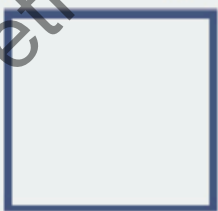


Petroleum Extension-The University of Texas at Austin



Petroleum Geology and Reservoirs

3rd Edition

Well Servicing and Workover, Lesson 2



The University of Texas at Austin
Petroleum Extension (PETEX™)

PETEX™ WELL SERVICING AND WORKOVER PUBLICATIONS

A Primer of Oilwell Service, Workover, and Completion

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Contents



Figures	vii
Tables	xii
Foreword	xiii
Preface	xv
Acknowledgments	xvii
Units of Measurement	xviii
Basic Concepts of Geology	1
Uniformitarianism	4
Geological Time	6
The Formation of the Earth	7
Plate Tectonics	11
Rocks and Minerals	16
Igneous Rock	18
Sedimentary Rock	19
Metamorphic Rock	21
Summary	22
Sedimentary Rocks	23
Origins of Sedimentary Particles	24
Clastics	25
Physical Weathering	25
Chemical Weathering	27
Pyroclastics	27
Nonclastics	28
Sedimentary Processes	29
Transport of Sediment	29
Mass Movement	30
Stream Transport	31
Wind and Glaciers	32
Lithification	33
Compaction	33
Cementation	34
Depositional Environments	35
Continental Environments	36
Fluvial Environments	36
Lacustrine Environments	36
Alluvial Environments	36
Glacial Environments	36
Aeolian Environments	38
Transitional Environments	38
Deltaic Environments	38
Beach Environments	39
Marine Environments	40

Shelf Environments	41
Outer Continental Environments	41
Types of Sedimentary Rock	42
Clastics	42
Conglomerates	43
Sandstones	44
Shales	45
Carbonates	46
Evaporites	47
Summary	48
Stratigraphy	49
A Definition of Stratigraphy	49
Stratigraphic Representations	50
Maps	51
Contour Maps	51
Topographic Maps	52
Subsurface Contour Maps	53
Vertical Cross Sections	55
Stratigraphic Columns	56
Block Diagrams	57
Determining the Age of Rock	58
Methods of Absolute Dating	58
Methods of Relative Dating	59
The Faunal Succession	59
Superposition	60
Lateral Continuity and Correlation	60
Original Horizontality	62
Situating Certain Geological Features in Time	63
Summary	69
Oil and Gas Accumulation	71
The Chemical Composition of Hydrocarbons	72
The Origins of Hydrocarbons	74
Biological Source Materials	74
Conditions Affecting Formation	76
Source Rocks	77
Migration of Fluids	77
Primary Migration	78
Secondary Migration	78
Accumulation of Fluids in Traps	80
Differentiation of Fluids	80
Types of Traps	82
Structural Traps	82
Anticlinal Traps	82
Fault Traps	84
Stratigraphic Traps	86

Primary Stratigraphic Traps	87
Secondary Stratigraphic Traps	90
Hydrodynamic Traps	91
Combination Traps	92
Factors Affecting the Productivity of Reservoirs	92
Closure	92
Timing	93
Summary	94
Exploration	95
Surface Geographical Studies	96
Remote Sensing	96
Aerial Photographs and Satellite Images	97
Landsat	98
Radar	98
Oil and Gas Seeps	99
Geophysical Surveys	99
Magnetic and Electromagnetic Surveys	99
Magnetometer Surveys	100
Magnetotelluric Surveys	100
Gravity Surveys	101
Seismic Surveys	101
Seismic Survey Methods	103
Analyzing Seismic Data	104
Studies Conducted During Drilling	105
Well Logs	105
Driller's Logs	105
Wireline Logs	106
Electric Logs	107
Nuclear Logs	108
Acoustic Logs	109
Sample Logs	110
Drill Stem Tests	111
Strat Tests	111
Stratigraphic Correlation	111
The Role of Electronic Media in Exploration	112
Data	112
Digital Maps and Models	112
Geographic Information Systems	113
Summary	113
Drilling	115
Collecting Data During Drilling	116
Sample Logs	117
Testing the Formation	120
Measurement While Drilling and Logging While Drilling	122

Optimizing Drilling	124	
Bit Type	124	
Weight on Bit and Rotary Speed		124
Drilling Fluid Properties	125	
Bit Hydraulics	126	
Managing Drilling Challenges		127
Hole Deviation	127	
Sloughing or Swelling Shale		129
Lost Circulation	130	
Pressure Control	131	
Summary	134	
Evaluation and Development	135	
Evaluating a Prospect	136	
Determining Porosity and Permeability		137
Estimating Reserves	138	
Generating Models	139	
Abandoning or Completing a Well		140
Evaluating a Discovery to Optimize Production		141
The Rate of Production	142	
Completing a Well	142	
Summary	146	
Production	147	
Evaluating the Drive of a Reservoir		148
The Flow of Fluids in Reservoirs		148
Pressures Affecting Production		150
Drive Mechanisms	155	
Solution-Gas Drive		156
Gas-Cap Drive	158	
Water Drive	160	
Gravity Drainage	162	
Combination Drives	162	
Material Balance	164	
Initiating Flow in a Well	165	
Improving Recovery	165	
Drive Mechanism Enhancement		166
Fluid Properties Enhancement		166
Programs Addressing Heterogeneities		167
Summary	168	
Appendix	169	
Glossary	177	
Review Questions	225	
Index	239	
Answer Key	251	

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Virginia Doshier

Editor, PETEX

The University of Texas at Austin

Units of Measurement

Throughout the world, two systems of measurement dominate: the English system and the metric system. Today, the United States is one of only a few countries that employ the English system.

The English system uses the pound as the unit of weight, the foot as the unit of length, and the gallon as the unit of capacity. In the English system, for example, 1 foot equals 12 inches, 1 yard equals 36 inches, and 1 mile equals 5,280 feet or 1,760 yards.

The metric system uses the gram as the unit of weight, the metre as the unit of length, and the litre as the unit of capacity. In the metric system, 1 metre equals 10 decimetres, 100 centimetres, or 1,000 millimetres. A kilometre equals 1,000 metres. The metric system, unlike the English system, uses a base of 10; thus, it is easy to convert from one unit to another. To convert from one unit to another in the English system, you must memorize or look up the values.

In the late 1970s, the Eleventh General Conference on Weights and Measures described and adopted the *Système International (SI) d'Unités*. Conference participants based the SI system on the metric system and designed it as an international standard of measurement.

The Drilling Technology Series gives both English and SI units. And because the SI system employs the British spelling of many of the terms, the book follows those spelling rules as well. The unit of length, for example, is metre, not meter. (Note, however, that the unit of weight is gram, not gramme.)

