precipitation, 490
inspections, worksite, 552	Klinkenberg effect, 8, 13–14, 57, 57 (figure)
instrument air systems, solar-powered, 689–690	, , , , , , , , , , , , , , , , , , , ,
integrated oil sands mining operations. See oil sands mining	L
interaction matrix, 551	labeling, safety, 560
interfacial tension (IFT)	laboratory studies
asphaltene precipitation studies, 488	core sample electric properties, 60, 60 (figure)
effect on oil recovery, 277, 277 (figure)	microbial enhanced oil recovery, 470-473
overview, 69, 69 (figure)	relative permeability, 74–75, 74 (figure)

reservoir fluids, 68-69, 68 (table) marine environments See also core analysis environmental concerns, 542-543 laminar flow, 56, 56 (figure), 57, 398-400, 411-412 methane hydrate accumulation in, 333, 334 (figure) laminar-inertial-turbulent (LIT) flow analysis, 400, 402-403, 402 See also deepwater development (figure), 403 (figure), 403 (table) market allocation model (MARKAL/TIMES), 49 (table), 50 (figure) Marrat oil wells, Kuwait, 497–498, 497 (figure), 498 (figure) land, environmental concerns related to, 540-542, 541 (table) lateral MIST process, 272–273, 273 (figure) mass conservation, 180 laterolog tools, 16 material balance (MB) method, 45, 415-418, 416 (figure) Layers of Protection Analysis, 551 material failure. See failure leak detection, 524 mathematic model of petroleum migration, 125 leak-off tests (LOTs), 100-101, 100 (figure) matrix (micropores), coal, 7-8 learning curve, semisubmersible projects, 628, 629 (figure) matrix (primary porosity), 11, 55 leases, semisubmersible project, 618-619, 623-624, 625 (table) matrix shrinkage, in CBM reservoirs, 8 left-hand walk (LHW), 224 maturation of organic matter, 377-378 Leverett J-function (JF), 70, 71 (figure) maximum flow rate, 401 life-cycle economics, semisubmersible projects, 645, 647 (table) maximum operation pressure (MAOP), 510-511, 510 (figure) life-cycle stages, 571, 572 (figure), 614 (figure), 617 (figure), 652 maximum permeability, 14 Ligera 10178 platform conductor severance and removal cost, 587 McMillan-Mayer SAFT approach, 491-492 measurement-while-drilling (MWD) systems, 16, 219 light oil, 3 light tight oil (LTO), 335, 346 mechanical control of hydrate accumulations, 439 light-scattering technique (LST), 487, 489 mechanical entrapment, polymer, 260 (table) line heaters, 242, 242 (figure), 242 (table) mechanical shoe seals, 520, 520 (figure) line packing, natural gas, 523 mechanical specific energy (MSE), 208-209 linear curve-fitting models, 46 mechanical stability of polymers, 261 (table) linear elastic fracture mechanics (LEFM), 94-95 mechanical treatments, asphaltene deposition, 499 linear systems of equations, numerical solution of, 188–189, 188 mechanical wellbore intervention, 267 (table) medium oil, 3 (figure), 189 (figure), 189 (table) linear thermal expansion coefficient, 90, 96 memorization, neural network, 151 mercury injection, 13, 59, 59 (figure), 70 liquefaction, petroleum product, 508-509 liquefied natural gas (LNG), 666, 669-671, 671 (table). See also mesh-centered gridding, in numerical reservoir simulation, 185, natural gas 185 (figure) liquefied petroleum gas (LPG) pipelines, 513-514 Messoyakha gas hydrate deposit liquid constraint, gravity separator design, 234, 234 (table), 235, geology of, 453, 453 (figure) 235 (table) overview, 452-453 liquid fuels, 31-33, 32 (figure). See also specific fuels reserves and production history, 453–454, 454 (figure) liquid permeability, 56-57 reservoir behavior analysis, 454, 454-456 (figure), 455 (table), liquid phase, reservoir fluid phase behavior, 66-67, 67 (figure) 456-458, 457 (figure) liquid-level control, gravity separator, 237-238, 237 (figure), 238 metagenomics, 464 (figure), 464-467 (figure) meters liquid-liquid (L-L) solubility approaches, 490-491 for pipelines, 511 primary production facilities, 246-247, 246 (figure) liquid-rich shales (LRS), 335, 346 liquids. See fluids methane emissions, 537-538, 537 (figure) Lobster platform removal cost estimate, 590 methane hydrates, 332-335 logging, well. See well logging accumulation of, 333, 334 (figure) logging while drilling (LWD), 16, 219 composition of, 443, 443 (figure) long-range energy alternative planning model (LEAP), 49 (table), defined, 321 51 (figure) dissociation prediction, 431 (figure) formation of, 446 low-dosage hydrate inhibitors (LDHI), 437-438 Lower Tertiary (Wilcox) trend, 605-606, 607 (figure) general discussion, 346 low-pH microgels, 268 hydrate formation zone, 447, 448 (figure) low-salinity water flooding (LSW), 291-292 influence on environment, 436 lumped models, hydraulic fracturing, 355, 356 (figure) overview, 302, 332-333, 397 production mechanisms, 334-335 recent developments and field testing, 335 M reservoir types, 333-334 macropores, coal, 7-8 See also coalbed methane maintenance, storage and transportation, 525-526, 525 (figure) methanogens, 463, 463 (table) Makogon, Dr. Y. F., 434 (figure), 434-435 methanol, in hydrate control, 438 (figure), 438-439, 440 maltenes, 486 micellar flooding, 283-285 managed pressure drilling (MPD), 214-215, 214 (figure), 215 (figure) micelles, critical concentration of, 278, 279 (figure) manifolded system, subsea wells, 610, 611 (figure) microbial enhanced oil recovery (MEOR), 468-475 Marcellus Shale, 378, 379 (figure)

biopolymers and biofilms, 470	mobility ratio, 257–258
biosurfactants, 286, 287, 469-470	mobility-control processes, in EOR, 256, 265-266. See also
cyclic, 286	polymer flooding
energy future, 706	mobility-induced viscous fingering, 258, 258 (figure)
enhanced water flooding, 286	model for analysis of energy demand (MAED), 49 (table)
field trials, 473-475	model for energy supply strategy alternatives and their general
fundamentals and mechanisms, 468-470, 469 (table)	environmental impacts (MESSAGE), 49 (table)
laboratory studies, 470-473	model for optimization of dynamic energy systems with time-
microbial gases, solvents, and acids, 470	dependent components and boundary conditions (MODEST),
organic oil recovery, 286–287	49 (table)
overview, 286–287, 468	modeling, reservoir, 18. See also specific modeling types
microbiology of petroleum reservoirs, 461-475	modular energy system analysis and planning (MESAP), 49 (table
culture-dependent study techniques, 463-464	Mohr circle diagram, 86–87, 87 (figure), 93, 93 (figure)
future perspectives, 475	Mohr-Coulomb failure criterion, 93-94, 93 (figure), 94 (figure)
metagenomics, 464 (figure), 464–467	moisture control, gas hydrates, 437
overview, 461–463, 463 (table)	molecular weight (MW)
problems associated with studying, 467-468	asphaltene, 484–485
See also microbial enhanced oil recovery	crude oil, 65
microemulsion phase behavior, 278-280, 279 (figure), 281	gas, 63
microemulsion polymer flooding systems, 284 (table)	polymer, 260, 264 (table), 269 (table)
microemulsion viscosity, 281, 284 (table)	monitoring, in environmental management, 548–549. See also
microfluidic channel experiments, 495	specific monitoring types
microgels, 267, 268	monitoring system, drill rig, 205
micropores, coal, 7–8	monoborate, 359
microscopic sweep efficiency, 276 (figure), 277	monobore well technology, 213
microscopy, in asphaltene precipitation studies, 487, 489	monoethylene glycol (MEG), 438–439
microseismic monitoring, 373, 388	mooring systems, floating platforms
microspheres, 267–268	decommissioning cost, 590–591, 593
Middle East	overview, 577, 578 (figure), 601–602, 601 (figure)
energy future, 706–707	removing, 582
EOR technique implementation in, 699–700	Morpeth MTLP, 591
oil production, 661, 662, 662 (figure), 663, 663 (figure), 664	morphology of hydrate crystals, 444, 444–445 (figure)
(figure)	mud circulation system, drill rig, 201–202, 202 (table), 204 (figure
midstream oil production processes, 679	mud pressure bounds, 210–211, 210 (figure), 211 (figure), 212 (figure
migration history. See hydrocarbon migration and accumulation	mud-pulse-telemetry (MPT), 219
history simulation	mudrock, 375
mineralogy of shale and mudstone, 376–377, 376–377 (figure)	muds, drilling, 530, 538–539, 555, 555 (figure)
minimum miscibility enrichment (MME), 275, 276 (figure)	mudstone
minimum miscibility pressure (MMP), 275, 275 (figure), 276 (figure)	mineralogy of, 376–377 (figure), 376–377
mini-tension leg platforms (MTLPs), 578, 579–580 (table), 580	oil and gas production from, 387–389
(figure), 590–591, 590 (table), 600 (figure) Miocene trend, 605, 607 (figure)	overview, 375
miscible gas injection processes, 271–275	See also shale- and mudstone-hosted oil and gas multicycle curve-fitting models, 46
carbon dioxide flooding, 274–275	Multidrain SAGD, 311
first contact miscible, 271–273, 272 (figure), 273 (figure)	multiphase flow
minimum miscibility enrichment, 275, 276 (figure)	hydrate control and, 441
minimum miscibility pressure, 275, 276 (figure), 276 (figure)	well performance analysis, 412
multiple contact miscible, 273–274	wellbore and outflow performance analysis, 408–411
overview, 271, 272 (table)	multiphase problems, numerical reservoir simulation, 187
WAG process, 270	multiple contact miscible (MCM), 271, 272 (table), 273–274
miscible injectant stimulation (MIST), lateral, 272–273, 273 (figure)	multiple linear regression, 171, 171 (figure)
Mississippian Limestone Play (MLP), 368–369	multiproduct pipelines, 513, 513 (figure)
mitigation strategies, asphaltene deposition, 498–499	multiscale geothermal field, dynamic simulation of, 117–118,
mixed porosity system reservoirs, 6	118 (figure)
mobile offshore drilling units (MODUs)	multiscale modeling, 111, 111 (figure)
floating, 226–228, 229 (figure), 230, 230 (figure)	multistage hydraulic fracturing, 388
overview, 225	multistage triaxial compression test, 97
semisubmersible, 227, 230 (figure)	
submersible, 225, 227 (figure), 228 (figure)	N
mobile offshore production units (MOPUs), 578, 579 (figure), 601.	Na Kika project, 653. <i>See also</i> semisubmersibles
See also floating systems; semisubmersibles	nanoparticle-modified VES systems, 362, 362 (figure)
mobile oil zone (MOZ), THAI process, 314, 314 (figure), 315	nanoscale aspects of hydrates, 441, 442 (figure)
	T =

```
naphthenes, 65
                                                                                  hydrate control, 436-442, 438 (figure), 439 (figure),
naphthenic acids, 317
                                                                                     440 (figure), 441 (figure), 442 (figure)
national energy modeling system (NEMS), 49 (table)
                                                                                  location of deposits, 447-451, 450 (figure)
natural bitumen. See bitumen
                                                                                  morphology of hydrate crystals, 444, 444-445 (figure)
                                                                                  overview, 9, 241-242, 429-430, 442
natural gas
     compression, 242-244, 243 (figure), 244 (figure)
                                                                                  phase diagram, 431 (figure)
     consumption, 26 (figure), 29-31, 29 (figure), 30 (figure),
                                                                                  preventing formation of, 241-242, 242 (figure), 242 (table)
                                                                                  properties of, 445-446, 445 (figure)
       30 (table), 669, 671 (figure)
     data reliability, 41-43
                                                                                  and regional ecology and global changes, 435-436
     deepwater, 35-36, 36 (figure)
                                                                                  removal of, 439-440
     dehydration, 244-245, 244 (figure), 610-611
                                                                                  thermal properties, 446
     depletion estimation, 45-48
                                                                                  zone of formation, 446-447, 448 (figure), 449 (figure)
     energy future, 33-34, 33 (figure), 34 (figure)
                                                                                  See also methane hydrates
     generation from source rocks, 377-378, 378 (figure),
                                                                             natural gas production engineering, 395-425
                                                                                  field development and performance prediction, 420-425, 421
       379 (figure), 380 (figure)
                                                                                     (figure), 422 (figure), 424 (figure), 425 (figure), 425 (table)
     gravity separator emissions, 238
     history of, 529
                                                                                  overview, 397 (figure), 397-398
     liquefied, 666, 669-671, 671 (table)
                                                                                  reserves assessment, 415-420, 416 (figure), 419 (figure), 420
     major producers of, 529
     overview, 21, 26-27
                                                                                  reservoir deliverability and inflow performance analysis,
     phase behavior, 66-67, 67 (figure)
                                                                                     398-404, 401 (table), 402 (figure), 403 (figure), 403 (table),
     pipelines for, 513-514
                                                                                  well and system performance analysis, 411–414, 411 (figure),
     price of, 667, 668 (figure), 671
     production history, 666-669, 668 (figure)
                                                                                     412 (figure), 413 (figure), 413 (table), 414 (figure), 414
     production process overview, 529-531, 530 (figure)
     production rates, 26 (figure), 29-31, 29 (figure), 30 (figure),
                                                                                  wellbore and outflow performance analysis, 404-411,
                                                                                     409 (table)
       30 (table), 669, 669 (figure), 670 (figure)
     refining, 531
                                                                             naturally fractured reservoirs, 11, 17-18, 58, 58 (figure)
     reserves
                                                                             naturally occurring radioactive material (NORM), 238-239,
          contemporary, 669, 669 (figure), 670 (figure)
                                                                                560, 560 (figure)
          energy future, 694, 696, 696 (figure)
                                                                             near-infrared (NIR), 485, 487, 489
          estimation methods, 43-45
                                                                             negative salinity gradient, 283
          general discussion, 27-29
                                                                             Neumann-type boundary condition, 186, 186 (figure)
                                                                             neural networks. See artificial neural networks
