Chapter VIII

"…
Y he sabido que el guerrero
que murió lleno de honor
ni murió ni fue guerrero,
como me engrupiste vos
...;"

And I've known that the "warrior"
who died with full honors,
didn't die, nor he was a warrior
as you lied to me"

Enrique Santos Discepolo - "Chorra"-

EPILOGUE

This chapter is rather different from the remaining chapters in this book. On arriving at this point, I will detach from the formal approach and will try to establish a more direct dialogue with the reader. This is why the writing style is no longer impersonal and adopts the first person.

A BIT OF HISTORY

The initial subtitle envisaged for this book was the following:

"A journey through the fantasy of the relative permeability concept."

However, it was not possible to write this sentence on the book cover without arousing a certain degree of suspicion in the specialized reader. Now, near the end of the book, I can assume that those who read these paragraphs will not feel uncomfortable with this sentence. Perhaps they do not share all my conclusions and assertions along these pages, but they will surely understand the intention behind the expression.

It could be said that this sentence summarizes my own experience in one of the fields I have worked in during my extended professional career. So I am going to comment my personal experience in the hope that my own history could contribute to place the contents of this book in the right perspective.

I hold a university degree in Chemical Sciences, which helped me to develop a microscopic vision of the world and get a professional experience related to the study of models and their practical applications to describe reality.

After basic studies comprising four years, I made my professional specialization in Organic Chemistry. In this two-year specialization, one of the courses was called "Natural Products" (organic chemistry products, of course). Surprisingly, oil was not included in the program. I really "discovered" the oil world when I get my second job, at INLAB S.A., in 1978, six months after I get my university degree.

Due to my professional grounding, I joined the company mainly to work in PVT and Organic Geo-chemical areas but, as the company was starting business, I was able to participate in the implementation of numerous measurement techniques. Among the first ones was the measurement of relative permeability curves, where experimental and calculation methodology needed to be tuned up.

I remember quite well the interest aroused by the first experimental measurement, and the numerous observers surrounding the main experimenters. It was the first time I saw "oil" being produced from a porous medium, through water injection.

I also remember my frustration when I found that it was necessary to make a series of complex calculations to obtain relative permeabilities curves at a time when computers were just starting to be available.

My original intention was to make the simple calculations presented in Chapter II. I did not do them because someone explained the essentials of the front displacement theory to me, the existence of a saturation front and, particularly, the need to solve the equations in the output face of the sample.

I delayed the simple calculations by almost 18 years after this first experience!!

Meanwhile, I had somehow interrupted my activities related to the hydrocarbon industry (four years working for the nuclear industry), I had become the head of the sector responsible for routine measuring and reporting relative permeability curves, and I had developed and published a numerical adjustment program to solve the frontal advance theory equations.

I had never used measurements with other purpose than to report the results of calculations. In reservoir labs, relative permeability curves are generated but not used to describe reservoirs. In the lab, the reservoir has the dimensions of a "plug".

Later on I also became a teacher and found, somewhat surprisingly, that I had a solid knowledge of reservoirs. I was not able to apply the results of the measurements, but I knew a lot as regards the origin, applicability and limitations of many of the data used in reservoir modeling.

I attended some courses, I had talks with many people, I made many friends and ... I found that lab relative permeabilities were not very useful. It was always necessary to, somehow, modify them in order to be used. Sometimes they were small modifications, others very noticeable ones.

… A frustrating situation.

After all, an important part of my professional activity had been spent working with things which not only were quite useless, but were also considered “a necessary evil” by many professionals.

I started to look for alternatives

This was the start of my journey through the fantasy of the relative permeability concept. Everywhere there was something that didn't fit.

I read a good number of publications. I learned a lot from them. I disagreed with some others. I also learned from them.

I walked again the steps of the frontal advance theory. I found some surprising things. Perhaps I may document them in due time.

I designed particular experiences, some of them as routine work and others as part of the researches done by some students.

I co-authored some publications.

And one day I became aware of a point I had been overlooking over the years while trying to understand why relative permeabilities were the subject of so many controversies.

I cannot say that I “discovered” the difference between **injection, conduction** and **production**, since this would be an absurd contribution to the reservoir engineering theory. But I can definitely assert that I became aware that relative permeabilities are not useful to describe production of fluids when the three verbs mean different things.

Relative permeabilities are only applicable when the three verbs coincide in the description of fluid motion. In the remaining situations, relative permeabilities are a fantasy concept.

And, in real reservoirs, when two or more fluids travel simultaneously, the three verbs differ noticeably among them. That is the third chapter of this book.

I had finally reached the core of the issue. Relative permeabilities express something different from what they are supposed to represent. The average fluid saturation to production capacity relationship is the variable of real of interest. I expect the proposed name for this functional relationship becomes appropriate: **"Specific Productivity**.”

The word “productivity” is nearly mandatory to differentiate this new concept from "conduction", rooted in Darcy equation. And the qualifying adjective "relative" is not preserved in order assure the fully differentiation of these curves from the ones they are intended to replace during dynamic reservoir characterization.

The remaining story is documented in this same book:

In Chapter IV I document two significant theoretical inconsistencies generated by the relative permeability concept when used beyond its applicability range.

In Chapter V, with the help of heterogeneous systems, I analyze the improper use of averaging methods based only on mathematic algorithms that do not contemplate the physical reality of the phenomena they are trying to describe.

In Chapter VI, I show the limitations of numerical simulators based on the relative permeability concept.

Chapter VII represents the current point of my personal journey. In that chapter I apply the specific productivity concept to simplified scenarios.

