

Oil and Gas Production in Nontechnical Language

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FOREWORD

I often have thought that what oil and gas companies actually do to discover and produce hydrocarbons must be a mystery to many people outside the E&P community, and so they cannot fully appreciate the large sums of capital put at risk. They may not even realize that it is in production operations that all the upstream efforts of those companies turn into revenue, into money.

Still, that simple view fails to account for the value generated by almost countless numbers of people that provide the services, materials, and capital vital to successful E&P ventures. As authors Bill Leffler and Martin Raymond point out in this book, more than 80 percent of the money that oil and gas companies spend goes not to their own engineers, scientists, and operating staff, but to service companies and suppliers. And that doesn't even count the support services within the oil and gas companies.

I don't doubt that in those specialized companies and support groups there are many, many people who want to and ought to know more about the processes of producing oil and gas. And I am also convinced that if they did, both they and the companies they support would achieve continuously increasing levels of efficiency and effectiveness.

This book by Leffler and Raymond is a broad leap across the gap between the mysteries of production operations and the need for better understanding by those who help make it happen. This book won't tell engineers and operating people how to do their jobs, but it will make clear to people who have to deal with them what those engineers and operating people are trying to achieve—and why.

Martin Raymond's long career in production and Bill Leffler's broad oil and gas background and credentials as a writer make them the right team to create this essential book.

John F. Bookout
President and CEO (retired),
Shell Oil Company

PREFACE

BEGINNING IS EASY. CONTINUING IS HARD.

—JAPANESE PROVERB

Who?

To petroleum engineers and geologists, the basics of oil and gas production are virtually second nature. That's what they do. But what about the rest of the world—the mud salesman, the information technology specialist, the environmentalist, the accountant, the facilities engineer, the seismic crew member, the . . . well, you get it. All these people have to deal with petroleum engineers and geologists, providing them with goods and services. How do they get a grip on the challenges of extracting oil and gas from the ground? How do they relate announcements about new technologies and innovations to what their clients are currently doing? And how does another group, those abruptly thrust into the industry—a landowner, a royalty-interest owner, or an incredibly lucky heir—catch up?

We wrote this book with all those people in mind. Some are engineering graduates. Many have only a vaguely related technical education. Others don't even have that arrow in their quivers. So this book attempts to reduce the technology to understandable prose. Oh, there are one or two sections that have formulas, but that's all. There may be complicated charts and diagrams, but each one has an easy explanation—even though we acknowledge that production is a complicated business.

However, nothing stays the same and that's why our publisher, PennWell, felt that the first edition of this best-selling book needed an update. In the decade and a half since we produced the first edition, the technology of the oil and gas industry has made remarkable, at times unbelievably innovative, strides. The improvements to equipment and operations and the changes from what couldn't be done to the routine and from wish lists to actual

operations have all been motivated by the necessity to reduce time and cost. The monumental cost of deepwater operations and exploiting unconventional oil and gas accumulations had to be reduced. And it has been! But with progress has come the collateral effect of a nearly incomprehensible expansion of the language describing these innovations. We have been tasked with the responsibility of being true to the “in Nontechnical Language” part of our title. That has been difficult and where we have missed the mark, excuse us, please. Our mission is still to educate all those whose lives are touched by the E&P portion of our remarkable industry

Why?

The gap in time between this second edition and the first has seen dramatic changes in bringing hydrocarbons to the surface from their resting place in the earth. Most notably are the technologies associated with the exploitation of shale oil and gas. While not with as much notoriety, advances in geologic understanding, seismic methods, operating in harsh environments such as deepwater, logging and completions, and even mineral rights negotiations have sped forward. We have brought all those subjects up to date.

What?

The meat of this book is in the second two-thirds. But at any proper meal, an appetizer, soup, and salad should come first. That’s why the first third has the “upstream part” of the upstream—some geology and geophysics, some legal stuff, and drilling. All the petroleum engineers and the geologists had to learn it before they could function. Without it, the business of production would remain a mystery to them also.

Most of the last two-thirds of this book deal with the theory and operations that take place at the lease:

- Describing what’s in the subsurface,
- How it reacts when tapped by a well, and
- How to make the commodity saleable.

Toward the end, two short chapters deal with the people running the show and how they decide what part of the business would make them the most money.

Where?

The scale and scope of oil and gas production cover both the world's largest field, Ghawar in Saudi Arabia, which produces over five million barrels a day, as well as a one-stripper-well field in West Texas averaging two barrels a day. Most of the world's oil fields are more like the one in West Texas than the one in Saudi Arabia. Look at the distribution of oil reserves by field size in figure P-1. Nearly 90 percent of the oil to be produced from fields already discovered will come from only 10 percent of all fields. But still, the other 90 percent of the fields represent ongoing and nearly endless business activities and opportunities for potential readers of this book.