          historical data, 27 (figure), 28 (figure)
          overview, 26 (figure)
                                                                             neutron radiation, 16
          top ten countries, 27 (table)
                                                                             Newtonian fracturing fluids, planar-3D model for, 356-358
     reserve-to-production ratio, 26 (figure), 28-29
                                                                             Newtonian liquids, 208, 208 (figure)
     as reservoir fluid, 62-63, 62 (table), 63 (figure)
                                                                             Newton's Law, 233, 234
     role in world energy market, 657, 658 (figure)
                                                                             Nigeria, regulatory framework in, 536
     semisubmersible production of, 628, 631 (table),
                                                                             nitrate reducers, 463
       632 (figure)
                                                                             nitrogen (N<sub>2</sub>)
     storage, 523, 523 (figure)
                                                                                  enhancing recovery of CBM with injection, 8
     in USOSC, 680
                                                                                  in FCM, 272
     See also natural gas production engineering; reservoir fluids;
                                                                                  in immiscible gas flooding, 276
       specific production techniques; specific unconventional
                                                                                  in MCM, 274
       resources; unconventional hydrocarbon resources
                                                                             nitrogen foam, 363
natural gas from coal. See coalbed methane
                                                                             Niuzhuang-Wangjiagang region. See Dongying Sag petroleum
natural gas hydrates, 241-245, 429-458
                                                                                system simulation
                                                                             NODAL Analysis<sup>TM</sup>, gas well, 411-414, 411 (figure), 412 (figure),
     commercial production, 452-454, 453 (figure), 454-456
       (figure), 456–458, 457 (figure)
                                                                                413 (figure), 413 (table), 414 (figure), 414 (table)
     composition of, 442-443
                                                                             noise hazards, 546
     decomposition of, results of studying, 451 (table), 451-452
                                                                             nonfossil fuels, 33, 34-35, 34 (figure). See also renewable energy
     deposits of, 429, 430 (figure)
     dissociation conditions, 432 (figure)
                                                                             nonionic surfactants, 278 (table), 282
     dissociation prediction, 431 (figure)
                                                                             non-Newtonian liquids, 208, 208 (figure)
     formation of
                                                                             nonrenewable energy sources, 657-660. See also specific energy
          conditions for, 241, 242 (figure)
          and location of deposits, 447-448, 448 (figure)
                                                                             nonwetting phase, defined, 69
          overview, 442, 442 (figure), 443 (figure)
                                                                             nonwetting phase trapping, 71, 71 (figure)
          properties of hydrate, 445-446
                                                                             normal geothermal field, 116
          results of studying, 451-452, 451 (table)
                                                                             normal strain, 84-85, 85 (figure)
     history of research on, 431-435
                                                                             normal-compaction section submodel of thermal evolution, 117
```

North America	overview, 461–462
associations pertaining to oil and gas industry, 547	price of, 661, 662, 663, 663 (figure), 693, 694 (figure)
energy future, 706–707	production
major incidents in, 544-546 (table)	contemporary, 664–666, 666 (figure)
regulatory framework in, 532-533	historical data, 25 (figure)
N-SOLV technology, 316, 345	history of, 660–664, 662 (figure), 663 (figure), 664 (figure)
nuclear magnetic resonance (NMR) method, 488	overview, 22 (figure), 24–26
nuclear power, 35	top ten countries, 26 (table)
nucleation, natural gas hydrates, 445	prospective outlook on, 21
nucleic acids extraction, 465-466	relative permeability, 73
numerical reservoir simulation, 177–195	reserves
discretized form of flow equations, 182-185, 182 (figure),	contemporary, 664-666, 665 (figure)
183 (figure), 185 (figure)	energy future, 693-694, 695 (figure), 696
documentation, 193–194	estimation methods, 43–45
flow equations in rectangular coordinates, 180-182, 180 (figure)	historical data, 23 (figure), 24 (figure)
formulations, 180	overview, 21–24, 22 (figure)
fundamentals of, 180	top ten countries, 23 (table)
general discussion, 194–195	reserve-to-production ratio, 22, 22 (figure), 23, 24 (figure),
gridding, boundary types, and conditions, 185–187, 185	695 (figure)
(figure), 186 (figure), 187 (figure)	as reservoir fluid, 64 (table), 65-66, 66 (figure)
model selection and construction, 190–192, 191 (figure),	reservoir rock wettability, 71–72, 71 (figure)
192 (table)	role in world energy market, 657, 658 (figure)
numerical solution of linear systems of equations, 188–189,	semisubmersible production of, 628, 631 (table), 632 (figure)
188 (figure), 189 (figure), 189 (table)	trace, removal from wastewater, 239–241, 240 (figure)
overview, 177–180, 178 (figure)	See also energy future; microbiology of petroleum reservoirs;
predictions, 193, 194 (figure)	petroleum geomechanics; reservoir fluids; <i>specific entries</i>
properties required to construct, 178, 179 (table)	under "hydrocarbon"; specific oil types; unconventional
reservoir characterization, 190	hydrocarbon resources; upstream oil supply chain
statement and prioritization of objectives, 189–190	oil field data mining
validation, 192–193, 192 (table), 193 (figure), 194 (figure)	artificial neural networks, 149–152, 150 (figure), 151 (figure)
variation, 172 173, 172 (table), 173 (figure), 171 (figure)	production optimization
0	data availability and statistical analysis, 168–170, 169
oblique shearing mechanism, 114, 114 (figure)	(table), 170 (table)
occupational hazards	data-driven modeling, 170–173, 171 (figure), 172 (figure)
health and safety management systems, 549–553, 550 (figure),	full-asset type curve analysis, 174, 175 (figure)
551 (figure), 552 (figure), 553 (figure)	single-well, single-parameter sensitivity analysis, 173,
minimizing, 557–562, 558 (figure), 559 (figure), 560 (figure),	173 (figure)
561 (figure), 562 (figure), 563 (figure)	single-well, type curve analysis, 173, 174 (figure)
overview, 543, 546–547	single-well, type curve analysis, 174, 174 (figure)
	reservoir characterization
See also safety	
Occupational Health and Safety Advisory Services (OHSAS), 553	overview, 152–153, 152 (figure)
off-bottom test (OBT), 224	seismic survey, 154
Offset SAGD, 312	seismic to well logs, 153–154, 153 (figure)
offshore conditions, gas hydrate formation in, 449 (figure)	synthetic model, 154–161, 155 (figure), 155 (table), 156 (figure), 157 (figure), 158 (figure), 158 (table),
offshore drilling	
bottom-founded systems, 225–226, 226 (figure), 227 (figure),	159–161 (figure), 161 (table)
228 (figure), 229 (figure)	Valley Field case study, 161–164, 162 (figure), 163
floating systems, 226–228, 229 (figure), 230, 230 (figure)	(figure), 164 (table), 165–168 (figure), 165 (table)
overview, 225	oil recovery factor
See also decommissioning cost estimation in deepwater	incremental, 256, 256 (figure)
GOM; deepwater development; semisubmersibles	secondary oil recovery, 255
offshore pipelines, 514, 514 (figure)	oil reservoirs, 3, 4. See also microbiology of petroleum reservoirs;
offshore reservoirs, deepwater, 302, 341–342, 341 (figure), 342	reservoirs
(table), 343 (figure), 344 (figure), 346–347	oil sands mining
oil	bitumen extraction, 317
consumption, 22 (figure), 24–26, 25 (figure), 26 (table), 666,	bitumen upgrading, 318–319, 320 (figure), 320 (table)
667 (figure)	challenges of, 319, 320 (figure)
data reliability, 41–43	energy future, 37–38, 38 (figure)
deepwater, 35–36, 36 (figure), 343–344	environmental concerns, 537
depletion estimation, 45–48	general discussion, 345–346
generation from source rocks, 377–378, 378 (figure)	oil sand tailings, 317–318, 318 (figure), 318 (table), 319 (table)
in Messoyakha gas hydrate deposit, 456, 457 (figure)	overview, 302, 316–317

production overview, 531	paraffin wax control, 441
Oil Sands Safety Association, 547	parallel plate coalescer, removing trace oil with, 239-240, 240 (figure)
oil shale	passive solar energy, 684
defined, 373, 375	pattern flooding, 251, 252 (figure), 253, 253 (figure)
energy future, 39, 39 (figure), 39 (table)	PDC bits, 205, 206, 206 (figure)
overview, 302	peak production to reserves ratio, semisubmersible projects, 631,
potential for technology improvement, 390	635, 637 (table)
potential resources, 379–380, 381 (figure)	pendulum force, 224, 224 (figure)
retorting, 384–387, 385 (figure)	Peng-Robinson (PR) EOS, 67
See also kerogen; shale oil	perceptrons, 149
oil spills, 539, 541, 542, 554	performance forecasting, gas field
oil-based fracturing fluids, 351. See also hydraulic fracturing	build-up production period, 421 (figure), 421–422
oil-based mud (OBM), 207	decline production period, 422 (figure), 422–423
oilfield processes, USOSC, 680-681	example of, 423–425, 424 (figure), 425 (figure), 425 (table)
onshore conditions, gas hydrate formation in, 448 (figure)	plateau production period, 422
open-hole logging, 16	performance indicators, environmental, 548
operating expenses, semisubmersible projects, 644	peripheral flooding, 251, 252 (figure)
operating pressures	Perkins, Kern, and Nordgren (PKN) model, 355, 355 (figure),
gravity separator, 236–237, 237 (figure)	357 (table)
topsides facilities, 610, 612 (table)	permafrost areas, gas hydrate deposits in, 447-448, 450-451, 450
operator liability, decommissioning, 597	(figure)
optimal depletion theory, 48	permeability
optimal renewable energy model (OREM), 49 (table)	absolute, 11, 13–14
optimization, drilling, 208–210, 209 (figure). See also production	CBM reservoirs, 8, 330–331
optimization, data mining for	core analysis, 13–14
optimization energy systems modeling platforms, 49 (table),	directional, 6, 10
50–51, 50 (figure)	effective, 11, 73, 74
optimum offtake pattern, 425	fracture, 58
optimum salinity concentration, 280–281	grain size and pore size distributions, 58–59
Ordovician period, 378, 379 (figure)	horizontal, 10–11, 14
organic oil recovery, 286–287	in situ permeability modification processes, 266–270, 266
Organization for Economic Co-operation and Development	(figure), 267 (figure), 267 (table), 268 (table), 269 (table)
(OECD) countries	liquid, 56–57
natural gas consumption, 29, 29 (figure), 33, 33 (figure), 34 (figure)	maximum, 14
natural gas production, 30 (figure)	reservoir, polymer flooding as reducing, 259-260
natural gas reserves, 27–28, 27 (figure)	reservoir rock, 2, 10–11, 56–57, 56 (figure), 57 (figure),
nonfossil fuels in, 35	58 (figure)
oil consumption, 25 (figure)	unconventional reservoirs, 77–78, 78 (figure)
oil production, 25 (figure)	vertical, 10–11, 14
oil reserves, 23 (figure)	See also relative permeability
projected energy consumption, 31, 31 (figure), 32 (figure)	perturbed chain form of the statistical associating fluid theory
share of consumption for fuel types, 34 (figure)	(PC-SAFT) equation of state, 491, 492, 492 (figure)
Organization of Petroleum Exporting Countries (OPEC)	petrographic classification of kerogen constituents, 338 (table)
oil production, 25 (figure), 661, 662	petroleum accumulation. See hydrocarbon migration and
oil reserves, 22–23, 23 (figure)	accumulation history simulation
projections of liquid fuel production, 32, 32 (figure)	petroleum expulsion. See hydrocarbon expulsion history
orifice meters, 246, 246 (figure)	petroleum generation. See hydrocarbon generation history
original-gas-in-place (OGIP), assessment of, 76–77, 415, 416, 416	petroleum geomechanics, 83–103
(figure), 418, 419–420, 419 (figure), 420 (figure)	application considerations, 101–102, 101 (figure), 102 (figure)
outflow performance	basic parameters for continuous materials, 95–96
well performance analysis, 411–414, 411 (figure)	characterization, 95–102
wellbore performance analysis, 404-411, 409 (table)	deformation and strain, 83-85, 84 (figure), 85 (figure)
overbalanced drilling fluids, 207–208, 208 (figure)	elasticity, 87–89, 88 (figure), 89 (figure)
overcompaction section submodel of thermal evolution, 117	failure, 92–95, 93 (figure), 94 (figure), 95 (figure)
overtraining, neural network, 151	inelasticity, 91–92, 91 (figure), 92 (figure)
ownership, semisubmersible projects, 644	overview, 83
oxidizers, as breakers for fracturing fluids, 359, 360	poroelasticity, 89–90
	sources for geomechanical parameters, 96–101, 96 (figure),
P	97 (figure), 98 (figure), 99 (figure), 100 (figure)
$p^2$ -approach	stress, 85–87, 86 (figure), 87 (figure)
deliverability and inflow analysis, 398–399, 400, 402, 402 (figure)	surveillance, 102–103
gas well performance analysis, 414	thermal effects, 90–91

point-the-bit RSS, 220, 221 (figure)

```
petroleum migration history. See hydrocarbon migration and
                                                                             Poiseuille's equation, 59
  accumulation history simulation
                                                                             Poisson's ratio, 88, 88 (figure), 95, 99, 99 (figure)
petroleum pipelines. See pipelines
                                                                             pollution. See environmental concerns
                                                                             polyborate, 359
petroleum reservoirs. See microbiology of petroleum reservoirs;
                                                                             polymer flooding, 256-265
  reservoirs
petroleum system simulation. See 3D dynamic simulation of
                                                                                  ASP flooding, 285-286
                                                                                  design of, 262-263
  pool-forming
petroleum transmission ratio, 129-130
                                                                                  field applications, 263-265
Petronius compliant tower, 576 (figure)
                                                                                  flow of polymers through porous media, 258, 259 (figure)