To aid U.S. readers in making and understanding the conversion system, we include the table on the next page.

English-Units-to-SI-Units Conversion Factors

Quantity or Property	English Units	Multiply English Units By	To Obtain These SI Units
Length, depth, or height	inches (in.)	25.4	millimetres (mm)
		2.54	centimetres (cm)
	feet (ft)	0.3048	metres (m)
	yards (yd)	0.9144	metres (m)
	miles (mi)	1609.344	metres (m)
		1.61	kilometres (km)
Hole and pipe diameters, bit size	inches (in.)	25.4	millimetres (mm)
Drilling rate	feet per hour (ft/h)	0.3048	metres per hour (m/h)
Weight on bit	pounds (lb)	0.445	decanewtons (dN)
Nozzle size	32nds of an inch	0.8	millimetres (mm)
Volume	barrels (bbl)	0.159	cubic metres (m ³)
		159	litres (L)
	gallons per stroke (gal/stroke)	0.00379	cubic metres per stroke (m ³ /stroke)
	ounces (oz)	29.57	millilitres (mL)
	cubic inches (in. ³)	16.387	cubic centimetres (cm ³)
	cubic feet (ft ³)	28.3169	litres (L)
		0.0283	cubic metres (m ³)
	quarts (qt)	0.9464	litres (L)
	gallons (gal)	3.7854	litres (L)
	gallons (gal)	0.00379	cubic metres (m ³)
	pounds per barrel (lb/bbl)	2.895	kilograms per cubic metre (kg/m ³)
barrels per ton (bbl/tn)	0.175	cubic metres per tonne (m ³ /t)	
Pump output and flow rate	gallons per minute (gpm)	0.00379	cubic metres per minute (m ³ /min)
	gallons per hour (gph)	0.00379	cubic metres per hour (m ³ /h)
	barrels per stroke (bbl/stroke)	0.159	cubic metres per stroke (m ³ /stroke)
	barrels per minute (bbl/min)	0.159	cubic metres per minute (m ³ /min)
Pressure	pounds per square inch (psi)	6.895	kilopascals (kPa)
		0.006895	megapascals (MPa)
Temperature	degrees Fahrenheit (°F)	$\frac{°F - 32}{1.8}$	degrees Celsius (°C)
Mass (weight)	ounces (oz)	28.35	grams (g)
	pounds (lb)	453.59	grams (g)
		0.4536	kilograms (kg)
	tons (tn)	0.9072	tonnes (t)
	pounds per foot (lb/ft)	1.488	kilograms per metre (kg/m)
Mud weight	pounds per gallon (ppg)	119.82	kilograms per cubic metre (kg/m ³)
	pounds per cubic foot (lb/ft ³)	16.0	kilograms per cubic metre (kg/m ³)
Pressure gradient	pounds per square inch per foot (psi/ft)	22.621	kilopascals per metre (kPa/m)
Funnel viscosity	seconds per quart (s/qt)	1.057	seconds per litre (s/L)
Yield point	pounds per 100 square feet (lb/100 ft ²)	0.48	pascals (Pa)
Gel strength	pounds per 100 square feet (lb/100 ft ²)	0.48	pascals (Pa)
Filter cake thickness	32nds of an inch	0.8	millimetres (mm)
Power	horsepower (hp)	0.75	kilowatts (kW)
Area	square inches (in. ²)	6.45	square centimetres (cm ²)
	square feet (ft ²)	0.0929	square metres (m ²)
	square yards (yd ²)	0.8361	square metres (m ²)
	square miles (mi ²)	2.59	square kilometres (km ²)
	acre (ac)	0.40	hectare (ha)
Drilling line wear	ton-miles (tn•mi)	14.317	megajoules (MJ)
		1.459	tonne-kilometres (t•km)
Torque	foot-pounds (ft•lb)	1.3558	newton metres (N•m)

Basic Concepts of Geology



In this chapter:

- The vast expanse of geological time
 - How the Earth was formed
 - How Earth's mobile crust creates geological features
 - How fossil fuels came to exist
 - Types of rocks and minerals
-

What comes to mind when you hear the word *geology*? We tend to think of geology in terms of landscapes too vast to fully comprehend—waterfalls, volcanoes, mountain ranges, canyons—created by forces beyond our control (fig. 1).

In the search for *petroleum*, geology—the study of the physical history of the Earth—is the branch of science that is of primary interest. *Fossil fuels* accumulate deep in the Earth's *crust*. Geology makes it possible to find these accumulations that are invisible at the surface. It also reduces the risk of drilling *dry holes* and increases profitability—first, by suggesting the most efficient way to drill a well, and second, by suggesting how to recover as much of the *hydrocarbons* as possible.

Petroleum geologists are most concerned with rocks formed in the Earth's surface by processes closely associated with both climate and life. The way these rocks are created and change, as well as how oil and gas form and accumulate in them, are the principal concerns. For a thorough understanding of these processes, it is necessary to look back in time to the beginning of the Earth itself.

Knowledge of geology is needed to find hydrocarbons hidden in layers of underground rock.

Sedimentary Rocks



In this chapter:

- The origins of sedimentary rock particles
 - How rock particles are transported
 - How sedimentary rocks are formed
 - Environments where sedimentary rocks are found
 - Types of sedimentary rocks and their characteristics
-

Petroleum geologists are interested in sedimentary rocks because they contain nearly all the world's oil. To understand the correlation between petroleum and sedimentary rock, we must learn more about *sedimentation*—in other words, how sedimentary particles are formed, transported, deposited, and transformed into the great sheets of rock (fig. 19) that cover most of the world's land area.



Figure 19. Layers of compacted sediment are visible in these columns along the coast of Australia. The columns are the remaining vestiges of vast sheets of limestone eroded by the Southern Ocean.

Oil and Gas Accumulation



In this chapter:

- How hydrocarbons develop from organic matter
- Conditions that allow hydrocarbons to form
- The migration of fluids through rock
- Hydrocarbon traps
- Conditions that make a reservoir productive

In the nineteenth century, early geologists observed that rocks in which oil is found had once been loose sediment piling up in shallow coastal waters where fish, algae, plankton, and corals had lived (fig. 59). As a result of such insights, it seemed possible that oil and gas had something to do with the decay of dead organisms. Later advances in microscopy revealed that oil-producing and oil-bearing rocks often contain fossilized creatures too small to be seen with the unaided eye. Chemists also discovered that carbon-hydrogen ratios in petroleum are much like those in marine organisms and that certain complex molecules found in petroleum *source rocks* are otherwise known to occur only in living cells. But it was the fact that most source rocks could be shown to have originated in environments rich in life that clinched the organic theory of the origin of hydrocarbons.

Source rocks for hydrocarbons exist in areas where there were once living organisms.

