Modeling of Rock-Fluid Data

Credit to Mr. Ahmed Alher

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Introduction

Rock-fluid properties are used in reservoir engineering and simulation to describe multiphase flow in the reservoir. As a consequence, the definition of correct sets of properties and their spatial distribution is of primary importance in the accuracy of the results.

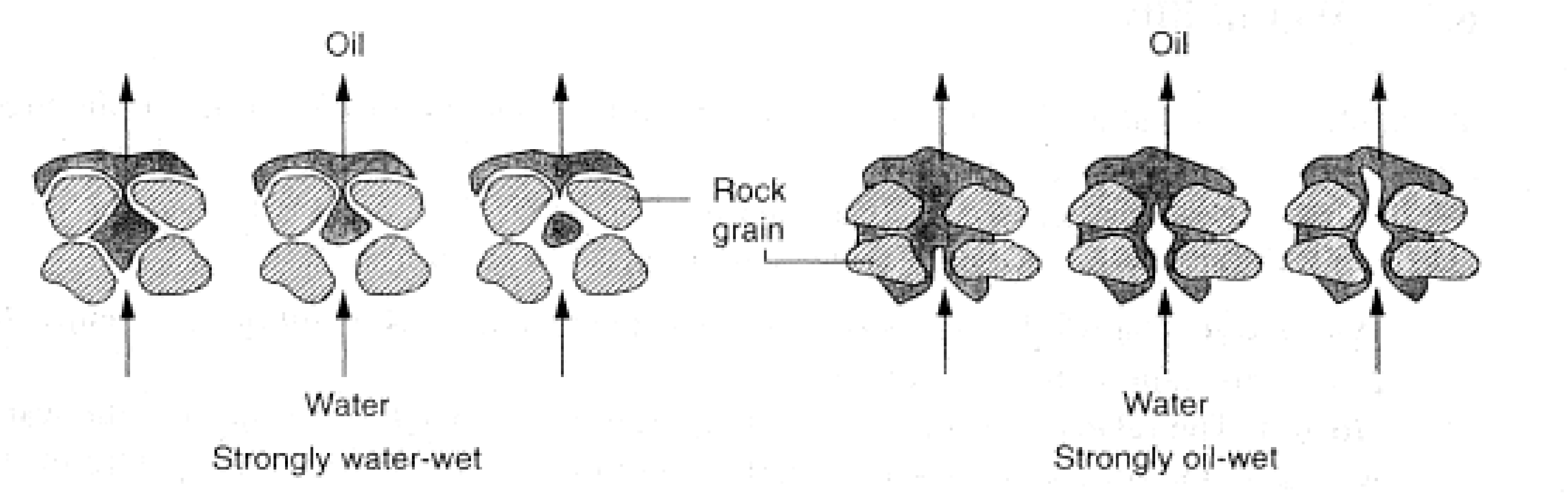
There are three rock-fluid properties, wettability, capillary pressure and relative permeability.

Wettability

- **Wettability** is defined as the tendency for one fluid to adhere to a rock surface in the presence of other immiscible fluids.
- Different wettability states can be defined for actual petroleum reservoirs, depending on the relative distribution of reservoir fluids with respect to the rock framework.
- **Water wet.** The whole rock surface is coated with water, while oil or gas occupy the central position of the largest pores.
- **Oil wet.** the oil coating the rock surface and the water residing in the center of the largest pores.
- **Intermediate wettability.** This term applies to reservoirs rocks where there is some tendency for both oil and water to adhere to the pore surface.

Wettability

The importance of wettability is related to the fact that the relative distribution of fluids within the pore network is critical to the microscopic flow properties. In other words, water wet and oil wet reservoir behave differently with respect to a displacement process.