phase behavior
                                                                                  general screening guidelines, 261-262, 262 (table), 263 (table)
     numerical reservoir simulation, 181-182
                                                                                  mechanisms of oil recovery by, 258-260, 259 (figure), 260 (table)
     reservoir fluids, 66-69, 67 (figure), 68 (figure), 68 (table)
                                                                                  overview, 256
     surfactant, 278-281, 279 (figure), 280 (figure)
                                                                                  polymer stability, 260-261, 261 (table), 264 (table)
phase diagrams, for reservoir fluid, 2-4, 3 (figure)
                                                                                  recent trends, 263, 264 (table)
phase judgment submodel of petroleum migration, 124-125
                                                                                  reservoir conformance and volumetric sweep efficiency,
                                                                                    256-258, 257 (figure), 257 (table), 258 (figure)
phase states of gas-water systems, 430, 431 (figure)
phase trapping, surfactant, 283
                                                                                  surfactant flooding and, 281
photovoltaic (PV) solar energy, 684, 684 (figure), 685 (figure), 686
                                                                             polymer gels, for conformance control, 266 (figure), 266-270, 267
physical state of fluids, reservoir classification based on, 2–4, 3 (figure)
                                                                                (figure), 267 (table), 268 (table), 269 (table)
physical treatment, wastewater, 556 (table)
                                                                             polymer retention, 259-260, 260 (table)
pipe rams, 204-205, 205 (figure)
                                                                             polymerase chain reaction (PCR), 465
pipelines, 509-516
                                                                             polymer-enhanced foams, 266
     asphaltene deposition in, 492-493, 495-496, 496 (figure)
                                                                             polymeric fracturing fluids, 351
     basic conceptions about pipe flow, 510, 510 (figure)
                                                                             Pompano platform, 573, 591
                                                                             pool-forming simulation. See 3D dynamic simulation of pool-forming
     classification, 509-516, 510 (table)
     construction, 515, 515 (figure)
                                                                             popping and swelling microgels, 267
                                                                             pore collapse, 91, 94
     corrosion prevention, 523-524, 524 (figure)
                                                                             pore compressibility, 61, 61 (figure)
     cost of, 515-516
                                                                             pore pressure, 89, 90, 210-211, 211 (figure), 212 (figure)
     crude oil and refined product, 513, 513 (figure)
     decommissioning cost, 585 (table), 587-588, 588 (table), 592-593
                                                                             pore size distribution, reservoir rock, 58-59, 59 (figure)
     decommissioning stages, 581-582
                                                                             pore space, reservoirs, 9-10
     export, 607, 608 (figure), 611, 623, 624 (table), 625 (figure)
                                                                             pore systems, 6, 89
     filling and discharging practice, 526, 526 (figure)
                                                                            pore volume compressibility, 97-98
                                                                            poroelasticity, 89-90, 95
     fire and explosion hazards, 546
     fire prevention and extinguishing, 525
                                                                            porosity
     general design, 510-511, 511 (figure)
                                                                                  absolute, 10, 55
     groundwater protection, 524-525, 525 (figure)
                                                                                  in CBM reservoirs, 8
     history of, 507, 508 (figure)
                                                                                  core analysis, 13
     issues with, 666
                                                                                  defined, 89
                                                                                  deformation parameters, 95
     leak detection, 524
     maintenance and repairs, 525-526, 525 (figure)
                                                                                  dual-porosity systems, 11, 17
     major components, 511, 512 (figure)
                                                                                  effective, 10, 55
     natural gas and LPG, 513-514
                                                                                  fracture, 58
     offshore, 514, 514 (figure)
                                                                                  grain size and pore size distributions, 58-59
     operations, 512-513, 513 (figure)
                                                                                  primary, 11, 55
     SCADA and pipeline control system, 514, 515 (figure)
                                                                                  reservoir rock, 2, 10, 55, 56 (figure)
     in USOSC, 680
                                                                                  secondary, 6, 11, 55
     in world, 516
                                                                                  storage, 6
piping, analysis of, 404-411
                                                                                  total or absolute, 10
planar 3D models (PL3D), hydraulic fracturing, 356-358, 357 (table)
                                                                            porosity-depth curve model, 115-116, 115 (figure)
plastic viscosity (PV), drilling fluids, 208, 208 (figure)
                                                                             porous media
                                                                                  asphaltene deposition in, 493-495, 496-497
plasticity, 91-92, 91 (figure), 92 (figure)
plateau production period, gas field, 421 (figure), 422, 423-424
                                                                                  flow of polymers through, 258, 259 (figure)
platform deformation, monitoring, 102
                                                                                  foam flooding, 265-266
plug analysis, 12, 13, 16
                                                                                  gas hydrate formation in, 442, 443 (figure)
plugging
                                                                            positive displacement mud motor (PDMM), 200-201, 203 (figure)
     microbial, 470, 472
                                                                             power swivel rotary systems, 200, 203 (figure)
     well, 581, 585-586, 585 (table), 586 (figure), 591, 593
                                                                             power system, drill rig, 198
plugs, gas hydrate, 439 (figure), 439-441, 440 (figure)
                                                                             precipitation
                                                                                  polymer, 260 (table)
point-distributed gridding, in numerical reservoir simulation, 185,
   185 (figure)
                                                                                  surfactant, 281
```

See also asphaltene precipitation

```
prediction stage, numerical reservoir simulation, 193, 194 (figure)
                                                                                   polymer flooding, 263, 264 (table)
presalt, 673
                                                                                   recycle and reuse of, 554-555
present value curves, semisubmersible projects, 645, 647 (figure)
                                                                                   topsides facilities, 611
pressure
                                                                              producing wells, semisubmersible projects, 629, 634 (figure)
                                                                              product tankers, 517–518, 517 (figure), 517 (table)
     bottomhole, 406-407, 417
                                                                              production
     bubble-point, 3, 66–67, 67 (figure)
     constant bottomhole, 214, 215 (figure)
                                                                                   crude oil, stages of, 249-255, 250 (figure), 252 (figure),
     in deliverability and inflow analysis, 398-404
                                                                                      253 (figure), 254 (figure)
     dew-point, 3, 66-67, 67 (figure)
                                                                                   decline analysis, 416-417
     formation pore fluid, 210-211
                                                                                   deepwater oil and gas, 35-36, 36 (figure)
     fracture, 210-211, 211 (figure), 212 (figure)
                                                                                   energy future, 31-35, 31 (figure), 32 (figure), 33 (figure),
     maximum operation, 510-511, 510 (figure)
                                                                                      34 (figure)
     minimum miscibility, 275, 275 (figure), 276 (figure)
                                                                                   life-cycle stages, 652
     operating, 236-237, 237 (figure), 610, 612 (table)
                                                                                   Messoyakha gas hydrate deposit history, 453-454, 454 (figure)
     pipe flow basics, 510, 510 (figure)
                                                                                   natural gas
     pore, 89, 90, 210-211, 211 (figure), 212 (figure)
                                                                                        contemporary, 669, 669 (figure), 670 (figure)
                                                                                        history, 666-669, 668 (figure)
     reservoir fluid phase behavior, 66-67, 67 (figure)
     reservoir fluid phase diagram, 2-4, 3 (figure)
                                                                                        process overview, 529-531, 530 (figure)
                                                                                        rates of, 26 (figure), 29-31, 29 (figure), 30 (figure), 30 (table)
     saturation, 3
     subsurface, 1
     vapor, 509
                                                                                        contemporary, 664-666, 666 (figure)
     well performance analysis, 411
                                                                                        historical data, 25 (figure)
                                                                                        history of, 660-664, 662 (figure), 663 (figure), 664 (figure)
     wellbore, 210-211, 210 (figure), 211 (figure), 212 (figure)
     wellbore and outflow performance analysis, 404-411
                                                                                        overview, 22 (figure), 24-26
      See also capillary pressure
                                                                                        top ten countries, 26 (table)
pressure control, gas hydrates, 437, 439-440
                                                                                   process overview, 529-531, 530 (figure)
pressure coring, 12
                                                                                   prospective outlook on, 21
pressure transient testing (well testing), 12, 17
                                                                                   reservoir classification based on, 4-5, 6-9
pressure vacuum vent valve, 521, 521 (figure)
                                                                                   risk involved, 617 (figure)
pressure versus temperature (p-T) diagram, 67, 67 (figure)
                                                                                   semisubmersible projects
pressure-matching process, 192, 193 (figure)
                                                                                        capacity-reserves relations, 636, 637 (figure), 638 (figure)
pressure-transient analysis (PTA), 417
                                                                                        initial production rates, 630, 635 (table), 636 (figure)
pressurized mud cap drilling (PMCD), 214-215, 215 (figure)
                                                                                        oil and gas, 628, 631 (table), 632 (figure)
price variation risk, semisubmersible project, 618
                                                                                        peak production to reserves ratio, 631, 635, 637 (table)
Priestley, Joseph, 433 (figure), 433-434
                                                                                        producing wells, 629, 634 (figure)
primary porosity, 11, 55
                                                                                        production capacity, 631, 636 (table)
primary production facilities, 233-247
                                                                                        production cost, 644
     changing conditions, 247
                                                                                        revenue, 638 (table), 639 (figure), 640 (figure), 641 (figure)
     dehydration, 244-245, 245 (figure), 245 (table)
                                                                                        scale of, 628-629, 632 (figure), 633 (figure)
     gas compression, 242-244, 243 (figure), 244 (figure)
                                                                                        unit production, 630, 634 (figure)
     hydraulic fracturing water, 241
                                                                                   shale-hosted hydrocarbon, projected, 389–390, 389 (figure)
     meters, 246-247, 246 (figure)
                                                                                   unconventional gas, 40-41, 41 (figure), 42 (table)
     natural gas hydrates, 241-242, 242 (figure), 242 (table)