Exploration



In this chapter:

- Narrowing the exploration area with surface imaging
 - Assessing subsurface structures with surveying equipment
 - Locating hydrocarbons by sampling and testing the formation
 - Using digital assets to manage data
 - Producing maps and models with software
-

Finding petroleum was once a matter of guesswork and good luck. In the early days of *exploration*, drilling near oil or natural gas seeps was the most successful method for finding hydrocarbons under the ground. Today, petroleum *explorationists* with extensive geological training use sophisticated technologies and scientific principles to find oil and gas.

Surface and subsurface geological studies drive the discovery of oil and gas. Various types of data—from tests, logs recorded while drilling, and surveys such as aerial photographs (fig. 82)—give an indication of where to drill an exploratory well. Specialists examine rock fragments and samples brought up while drilling the exploratory well and run special tools into the hole to get more information about the formations underground. By examining, correlating, and interpreting this information, explorationists can accurately locate subsurface structures that might contain hydrocarbon accumulations worth extracting.

Exploration is the search for oil and gas underground. It usually involves drilling exploratory wells.

Drilling



In this chapter:

- Technology used in drilling
 - Collecting samples to study the formation
 - Testing the formation during drilling
 - Optimizing drilling by adjusting parameters
 - Handling common problems that arise during drilling
-

Drilling a well is a careful, considered process. Before drilling, well plans are engineered and numerous contractors are hired to provide materials and services. During drilling, the well is carefully monitored by the crew and by specialists engaged in tasks such as log interpretation and drill-stem testing. One of these specialists is the geologist, who studies samples from the formation, supports the crew during drilling, and makes a recommendation about whether to abandon the well or complete it for production.

In order for a well to be profitable, it must be drilled quickly and expertly. The crew must avoid problems such as a *crooked hole*, a cave-in of the well, the sticking of *pipe* or tools to walls of the well, and the loss of drilling fluids into a highly permeable formation.

Evaluation and Development



In this chapter:

- Steps to evaluating a prospect for profitability
- Calculations and computer models used for evaluation
- Deciding whether to abandon or complete a well
- Optimizing production through careful planning
- Steps to completing a well

By the time an exploratory well has reached *total depth (TD)*, the geologist may already have a pretty good idea of the well's chances for production. He or she, alongside others working for the operator, will nonetheless conduct an evaluation of the prospect's profitability before making a recommendation on whether to complete the well.

Reservoirs that contain oil or gas in exploitable quantities are not usually found during exploratory drilling. So most wells are *plugged and abandoned* (fig. 112), rather than being completed. When, however, a *discovery* looks as if it will yield a profit, the reservoir or field is developed and promising wells are completed. At this stage, another evaluation is performed to maximize production.

A prospect is an area under exploration for oil and gas; a discovery is a new oil and gas field that has been identified by exploration.

Production



In this chapter:

- How fluids and pressures change during production
- Drive mechanisms in different types of reservoirs
- Artificial means of starting flow in a well
- Continuous evaluation during production
- Improving recovery during production

Profit-driven decisions are made not just during the exploration and development phases, but also during the production phase, when wells are maintained and the productive life of the reservoir is extended. During this phase, the operator must decide how best to initiate flow in wells and which techniques will allow for the maximum recovery of hydrocarbons. Since the balance of fluids and pressures in the reservoir change in response to production, this second task requires forward planning and continuous reevaluation after production is underway.

Conditions change during production. Computer programs allow for models to be continuously updated by changing the variables.

Index



- abandoning a well, 115, 135, 136*f*, 140–141
- abnormally pressured shale, 129
- abnormal pressure, 132
- abrasion, 38
- absolute age, 59
- absolute dating, 58
- acidizing, 165
- acoustic logs, 109, 109*f*
- adsorb, 24, 155
- aeolian (depositional) environment, 38, 38*t*
- aeolian deposits, 38
- aerial photographs, 96*f*, 97
- age. See *absolute age*; *relative age*.
- air gun, 104, 104*f*
- algae, 8, 19*f*, 77
- alluvial (depositional) environment, 36, 38*t*
- alluvial fan, 36, 37*f*
- anaerobic bacteria, 75
- angular unconformity, 68, 68*f*, 90
- annulus, 126
- anticlinal traps, 82–83, 83*f*
- anticline
 - accumulation of fluids in, 80, 80*f*
 - closure in, 93, 93*f*
 - faulted traps, 92*f*
 - hydrodynamic traps and, 91*f*
 - overview of, 63
- aromatics, 73*f*
- artificial lift
 - drive mechanisms and, 155
 - for optimizing production, 141
 - permeability and, 137
 - pump jack, 141*f*
 - in a solution-gas drive, 157
 - water production and, 154
- associated gas, 155. See also *natural gas*.
- atolls, 89
- bacteria, 8
- barite, 129
- barrels of oil, 138, 157
- base map, 51
- basement rock, 100
- basins, 19, 20, 22
- beach (depositional) environment, 35*f*, 38*t*, 39, 39*f*
- bedrock, 26*f*, 30
- beds, sedimentary, 8, 75
- benzene, 72, 73*f*
- BHA. See *bottomhole assembly (BHA)*.
- bioherm, 89, 89*f*
- biological sources for hydrocarbons, 74
- bits
 - coring, 119, 119*f*
 - cuttings, 117, 117*f*
 - hole deviation and, 128, 128*f*
 - hydraulics and, 124, 126, 126*f*
 - types of, 124
- bit walk, 128
- block diagrams, 50, 57, 57*f*. See also *models*.
- blowout, 116, 116*f*, 125, 130, 131–132
- blowout preventers, 132, 133*f*
- borehole, 106*f*, 109*f*, 110, 111. See also *wellbore, pressure around*.
- bottomhole, 155
- bottomhole assembly (BHA), 128, 129*f*
- bottomhole pressure, 152, 152*f*, 153*f*, 154*f*, 155. See also *pressure drop*.
- bottom water reservoir, 160, 160*f*
- breccias, 43, 43*f*
- buoyancy, 91
- calcareous, 19*f*, 46
- calcite, 20, 28, 34, 46
- calcium carbonate, 20, 26, 28
- calcium oxide, 34
- Cambrian period, 9*f*, 10*f*
- capillarity, 149, 150
- capillary pressure, 150, 155

