To my Mother

To my Wife

To my Daughters

With a genuine hope for a future of peace and freedom for each and every human being.

Forewords

The following introductory comments were made by some of the conspicuous reservoir engineers who helped the author with the final corrections of the original “manuscript”.

“You do not know what you see, but you see what you know.”

Jean Piaget

Piaget’s quote summarizes my feelings when faced with the ideas presented in this book. For some time I had been feeling that something “was not working" when trying to describe fluid motion in the reservoir through relative permeability curves. However, I was not able to identify where the difficulty was.

When I went over the differentiation made by Marcelo among **injection, conduction** and **production,** I felt he had become aware of something that has always been in front of our eyes but has remained unobserved. This re-evaluation of the difference among the mentioned three concepts sheds light on a problem that has been repeatedly glimpsed and evaded.

The most outstanding merit of this book lies in the identification of the problem; and, above all and for the first time, its straightforward proposal of a different solution where formerly “only patches were placed.”

Norberto Galacho.

Really good! As the time this book reaches readers, we will be able to assert that “Reservoir Engineering is possible in Argentina”. It may be the end of pure empiricism exalted to exacerbation and the beginning of an “era” among us (Reservoir Engineers), of analysis, discussion and reflection. There is no doubt that Marcelo’s ideas will at least cause a conflict in the analyst or reader, who will have to discuss old paradigms and decide if a change is needed. From my point of view, the position does not imply “not to measure” but to know “what for”, “how to measure” and finally “how to use measurements”. That is the challenge.

Miguel Angel Laffitte

In spite of the fact that the relative permeability concept is deeply rooted and seems natural, it is in fact a simple macroscopic approximation to a complex microscopic problem. Marcelo argues more about its use or application to explain the displacement phenomena than about the concept itself. However, it is the starting point on the road to search for different formulations, whose application requires only an appropriate description of the reservoir (including all the inherent complexities) and the fluids, and not the necessarily assumptions or simplifications, which, in general, are not applicable.

I hope and wish this is our opportunity to start introducing a great change, which would be feasible due to the full participation and cooperation of those people interested in the topic.

Antonio A Paradiso

Dear readers: Hold on! This is an amusing and clear book, however its reading is hard and not suitable for dogmatic people. It is difficult to say how much you agree with this book. Perhaps you discover things that you looked at years ago, but you were unable to see; or you may disagree with others. Many times you will be unable to say whether you agree or not, and you may need to postpone the judgment till knowledge is consolidated.

Marcelo suggested to “beat hard” the relative permeability curves, but he goes further. He questions deeply rooted issues, such as numeric simulation itself. I can not say how much I agree and I must postpone my judgment. Hold on!

Juan Rosbaco

Introduction

"…
In its effort to describe the world, science can only proceed by means of a series of images or models which are increasingly realistic. The simpler ones are continuous and perfectly homogeneous, …
…
Physics has been successful in identifying a great number of fields where such images are truly adequate, particularly as a ground? where corrective terms are later added. But in other fields, reality turns to be such irregular that the continuous and perfectly homogeneous model fails and cannot be used; not even as a first approximation…

Benoît Mandelbrot – "Fractals: Form, Chance and Dimension,".

INTRODUCTION

It may be claimed that relative permeability curves are currently the essential tool to model and forecast the dynamic behavior of two or more fluids in hydrocarbon reservoirs.

However, the analysis of the present book seems to indicate that routinely use of these curves is based on some concepts and assumptions that are rarely found in the production of real oil and gas reservoirs.

This divergence between the theoretical model and reality is, precisely, the connecting thread in this work. The development includes a deep analysis of the historical and conceptual reasons that led to the use of relative permeability curves in reservoir engineering. The same analysis evidences the faults associated to the use of this calculation tool and leads to the generation of new tools to describe multiphase flow.

However, a word of caution is necessary. When you go over the pages, you may feel the need to eradicate some traditional concepts that have been historically accepted as axioms. The author's experience itself shows that it is not an easy task. The main challenge while writing this book consisted in proposing the new ideas in a well planned way in order to minimize the effort needed to internalize them and transform these new ideas into better application tools.

One thing is granted. After going over this work, it may be very difficult to continue using the relative permeability concept in the same way as it is presented in traditional literature.

In a few words, the reading of this book may be defined as an amusing journey towards a better understanding and modeling of hydrocarbon production. The author hopes every reader enjoys the journey as much as he did.

Regarding the overall style of this work, it is useful to explain in advance that it is not a theoretical but a conceptual and applied book. Therefore, the use of equations has been minimized, and great effort has been paid in clarifying the concepts presented through examples and graphs of different complexity.

WHO IS THIS BOOK INTENDED FOR?

This book is intended for a broad spectrum of readers.