                                                                                   unconventional oil, 36-40, 37 (figure), 38 (figure), 38 (table),
                                                                                      39 (figure), 40 (figure), 40 (table)
     solids separation, 241, 241 (figure)
     trace oil removal from wastewater, 239-241, 240 (figure)
                                                                                    See also primary production facilities; specific production stages
      See also gravity separation
                                                                                      and techniques
primary recovery, 249, 250 (figure), 461, 530, 699, 700 (figure)
                                                                              production data analysis (PDA), 415, 416-420, 419 (figure),
principal component analysis (PCA), 485
                                                                                 420 (figure)
process controls, 559-560
                                                                              production engineering. See natural gas production engineering
                                                                              production facilities. See primary production facilities
process heating and cooling, topsides facilities, 610
processing
                                                                              production optimization, data mining for, 168-175
     environmental concerns related to, 537
                                                                                   data availability and statistical analysis, 168-170, 169 (table),
     offshore, 606, 608 (figure), 610
processing plants, 540, 559, 559 (figure)
                                                                                   data-driven modeling, 170-173, 171 (figure), 172 (figure)
                                                                                   full-asset type curve analysis, 174, 175 (figure)
produced water
     CBM development, 331-332
                                                                                   single-well, single-parameter sensitivity analysis, 173, 173 (figure)
     characteristics and compositions of, 539 (table)
                                                                                   single-well, type curve analysis, 173, 174 (figure)
     defined, 538
                                                                                   single-well uncertainty analysis, 174–175, 175 (figure)
     environmental concerns, 538, 538 (figure), 539 (table)
                                                                              production periods, gas field
                                                                                   build-up, 421-422, 421 (figure)
     gravity separation, 238–239, 238 (table)
     hydraulic fracturing, 328, 366, 366 (table)
                                                                                   decline, 421 (figure), 422-423
     Messoyakha gas hydrate deposit, 456
                                                                                   plateau, 421 (figure), 422, 423-424
```

production platforms, 679. See also specific platform types; specific	quartz crystal microbalance with dissipation (QCM-D)
platforms	experiments, 493
productivity index (PI), gas well, 399, 400, 418, 420, 420 (figure)	quartz crystal resonator (QCR) technique, 488, 489
profitability, semisubmersible projects, 645, 647 (figure),	
647 (table), 648, 648 (figure)	R
propane, PVT relations of, 67, 67 (figure)	radial fluid flow, 56, 56 (figure), 57
property modeling, 110	radiation exposure, 546, 560, 560 (figure)
proppant transport model, 357–358	radioactive heat generation rate, 119, 119 (table)
proppants, hydraulic fracturing, 325–327, 326 (table), 327 (table),	radioactive logging, 16
336, 351	radioactive material
propped hydraulic fracturing, 354–358	in produced water, 238–239
derivation of planar-3D model, 356–358	in waste, 541, 541 (table)
model comparison, 357 (table)	ram preventers, BOP stack, 204–205, 205 (figure)
overview, 354–355	rate of penetration (ROP), 209–210, 209 (figure)
pseudo-3D and 3D models, 355–356, 356 (figure)	rate-of-return curves, semisubmersible projects, 645, 648,
two-dimensional models, 355, 355 (figure)	648 (figure)
prospective outlook on long-term energy systems (POLES),	rate-transient analysis (RTA), 415, 416–419
49 (table), 52 (figure)	Rawlins and Schellhardt analysis, 400–401, 403–404, 404 (figure)
prospective outlook on world oil and gas reserves, 21–52	reactive control strategy, 254
data reliability, 41–43	real gas, 63, 63 (figure)
energy future	reciprocating compressors, 243, 243 (figure)
deep-water oil and gas outlook, 35–36, 36 (figure)	reclamation, oil sand tailings, 318, 319 (table)
fuel production and consumption, 31–35	recovery. See production; specific hydrocarbon resources; specific
unconventional gas, 40-41, 41 (figure), 42 (table)	recovery techniques
unconventional oil, 36-40, 37 (figure), 38 (figure),	recovery factor, 255, 256, 256 (figure)
38 (table), 39 (figure), 39 (table), 40 (figure),	recovery phases, 461, 699, 700 (figure). See also specific recovery
40 (table)	phases
energy systems models, 48, 49-50 (table), 50-52	recovery technology, reservoir classification based on, 6-9
estimation methods, 43-48, 43 (figure), 47 (figure)	rectangular coordinates, flow equations in, 180-182, 180 (figure)
fuel production and consumption, 31-35, 32 (figure), 33	recycling
(figure), 34 (figure)	fracture-fluid, 328
natural gas, 26-31, 26 (figure), 27 (figure), 27 (table),	wastewater, 554–555
28 (figure), 29 (figure), 30 (figure), 30 (table)	Red Hawk spar, 571
oil, 21-26, 22 (figure), 23 (figure), 23 (table), 24 (figure),	redevelopment, risk involved, 617 (figure)
25 (figure), 26 (table)	reduced-pressure desorption, CBM production through, 331–332
total world energy consumption, 31 (figure)	331 (figure), 332 (figure)
protective equipment, 561	refined product pipelines, 513, 513 (figure)
proved reserves, 693–694, 695 (figure), 696 (figure). See also	refining
reserves	environmental concerns, 537
pseudo-3D models, hydraulic fracturing, 355–356, 356 (figure),	environmental management, 549, 549 (figure)
357 (table)	in production process, 531
Pseudomonas aeruginosa strains, in MEOR, 472	wastewater discharge from, 540
pseudo-pressure approach	refractive index (RI) method, 487
deliverability and inflow analysis, 398, 400–401, 402–403, 403	regional ecology, effects of gas hydrates on, 435–436
(figure), 403 (table)	regional energy scenario generator (RESGEN), 49 (table)
well performance analysis, 411–412	regression models, decommissioning cost algorithms, 586, 587,
pseudo-steady state (PSS) flow, 399, 400	588, 589
pseudo-time concept, MB, 417–418	regulations, and decommissioning cost algorithms, 584
pseudo-time variable, deliverability and inflow analysis, 399	regulatory framework, 532–537
pulse decay method, 78	relative permeability
pump-off test (POT), 210	defined, 11, 73
pumps	factors affecting, 73–74
for pipelines, 511, 512 (figure)	laboratory measurements of, 74–75, 74 (figure)
solar, 689	numerical reservoir simulation, 182
purification, natural gas, 531	of reservoir rock, 14–15
push-the-bit RSS, 220–221, 221 (figure)	and rock wettability, 73-74, 74 (figure), 74 (table)
pyrolysis, 339-340, 339 (figure), 377-378	three-phase, 73, 74
	two-phase, 74–75, 74 (figure)
Q	relative permeability modification (RPM), 268, 268 (table)
quality maps, for well configuration, 254-255, 254 (figure)	release prevention barriers (RPBs), 524–525, 525 (figure)
quantitative evaluation of traps, 130–133, 132 (figure), 145–146,	releveling, storage tank, 522
145 (figure), 146 (table)	remediation strategies

7.31

```
asphaltene deposition, 498-499
                                                                              reservoir complexity, 612
     in environmental management, 549
                                                                              reservoir conformance, polymer flooding, 256-258, 257 (figure),
remote terminal units (RTUs), solar, 687, 687 (figure)
                                                                                 257 (table), 258 (figure)
                                                                              reservoir engineering. See numerical reservoir simulation
renewable energy sources
     comparative analysis between fossil fuels and, 657-660,
                                                                              reservoir fluids, 62-75
                                                                                   capillary pressure and wettability, 69-73, 69 (figure), 70
       659 (figure), 659 (table), 660 (table)
     energy future, 35
                                                                                      (figure), 71 (figure), 72 (figure)
     technical potential of, 683 (figure)
                                                                                   crude oil, 64 (table), 65-66, 66 (figure)
     trends in focus on, 663
                                                                                   fluid saturation, 55-56
     See also specific renewable energy sources
                                                                                   formation damage, 75
repairs, storage and transportation, 525-526, 525 (figure)
                                                                                   formation water, 69
representative elementary volume (REV), 180, 180 (figure)
                                                                                   gas, 62-63, 62 (table), 63 (figure)
reserves
                                                                                   phase behavior, 66-69, 67 (figure), 68 (figure), 68 (table)
     data reliability, 41-43
                                                                                   properties of, 65-66
     depletion estimation, 45-48, 47 (figure)
                                                                                   relative permeability, 73–75, 74 (figure)
     energy future, 693-694, 694 (figure), 695 (figure), 696, 696 (figure)
                                                                                   reservoir classification based on initial state of, 2-4, 3 (figure)
     estimation methods, 43-45, 43 (figure)
                                                                                   rock and fluid interactions, 69-75, 69 (figure), 70 (figure),
     of gas in GHDs, determining, 448, 450-451
                                                                                      71 (figure), 72 (figure), 74 (figure)
     Messoyakha gas hydrate deposit, 453-454, 454 (figure)
                                                                              reservoir management, 177-178, 251, 252 (figure), 253-255, 254
          contemporary, 669, 669 (figure), 670 (figure)
                                                                              reservoir rock, 2 (figure)
          energy future, 694, 696, 696 (figure)
                                                                                   capillary pressure and wettability, 69-73, 69 (figure),
          estimation methods, 43-45
                                                                                      70 (figure), 71 (figure), 72 (figure)
          general discussion, 27-29
                                                                                   characteristics of, 9-16
          historical data, 27 (figure), 28 (figure)
                                                                                   compressibility, 60-61, 61 (figure)
                                                                                   core acquisition and analysis, 61-62
          overview, 26 (figure)
          top ten countries, 27 (table)
                                                                                   defined, 375
     oil
                                                                                   depositional environments, 5-6
          contemporary, 664-666, 665 (figure)
                                                                                   evaluation of, 11-16
          energy future, 693-694, 695 (figure), 696
                                                                                   and fluid electric properties, 59-60, 60 (figure)
          estimation methods, 43-45
                                                                                   fluid saturation, 55-56
          historical data, 23 (figure), 24 (figure)
                                                                                   formation damage, 75
          overview, 21-24, 22 (figure)
                                                                                   fracture permeability and porosity, 58, 58 (figure)
          top ten countries, 23 (table)
                                                                                   grain size and pore size distributions, 58–59, 59 (figure),
     semisubmersible projects
                                                                                      59 (table)
          capacity-reserves relations, 635, 636, 637 (figure),
                                                                                   heterogeneous, 11, 16
             638 (figure)
                                                                                   overview, 2
          peak production to reserves ratio, 631, 635, 637 (table)
                                                                                   permeability, 2, 10-11, 56-57, 56 (figure), 57 (figure),
          project costs, 627-628, 628 (figure)
                                                                                      58 (figure)
          remaining, 640-641, 643 (table), 644 (table)
                                                                                   porosity, 2, 10, 55, 56 (figure)
                                                                                   relative permeability, 73–75, 74 (figure)
          reserves-production trajectories, 641, 645 (figure)
          well reserves, 641, 646 (figure)
                                                                                   rock and fluid interactions, 69–75, 69 (figure), 70 (figure),
     unconventional gas, 41 (figure)
                                                                                      71 (figure), 72 (figure), 74 (figure)
     unconventional oil, 37 (figure)
                                                                                   total organic content, 76, 76 (table), 77 (figure)
     validating, in numerical reservoir simulation, 192
                                                                                   unconventional reservoirs, 75-79
     See also natural gas production engineering
                                                                                    See also petroleum geomechanics; specific rock types
reserve-to-production (R/P) ratio