- caprock, 82
- carbon, in hydrocarbon molecules, 72
- carbon dioxide, 27, 75
- carbonate minerals, 27
- carbonates, 46–47
- carbonation, 27
- casing, 130, 142, 150
- casinghead gas, 155
- catastrophism, 4
- cave-ins, 45*f*, 115, 129
- caves/caverns, 26*f*, 29, 46
- cementation, 33, 34, 46, 90
- Cenozoic era, 9*f*, 93
- chalk, 19*f*
- chemical weathering, 27
- choke line, 132
- Christmas tree, 142, 143*f*
- circulation, loss of, 129, 130, 130*f*
- clastics, 25–27, 34, 42–45, 42*f*
- clastic texture, 20
- clasts, 25
- clay
 - composition of, 45
 - in the formation of petroleum, 75
 - grain size of, 24, 24*t*, 42*t*
 - as a metamorphic rock, 21
 - slump, 30
- closure, 92, 93*f*
- coal, 36, 47
- cohesive particles, 24
- combination drive, 162, 163*f*, 164
- combination traps, 82, 92
- compaction, 33, 45, 78, 90
- completed wells. *See well completion.*
- completion zone, 150, 152
- compression, 7, 63*f*, 65
- condensate-gas ratio, 155
- condensates, 155
- conductivity, 106
- conductor line, 106
- conglomerates, 24*t*, 42*t*, 43
- coning, 142, 155, 162, 162*f*
- continental crust, 15, 40*f*
- continental (depositional) environment, 35*f*, 36–38, 38*t*
- continental drift, 11, 11*f*, 14*f*
- continental rise, 41
- continental shelf, 41
- continental slope, 40*f*, 41
- continents, breakup of, 14*f*
- contour maps, 51
- contours, 51, 52, 52*f*, 53
- conventional well completion, 144, 145*f*
- convergence zone, 15*f*
- coral reefs, 72*f*, 89
- core, Earth's, 7, 7*f*
- core bit, 119, 119*f*
- core samples, 105, 110, 110*f*, 119, 119*f*
- coring, sidewall, 118, 118*f*
- correlation, 61
- Cretaceous period, 9*f*, 56*f*
- crooked hole, 115, 127*f*, 128
- cross-cutting relationship, 64–66, 67*f*, 68
- cross section
 - of Earth, 7*f*
 - of a lens trap, 87*f*
 - overview of, 50
 - stratigraphic, 66, 67*f*, 111*f*
 - through magnetotelluric surveys, 100
 - vertical, 55, 55*t*, 66
- crude oil, calculating recoverable, 138
- crust
 - formation of, 18
 - fossil fuels in, 1
 - oceanic, 12, 12*f*, 15, 15*f*
 - overview of, 7, 7*f*
 - spreading of, 12, 12*f*
 - stability of, 13
 - subduction and, 15*f*
- crystalline texture, 18, 18*f*, 21, 34, 42, 42*f*
- crystallization, 17*f*, 18, 34
- cuttings
 - bit, 117, 117*f*
 - drilling fluids and, 125
 - evaluating a well with, 137*f*
 - examining, 105
 - hydraulic horsepower and, 126, 126*f*
- cuttings samples, 110, 117
- darcy, 137
- data collection. *See also evaluating wells.*

- measurement and logging while drilling, 116, 122, 123*f*
 sample logs, 117–119
 sources of for explorationists, 112, 134, 136
 wireline and drill stem tests, 120, 121*f*, 122
- datum, 51
 deflation, 38
 deflection, 128
 deflocculating agent, 130
 deformation, 63, 64, 82
 delta. See *deltaic (depositional) environment; marine delta*.
 deltaic (depositional) environment, 35*f*, 38, 38*t*
 density, drilling fluid and, 132, 153
 density, gravity surveys and, 101
 depletion drive. See *reservoir drives*.
 depletion of a well, 140*f*, 159, 163*f*
 deposition, 4, 5, 5*f*, 87
 depositional environments
 continental, 35*t*, 36–38, 38*t*
 marine, 35*t*, 38*t*, 40–41, 40*f*, 74*f*
 overview of, 35, 35*f*, 38*t*
 transitional, 35*t*, 38–39, 38*t*
 depth, relationship to hydrocarbon formation, 76, 76*f*
 detritus, organic, 10, 74–75, 74*f*, 77
 development wells, 141
 diagenesis, 33, 90
 diamond bit, 124, 125*f*
 diapirism, 82, 83
 differential pressure, 130*f*, 132
 differential sticking, 130, 130*f*. See also *sticking*.
 differentiation of fluids, 80–81
 dip-slip fault, 65–66
 directional wells, 122, 127, 127*f*
 disconformity, 68, 68*f*
 discovery, 135, 141. See also *field*.
 displacement, fluid migration and, 78, 148, 149, 156, 161
 displacement, from faults, 64–65, 66, 84
 dissolved gas, 79
 dolomite, 47
 dolomitization, 93
 dome, 83
 downhole, determining conditions in, 120, 121*f*, 122, 129, 136, 168
 downthrown side, 66, 86
 drill bits. See *bits*.
 drill collars, 128
 driller's logs, 105
 drilling
 collecting data during, 116–123, 134
 hole deviation, 127–128
 lost circulation and, 129, 130, 130*f*
 optimizing, 124–126
 overview of, 115–116
 pressure control during, 131–132
 sloughing or swelling shale, 45*f*, 129, 129*f*
 drilling fluids, 124, 125, 130, 130*f*
 drilling mud. See also *mud*.
 blowouts and, 132
 differential sticking and, 130*f*
 hydrostatic pressure and, 131
 lost circulation and, 130
 weight of, 125, 129, 132
 drilling parameters. See *optimization*.
 drill pipe, sloughing and, 129
 drill stem, 122
 drill stem tests (DSTs), 111, 120, 121*f*
 drill string, 122, 127, 130
 drive mechanisms, 155, 166
 drones, 97, 97*f*
 dry holes, 1, 140
- Earth, formation of, 1, 3, 6, 7–10, 7*f*
 edgewater reservoir, 160, 160*f*
 effective permeability, 148
 effective porosity, 137
 electric well logs, 107–108
 electromagnetic surveys, 99
 elements, 7, 16, 21, 58
 elevation, contour maps and, 51
 encroaching, 155
 entrained gas, 156
 epeiric seas, 75
 erosion
 causing unconformities, 66
 geological pace of, 4
 overview of, 19
 uniformitarianism and, 5, 5*f*
 by water, 2*f*, 3
 by wind, 3, 38