Wettability

- It is generally accepted that wettability results from the adsorption of molar compounds on the rock surface, However, several factors are believed to affect the preferential wettability of a reservoir rock:
- Oil and formation water compositions.
- Rock mineralogy.
- Amount of connate water saturation. The lower the connate water, the higher the oil wetting character of the rock.
- Wettability is determined in the laboratory on core plugs by **wettability index,** *0* indicates a neutral rock, while values of + 1 and - 1 indicate strongly water wet and strongly oil wet characteristics, respectively.

Relative Permeability

- The absolute, or specific permeability, is a property of the porous medium and it is independent of the saturating fluid, provided that there is no reaction between the rock and the fluid.
- When more than one fluid phase is present in the pore space, as it is the case in petroleum reservoirs, the concept of permeability must be applied to each phase separately, because it depends upon the quantity and distribution of the particular fluid phase within the pore system.
- On this basis, we can define an **effective permeability** to a specified fluid. which, like absolute permeability, can still be determined from the application of Darcy's law.

Relative Permeability

- This is the widely used concept of **relative permeability** (relative to the absolute), which can be expressed as:

$$kr_o = \frac{k_o}{k} \qquad kr_g = \frac{k_g}{k} \qquad kr_w = \frac{k_w}{k}$$

- The concept of relative permeability is fundamental in the **simulation** of the dynamic behaviour of a reservoir, since it **expresses the relative contribution of each phase to the total multiphase flow**.
- As any reservoir engineer has experienced. the correct definition of a set of relative permeability functions is one of the most difficult and, at the same time, one of the most important steps in the construction of a reliable simulation model and for this reason a great deal of attention must be paid to this phase of the study.

laboratory measurements of Relative Permeability

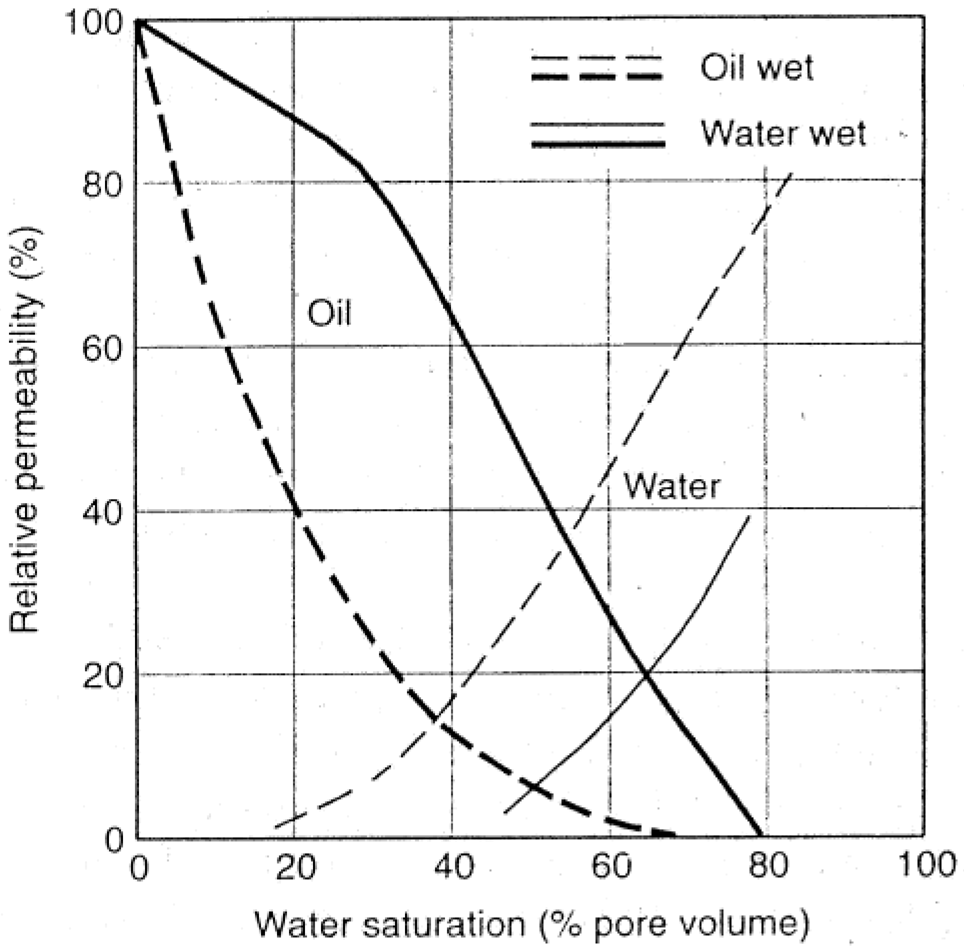
- Relative permeability can be measured in the laboratory on core samples.
- **Steady State.** in the steady state method, a fixed ratio of fluids is forced through the test sample, until pressure and saturation equilibrium is reached. The effective permeability of each fluid phase is calculated as a function of saturation by direct application of Darcy's law.
- **Unsteady State.** These types of experiments are performed by measuring the effluent from a core during an imposed displacement process, in terms of cumulative production, and back calculating the relative permeability ratio consistent with that outcome.