                                                                              reservoir simulation, 45. See also numerical reservoir simulation
     natural gas, 26 (figure), 28-29
                                                                              reservoirs, 1-18
     oil, 22, 22 (figure), 23, 24 (figure), 695 (figure)
                                                                                   classification of
     reserve depletion estimation, 45
                                                                                        depositional environments, 5-6
reservoir characterization
                                                                                        initial state of fluids, 2–4, 3 (figure)
     defined, 18
                                                                                         pore systems, 6
     numerical reservoir simulation, 190
                                                                                        production/drive mechanism, 4-5
     oil field data mining in
                                                                                         recovery/production technology, 6-9
          overview, 152-153, 152 (figure)
                                                                                   conventional, 6
          seismic survey, 154
                                                                                   cyclic steam stimulation, selecting for, 304, 305 (table)
          seismic to well logs, 153-154, 153 (figure)
                                                                                   deepwater offshore, 302, 341-342, 341 (figure), 342 (table), 343
          synthetic model, 154-161, 155 (figure), 155 (table),
                                                                                      (figure), 344 (figure), 346-347
             156 (figure), 157 (figure), 158 (figure), 158 (table),
                                                                                   deliverability and inflow performance analysis, 398-404, 401
                                                                                      (table), 402 (figure), 403 (figure), 403 (table), 404 (figure)
             159-161 (figure), 161 (table)
          Valley Field case study, 161-164, 162 (figure), 163
                                                                                   depressurization, for methane hydrate production, 334-335
             (figure), 164 (table), 165-168 (figure), 165 (table)
                                                                                   depth, 1, 2 (figure)
```

Dongying Sag petroleum system, 135–136, 135 (figure)	roofs, storage tank, 519-521
geophysical well logging, 16–17	rotary control device (RCD), 214, 214 (figure)
heterogeneity and performance of, 17-18	rotary drilling, 197, 197 (figure)
hydrocarbon source rock, 1	rotary screw compressors, 243
modeling, 18	rotary speed, 209, 209 (figure)
overview, 1–2	rotary systems, drill rig, 199–201, 202 (figure), 203 (figure),
permeability reduction caused by polymer flooding, 259–260	204 (figure)
steam flooding, selecting for, 308, 308 (table)	rotary table and kelly system, 199-200, 202 (figure)
steam-assisted gravity drainage, selecting for, 309, 310 (table)	rotary vane-style compressors, 243, 244 (figure)
structure, 1	rotary-percussion drilling, 197, 197 (figure)
unconventional, 6-9, 75-79	rotary-steerable systems (RSS), 220–221, 221 (figure)
volumetrics, 415	routine core analysis, 13
well, reservoir, and facility management, 701–704, 702 (figure),	royalty payments, semisubmersible projects, 644
703 (figure)	runoff, stormwater, 539, 559
well testing, 17	Russell volumeter, 55, 56 (figure)
See also microbiology of petroleum reservoirs; numerical	Russian Federation, regulatory framework in, 534
reservoir simulation; reservoir characterization; reservoir	Russian redefation, regulatory framework in, 33 r
fluids; reservoir rock; specific reservoir types	S
resilient toroid seals, 520, 521 (figure)	safeguarding, 560
resins, 267 (table), 485–486, 486 (figure)	safety
resistivity, 15, 16, 60	associations for, 547–548
restored wettability, 72	concerns and issues, 543, 544–546 (table), 546–547
restored wettability, 72 restored-state core analysis, 14, 15	handling of petroleum product, 523–526
restrictions, gas hydrate, 439–441, 439 (figure), 440 (figure)	health and safety management systems, 549–553, 550 (figure),
retorting	
<u>~</u>	551 (figure), 552 (figure), 553 (figure)
kerogen, 339 (figure), 339–340	hydrate control, 439–440
oil shale, 384–387, 385 (figure)	minimizing hazards, 557–562, 558 (figure), 559 (figure),
retrograde condensation, 3–4	560 (figure), 561 (figure), 562 (figure), 563 (figure)
retrograde gases. See gas condensate reservoirs	regulations, 532–537
reusing wastewater, 554–555	St. Malo project, 655. <i>See also</i> semisubmersibles
revenue, semisubmersible production, 638 (table), 639 (figure),	salinity
640 (figure), 641 (figure)	microbiology of petroleum reservoirs, 462
reverse ISC, 314	negative salinity gradient, 283
reversibility, asphaltene precipitation, 489–490	surfactant phase behavior and, 278–281, 279 (figure), 280 (figure)
reversible-micellization model, 491	Salsa platform removal cost estimate, 590
rheology	salt plugs, 440, 440 (figure)
drilling fluids, 208, 208 (figure)	salts, in hydrate control, 438, 438 (figure)
fracturing fluids, 363	sanctioning of offshore development projects, 614, 615 (figure)
Rhodococcus strains, in MEOR, 472	sand-dominated reservoirs, methane hydrates in, 333–334
rig-based rotary systems, 199–200, 202 (figure)	sand-pack columns experiments, MEOR, 470–473
right-hand walk (RHW), 224	sandstone. See reservoir rock
rim seals, storage tank, 519–520, 520 (figure)	SARA analysis, 485–486, 486 (figure)
riserless drilling, 215, 216 (figure)	saturates, 485–486, 486 (figure)
risers	saturation
decommissioning cost, 582, 585 (table), 589 (figure), 593	capillary hysteresis and, 70–71, 71 (figure)
deepwater systems, 610	fluid, 14, 55–56, 181–182
floating systems, 577, 578 (figure)	numerical reservoir simulation, 181-182
offshore pipelines, 514, 514 (figure)	relative permeability measurement and, 15
semisubmersibles, 601, 601 (figure)	saturation pressure. See bubble-point pressure
risk, semisubmersible project, 616–618, 616 (figure), 617 (figure),	saturation-matching process, 192-193, 194 (figure)
618 (figure), 641	scale
risk analysis, 550 (figure), 550-552	inhibiting formation of, 440
risk matrix, 617–618, 618 (figure)	of semisubmersibles, 628–629, 632 (figure)
rock and liquid expansion drive, 5, 250 (table)	scale economies, semisubmersible projects, 628, 629 (table),
rock stratum evaluation submodel, 127	630 (figure)
rock stratum temperature, ancient, 120–121	sea transportation, 516-518, 516 (table), 517 (figure), 517 (table),
rocks	518 (figure), 518 (table)
radioactive heat generation rate of, 119 (table)	seabed chemical injection, for hydrate control, 439
surfactant retention in rock formations, 281-283, 282 (table)	seafloor assembly (SFA), 226-227, 229 (figure)
See also petroleum geomechanics; reservoir rock;	seafloor deformation monitoring, 102
specific rock types	seafloor massive methane hydrate deposits, 334
roller cone (RC) bits, 205, 206, 206 (figure)	secondary containments, 525

```
secondary gas hydrate crystals, 444, 444-445 (figure)
                                                                                   structural components, 601-602, 601 (figure), 602 (figure)
secondary porosity, 6, 11, 55
                                                                                   See also floating systems
secondary recovery, 249-255, 250 (figure), 252 (figure), 253
                                                                              sensitivity analysis, 173, 173 (figure)
   (figure), 254 (figure), 461, 530, 699, 700 (figure)
                                                                              separation processes
sector models, numerical reservoir simulation, 191
                                                                                   crude oil refining, 531
security hazards, 547, 560-561
                                                                                   natural gas refining, 531
Security Vulnerability Analysis, 551
                                                                                   topsides facilities, 610, 612 (figure)
sedimentary rocks, 2, 5-6. See also reservoir rock; shale- and
                                                                                   in USOSC, 679, 680
   mudstone-hosted oil and gas; specific rock types
                                                                                   See also gravity separation
segregation arrangements in process plants, 559, 559 (figure)
                                                                              sequence-based approach, metagenomics, 465-466
seismic activity, and hydraulic fracturing, 329, 388, 541
                                                                              sequential-solution method, flow equations, 185
seismic data
                                                                              settlement, storage tank, 522
     correlation of surface seismic with VSP, 156–157, 156 (figure),
                                                                              Shaft and Tunnel Access (SATAC), 311
                                                                              shale (rock)
     correlation of VSP with well logs, 157-159, 157 (figure),
                                                                                   capillary pressure by isotherms, 78-79, 78 (figure)
        158 (figure), 158 (table), 159-161 (figure), 161 (table)
                                                                                   defined, 375
     modeling of well logs from, 153-154, 153 (figure)
                                                                                   mineral composition of, 75-76, 76 (table)
     seismic surveys, 154
                                                                                   mineralogy of, 376-377 (figure), 376-377
     synthetic models derived from, 155 (figure), 155 (table),
                                                                                   original gas in place, 76-77
        156 (figure)
                                                                                   permeability, 78, 78 (figure)
     Valley Field case study, 161-162
                                                                                   potential resources, 382, 382 (figure), 383 (figure)
seismic surveys, 154, 530, 703-704, 703 (figure)
                                                                                   total organic content, 76, 76 (table), 77 (figure)
                                                                                   See also gas shale; kerogen; oil shale; shale gas; shale oil
selective plugging, 470, 472
self-heating retorting process, 340
                                                                              shale- and mudstone-hosted oil and gas, 373-390
semisubmersibles, 599-648
                                                                                   extraction methods
     cost, 623-627, 625 (table), 626 (table), 627 (table)
                                                                                        oil shale retorting, 384-387, 385 (figure)
     cost relations, 627–628, 628 (figure), 629 (figure), 629 (table),
                                                                                        overview, 383-384
                                                                                        production from thermally mature mudstone, 387-389
        630 (figure)
     decommissioning cost algorithms, 590-591, 590 (table)
                                                                                   generation of hydrocarbons from source rocks, 377-378, 378
     deepwater geology, 603, 605-606, 607 (figure)
                                                                                     (figure), 379 (figure), 380 (figure)
     deepwater inventory, 578, 579 (figure)
                                                                                   overview, 373-374
     deepwater systems, 599, 606-607, 608 (figure)
                                                                                   potential for technology improvement, 390
     development, 619, 620-621 (figure), 622-623, 622 (figure),
                                                                                   potential resources, 378-383, 381 (figure), 382 (figure), 382
       622 (table), 623 (figure), 624 (table), 625 (figure)
                                                                                     (table), 383 (table)
     development cost, 612-616, 613 (figure), 614 (figure),
                                                                                   production projections, 389-390
       615 (figure)
                                                                                   terminology, 374-377, 374 (figure), 376 (figure), 377 (figure)
     expected ultimate recovery, 640-641, 642 (figure), 643 (table),
                                                                              shale gas
       644 (table), 645 (figure), 646 (figure)
                                                                                   defined, 321, 377
     exploration, 618-619, 619 (table)
                                                                                   development in United States, 673-674, 674 (table)
     floating production units, 600–602
                                                                                   developments related to, 672-673, 672 (figure), 673 (figure)
     Gulf of Mexico inventory, 602-603, 603 (figure), 603 (table),
                                                                                   energy future, 40-41, 41 (figure), 42 (table)
        604 (figure), 605 (figure), 606 (figure)
                                                                                   environmental concerns, 537, 675
     history of, 600-601
                                                                                   fracturing-fluid flowback, 327-328
     methodology for economic evaluation, 641, 643-644, 646 (figure)
                                                                                   horizontal or directional drilling, 322-323, 324 (figure)
     MODUs, 227, 230 (figure)
                                                                                   hydraulic fracturing fluids and proppants, 325-327, 326
     offshore components, 607-611, 609 (figure), 611 (figure),
                                                                                     (table), 327 (table)
       612 (figure), 612 (table)
                                                                                   hydraulic fracturing overview, 325, 325 (figure)
     overview, 577, 577 (figure), 599-600
