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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Acknowledgments

PETEX would like to express its sincere thanks to Chris Zahm of the Bureau of Economic Geology of The University of Texas at Austin for reviewing portions of the material in this edition.

In addition, we would like to thank all who contributed illustrations to the book. Their names appear next to the illustrations; more information on the contributors is available in the Figure Credits at the back of the book.

This edition is updated and expanded, but it would not have been produced without the efforts of W. E. Boyd, who wrote the first edition, and of the Human Resources Committee of the Association of Oilwell Servicing Contractors (AOSC), who sponsored that edition.

Many staff members have contributed to this third edition of the book, including Debbie Caples, Senior Graphics Designer; E.K. Weaver, Graphics Designer; and Leah Lehmann, Proofreader and Digital Librarian.

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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).

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

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.

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.

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

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.

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.

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Catalog No. 3.70230
ISBN 978-0-88698-275-1
0-88698-275-8