As usually happens with real stories, this story has many secondary archives. In this case, the “minor” stories are formed by the vast diversity of situations and variables being faced by the reservoir engineer while characterizing Oil and Gas reservoirs. These situations, strongly linked with the main story, are developed in the appendixes to this book to avoid “diluting” the main message. The topics addressed in the appendixes are not unimportant. On the contrary, many readers will realize that some topics "relegated" to the appendixes hold primary importance. But they rank at second place in importance when compared to the main message of this book.

Chapter I deserves a special mention. The development thereby included has been widely appreciated by many people who, as they told me, using that model they have been able to understand, for the first time, the relative permeability

concept. The bad thing about it is that its title is, precisely, "The relative permeability concept" and, as such, for real applications, it is just …fantasy…

Perhaps it is useful to reread that chapter in the light of later discussions. Then it will be possible to detect in that case, the same flaws associated to the relative permeability concept. It is particularly "wrong" the saturation analysis on one plane (the transversal section), not including average saturations during an unsteady-state displacement. Trying to describe the specific productivity curves (SPC) for this model could be a very good exercise.

Rereading the introductory quote to the first chapter is also quite important.

THE WAY TO GO

When presenting the concepts included in this book at different forums, I have quite frequently received a "negative" comment. Basically, the "complaint" is that I devote too much effort to point out methodological and conceptual errors, instead of providing the tools to solve them.

Therefore I feel compelled to detail the steps to be followed in order to get useful applicability for these ideas.

The first step is to convince the interested parties of the need to change. Only when fully convinced of the existence of a serious failure in the "accepted" methodologies is it possible to change them.

Until that point is reached, all we (technicians) do is to add "patches" intended to solve the cases where theory does not work. This is a frequent and inevitable practice in all fields of human endeavor. Looking back, based on the arguments presented in this work, I have the sensation that "patches" have been the rule to describe fluid production in oil and gas reservoirs.

Directly in this line, the purpose of my insistence on the conceptual and numerical failures related to the relative permeability curves and in the routine numerical simulation practices, is to draw attention to the current use of an erroneous theory.

In other words, the message I try to convey is something like this: "Let us stop putting "patches,"… let us build a model having less errors!"

The second step consists in developing the applications. This is a demanding task requiring the participation of many experts.

I think that my future contributions to this second stage will take more time and effort than I have already invested in detecting the reason for the "patches" I mentioned in the previous paragraphs. The formulation of a more solid conceptual alternative than that currently in use is not an easy task, but is unavoidable if a better reservoir description is expected.

The keys for this proposal to be effective include some strategies that it is advisable to list, although they have already been mentioned in this work:

- ✓ **Identify properly the questions** that need to be answered at reservoir scale.
- ✓ **Design lab measurements** so that they contribute to effectively answer such questions.
- ✓ **Build specific productivity curves** as a result of geological, lab, well, and production history information integration. At this stage, the criterion of the reservoir engineer or geologist is a key element.
- ✓ **Develop calculation tools** able to use the specific productivity concept, particularly numerical simulators These tools should be designed to :
  - ▫ **Honor** the physics of real displacements.
  - ▫ **Model** the variables of interest in reservoir characterization (average saturations, production and fluid injection).
  - ▫ **Decrease** (not increase, as present tendency does) the number of areal cells.
  - ▫ **Increase** vertical discretization of the reservoir. In other words, the use of pseudo-functions (designed to decrease the vertical gridding) must be minimized.
  - ▫ **Facilitate**, through adequate algorithms, the generation of specific productivity curves for each face, of each cell, depending upon the location and size of the latter, and on the exploitation strategy.

The third step (that should be possibly included as the initial step) is to recover the key function of the reservoir engineer or geologist for realistic reservoir description.

The increasing complexity of calculation tools, the diversity of specialization fields, and the prioritization of immediate goals over mid and long term goals have led us to a situation where frequently the reservoir engineer or geologist

relegates the reservoir to a second place and focuses attention to the well or to production facilities more than to the reservoir itself.

"Understanding" the reservoir is not an easy task. Reservoir engineering is more an art than an exact science. And as such, it is conditioned by subjective interpretations and opinions.

Standardized prescriptions to operate a reservoir rarely lead to the best possible answer. Each reservoir requires its own "prescription". And that implies highly skilled reservoir engineers ready to face particular scenarios.

The reservoir engineer should actively participate in all the processes associated to the reservoir dynamic and static characterization. These tasks range from the understanding of the geological model to conceptual and detailed numerical simulation.

Many activities, when performed by those who do not have a global vision of the reservoir, may be based on erroneous models and lead to results very far from physical reality

FINAL WORDS

Some years ago, while on a technical conversation, a conspicuous reservoir engineering (Antonio Paradiso) made some comment, midway between joy and resignation, related to the need that relative permeability curves should have to "disappear". At that time, I had already generated and reported hundreds of relative permeability curves and had published a special calculation methodology for them, so I was very far from suspecting that one day I would write a book fully discouraging their use in reservoir characterization.

I am not sure to have fully satisfied the request, but at least the specific productivity curves I propose for their replacement are no longer an exclusive lab product. I expect this is a step forward in the right direction.

And … I hope not to abuse of the greatest work of our gaucho[1] poetry, if I close this work with the words José Hernández used to end his own:

"...	
Más naides se sienta ofendido,	*Yet don't let anyone take offense,*
Pues a ninguno incomodo;	*I don't plan any folks to gall;*
Y si canto de este modo	*If I've chosen this fashion to have my say,*
Por encontrarlo oportuno,	*It's because I thought it the fittest way,*
no es para mal de ninguno	*And it's not to make trouble for any man,*
sino para bien de todos	*But just for the good of all"*

José Hernández – "Martín Fierro"

[1] Former inhabitant of Argentine pampa