- estuary, 38
- evaluating wells. See also *data collection*.
 determining porosity and permeability, 137, 137f
 estimating reserves, 138
 generating models, 139
 for optimal production, 141
 overview of, 135, 136, 146
- evaporites, 47, 47f, 77
- exploration for hydrocarbons
 electronic media in, 112–113
 geophysical surveys, 99–100
 gravity surveys, 101
 overview of, 95, 113
 seismic surveys, 101–104
 studies during drilling, 105–111
 surface geographical studies, 96–99
- explorationists, petroleum, 95, 112, 113
- exploratory wells
 drill stem tests, 111
 geological studies and, 95
 plugged and abandoned, 115, 135, 136f, 140–141
 sample logs for, 110
 strat tests and, 111, 111f
 well logs for, 105–109
- facies, 54, 167, 167f
- fault, 13, 64, 65–66, 65f
- fault plane, 65
- fault traps, 84–86, 84f, 85f
- faunal succession, 59
- feldspar, 16f, 18f, 24, 44
- fields. See also *discovery*.
 abandoning or completing, 141
 classification of, 112
 evaluating, 135, 136, 138
 modeling, 139
 developing, 141
- filter cake, 126f, 130
- filtration control, 126f, 130
- fingering, 142
- fishing, 116
- fissuring, 93
- flooding, reservoir, 155. See also *waterflooding*.
- fluid contact. See *gas-oil contact*; *oil-water contact*.
- fluid loss, 115
- fluid potential, 79
- fluids
 differentiation of, 80
 enhancing for improved recovery, 166
 flow of in the reservoir, 148–150
- fluvial, 35f
- fluvial (depositional) environment, 36, 38t, 167
- fluvial deposits, 36
- folding, 62, 63–64, 63f
- Foraminifera*, 28, 28f, 77
- formations
 bit types for, 124
 disruptions of, 63
 highly permeable, 130
 naming of, 61
 pressure of, 132, 152, 152f
 properties of, 124
 sampling, 117–119
 showing characteristics of in a vertical cross section, 55
 slanted, 128, 128f
 testing, 120
 water in, 155
- fossil correlation, 61
- fossil fuels, 1, 22
- fossils, 8, 10f, 11, 59f, 71
- fracture, 64
- free gas, 148, 155. See also *natural gas*.
- frost wedging, 25, 25f, 30
- gamma ray log, 107f, 108
- gas. See *natural gas*.
- gas cap
 gas-cap drive and, 153, 153f, 158f, 159
 overview of, 80, 81f, 148
 shrinking, 155
- gas-cap drive, 153, 158–159, 158f, 159f, 163f
- gas-cap reservoir, 142
- gas-expansion drive reservoir, 162
- gas molecules, 72
- gas-oil contact, 81f, 158, 159
- gas-oil ratio
 gas-cap drive and, 158–159, 158f, 159f
 production and, 153, 153f, 157, 157f
 in a water-drive reservoir, 161, 162
 well classification and, 155
- gas seep, 79, 79t, 95, 99

- gas-water contact, 81, 81*f*
 gas wells, 155. See also *natural gas*; *nonassociated gas reservoir*.
 gas zone, 148, 149, 159
 gel strength, 125
 geocellular model, 139, 139*f*
 geographical studies, 96–99
 geographic information systems, 113
 geologist. See *petroleum geologists*.
 geology
 formation of the Earth, 1, 3, 6, 7–10, 7*f*
 overview of, 1–3
 pace of changes in, 3, 5, 6, 9*f*, 77
 plate tectonics, 11–15
 rocks and minerals, 16–21
 studies in, 95
 uniformitarianism, 4–5
 geophones, 102, 103*f*
 geophysical exploration, 99
 geophysical surveys, 99–100
 glacial (depositional) environment, 35*f*, 36, 37*f*, 38*t*
 glacial till, 36, 37*f*
 glaciers, sedimentary processes and, 32
 gouge, 84
 gradualism, 4–5
 grain size
 classification of sediment particles by, 24, 24*t*
 clastic sedimentary rocks, 42, 42*t*
 in conglomerates, 43
 in igneous rocks, 18
 range of, 16
 in shale, 45
 granite, 12, 18*f*
 gravel, 24, 24*t*, 42*t*
 gravimeter, 101
 gravity, 149
 gravity drainage, 162, 163*f*
 gravity meter, 101
 gravity, sedimentary processes and, 29, 62, 78
 gravity surveys, 101
 growth fault, 65*f*, 66, 86, 86*f*
 half-life, 58
 halite. See *rock salt*.
 hazard mitigation, 130
 heat, hydrocarbon formation and, 3, 17*f*, 75, 77, 93
 heterogeneities, 167
 high-viscosity drilling fluid, 125
 hole deviation, 127–128
 Hubbard Glacier (Alaska), 98*f*
 Hutton, James, 4
 hydraulic fracturing, 165, 165*f*
 hydraulic horsepower, 126, 126*f*
 hydraulics. See *bit hydraulics*.
 hydrocarbons. See also *oil, formation of*.
 chemical composition of, 72, 73*f*
 conditions affection formation of, 76, 76*f*
 migration of fluids and, 77–79, 78*f*
 origins of, 74–75
 source rocks for, 77
 types of reservoirs, 148
 hydrodynamic traps, 82, 91, 91*f*
 hydrogen atoms, 72
 hydrolysis, 27
 hydrophones, 104, 104*f*
 hydrostatic pressure, 126*f*, 131, 131*f*, 152, 154*f*, 162
 hydrous aluminum silicates, 24
 igneous rock. See also *rocks*.
 classification of, 17, 34, 42
 as a hydrocarbon trap, 99
 in an intrusion, 66
 magnetic surveys and, 99
 metamorphic rocks and, 21
 overview of, 18
 in the rock cycle, 17*f*
 impactors, 103, 103*f*
 impermeable formations
 differential sticking and, 130*f*
 identifying with a gamma ray log, 108
 in a lithofacies map, 167*f*
 pressure control and, 132
 secondary migration and, 78
 traps and, 82, 84, 88
 induction log, 108
 infill drilling, 167
 injection wells, 166, 166*f*
 insert bit, 124
 interbedded, 45
 interface zone, 142
 interstices, 78