                                                                                   operational challenges, 328-329
                                                                                   overview, 8-9, 302, 374-375, 374 (figure)
     production
          capacity-reserves relations, 636, 637 (figure), 638 (figure)
                                                                                   potential resources, 382-383, 383 (table)
                                                                                   production overview, 531, 532 (figure)
          initial production rates, 630, 635 (table), 636 (figure)
          oil and gas, 628, 631 (table), 632 (figure)
                                                                                   production projections, 389-390, 389 (figure)
          peak production to reserves ratio, 631, 635, 637 (table)
                                                                                   recent developments, 329
          producing wells, 629, 634 (figure)
                                                                                   See also hydraulic fracturing
          production capacity, 631, 636 (table)
          production cost, 644
                                                                                   advances in production, 337
          revenue, 636-638, 638 (table), 639 (figure), 640 (figure),
                                                                                   defined, 377
             641 (figure)
                                                                                   energy future, 39, 39 (figure), 39 (table), 697
                                                                                   field development, 336-337
          scale of, 628-629, 632 (figure), 633 (figure)
          unit production, 630, 634 (figure)
                                                                                   general discussion, 346
     profitability, 645, 647 (figure), 647 (table), 648, 648 (figure)
                                                                                   geophysical technologies, 336
     project risk, 616-618, 616 (figure), 617 (figure), 618 (figure)
                                                                                   operational challenges, 337
```

```
overview, 302, 335-336, 373
                                                                             solubility models of asphaltenes, 483, 490-491
     potential resources, 379-380, 381 (figure)
                                                                             solubilization ratio, 280-281
     production projections, 389
                                                                             solution gas, 62, 62 (table)
     unconventional production wells, 336
                                                                             solution gas-oil ratio, 65-66, 66 (figure)
     See also kerogen; oil shale; tight gas
                                                                             solution-gas drive reservoirs, 4, 4 (figure)
shallow-water flows, 609
                                                                             solvent-mediated processes, 316, 317 (figure)
shape factors, 399, 400
                                                                             solvents
                                                                                  for asphaltene deposition treatment, 498-499
shear deformation, 84, 84 (figure)
shear failure, 93-94, 93 (figure), 94 (figure)
                                                                                  FCM, 272, 273
shear modulus, 88, 88 (figure)
                                                                                  microbial, 470
shear rams, 205, 205 (figure)
                                                                             sonic logging, 17
                                                                             sour fluids, topsides facilities, 611
shear strain, 85, 85 (figure)
shearing mechanism recovery method, 114–115, 114 (figure)
                                                                             source rock
shear-thickening behavior of polymer solutions, 259, 259 (figure)
                                                                                  defined, 1, 375
shear-thinning behavior of polymer solutions, 258–259, 259 (figure)
                                                                                  generation of hydrocarbons from, 377-378, 378 (figure),
Shell In Situ Conversion Process, 384-386, 385 (figure)
                                                                                    379 (figure), 380 (figure)
shipping industry, 516, 516 (table)
                                                                                  See also reservoir rock; shale- and mudstone-hosted oil and gas
shutdown, emergency, 562
                                                                             South America, regulatory framework in, 535-536
shut-in procedures, 213-214
                                                                             spatial discretization, 182, 182 (figure), 183-184
sidewall coring, 12, 61
                                                                             special core analysis, 14-16
sieve analysis, grain size distribution by, 59, 59 (table)
                                                                             specific gravity, 63, 65
siltstone, 375
                                                                             spectroscopy, 487
simulation models
                                                                             spontaneous imbibition method, 73
     energy systems models, 49 (table), 51, 51 (figure)
                                                                             stable flow condition, 412, 412 (figure)
     reserve depletion estimation, 46-47, 47 (figure)
                                                                             stable isotope probing (SIP), 465
     See also numerical reservoir simulation; 3D dynamic
                                                                             staged hydrocarbon expulsion model, 122, 122 (figure)
                                                                             stages of separation, topsides facilities, 610, 612 (figure)
       simulation of pool-forming
single steel drilling caisson (SSDC), 225, 228 (figure)
                                                                             static geological modeling, 3D, 109-112, 110 (figure), 111 (figure)
single-parameter sensitivity analysis, 173, 173 (figure)
                                                                             static parameters, geomechanical, 96, 99, 99 (figure)
single-phase flow
                                                                             statistical analysis, 171, 171 (figure)
     deliverability and inflow analysis, 398-400
                                                                             steady-state (SS) flow, 14-15, 74, 74 (figure), 400
     numerical reservoir simulation, 181, 187
                                                                             steam and gas push (SAGP), 311
     well performance analysis, 411
                                                                             steam flooding/steam drive, 288-289, 288 (figure), 289 (table),
     wellbore and outflow performance analysis, 405-408
                                                                                307-309, 307 (figure), 308 (table), 344
single-phase liquid, 3, 73
                                                                             steam generation from solar power, 688-689, 688 (figure)
single-well, single-parameter sensitivity analysis, 173, 173 (figure)
                                                                             steam soak. See cyclic steam stimulation
single-well, type curve analysis, 173, 174 (figure)
                                                                             steam-assisted gravity drainage (SAGD), 9, 289-290, 290 (figure),
Single-Well SAGD (SW-SAGD), 311
                                                                                309-313, 309 (figure), 310 (table), 312-313 (table), 344
                                                                             steerable assemblies, 219-220, 220 (figure)
single-well uncertainty analysis, 174-175, 175 (figure)
site clearance and verification, 582
                                                                             steering tools, subsurface, 219–221, 220 (figure), 221 (figure)
                                                                             stimulation, unconventional production wells, 336. See also
slick drill string, 198, 200 (figure)
slickwater fracturing fluid, 325, 327 (table), 352, 360-361, 362 (figure)
                                                                               hydraulic fracturing
slim-tube displacement tests, 275, 275 (figure)
                                                                             stochastic methods, reserve estimation, 44-45
slips, as workplace hazard, 543
                                                                             stock tank oil density, 65
smart completions, 609
                                                                             Stone model, 73
smart field configurations, 702, 702 (figure)
                                                                             storage, 518-523
smart pigs, 525, 525 (figure)
                                                                                  corrosion prevention, 523-524, 524 (figure)
smart water flooding, 701
                                                                                  cryogenic tanks, 522-523, 523 (figure)
Soave-Redlich-Kwong (SRK) EOS, 67-68
                                                                                  emission, 521-522, 522 (figure)
soil contamination, 540-541, 541 (table)
                                                                                  filling and discharging practice, 526, 526 (figure)
                                                                                  fire prevention and extinguishing, 525
solar energy
     background of, 683-684, 683 (figure)
                                                                                  fixed roofs, 521, 521 (figure)
     challenges faced by, 686
                                                                                  flexible piping system, 520
     economics of, 685-686
                                                                                  floating roofs, 519
     potential of, 685, 686 (figure)
                                                                                  foundation, 522
     storage, 686
                                                                                  fundamentals, 518-519
     technologies, 684, 684 (figure), 685 (figure)
                                                                                  general design, 519
     in upstream oil supply chain, 686-690, 687 (figure), 687
                                                                                  groundwater protection, 524-525, 525 (figure)
       (table), 688 (figure), 690 (figure)
                                                                                  history of, 507
solid scale, inhibiting formation of, 440
                                                                                  hot tanks, 522
                                                                                  leak detection, 524
solid waste management, 541
solids separation, 241, 241 (figure)
                                                                                  maintenance and repairs, 525-526, 525 (figure)
```

natural gas, 523, 523 (figure), 666	supervised neural networks, 150
properties of petroleum products, 508–509	supervisory control and data acquisition (SCADA) systems,
rim seals, 519–520, 520 (figure), 521 (figure)	512–513, 514, 515 (figure), 687
roofs, 519–521, 520 (figure)	supply chain. See upstream oil supply chain
safe handling of petroleum product, 523–526	surface deformation, monitoring, 102
settlement and releveling, 522	surface piercing articulating risers (spars), 600 (figure)
solar energy, 686	decommissioning cost algorithms, 590–591, 590 (table)
standards and regulations, 507	
	deepwater inventory, 580–581, 581 (figure)
venting, 521, 521 (figure)	overview, 577, 577 (figure)
storage porosity, 6	See also floating systems
storativity coefficient, 11, 17	surface processing, oil shale, 384
stormwater runoff, 539, 559	surface seismic
strain, 83–85, 84 (figure), 85 (figure)	correlation with VSP, 156–157, 156 (figure), 157 (figure)
strain hardening, 92	synthetic models derived from, 155–156, 155 (figure),
stratigraphic traps, 1	155 (table), 156 (figure)
stratum framework model, 110	surface-prepared gels, 267, 267 (figure)
See also structure-stratum framework simulation	surfactant flooding, 277–285
strength parameters, in petroleum geomechanics, 96	adding polymer to, 281
stress	ASP flooding, 285–286
change monitoring, 103	critical micelle concentration, 278, 279 (figure)
effective, 8, 89–90, 93–94	field applications, 283–285, 285 (figure)
fluid potential, 125	microemulsion viscosity, 281
gradients, expressing components as, 87, 88 (figure)	overview, 277, 277 (figure)
overview, 85–87, 86 (figure), 87 (figure)	phase behavior, 278–281, 279 (figure), 280 (figure)
parameters for, 96	retention in rock formations, 281–283, 282 (table)
in situ, 87, 99–101	surfactant classification, 277, 278 (table)
subsurface measurement of, 100 (figure), 100–101	trends in, 283, 284 (table)
thermal, 90–91	See also biosurfactants
total, 89	surveillance, of petroleum geomechanics, 102–103
yield, 91, 91 (figure)	sustainable source energy, 658
stress intensity factor, PL3D hydraulic fracturing model, 357	sweep efficiency, FCM, 272–273, 273 (figure)
strip-mining techniques, oil sands, 531. <i>See also</i> oil sands mining	Syncrude and Suncor froth treatments, 317
structural deformation recovery, 113–116, 113 (figure),	synthetic crude oil (SCO), 318–319
114 (figure), 115 (figure)	synthetic model, reservoir characterization, 154–161
structural traps, 1	methodology, 156–159, 157 (figure), 158 (figure), 158 (table)
Structure 23800 pipeline decommissioning cost, 588	159–161 (figure), 161 (table)
structures	model output, 156
deepwater	overview, 154–155, 155 (table)
decommissioning, 582, 593, 597	surface seismic and VSP-derived models, 155 (figure),
overview, 599, 600 (figure)	155 (table), 155–156, 156 (figure)
reservoir, 1	synthetic-based mud (SBM), 207
See also specific structure types	system design, 3D dynamic simulation of pool-forming, 109,
structure-stratum framework simulation	133–134, 133 (figure)
3D dynamic, 112–116, 112 (figure), 113 (figure), 114 (figure),	system performance analysis, gas well, 411-414, 411 (figure),
115 (figure)	412 (figure), 413 (figure), 413 (table), 414 (figure),
