Computer-Assisted
Reservoir Management

Abdus Satter
Jim Baldwin
Rich Jespersen

PennWell

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preface

This book grew out of a course developed and presented at Texaco over the past few years. It was eventually presented as an SPE short course with the same title. Our goal is to provide the fundamental background for the concepts and to share examples of the computerized techniques that we believe are the key to optimizing the management of oil and gas reservoirs in today's competitive business environment.

The concepts discussed here are not new. Geoscientists and engineers have long dreamed of the ability to create mathematical models of their reservoirs with which they could try out various operating scenarios before actually implementing the most profitable plan. The tremendous improvements in computer performance have made it possible to enhance software to fulfill those dreams.

Previously in the domain of specialists using expensive mainframe computers, many valuable software tools are now readily available on the desktop of the practicing geoscientist and petroleum engineer. This is both a blessing and a curse. It allows the analysis of reservoir data to be done very rapidly and much more thoroughly than previously. However, at the same time, it places a greater responsibility on the practitioner to understand the principles behind a wide variety of reservoir management tools. It is all too easy to put some numbers into the "black box" and come up with results that are quite meaningless. Hopefully, the basics presented in this book will serve to inform the reader about the vast array of software tools available to assist him or her. We also hope to be able to stimulate a greater communication among colleagues of all disciplines to ensure that the data are thoroughly understood and software is used as intended. Teamwork is more important than ever if we are to manage our reservoirs in a way that will make our projects profitable and our companies successful.

Abdus Satter *James O. Baldwin* *Richard A. Jespersen*

foreword

W. John Lee
Peterson Chair and Professor of Petroleum Engineering
Texas A&M University

Two trends in technology development have accelerated in importance in the petroleum industry during the last decade: Information Technology and Integrated Reservoir Management. This book provides a concise overview of the intersection of these technologies and their application in the industry's attempts to maximize the profitability of petroleum reservoirs.

One of my personal concerns as use of computer software has exploded in petroleum reservoir applications has been the tendency by some to regard software as a "black box" whose contents are very mysterious, virtually infallible, and universally applicable. The authors of this book share this concern, and deal with it directly by explaining in clear and simple language the physical and geological principles that underlie the types of software currently used in the reservoir management process. If the engineer or geoscientist will simply learn the underlying assumptions and applicable conditions of a given software package—erroneous conclusions derived from its use will diminish greatly.

Despite many years of emphasis on integrated teams developing and monitoring reservoir management plans, many of us still feel uncomfortable with our knowledge outside our limited areas of expertise. The authors understand this need, and have provided simple, clear explanations for the technical areas most often involved in reservoir management. I believe that the explanations will be useful to generalists and to specialists outside of their areas of expertise. The technical areas discussed include well log analysis, seismic data analysis, mapping and data visualization, geostatistical data analysis, pressure transient test analysis, and production performance analysis (including reservoir simulation).

Many of us have difficulty "keeping up" with available representative, quality software to solve problems that arise in reservoir management. Again, the authors have helped us. They provide illustrations of applications of typical software and, more importantly, provide listings of stand-alone and integrated software packages.

Finally, the authors have recognized the power of using examples as a teaching technique. The case studies in concluding chapters bring everything together: the problems, the reservoir management strategies for dealing with those problems, the software for implementing the strategies, and the results and decisions that form from this use of modern technology.

This book will prove to be of significant value to geoscientists and engineers in the petroleum industry.

Chapter ONE
INTRODUCTION

OVERVIEW

Sound reservoir management practice[1] involves goal setting, planning, implementing, monitoring, evaluating, and revising unworkable plans. Success of a project requires the integration of people, technology, tools, data, and multi-disciplinary professionals working together as a well-coordinated team.

Integrated computer software plays a key role in providing reservoir performance analysis, which is needed to develop a management plan, as well as to monitor, evaluate, and operate the reservoir. It is also useful in day-to-day operational activities.