laboratory measurements of Relative Permeability

At least 3 major factors must be considered, which may affect the meaning of laboratory-derived relative permeability curves.

- ***Wettability***

Wettability affects relative permeability because it is a major factor in controlling the location, flow and distribution of fluids in a porous system.

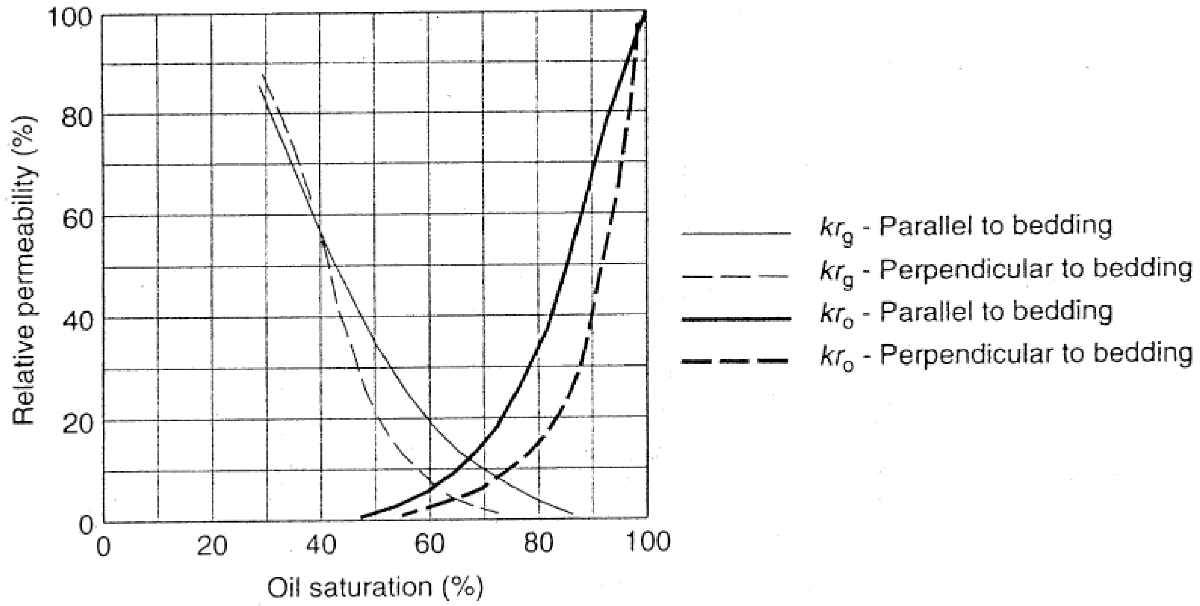


laboratory measurements of Relative Permeability

- **Core Scale heterogeneity**

The problem shows sets of relative permeability curves obtained on plugs cut with a different orientation than the prevalent heterogeneity at the core scale.