- ✓ Some developments explore the theoretical and conceptual essentials of multiphase flow in porous media. From this point of view, the work would be intended for reservoir engineering students or for those who are starting to study the subject.
- ✓ Other specific topics are addressed intending to modify some commonly used procedures, which are inconsistent with the physical reality that they try to describe. In this case, the work would be addressed to reservoir engineers or geologists with broad experience in reservoir characterization.

This mixing of different points of view is unavoidable since the first necessary stage is to break down some crucial concepts in order to propose new calculation tools to remedy the mistakes pointed out in the text. Thus, although many discussions begin analyzing basic reservoir engineering concepts, this book cannot be taken as introductory to the subject. Some calculation formulas and routine procedures are used without a detailed introduction. In those cases, the interested reader is referred to specialized books on reservoir engineering.

Regarding the practical application of the developments here presented, an imperative remark must be made. The improvement on "the state of the art" procedures will be fully appreciated only when added to routine practice.

However, to reach this goal, the calculation tools should be modified to manage algorithms describing fluid **injection** and **production**, instead of **conduction** as they presently do

Until this change takes place, the present work will mainly contribute to develop a critical thinking in professionals who routinely perform reservoir dynamic characterizations, and to explain why the current calculation tools (particularly relative permeabilities) do not lead to an adequate description of fluid production.

BOOK ORGANIZATION

Because a deeply rooted concept in reservoir engineering practice is seriously questioned in this book, its organization follows a special pattern.

Using a simple model, the traditional relative permeability concept is introduced in the first chapter. This approach allows the visualization of the relevant variables. The following chapters are devoted to discuss the scope, uses and limitations of the relative permeability concept.

In the second chapter, the reader is faced with a real experiment where an "intuitive" solution is compared to the standard accepted solution for multiphase displacement. At this point, the reader may be surprised by the difference between the assumptions used by labs when reporting relative permeability curves and the information that is really required for the dynamic description of real reservoirs.

Chapter III deals with a topic that seems to have been ignored up to the date: The relative permeability curves, which were born associated to the fluid conduction concept, are not adequate to describe fluid production in unsteady-state systems.

Chapter IV contains an analysis of the countless inconsistencies which result from forcing the use of the relative permeability concept beyond the few situations in which it is really applicable.

Chapter V provides a critical analysis of common averaging techniques and their relationship to the unavoidable heterogeneities that are present in natural porous media.

Chapter VI shows some interesting aspects related to the oversimplifications in routine numerical simulation of reservoirs.

In Chapter VI some situations are analyzed where the new concepts presented in the present work become essentials.

Chapter VIII offers a conceptual summary of the entire development, based on the author's own experience, and proposes the general way to implement the new tools.

Finally, the appendixes present a series of supplementary topics which, although significant by themselves, rank second in importance in relation to the topic of the book.

ACKNOWLEDGMENTS

As many other human works, this book is essentially the result of an individual voluntary action. At some point in time, I had enough arguments and strength to undertake the task of writing a book.

However, when analyzing the origin, both of arguments and strength, I realize that my own contribution to them is not significant.

The numerous teachers (holding "official" degrees or not) I met in my life provided me with the arguments.

Some of them helped me to develop my critical thinking. Undoubtedly, at this point, the major contribution comes from the guiding hand of my father. I would like to dedicate the results of this effort to his memory. Afterwards I had numerous teachers who helped me to keep alive the desire to learn and to understand. I cannot take the risk of mentioning some of them without unfairly omitting others.

I want to thank them all.

Other people provided me with the necessary information and the valuable example of their love for the work they do. The teachers and friends belonging to this group are countless. Again, it would be unfair to mention just some of them.

The experience I gained at Inlab Co. is particularly significant. All the measurements were made in this lab and the technical and human contact with those who shared with me long working days, contributed to feed the ideas I finally present in the present work.

The strength to undertake this task came from two main sources:

- ✓ **The unavoidable debt with the society**. Together with the genetic legacy, each of us has received a cultural legacy impossible to pay back. This legacy is mainly based on the knowledge transmitted through books which, at the right time, someone had the courage and the skill to write. From this point of view, each of us is

"indebted" to pass this legacy to the next generation. Others made it for our benefit. Some of us must do the same for those who will follow us. If we believe we can make any contribution to knowledge, we are obliged to do it. Others will decide whether the contribution is useful.

- ✓ **The family support**. It is not possible to perform a task like this without a significant family support. In my case, I feel an everlasting gratitude to my wife. She even had the courage to learn some concepts of my own specialization to help me better transmit my own ideas.

On the support received during the final stages of this work, I want to express my gratitude to those who accepted the difficult task of reading and criticizing my first writings. Each of them made significant contributions to the message in this book. In alphabetical order they are Rafael Cobeñas, Rafael Cullen (father and son), Norberto Galacho, Miguel Laffitte, Antonio Paradiso and Juan Rosbaco.

I mention them because I am heavily indebted to them, but I want to release them from any error that may appear in the present work. That is my unavoidable responsibility.