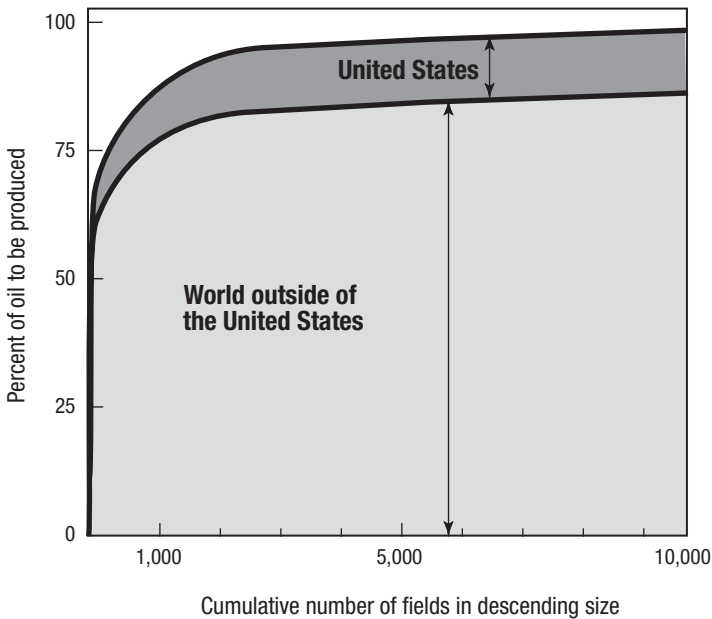


Fig. P-1. Ultimate oil recovered in the world by field size. Only a few hundred fields account for most of the oil that will ever be produced. A seemingly endless number of small fields make up the remaining share.

How?

While we labored over the prose and illustrations of this book, our wives, Eileen and Pat, patiently (almost always) let each of us huddle for long, uncommunicative hours. Without such tolerance, a less satisfying product would have emerged. Our thanks go to them. Ask any well-married author and you'll get the same story.

Besides that great boon, we had valuable help from a number of experts, Laura Raymond, Sam Peppiatt, Frank Wolfe, Bob Henley, Bob Glenn, George Dotson, Becky Hardin, Paul Burdick, Sally Tristan, and Mike Stone, to name the ones we leaned on most. Pat Raymond and Judy Curran provided additional insights from a less technical perspective. Always we interpreted what everyone said, so we have to take sole responsibility for what you see and read here.

M. S. R. and W. L. L.

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HOW DID WE GET HERE?

THE HISTORY OF PRODUCTION

WHAT IS HISTORY BUT A FABLE AGREED UPON?

—NAPOLEON BONAPARTE (1769–1821)

Oily Beginnings

In 1859, a character with the unlikely name of Uncle Billy reached down with a tin scoop into the hole he had just drilled, drew a sample of the fluids, and started the era of petroleum production. He smelled it; he tasted it; he rubbed it between his fingers and then giddily dispatched his goffer to town to notify Colonel Edwin Drake he had just struck oil.

Most petro-historians start with the travails of the colonel that led up to spudding the Drake well. But this is a book about production, not drilling, so it should start at the moment when he arrived on the scene, flushed with excitement at the news that his driller, Billy Smith, had hit an oil deposit 69.5 feet below ground, near the oil seeps in Titusville, Pennsylvania. Drake dragged an iron water pump from the equipment pile, lowered it into the well with sections of threaded shaft. He rigged the pump handle to the oscillating arm that Uncle Billy used to drive his cable tool drilling rig and began the world's first “modern” oil production—into a metal washtub.

The opportunities to improve Drake's simplistic operation abounded. Over the next century and a half, engineers tirelessly devised ingenious ways to move the oil (and eventually gas) from its resting place in the ground to the pipelines and trucks that hauled

Rotary drilling continued the inexorable march of efficiency that let oilmen reach deeper, more hidden, and more nearly unreachable targets and bring increased volumes of oil to market.

It was overproduction of oil that triggered public policy remedies. As the giant oil fields of Texas and Oklahoma came onstream at the beginning of the twentieth century, a stampede to produce every oil field as rapidly as possible (fig. 1-9) laid waste to the economics of the industry. Prompted by the court-established *rule of capture*, any landowner could—and usually did—drill a well to tap the petroleum that lay beneath. On the 92,000-acre East Texas Field, 3,612 wells were drilled. Wasted oil ran down the streams and bayous. Oversupply drove prices to 10 cents per barrel. In 1931, the governor of Texas declared martial law to control the chaos.

Henry L. Doherty, an oilman and firebrand of some repute, captured the imagination and support of the conservationists. Together, they badgered the governments of the largest producing states—Texas, Oklahoma, Kansas, Colorado, and Illinois—into forming the Interstate Oil Compact Commission (IOCC). Initially, the IOCC instituted voluntary cutbacks of oil production, but in 1935, mandatory reductions, called *prorations*, were introduced. The Texas Railroad Commission and its counterpart agencies in the other states set and enforced the rules. The federal government supported them by passing the Connelly Hot Oil Act, which prohibited moving excess oil production across state lines. It also established the authority of the state commissions to regulate well spacing, limit individual well production rates to protect reservoir pressures, and encourage unitization.

Everyone got something at the stroke of a pen: Proration meant higher, stable prices for the producers; conservationists and environmentalists were mollified; the state bureaucracies had a legitimate empire to administer; and the science of petroleum engineering gained new prominence.