A major breakthrough in reservoir modeling has occurred with the advent of integrated geoscience (reservoir description) and engineering (reservoir production performance) software designed to

INTEGRATION AND TEAMWORK

Successful operation throughout the life of the reservoir requires integration of geoscience and engineering, *i.e.*, people, technology, tools, and data (Fig. 2-2). It also requires synergy, *i.e.*, multi-disciplinary professionals working together as a team, rather than as individuals (Fig. 2-3).

People
- Management
- Geoscientists
- Engineers
- Land/Legal
- Field
- Financial

Data
- Geological
- Geophysical
- Engineering
- Financial

Integration

Tools
- Seismic Interpretation
- Tomography
- Data Acquisition
- Logging/Coring
- Completions/Facilities
- Geologic Modeling
- Pressure Transient
- Fracturing
- Reservoir Simulators
- Enhanced Oil Recovery
- Computer Software & Hardware

Technology
- Seismic
- Geologic
- Geostatistics
- Engineering
- Drilling & Completions
- Enhanced Oil Recovery
- Environmental
- Computer

Fig. 2-2 • Integration of Geoscience and Engineering

DATA	SOURCE
STRUCTURE & ISOPACH MAPS	3D SEISMIC & WELL LOGS
POROSITY, PERMEABILITY, & FLUID SATURATIONS	WELL LOGS, CORES, & CORRELATIONS
FLUID CONTACTS & FORMATION TOPS	WELL LOGS
RESERVOIR PRESSURE & TEMPERATURE	WELL TESTS
PVT PROPERTIES	BOTTOM HOLE SAMPLES & CORRELATIONS
RELATIVE PERMEABILITIES	CORES & CORRELATIONS
PRODUCTION RATES & HISTORY	WELL TEST & ALLOCATION SUMMARY

Table 4-1 • Data Sources

3-D data that were initially ambiguous begin to make sense. The usefulness of a 3-D seismic survey lasts for the life of a reservoir.

Three-dimensional seismic surveys help identify reserves that may not be produced optimally. The analysis can save costs by minimizing dry holes and poor producers.

A 3-D survey shot during the evaluation phase is used to assist in the design of the development plan. With the development and production, data are constantly being evaluated to form the basis for locating production and injection wells, managing pressure maintenance, performing workovers, etc. These activities generate new information (logs, cores, DSTs, etc.),

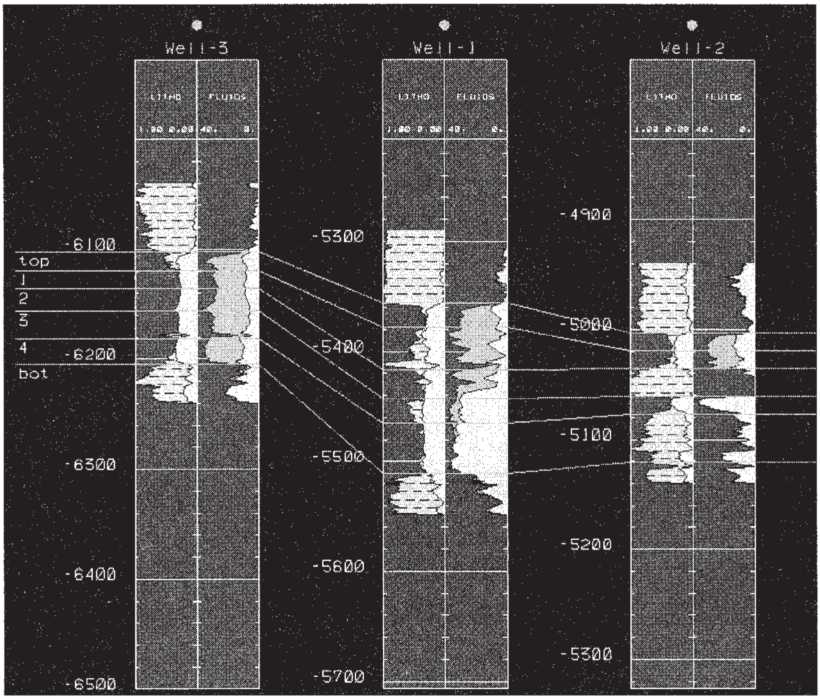

Fig. 5-5 • Log Cross-Section

Display items control

The display can usually be thought of as an overlay of many layers of information. Options allow viewing of selected items, properties, and model layers, such as:

