ABDUS SATTER
GHULAM M. IQBAL

RESERVOIR ENGINEERING

THE FUNDAMENTALS, SIMULATION, AND MANAGEMENT OF CONVENTIONAL AND UNCONVENTIONAL RECOVERIES

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Dedication

The authors would like to dedicate this book to their parents, who motivated them when they were young, and continue to motivate them unto this day after they are long gone.

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An introduction to reservoir engineering: Advances in conventional and unconventional recoveries

1

Introduction

Reservoir engineering, a core discipline of petroleum engineering, involves the efficient management of oil and gas reservoirs in a technical and economic sense. It evolved as a separate discipline in the first part of the twentieth century in order to maximize the production of oil and gas. Reservoir engineering teams set up a comprehensive plan to produce oil and gas based on reservoir modeling and economic analysis, which implements a development plan, conducts reservoir surveillance on a continuous basis, evaluates reservoir performance, and implements corrective actions as necessary. Reservoir engineering is dynamic and poses unique challenges, as new frontiers and resources in oil and gas are discovered across the world. Reservoir engineers are expected to come up with innovative technologies and novel strategies to extract oil and gas in the most efficient, safe, and economic way possible.

Modern reservoir engineering studies, projects, and practices are based on teamwork and an integrated approach. Geology, geophysics, geochemistry, petrophysics, drilling, production, computer-based simulation, and other areas of science and engineering come together to make it all happen. Regulatory, economic, and environmental aspects are included as well. Reservoir-related studies and efforts come to fruition in the form of reservoir engineering projects that optimize oil and gas production and maximize the economic value of the reservoir.

This book focuses on the fundamental concepts of reservoir engineering and how these concepts are applied in the oil and gas industry to meet technical challenges. Field case studies, highlighting the applications of reservoir engineering and simulation in both conventional and unconventional reservoirs, are presented. In essence, the book strives to prepare students for the job from day one, and provides professionals with valuable information regarding present-day tools, techniques, and technologies.

Advances in reservoir technologies

In the early twentieth century, production of petroleum was mostly based on onshore fields that were relatively easy to manage. Nevertheless, the ultimate recovery from the fields was less than satisfactory, with large portions of oil left in the ground. Reservoir engineering advanced rapidly in recent decades to meet the challenges posed by

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the new discoveries of oil and gas. Some of the state-of-the-art tools and technologies include the following:

- Horizontal drilling up to several miles underground, having one or more lateral branches
- Multistage hydraulic fracturing that facilitates production from shale – until recently this was thought to be impossible
- Fluid injection into reservoirs with complex geology to recover oil efficiently
- Thermal treatment of immobile oil sands
- Seismic monitoring of fine fractures and fluid fronts
- Simulation of robust reservoir models that are utilized to optimize the recovery of oil and gas

Wells are being drilled to produce oil economically in many geologic settings that were not accessible before, including deep-sea reservoirs, ultratight formations, and matured fields where large amounts of oil were previously left behind. As technology forges ahead, oil and gas are recovered in significant quantities from reservoirs that were not considered to be reservoirs at all only a few decades ago.

Some of the recent advances in reservoir engineering and related technologies are outlined in the following:

- *Horizontal wells*: Horizontal drilling is a game-changing technology that enables the effective development of many reservoirs in adverse geologic settings, onshore and offshore. Some horizontal wells are drilled as long as 7 miles in the lateral direction. The wells drill through oil and gas-bearing formations across various heterogeneities such as faults and compartments, which was not possible with vertical or deviated wells. Due to the large exposure in the formation, commercial production from very tight formations is possible. This holds the key to the development of certain unconventional reservoirs. As a horizontal well is drilled, detailed rock properties are obtained over the entire length of the drilled portion of the formation by employing measurement while drilling techniques. The wells have a smaller footprint on the ground as one horizontal well may replace the need to drill several vertical wells to produce the same amount of oil or gas.
- *Multistage fracturing*: Hydraulic fracturing technology, sometimes referred to as fracking, has revolutionized shale gas production. Unconventional shale gas and oil reservoirs are continuous over hundreds of miles. The volume of petroleum in place is substantial and the probability of finding the deposits are much higher than that of conventional drilling. However, the reservoirs are ultratight and were thought to be nonproducible in commercial quantities only a decade ago. Multistage fracturing of horizontal wells drilled in the ultratight organic-rich shale changed all that. A horizontal well is hydraulically fractured every few hundred feet to create a fracture network that combines with any natural fractures present and facilitates production from the semipermeable formation. The technology has changed the energy landscape in the United States, and the reverberations of multistage fracturing are felt across the world. In a related development, microseismic studies have enabled the visualization and characterization of the fine fractures created by multistage fracturing.
- *Extraction of oil sands*: Heavy and extra heavy oil were considered to be hardly producible in large quantities only a few decades ago. Drilling of horizontal wells along with steam injection ushered in a new era of extraction of oil sands, also referred to as tar sands or bitumen. A widely recognized technique comprises drilling dual horizontal wells in the formation that are vertically apart by a short distance, injecting steam through the upper well, and producing relatively light hydrocarbons from the lower well. The technology is referred to as steam-assisted gravity drive, as heated oil with reduced viscosity is moved toward the