- interstitial water, 78, 148
- intrusions, 66, 67*f*, 82, 99
- iron oxide, 34
- isolith map, 167
- isopach map, 54, 54*f*
- isotopes. See *radioactive isotopes, decay of*.
- joints, 25
- Jurassic period, 9*f*, 56*f*
- karst landscape, 26, 26*f*
- Katla volcano (Iceland), 30*f*
- kick, 132
- lacustrine (depositional) environment, 35*f*, 36, 38*t*
- landforms, 4
- Landsat, 98, 98*f*
- lateral continuity and correlation, 60–61, 61*f*
- lateral fault, 64*f*, 65*f*, 66
- layers. See also *stratigraphy*.
 in an anticline, 82–83
 conglomerate, 43
 disruption of, 63–64, 66, 67*f*, 68, 90
 in geographic information systems, 113
 hole deviation and, 128
 in an isopach map, 54, 54*f*
 lateral continuity and, 60–61
 limestone, 46, 46*f*
 original horizontality and, 62
 permeability and, 77
 sedimentation and, 3, 4, 6, 23*f*, 33
 in a stratigraphic column, 57
 in a structure map, 53, 53*f*
 superposition and, 60
 surveys of, 101–102, 104*f*, 107
 in a vertical cross section, 55
- leaching, 26, 46, 90, 93
- lease, 113
- lens/lens trap, 87, 87*f*
- life forms, 8, 10
- light hydrocarbons, 155
- lime. See *calcium oxide*.
- limestone
 classification of, 46
 Earth's formation and, 8
 as a metamorphic rock, 21
 overview of, 23*f*, 28–29, 46*f*
 porosity of, 77*f*
 as source rock for petroleum, 77
- liquids, 148
- lithic particles, 44
- lithification, 33–34, 45
- lithofacies map, 54, 55*f*, 167*f*
- lithology, 116
- lithology log, 117
- logging while drilling (LWD), 116, 122
- longshore currents, 39
- long-toothed roller cone bit, 124, 125*f*
- lost circulation, 129, 130, 130*f*
- magma, 17*f*, 18, 27, 66
- magnetic surveys, 99
- magnetometer survey, 100, 100*f*
- magnetotelluric survey (MT), 100
- mantle, 7, 7*f*, 12*f*, 15*f*
- maps, 51–54, 104, 112, 113
- marble, 21*f*
- marine (depositional) environment, 35*f*, 38*t*,
 40–41, 40*f*, 74*f*
- marine delta, 38, 39*f*
- marine organisms. See *organisms, formation of petroleum and*.
- mass movement of rock, 30
- material balance, 164
- meandering river, 5*f*
- measurement while drilling (MWD), 116, 122, 123*f*
- megascopic heterogeneities, 167
- member, rock, 61
- Mesozoic era, 9*f*, 10, 93
- metamorphic rock, 17, 17*f*, 21, 21*f*, 34. See also *rocks*.
- metamorphosis, 33
- methane, 72, 73*f*
- mica, 18*f*
- microfossils, 111
- microscopic heterogeneities, 167
- migration of fluid, 45, 77–79, 78*f*
- millidarcys (md), 137
- minerals
 abundant types of, 16*f*
 appearance of, 18*f*
 overview of, 16–17

- oxidation and, 27
 in sediments, 24
 solubility of, 26, 167
- models. See also *block diagrams*.
 digital, 112
 generating to evaluate a well, 139
 geocellular, 139, 139f
 gravity, 101
 macroscopic heterogeneities and, 167
 from seismic surveys, 102, 102f
 static and simulation, 139
 three dimensional, 50, 57, 57f, 102, 102f
- Monument Valley (Arizona), 66, 67f
- Morrison Formation, 61
- mountains, formation of, 8, 15
- mud, 41, 78f, 122. See also *drilling mud*; *sediment beds*.
- mud cake, 109f, 130f
- mudflow, 30
- mud logger/logging, 117
- mud pulse transducer, 122, 123f
- mud pumps, 132
- mud weight, 125, 129, 132
- multiple-zone completion, 144
- naphthenes, 73f
- National Aeronautics and Space Administration (NASA), 98
- natural drive, 141, 162, 164, 168
- natural gas. See also *associated gas*; *free gas*; *gas wells*; *gas-water contact*; *nonassociated gas reservoir*.
 dissolved, 79, 80, 156, 158
 effect on tubinghead pressure, 153f
 expansion in a solution, 156
 formation of, 3f, 71, 76
 in limestone, 46
 in oil accumulations, 148
 in the reservoir, 81f, 148
 in sandstone, 44
 seeps, 79, 79t, 95, 99
 in shale, 45
- neutron log, 108
- nonassociated gas reservoir, 81, 81f, 148. See also *gas wells*; *natural gas*.
- nonclastics, 28–29
- noncohesive particles, 24
- nonconformity, 68, 68f
- nonporous rock, 18
- normal fault, 65, 65f
- normally pressured formations, 132
- nuclear logs, 108
- oceanic crust, 12, 12f, 15, 15f
- offshore drilling, 99
- offshore sediment beds, 13, 75
- oilfields, 80
- oil, formation of, 3f, 36, 71, 74, 76. See also *hydrocarbons*.
- oil-gas reservoir, 81f, 148
- oil reservoirs
 flow of fluids in, 148
 formation of, 71, 76
 in limestone, 46
 overview of, 81f
 in sandstone, 44
- oil saturation, 80
- oil seeps, 79, 79t, 95, 99
- oil shale, 47
- oil-water contact, 79, 80, 81f, 91
- oil-wet reservoirs, 148
- oil zone, 80, 148, 149f, 160, 162f, 163f
- olefins, 73f
- open-hole wells, 144
- optimization, 124–126
- organic detritus. See *detritus, organic*.
- organic theory, 3, 3f, 71, 74
- organisms, formation of petroleum and, 3, 36, 71, 74–75, 74f
- original horizontality, 62, 62f
- original lateral continuity, 60–61, 61f
- outcrop, 61, 61f, 131f
- outer continental (depositional) environment, 35f, 38t, 41
- outwash plain, 36, 37f
- overbalanced drilling, 131
- overburden, 25, 78, 132
- overthrust anticline, 85, 85f
- overthrust fault, 65f, 66, 85, 85f
- oxidation, 27
- Paleozoic era, 8, 9f, 10, 93