- Surface components
  - well surface spots
  - well names
  - base map lines
  - base map text

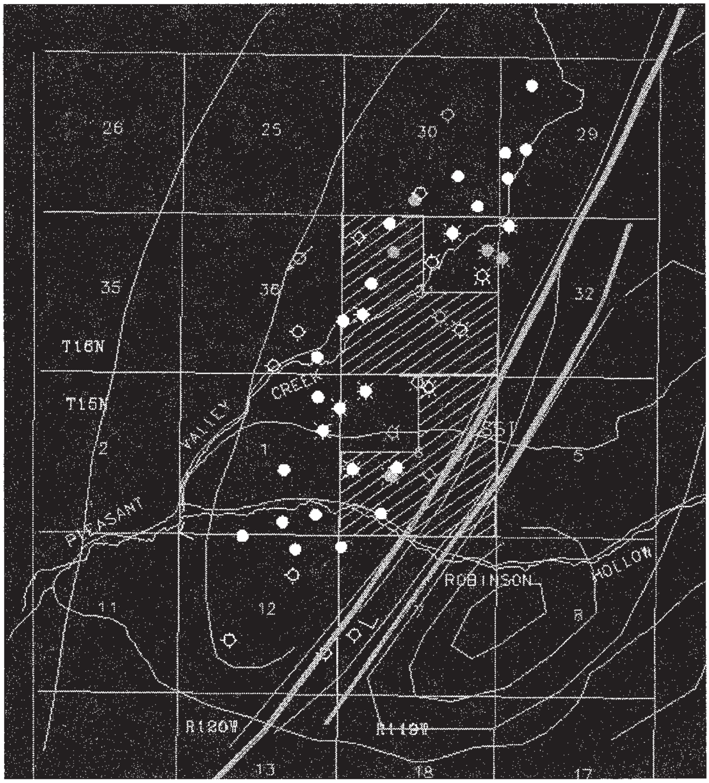

Fig. 7-1 • Base Map with Structure Control

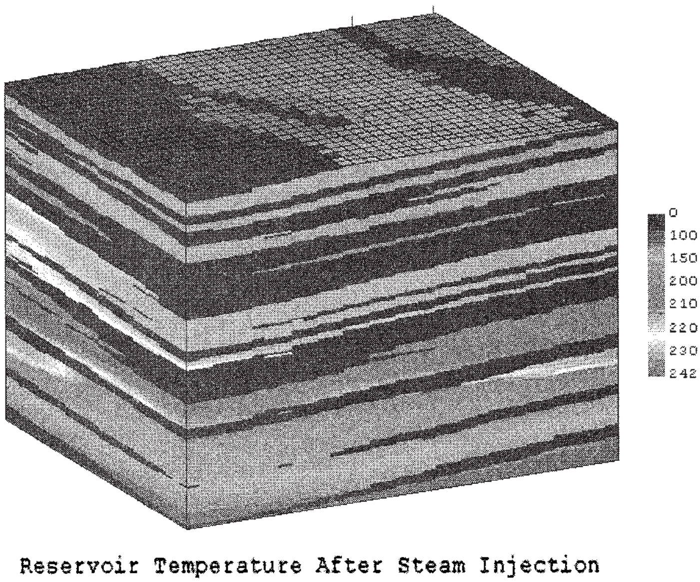

Fig. 8-19 • 3-Dimensional Temperature Model

- a measure of the uncertainty in predictions
- a method for integrating independent measurements of a reservoir property

We have seen that geostatistics offers 2- and 3-dimensional methods for determining likely property values away from points of measurement. These values are estimated by using the geological trends found in the measured data.

The statistics of the simulation process provide a means of determining the uncertainties involved in predicting reservoir properties. These uncertainties can be visualized by plotting numerous "realizations" of the map, by making probability maps of a particular scenario, and by plotting the calculated probability distribution functions.