3D static, 109-112, 110 (figure), 111 (figure)	414 (table)
Dongying Sag petroleum system example, 136–138,	systems simulation, reserve depletion estimation, 46-47, 47
136 (figure), 137 (figure), 138 (figure), 139 (figure)	(figure)
submersible MODUs, 225, 227 (figure), 228 (figure)	
subsalt wells, 609	T
subsea equipment, umbilicals, risers and flowlines (SURF)	tailings, oil sand, 317-318, 318 (figure), 318 (table), 319 (table)
deepwater systems, 606, 609–610, 611 (figure)	tailings ponds, 540, 542
semisubmersible projects, 623, 624 (table), 625 (figure)	tanker transportation, 517–518, 517 (figure), 517 (table)
subsea pipelines, 514, 514 (figure)	tar balls, 541
subsea systems, 600 (figure)	tar sands, 9. See also bitumen; oil sands mining
subsurface steering tools, 219–221, 220 (figure), 221 (figure)	taut moorings, 601–602, 601 (figure)
subsurface structure, reservoirs, 1	Taylor's Theorem, 182
Suez Canal, 516	technically recoverable resources (TRR), 352
Sukkar and Cornell method, 406	technogenic gas hydrates, 430
sulfate-reducing bacteria (SRB), 462–463, 463 (table), 470–471	technological advancements and innovation, 704–706,
sulfur dioxide (SO <sub>2</sub> ) hydrates, 433, 434 (figure)	704 (figure), 705 (figure)
Sumed pipeline, 516	telecommunication, solar energy in, 686-687, 687 (figure)

```
Telemark project, 654. See also semisubmersibles
                                                                                 hydrocarbon expulsion history, 122–123, 122 (figure)
telemetry systems, 219
                                                                                 hydrocarbon generation history, 121-122
temperature
                                                                                 hydrocarbon migration and accumulation history,
                                                                                    123-130, 126 (figure), 127 (figure), 131 (figure)
     average temperature and compressibility method, 406
                                                                                  relationship of all portions of model, 110 (figure)
     emulsion treater, 236
     microbiology of petroleum reservoirs, 462
                                                                                 static geological modeling, 109-112
     in petroleum geomechanics, 90-91
                                                                                 structure-stratum framework simulation, 112-116
     reservoir fluid phase behavior, 2-4, 3 (figure), 66-67, 67 (figure)
                                                                                 system design, 109, 133-134, 133 (figure)
     subsurface, 1
                                                                                 theory, 109
     See also geothermal field evolution simulation
                                                                                 trap quantitative evaluation, 130-133, 132 (figure)
temporal discretization, 182, 182 (figure), 184, 185 (figure)
                                                                                  See also Dongying Sag petroleum system simulation
                                                                            3D models, hydraulic fracturing, 355–356, 357 (table)
tendon systems, floating platforms
     decommissioning cost, 590-591, 593
                                                                            three-phase numerical reservoir simulation, 181–182
     overview, 577, 578 (figure), 601, 601 (figure)
                                                                            three-phase relative permeability, 73, 74
                                                                            three-phase separators, 234-235, 235 (table), 236 (table)
     removing, 582
tensile failure, 93
                                                                            Thunder Hawk project, 654. See also semisubmersibles
tensile strength testing, 98, 98 (figure)
                                                                            Thunder Horse project, 629, 653. See also semisubmersibles
tension leg platforms (TLPs), 600 (figure)
                                                                            tight gas, 321-329
     decommissioning cost algorithms, 590-591, 590 (table)
                                                                                 defined, 321
     deepwater inventory, 578, 580, 580 (figure)
                                                                                 energy future, 40-41, 41 (figure), 42 (table)
     overview, 577, 577 (figure)
                                                                                 field development, 321-322, 321 (figure), 322 (figure),
                                                                                    323 (figure), 324 (figure)
     See also floating systems
terminal velocity, 233
                                                                                 fracturing-fluid flowback, 327-328
Terra Nova FPSO, 341-342
                                                                                 horizontal or directional drilling, 322-323, 324 (figure)
tertiary recovery, 530, 699, 700 (figure). See also enhanced oil
                                                                                 hydraulic fracturing fluids and proppants, 325-327, 326
                                                                                    (table), 327 (table)
  recovery
                                                                                 hydraulic fracturing overview, 323, 325, 325 (figure)
Terzaghi effective stress, 89
thermal conduction, 116, 117
                                                                                 operational challenges, 328-329
thermal convection, 117
                                                                                 overview, 302, 377
thermal effects, in petroleum geomechanics, 90-91, 96
                                                                                 recent developments, 329
thermal expansion testing, 98
                                                                                  See also hydraulic fracturing
thermal field evolution. See geothermal field evolution simulation
                                                                            tight gas sands, 7, 77-78, 78 (figure), 377
                                                                            tight oil
thermal recovery methods
     cyclic steam stimulation, 287-288, 288 (figure), 304, 304
                                                                                 advances in production, 337
       (figure), 305-306 (table), 306-307
                                                                                 defined, 377
     electro-thermal dynamic stripping, 315
                                                                                 field development, 336-337
     expanding solvent SAGD, 289, 290 (figure)
                                                                                 general discussion, 346
     for methane hydrate production, 335
                                                                                 geophysical technologies, 336
     overview, 287, 302, 303-304, 468, 531
                                                                                 operational challenges, 337
     in situ combustion, 290-291, 291 (table), 292 (figure),
                                                                                 overview, 302, 335–336, 374–375, 374 (figure)
       313–315, 314 (figure), 315 (figure)
                                                                                 potential resources, 380, 382, 382 (table)
     steam flooding or steam drive, 288-289, 288 (figure), 289
                                                                                  production projections, 389, 389 (figure)
       (table), 307–309, 307 (figure), 308 (table)
                                                                                  rock formations producing, 376
     steam-assisted gravity drainage, 289-290, 290 (figure),
                                                                                  unconventional production wells, 336
       309-313, 309 (figure), 310 (table), 312-313 (table)
                                                                                  See also hydraulic fracturing
     thermal-assisted gravity drainage, 315-316
                                                                            time-lapse seismic monitoring, 703-704, 703 (figure)
     VAPEX, 289, 290 (figure)
                                                                            titanate, 358
thermal solar energy, 684, 686
                                                                            toe-to-heel air injection (THAI), 291, 292 (figure), 314-315, 314
thermal stability of polymers, 261 (table)
                                                                               (figure), 315 (figure), 344-345
thermal structure analysis, 118-120, 119 (table), 120 (table)
                                                                            toolface angle, 222, 223 (figure)
thermal treatments, asphaltene deposition, 499
                                                                            top drive rotary systems, 200, 203 (figure)
thermal-assisted gravity drainage (TAGD), 315-316
                                                                            top-down cost estimation, 582-583
thermally mature mudstone, oil and gas production from, 387-389
                                                                            topsides, deepwater systems, 606, 608 (figure), 610-611, 612
thermodynamic conditions, locating HFZs by, 447, 448 (figure),
                                                                               (figure), 612 (table)
                                                                            torque, in directional drilling, 224-225, 225 (figure)
thermodynamic inhibitors, 437, 438 (figure), 439
                                                                            total (absolute) porosity, 10, 55
thermodynamic models of asphaltenes, 485, 490, 491-492, 496
                                                                            total organic content (TOC), 76, 76 (table), 77 (figure)
thermodynamics, pipe flow, 510
                                                                            total stress, 89
thickened ice pads, 227, 229 (figure)
                                                                            toxicity
3D dynamic simulation of pool-forming
                                                                                 of hydraulic fracturing fluids, 366
     geothermal field evolution, 116-121, 117 (figure), 118 (figure),
                                                                                 oil sand tailings, 317-318, 318 (table)
       119 (table), 120 (table)
                                                                                  See also environmental concerns; waste; wastewater
```

trace oil removal from wastewater, 239-241, 240 (figure)	umbilicals
tractions, 85–86, 86 (figure)	decommissioning cost, 582, 585 (table), 588-589, 589
training, in health and safety management systems, 552	(figure), 593
trajectories, directional. See well trajectories, directional	deepwater systems, 609–610
trans-Alaska pipeline, 516	semisubmersible projects, 623, 624 (table)
transient PI method, 418, 420, 420 (figure)	uncertainty
transient testing, 12, 17	cost estimation, 583
transmissibility coefficients, 184	decommissioning cost algorithms, 584
transportation	semisubmersible project costs, 624–625, 626, 627
corrosion prevention, 523–524, 524 (figure)	uncertainty analysis, 174–175, 175 (figure)
environmental concerns, 537	unchanged plane-length mechanism, 114–115
filling and discharging practice, 526, 526 (figure)	unconfined compressive strength (UCS) test, 97, 99, 100 (figure)
fire prevention and extinguishing, 525	unconformable plane evaluation submodel, 129
groundwater protection, 524–525, 525 (figure)	unconventional hydrocarbon resources
history of, 507, 508 (figure)	decline curve analysis, 368
leak detection, 524	developments in, 672–673, 672 (figure), 673 (figure)
maintenance and repairs, 525–526, 525 (figure)	distribution of, 301, 302 (figure)
modes of, 509, 509 (table)	energy future, 697, 697 (figure), 698 (figure), 699 (figure)
natural gas, issues with, 666	gas, 40–41, 41 (figure), 42 (table), 321, 531, 532 (figure)
in production process, 530–531	general discussion, 346–347
properties of petroleum products, 508–509	oil, 36–40, 37 (figure), 38 (figure), 38 (table), 39 (figure),
safe handling of petroleum product, 523–526	39 (table), 40 (figure), 40 (table)
by sea, 516 (table), 516–518, 517 (figure), 517 (table), 518	overview, 301, 397
(figure), 518 (table)	terminology related to, 374–377, 374 (figure), 376 (figure),
standards and regulations, 507	377 (figure)
See also pipelines	trends in focus on, 663–664
trap quantitative evaluation, 130–133, 132 (figure), 145–146, 145	See also shale- and mudstone-hosted oil and gas; specific
(figure), 146 (table)	resources
traps, classification of, 1	unconventional locations, hydrocarbon accumulations
traveling block, 199 (figure), 199 (table)	in, 301. <i>See also</i> deepwater development; deepwater
treatment	offshore reservoirs
crude oil refining, 531	unconventional production wells, 336, 337
of produced water, 328	unconventional reservoirs
of waste, 554–555, 555 (figure)	capillary pressure by isotherms, 78 (figure), 78–79
of wastewater, 554–555, 556 (table)	defined, 301
triaxial compression testing, 93 (figure), 96–97, 96 (figure), 97 (figure)	hydrocarbon resource triangle, 302 (figure)
triethylene glycol (TEG), 438–439	original gas in place, 76–77, 77 (figure)
trips, as workplace hazard, 543	overview, 6–9, 75–76
TSP bits, 206, 206 (figure)	permeability, 77–78, 78 (figure)
tubing	total organic content, 76, 76 (table)
well performance analysis, 412, 413–414, 413 (table), 414	See also specific recovery methods; specific resources;
(figure), 414 (table)	unconventional hydrocarbon resources
wellbore and outflow performance analysis, 404–411	underbalanced drilling (UBD), 207, 214
turbine meters, 246, 246 (figure)	undercompaction section submodel of thermal evolution, 117
turbodrills, 201, 204 (figure)	underground disposal, flowback water, 328
turbulent flow, 398, 400	underground storage, natural gas, 523, 523 (figure)
Turkey, regulatory framework in, 535	undersaturated oil reservoirs, 4
two-dimensional (2D) models, hydraulic fracturing, 355, 355	uniaxial compaction coefficient, 95
(figure), 357 (table)	uniaxial-strain compaction, 101, 102 (figure)
two-phase flow, Beggs and Brill correlation for, 410–411	uniaxial-strain pore volume compressibility (UPVC) test,
two-phase relative permeability, 74–75, 74 (figure)	97–98, 98 (figure)
two-phase separators, 234, 234 (figure), 234 (table), 235 (figure)	unit development cost, semisubmersible projects, 628, 629 (figure).