To prorate, every well needed a documented, authorized *maximum efficient rate* (MER) of production. Engineers had to take into account the reservoir pressure, porosity, permeability, gas-to-oil ratio, water cut, and more at various production rates.

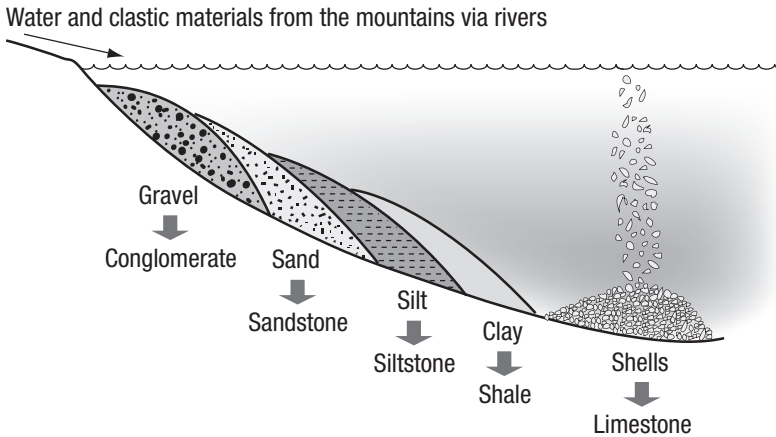


Fig. 2-9. Sediments to rock. Various size classes of sediments become different rocks after lithification.

Metamorphic rocks, the third major category of rocks, are sedimentary rocks that have been heated by proximity to igneous rocks or magmas or have been subjected to the high pressures and temperatures of deep burial (subduction) within the earth's crust. Slate is metamorphic rock formed from shale, marble is formed from limestone and dolomite, and quartzite is formed from sandstone. Generally, some of the oldest known rocks are metamorphic. They can be either sedimentary or igneous rocks that have been deeply buried and then sometimes uplifted close to the surface (again, by tectonic forces) where they are seen today.

Earth's history is one of repeating cycles of deposition, mountain building, and erosion. Coastlines moved back and forth as continental plates were pushed around and as volcanoes and rising mountains reformed continental margins. What was once a near-shore environment where sands and silts were deposited became an onshore region far from the sea or an offshore area where the currents carried nothing but the finest silts and clay. As a consequence, sedimentary layers were laid down with varying rock types (*lithologies*), alternating one over the other. Familiar vistas of the Grand Canyon (fig. 2-10), of mountainsides and sea cliffs (fig. 2-11), and even of local highway cuts throughout the countryside show layers of sandstone, shale, and limestone in infinite and stunning varieties of sequences often highly contorted into remarkable folded forms.

WHAT'S IN THE CONTAINER? THE PRIZE

FOR FOUR-FIFTHS OF OUR HISTORY, OUR PLANET WAS
POPULATED BY POND SCUM.

—J. W. SCHOPF (1942–), ASTROBIOLOGIST,
UNIVERSITY OF CALIFORNIA, LOS ANGELES

Of course, people in the oil patch don't call it a container—they say "reservoir." Sometimes they define it further, classifying it as *conventional* or *unconventional* reservoir. And then, in the unusual circumstances of, say, western Canada, there are the sticky hydrocarbons that some call tar sands or more often oil sands. Some differentiate tar sands and oil sands from other conventional reservoirs only because of the nonconventional extraction methods: mining. By the same token, most call shale reservoirs unconventional because of their reservoir characteristics. But whatever names people use, the reservoir contains the fluids they are interested in—oil and natural gas—and some fluids they are not—water and other miscellaneous gases.

A better understanding of the nature of the reservoir's contents comes from running through some of the factors that have varied over the history of the container—pressure, temperature, and time. These are crucial to the formation of hydrocarbons. They have an impact both on the kind of hydrocarbons that are present and on the way operators can produce them.

mineral owners includes a time limit, often three to five years. If the obligations, usually to drill, have not been met within that time frame, the royalty interest held by the company reverts to the mineral interest owner.

The acquiring parties are known as the *lessees* or *working-interest* owners (WIOs), and the mineral owners are known as the *lessors* or *royalty-interest* owners (RIOs). The lessees may continue to acquire other mineral leases until they have accumulated enough to drill an exploratory well, a wildcat, and to follow up any discovery with development wells. It is the development wells that will return the profit from the venture.

The Negotiation

When a landman knocks on the door of the mineral owner, a discussion, or better, a negotiation, will revolve around a number of points.

- Signing bonus for the mineral owner, which may amount to a few or thousands of dollars per acre. Where shale oil and gas have been the targets, bonuses in excess of \$15,000 per acre have been offered.
- Royalties for the mineral owner, usually between one-eighth and one-quarter of the revenue from the venture, but sometimes as high as one-half.
- Obligations, an important one being the period in which drilling operations must commence, often three years, but perhaps only sixty days.
- *Primary term*, the period in which production must begin, normally five or ten years.
- Amount of the mineral owner's acreage that will be in the prospective drilling unit, which determines the mineral owner's share of the revenues from the first well.
- How much of the prospective mineral owner's land will eventually be "held" by production—the acreage assigned to the producing wells.