This problem is generally avoided by cutting plugs in the more homogeneous parts of the cores but in fact small scale laminations are always present in reservoir formations and they have an impact on fluid flow.



laboratory measurements of Relative Permeability

- **Higher Scale Heterogeneity**
- when relative permeability is concerned, it becomes particularly important to assess what is the nature of the internal heterogeneity represented within the core plug sample and whether or not larger scale heterogeneities exist.
- whose effect cannot be captured in the plug. In such cases the direct assignment of core-derived relative permeability curves to the simulator gridblocks will lead to an incorrect simulation of the actual fluid flow in the reservoir.

Empirical Correlations to estimate Relative Permeability

- **Empirical Correlations**
- Empirical models of relative permeability have been proposed by many authors since the beginning of the 1950's.
- These models allow for the generation of relative permeability curves compatible with the rock under study in the absence of experimental data and in most cases they have the advantage of providing reasonably reliable data in a quick and convenient way.
- These models can be derived from **capillary pressure data** or **Residual and initial saturations**.

Empirical Correlations to estimate Relative Permeability

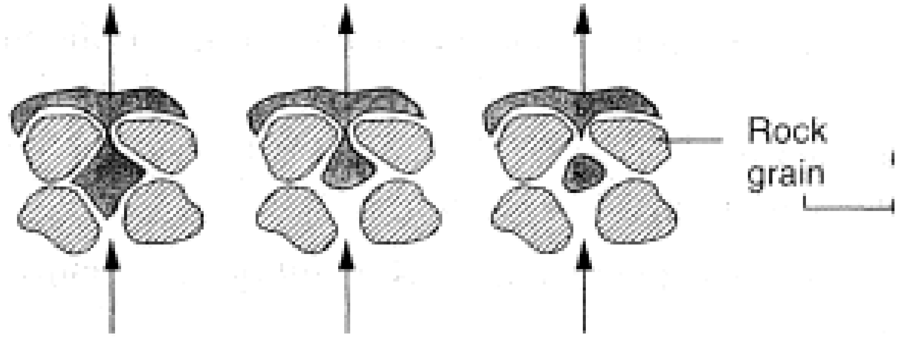
Common Empirical Correlations

- Wyllie and Gardner
- Torcaso and Wyllie
- Pirson
- Corey

These correlations are presented in

Tarek Ahmed "Reservoir Engineering Handbook" fourth edition, chapter Five, started at page 296