two-segment procedure, decline curve analysis, 368–369,	629 (table), 630 (figure)
368 (figure), 369 (figure)	unit production, semisubmersible projects, 630, 634 (figure)
type curve analysis, 173–174, 174 (figure), 175 (figure)	United Kingdom, regulatory framework in, 533–534
type-curve matching PDA method, 417–418, 420, 420 (figure)	United States
711	economy of, 352, 353 (figure), 354 (figure)
U	EOR technique implementation in, 700, 701 (figure)
U. S. Bureau of Mines (USBM) method, 72 (figure), 73	regulatory framework in, 532–533
Uinta Basin, 378, 381 (figure)	shale gas development in, 673–674, 674 (table)
ultra-large crude carriers (ULCC), 517 (table), 518	unconventional hydrocarbon resources in, 697, 698 (figure),
ultraviolet (UV), asphaltene precipitation studies with, 487	699 (figure)

See also decommissioning cost estimation in deepwater	viscosimetry, capillary, 487–488
GOM; Gulf of Mexico	viscosity
unitization, leases, 619	bitumen, 302–303, 302 (table)
unproved reserves, 693. See also reserves	crude oil, 66
unstable flow condition, 412, 412 (figure)	drilling fluids, 208
unstable geothermal field, 3D dynamic simulation of, 117–118, 118	floodwater, polymer flooding as enhancing, 258-259,
(figure)	259 (figure)
unsteady state method, 14, 74	heavy oil, 9, 302-303, 302 (table)
unsupervised neural networks, 150	microemulsion, 281, 284 (table)
upgrading	petroleum product, 509
bitumen, 318–319, 320 (figure), 320 (table)	real gas, 63, 63 (figure)
kerogen, 340	relative permeability and, 74
upscaling to field conditions, 101–102, 102 (figure)	viscosity-control scheme, polymer flooding, 264 (table)
upstream oil supply chain (USOSC), 679-690	viscous fingering, mobility-induced, 258, 258 (figure)
energy consumption in, 679, 681	viscous fracturing fluids, 351–352. See also hydraulic fracturing
greenhouse gas emissions, 681–683, 681 (figure), 682 (table),	vitrinite reflection rate, 120–121
683 (table)	volatile oil, 3, 68, 68 (figure), 68 (table)
oilfield processes, 680–681	volatility, petroleum product, 509
overview, 679–680, 680 (figure)	volume balance method, 112–116, 112 (figure), 113 (figure),
solar energy in, 686–690, 687 (figure), 687 (table), 688 (figure),	114 (figure), 115 (figure)
690 (figure)	volumetric deformation, 83–84, 84 (figure)
See also energy future	volumetric gas reservoirs, 5
Utica Shale, 378, 380 (figure)	volumetric method, reserve estimation, 44–45
ξ, (β)	volumetric strain, 85
V	volumetric sweep efficiency, 256–258, 257 (figure), 257 (table),
validation stage, numerical reservoir simulation, 192–193, 192	258 (figure)
(table), 193 (figure), 194 (figure)	vugular-solution porosity system, 6
Valley Field reservoir characterization	, agains contains percently ejectoring e
available data, 161–162, 163 (figure)	W
location of case study, 162 (figure)	wander, well trajectory, 223–224, 224 (figure)
methodology, 162, 164, 164 (table), 165–168 (figure), 165 (table)	warning signs, 560. See also safety
valves, for pipelines, 511, 512 (figure)	waste
vapor jet compressors, 244, 244 (figure)	from drilling, 538–539, 539 (figure), 542, 555, 555 (figure)
vapor pressure, petroleum product, 509	management of, 555
vapor-assisted petroleum extraction (VAPEX), 289, 290 (figure),	oil sand, 317–318, 318 (figure), 318 (table), 319 (table)
316, 316 (figure), 345	solid, 541
vaporizing-gas process, MCM, 273	wastewater
vehicular accidents, 543, 560	ecological effects, 542–543
Venezuela, regulatory framework in, 535–536	environmental concerns, 538–540, 538 (figure), 539 (figure)
venting, storage tank, 521, 521 (figure)	539 (table)
vertical drilling, for tight gas, 322–323, 324 (figure)	minimizing, 554–555
vertical triming, for tight gas, 322–323, 324 (figure) vertical permeability, 10–11, 14	trace oil removal from, 239–241, 240 (figure)
vertical permeability, 10–11, 14 vertical seismic profile (VSP)	treatment of, 554–555, 556 (table)
correlation of surface seismic with, 156–157, 156 (figure),	
157 (figure)	water cooling, 540
correlation with well logs, 157–159, 157 (figure), 158 (figure),	
158 (table), 159–161 (figure), 161 (table)	environmental concerns, 540
	formation, 62, 69, 456 hydraulic fracturing, use in, 241, 326–327
overview, 154	
versus seismic surveys, 154	minimizing consumption, 554–555
synthetic models derived from, 155 (figure), 155 (table),	used in oil shale processing, 386
155–156, 156 (figure)	See also produced water
Valley Field case study, 161, 162, 163 (figure), 164	water drive, 5, 125, 250 (table)
vertical sweep efficiency, 256–258, 257 (figure), 257 (table)	water flooding
vertical transverse isotropy (VTI), 88, 89 (figure), 95–96	enhanced, 286
vertical wells, for water flooding, 253, 254 (figure)	low-salinity, 291–292
vertical-horizontal wells configuration, SAGD, 311	problems related to, 256
vertical-well SAGD configuration (VSAGD), 311	and reservoir microbiology of, 467
very large crude carriers (VLCC), 517 (table), 518	in secondary oil recovery, 250–251, 252 (figure), 253–255,
VI wells and single HP well (VINGS-SAGD), 311–312	254 (figure)
Virgo 113 platform plugging and abandonment cost, 586	smart, 701
viscoelastic surfactant (VES)-based fracturing fluid,	water-alternating gas (WAG) process, 270–271, 270 (figure),
361–362, 362 (figure)	271 (figure)

water-based fracturing fluids, 351. See also hydraulic fracturing	exploration, 619, 619 (table)
water-based mud (WBM), 207	producing, 629, 634 (figure)
water-oil relative permeability, 73	reserves, 641, 646 (figure)
weather shields, 520	well counts, 622, 623 (figure)
weather-related hazards, 546-547	in USOSC, 680–681
weight-on-bit (WOB), 197, 198, 201 (figure), 209, 209 (figure)	Western Canadian Sedimentary Basin (WCSB), 303, 304 (figure)
weir, liquid-level control using, 237, 237 (figure)	Western Regional Air Partnership, 547
well, reservoir, and facility management (WRFM), 701-704, 702	Western States Air Resources Council, 547
(figure), 703 (figure)	wet gas, 3, 68, 68 (figure), 68 (table), 378
well control, 210–215	wetlands, environmental concerns for, 542
casing installation, 211, 213, 213 (figure)	wettability
drill rig, 202, 204–205, 205 (figure)	ASP flooding and, 285
kick detection and shut-in procedures, 213-214	capillary pressure, 69–71, 70 (figure)
managed pressure drilling, 214 (figure), 214-215, 215 (figure)	interfacial tension and contact angle, 69
mud pressure bounds and casing schedules, 210 (figure),	as LSW mechanism, 292
210–211, 211 (figure), 212 (figure)	and relative permeability, 73–74, 74 (figure), 74 (table)
and well placement configuration, 254	relative permeability measurement and, 15
well logging	reservoir rock, 71–73, 71 (figure), 72 (figure)
correlation of VSP with, 157-159, 157 (figure), 158 (figure),	restoration and measurements, 72 (figure), 72-73
158 (table), 159–161 (figure), 161 (table)	wetting phase, 69
modeling logs from seismic data, 153-154, 153 (figure)	wet-tree wells
overview, 11–12, 16–17	decommissioning cost, 585, 585 (table), 591
Valley Field case study, 161, 162	overview, 606, 608, 608 (figure), 609 (figure)
well monitoring system, drill rig, 205	semisubmersible projects, 623, 624 (table)
well performance analysis, gas, 411-414, 411 (figure), 412 (figure),	whiskery crystals, gas hydrates, 444, 444 (figure)
413 (figure), 413 (table), 414 (figure), 414 (table)	White Sands project, 315
well placement configuration, water flooding, 251, 252 (figure),	Who Dat project, 654–655. See also semisubmersibles
253–255, 254 (figure)	whole-core analysis, 12, 13, 16
well testing (pressure transient testing), 12, 17	Wien automatic system planning (WASP), 50 (table)
well trajectories, directional	Wilcox trend, 605–606, 607 (figure)
basic, 217, 217 (figure)	wireline logs, 11–12, 98–100, 219
coordinates, 221–222, 221 (figure), 222 (figure)	work breakdown structures, cost estimation, 583
measuring, 219	workplace hazards. See occupational hazards; safety
planning trajectory changes, 223, 223 (figure)	worksite inspections, 552
terminology, 216–217, 217 (figure), 218 (figure), 219 (figure)	world energy market, 657, 658 (figure). See also energy future
wellbore and outflow performance analysis, 404–411, 409 (table)	world energy model (WEM), 50 (table)
wellbore models, numerical reservoir simulation, 186–187,	
186 (figure)	Y
wellbore pressure, 210–211, 210 (figure), 211 (figure),	Yamal crater, 436, 436 (figure)
212 (figure)	yet-to-find hydrocarbon resources, 696, 696 (figure)
wellhead, 680, 681	yield point (YP), drilling fluids, 208, 208 (figure)
wells	yield stress, 91, 91 (figure)
completion of, 680–681	Young-Laplace equation, 69–70, 70 (figure)
for deepwater systems, 606, 607–609, 608 (figure), 609 (figure)	Young's modulus, 87, 88 (figure), 95, 99, 99 (figure)
plugging and abandonment, 581, 585–586, 585 (table), 586	7
(figure), 591, 593	<b>Z</b>
semisubmersible projects	Z-factor, gas, 63, 63 (figure)
cost of, 624–625, 626 (table), 627 (table)	zircon fission track, 121
development, 619, 620–621 (figure), 622 (figure),	zirconate, 358
622-623, 622 (table), 623 (figure), 624 (table)	zwitterionic surfactants, 278 (table)