- Pancake Rocks (New Zealand), 46*f*
- Pangea, 11, 13, 14*f*
- paraffins, 73*f*
- pay zone, 54, 138
- Pennsylvanian period, 10
- perforating gun/operation, 142, 144*f*
- permeability
 - changes in and reservoir productivity, 93
 - determining when evaluating a well, 136, 137
 - differential sticking and, 130*f*
 - effective, 148
 - gas wells and, 155
 - heterogeneities and, 167
 - hydrocarbon migration and, 78
 - lost circulation due to, 130
 - migration of fluid and, 77
 - overview of, 20, 20*f*
 - of sandstone, 44
 - traps and, 82, 148
- petroleum
 - clay and, 75
 - composition of, 72
 - estimating reserves in, 138
 - in evaporite formations, 47
 - formation of, 3, 3*f*, 13
 - high amounts of in sedimentary rock, 23
 - importance of porosity and permeability in finding, 20, 137
 - limestone and, 46
 - overview of, 1
 - sandstone and, 44
 - sedimentary processes in forming, 74–76
 - shale and, 45, 74, 75, 77
- petroleum engineer, 120
- petroleum explorationists, 95, 112, 113
- petroleum geologists, 1, 23, 69, 94, 98, 115
- petroleum geology, 3, 3*f*
- petroleum window, 76
- physical correlation, 61
- physical weathering, 25–26
- piercement dome, 83
- pinchout trap, 88, 89*f*
- plankton, 77
- plate tectonics, 11–15, 22, 29
- Pleistocene epoch, 9*f*, 77
- plugged and abandoned wells, 115, 135, 136*f*, 140–141
- pluton, 66
- pore throats, 148, 150
- porosity
 - acoustic logging and, 109
 - cementation and, 34
 - changes in and reservoir productivity, 93
 - determining when evaluating a well, 136, 137
 - effective, 137
 - hydrocarbon migration and, 78
 - lack of in metamorphic rocks, 21
 - limestone, 46, 77*f*
 - overview of, 3, 20, 20*f*
 - trapping oil and, 148
 - using in estimating reserves, 138
- Precambrian era, 8, 9*f*
- pressure
 - abnormal. See *abnormal pressure*.
 - condensate production and, 155
 - control of during drilling, 131–132
 - drilling fluids and, 125
 - fluid flow and, 149
 - in a gas-cap drive, 159
 - hydrocarbon formation and, 3, 17*f*, 75, 77, 93
 - production and, 150, 151*f*, 152–155, 152*f*, 154*f*
 - testing, 120, 121*f*
 - in a water-drive reservoir, 160, 161, 161*f*, 162
- pressure drop, 126, 150, 152, 152*f*. See also *bottomhole pressure*.
- pressure gradient, 131–132, 149
- pressure sink, 150
- pressurized gas or air, 125
- primary migration, 78, 78*f*
- primary recovery, 165
- primary stratigraphic traps, 86, 87–89
- production
 - combination drives and, 162, 164
 - determining the rate of, 142
 - drive mechanisms for, 155–164
 - factors affecting, 92–93
 - flow of fluids and, 148–150
 - gas-cap drive and, 158–159, 159*f*
 - gravity drainage and, 162
 - improving recovery during, 165–167
 - initiating flow in a well for, 165
 - material balance during, 164
 - maximizing, 141

- overview of, 147, 168
- pressure and, 150, 151*f*, 152–155, 152*f*, 154*f*
- rates of, 51
- solution-gas drive and, 157, 157*f*
- using maps to find potential, 54
- water-drive reservoirs and, 160–162, 161*f*, 164*f*
- prospects, 112
- protoplanet hypothesis, 7
- pumping, 165
- pump jack, 141*f*
- pyroclastic particles, 27

- quartz, 18*f*, 24, 44

- radar, 98
- radial flow, 150, 151*f*
- radioactive isotopes, age of rocks and, 58, 69
- radioactivity, age of rocks and, 6
- radioactivity logs, 108
- radiometric dating, 58, 69
- rate of penetration (ROP), 124
- rate sensitive, 164
- rate of production, 51
- reactive solids content, in drilling muds, 129
- reamers, 129
- reconnaissance surveying, 100
- recovery efficiency
 - addressing heterogeneities, 167
 - in estimating reserves, 138
 - in a gas-cap drive, 159
 - overview of, 165
 - production rate and, 142
 - in a solution-gas drive, 157
 - through drive mechanism enhancement, 166, 166*f*
 - through fluid property enhancement, 166
 - in a water-drive reservoir, 162
- relative age, 58
- relative dating
 - overview of, 59, 69
 - by faunal succession, 59
 - by geological features in time, 63–65
 - by lateral continuity and correlation, 60–61, 61*f*
 - by original horizontality, 62, 62*f*
 - by superposition, 60, 60*f*
- remote sensing
 - aerial photographs and satellite images, 97
 - Landsat, 98
 - overview of, 96
 - radar, 98
- reserves, oil, 93, 113, 138, 159
- reservoir drives
 - combination, 162, 163*f*, 164
 - enhancing for improved recovery, 166
 - evaluating, 148–150, 151*f*, 152–155, 168
 - gas-cap, 153, 158–159, 158*f*, 159*f*, 163*f*
 - gravity drainage, 162, 163*f*
 - natural, 141, 162, 164, 168
 - solution-gas, 153, 156–157, 156*f*, 157*f*
 - types of, 138
 - water, 160–162, 161*f*, 164*f*
- reservoir pressure, 157
- reservoir rock, 77, 78, 79, 82, 137, 148
- reservoirs
 - classification of, 112
 - created by an overthrust anticline, 85
 - differentiation of fluids in, 80–81
 - estimating reserves in, 138
 - evaluation of, 135, 136
 - factors affecting the productivity of, 92–93
 - flow of fluids in, 148–150
 - heterogeneities and, 167
 - impervious layers of rock and, 77
 - limestone, 46
 - sandstone, 44
 - timing of trap formation, 93
 - types of, 81*f*, 148
 - water-wet, 80, 81*f*, 148
- resistivity log, 108
- reverse fault, 65, 65*f*
- ridges, 12
- rift zones, 12, 12*f*
- rock bed, 79, 90
- rock cycle, 17, 17*f*
- rocks, 6, 16–17. See also *igneous rock*; *metamorphic rock*; *sedimentary rock*.
- rock salt, 47, 47*f*
- rockslide, sedimentary processes and, 30
- Rocky Mountain Overthrust Belt, 85
- roller cone bit, 124, 125*f*
- rollover anticline, 86, 86*f*
- rollover fault, 66

ROP. See *rate of penetration (ROP)*.

rotary speed, 124

royalties, 138

Sahara Desert, 96*f*

Sakurajima volcano (Japan), 98*f*

salt, 83. See also *rock salt*.

salt domes, 47, 83, 83*f*, 101

salt water, 45, 79, 108, 148

sample logs

cores, 119, 119*f*

cuttings, 110, 117, 117*f*

sidewall samples, 118, 118*f*

samples. See *core samples*; *cuttings samples*.

San Andreas fault (California), 63*f*, 64*f*, 66

sand, 24, 24*t*, 42*t*

sandstone, 8, 24*t*, 26, 42*t*, 44, 44*f*

satellite images, 97

saturation, 79

scanning electronic microscope (SEM), 28*f*

sea level, 51

seafloor spreading, 12*f*

sealing fault, 84, 93, 167

seawater, 39, 46, 131

secondary migration, 78, 78*f*

secondary stratigraphic traps, 86, 90–91

sedimentary environment. See *depositional environments*.

sedimentary particles, 24

sedimentary processes

in the formation of the Earth, 8

lithification, 33–34

overview of, 3

in petroleum formation, 74–76

role of water in, 13, 30*f*, 31

transport of sediments, 29–32

compression, 7, 19, 63*f*, 65

sedimentary rock. See also *rocks*.

carbonates, 46–47

chemical weathering, 27

classification of, 17

clastics, 25–27, 42–45

depositional environments, 35–41

evaporites, 47, 47*f*

igneous rock and, 21

limestone, 23*f*

nonclastic, 28–29

origins of sedimentary particles, 24

overview of, 19–20, 48

petroleum in, 23

physical weathering, 25–26

pyroclastics, 27

in the rock cycle, 17*f*

uniformitarianism and, 4

sedimentation, 23

sediment beds, 8, 13, 75. See also *mud*.