Relative permeability curve



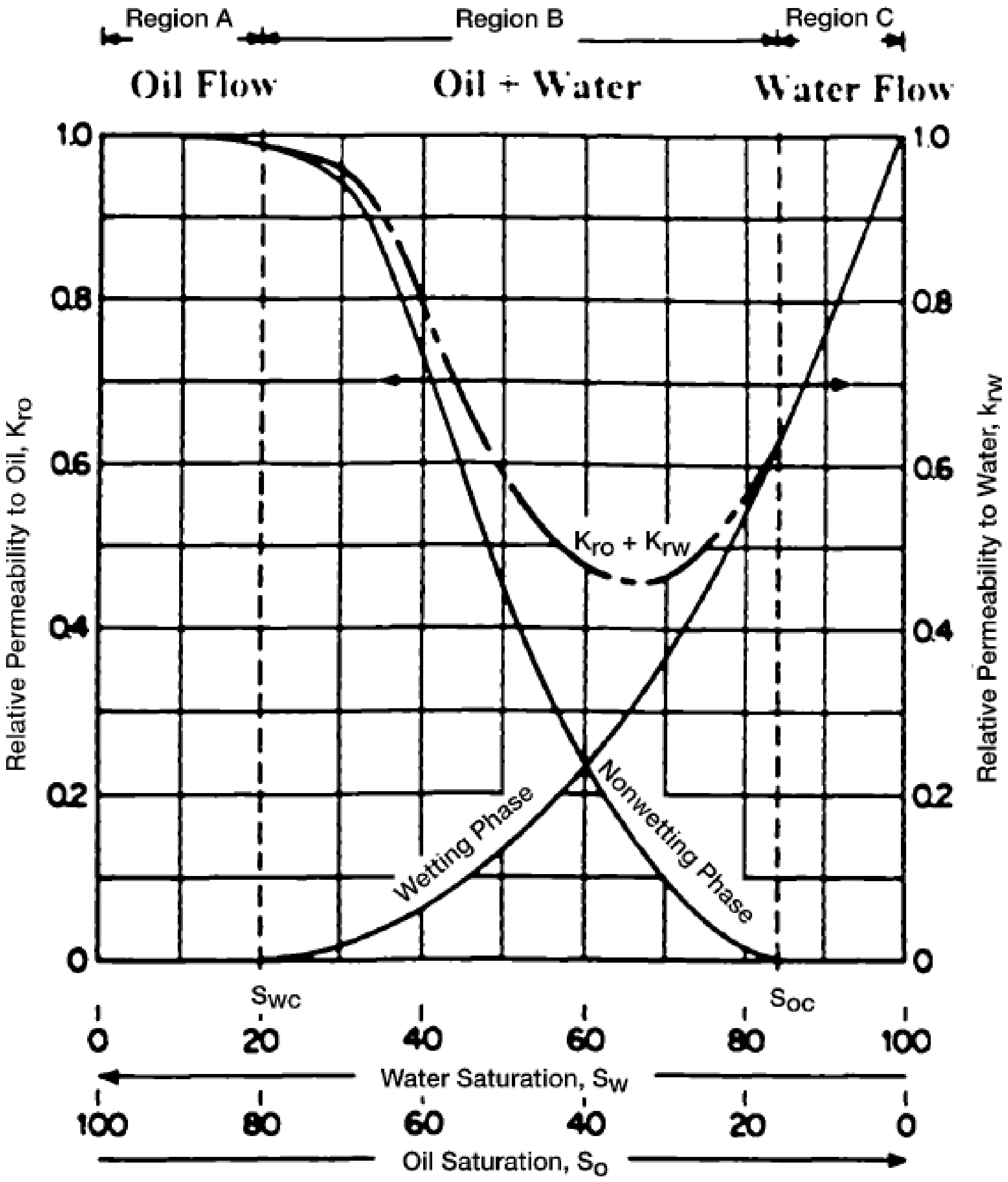
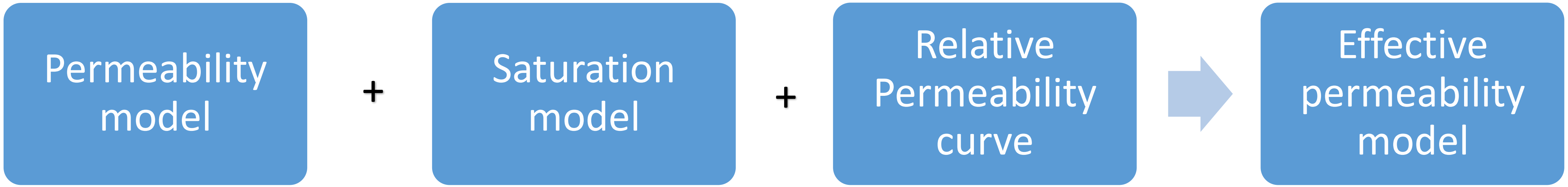


Figure 5-1. Typical two-phase flow behavior.

Effective permeability model



What Are You Going To Do In The Next Report?

- Read the Kro and Krw for the corresponding sw for each layer.
- Calculate the Ko and Kw for each cell of the model in the excel sheet.
- Write a good report individually explaining the pitfalls of relative permeability data and their importance in simulation process. Enjoy!