sediments, 36, 37*f*, 38–41. See also *unconsolidated sediments*.

seeps, 79, 79*f*, 95, 99

seismic data, 99

seismic exploration, 101

seismic surveys

analyzing data from, 104

marine, 104, 104*f*

methods of, 103, 103*f*

overview of, 101–102

three-dimensional model, 102, 102*f*

vibrator trucks, 101*f*

SEM. See *scanning electronic microscope (SEM)*.

shale

abnormally pressured, 129

classification of, 24*t*, 42*t*

Earth's formation and, 8

overview of, 45, 45*f*

petroleum formed in, 45, 74, 75, 77

sloughing or swelling, 45*f*, 129, 129*f*

shale shaker, 117, 117*f*

shelf (depositional) environment, 35*f*, 38*t*, 41

shoestring sand trap, 88, 88*f*

short-toothed roller cone bit, 124, 125*f*

shut-in well, 132

sidewall samples, 118, 118*f*

silica, 34

silicates, 16, 16*f*

silt, 3, 24, 24*t*, 42*t*, 75

silt grain, 45

siltstone, 24*t*, 42*t*, 45

simulation models, 139

slate, 21

sloughing, 45*f*, 129, 129*f*

slump, 30

solution gas, 80

solution-gas drive, 153, 156–157, 156*f*, 157*f*

- sonde, 106, 109*f*
 sonic log, 109
 sorting sediments, 38, 43
 source rocks, 71, 77
 spill point, 92
 spontaneous potential (SP) log, 107, 107*f*
 stabilizers, 128
 stalactites, 29, 29*f*
 stalagmites, 29
 static models, 139
 Steno, Nicolaus, 6
 sticking, 115, 125. See also *differential sticking*.
 stimulation, well, 137, 155, 165, 165*f*
 straight hole, 127, 127*f*
 strata, 49, 50*f*
 stratigraphic columns, 50, 56–57, 56*f*
 stratigraphic correlation, 111
 stratigraphic traps, 82, 86–91
 stratigraphy. See also *layers*.
 absolute dating with, 58
 block diagrams, 50, 57, 57*f*
 heterogeneities and, 167
 maps, 51–54
 overview of, 49, 69
 relative dating with, 59–68
 stratigraphic columns, 56–57, 56*f*
 types of representations of, 50
 vertical cross sections, 55, 55*f*, 66
 strat tests, 111, 111*f*
 stream transport, 31
 strike-slip fault, 66
 structural traps, 82–86
 structure map, 53, 53*f*
 stuck pipe. See *differential sticking*.
 subduction zone, 15, 15*f*
 subsurface contour maps, 53–55
 superposition, 60, 60*f*
 surface geographical studies, 96–99
 suspended oil droplets, 79
 suspension, 45, 78
 swabbing, 165
 synclines, 63
- talus slope, 30, 31*f*
 TD. See *total depth (TD)*.
 tectonic forces, sedimentary processes and, 29
 tectonic plates, 3
 temperature, relationship to hydrocarbon
 formation, 76, 76*f*
 Tethys Sea, 13
 texture, rock, 16
 thrust fault, 65
 till, glacial, 36, 37*f*
 topographic maps, 52, 52*f*
 topography, 96
 total depth (TD), 135
 total porosity, 137
 transitional (depositional) environment, 35*f*,
 38–39, 38*t*
 transition zones, in reservoirs, 80–81, 149, 149*f*
 traps
 accumulation of fluids in, 80, 80*f*
 anticlinal, 82–83, 83*f*
 combination, 82, 92
 fault, 84–86, 84*f*, 85*f*
 heterogeneities and, 167
 hydrodynamic, 82, 91, 91*f*
 overview of, 79, 82, 94
 role of water in, 91
 stratigraphic, 82, 86–91
 structural, 82–86
 timing of formation, 93
 trenches, 12, 15
 Triassic period, 9*t*, 56*f*
 trilobite, 10*f*
 tripped in/out, 122, 132
 tubing, 142, 152, 153*f*
 turbidity current, 41
 turbulent flow, 31
- ultimate recovery, 167
 ultraviolet (UV) light, hydrocarbons under, 117*f*
 unconformities, 66, 68, 90
 unconsolidated sediments, 33, 66. See also
 sediments.
 underbalanced, 125
 uniformitarianism, 4–5, 22
 United States Geological Survey (USGS), 98
 unitizing, 141
 unmanned aerial vehicles (UAVs). See *drones*.
 unsorted deposits, 36
 uplift, 62

vertical cross sections, 55, 55*f*, 66
 vibrator trucks, 101*f*, 103, 103*f*
 Victoria Falls, 2*f*
 viscosity, 125, 166
 void, 16, 18, 22, 137
 volcanic ash, 27
 volcanic islands, 15
 vugs, 46

water

causing mass movement of rock, 30
 coning of in reservoirs. See *coning*.
 fingering of in wells. See *fingering*.
 in continental environments, 36
 physical weathering and, 2*f*, 25–26
 role in traps, 91
 sedimentary processes and, 13, 30*f*, 31
 water-based mud, 125
 water drive, 160–162, 161*f*, 164
 water-drive reservoir, 142, 161*f*, 164*f*
 water encroachment, 164
 waterflooding, 166
 water production
 in a gas-cap drive, 159
 in a solution-gas drive, 157
 trend of in a well, 150
 in a water-drive reservoir, 162
 well pressure and, 154, 154*f*
 water saturation, 105, 167
 water vapor in gas wells, 155
 water-wet reservoirs, 80, 81*f*, 148
 water zone, 149, 149*f*

weathering of rocks, 19, 66

Wegener, Alfred, 11

weighting up mud, 129

weight of drilling fluid, 125

weight on bit (WOB), 124

welded tuff, 27, 27*f*

wellbore, pressure around, 150, 151*f*, 152. See also *borehole*.

well completion, 82, 140–141, 142, 144, 145*f*

wellhead, 142

wellhead pressure, 152, 153, 153*f*, 154

well logs

acoustic logs, 109, 109*f*

driller's logs, 105

electric logs, 107–108

nuclear logs, 108

overview of, 105

wireline logs, 106–107, 106*f*, 120

wells

completed, 140–141, 142, 144, 145*f*

coning of water and, 162

initiating flow from, 165

life of, 140*f*

well stimulation, 137, 155, 165, 165*f*

well stream, 162

White Cliffs of Dover (England), 19*f*

wind, 32, 32*f*, 38

wireline, 106

wireline logs, 106–107, 106*f*, 120

wireline test, 120, 122

WOB. See *weight on bit (WOB)*.

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