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РЕМАСШТАБИРОВАНИЕ ФАЗОВОЙ ПРОНИЦАЕМОСТИ В ГИДРОДИНАМИЧЕСКИХ МОДЕЛЯХ

UPSCALING OF PHASE PERMEABILITY IN HYDRODYNAMIC MODELS

Cognition of the world around us is one of the most significant parts of our life. When a man looked at the stars, he tried to understand structure of the Universe. But how can we learn something that is situated millions of miles away? Mathematics is only helper in this hard work. With mathematical model and pure calculations we can get the results which need expensive and bulky equipment. But any model is only view from some side of an initial effect or object. That is why there is no limit for improvement of mathematical research “tools”.

The hydrodynamic modeling is an important part of the modern projection of development of oil and gas fields. Oil and gas deposits in most cases lie on depths where any research is connected with complex equipment. But in the basis of any research we can find mathematical models. For example, a model of an infinite reservoir lies in the basis of analyses of well flow tests. That is why in the hydrodynamic model we have to choose initial information very carefully, because exactly parameters may be not true.

The mathematical modeling plays very important role in the development of oil and gas fields. A natural reservoir is a continues dynamical system in mathematical mean, that is system with continues changing time. If we want make some calculations we have to discretizate the original continues dynamical system that is means we must go to a discrete in time and in space dynamical system (fig. 1).

Parameters like a permeability, a phase permeability, a net-to-gross parameter and a porosity should be recalculated.

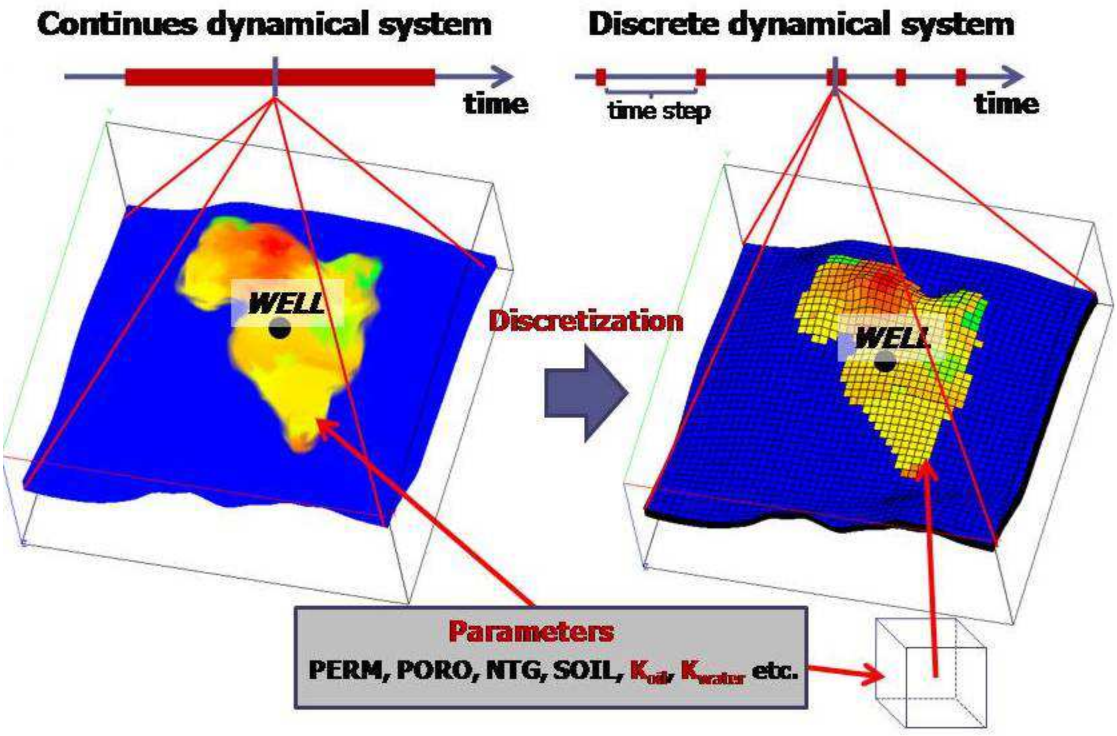

Figure 1. Scheme of discretization of natural reservoir

The permeability in fluid mechanics and the earth sciences is a measure of the ability of a porous material (often, a rock or unconsolidated material) to allow fluids (water, oil, gas) to pass through it. The term of absolute permeability states that the permeability value is a function of the material structure only (and not of the fluid). In multiphase flow in porous media, the phase permeability of a phase is a measure of the effective permeability of that phase. It can be viewed as an adaptation of Darcy's law to multiphase flow:

$$q_f = -\frac{k_f}{\mu_f} \nabla P_f, \; f = \text{oil, water.}$$

The phase relative permeability is the ratio of the phase permeability of that phase to the absolute permeability [1].

The phase relative permeability is an inseparable part of hydrodynamic model. We can obtain two-phase relative permeability curves from results of laboratory experiments on a core. But scale of pores and cores (fig. 2) is not comparable with a size of cell in geologic or hydrodynamic model (10-200 meters in horizontal plane). That is why one experiment is not absolute true in mathematical modeling.

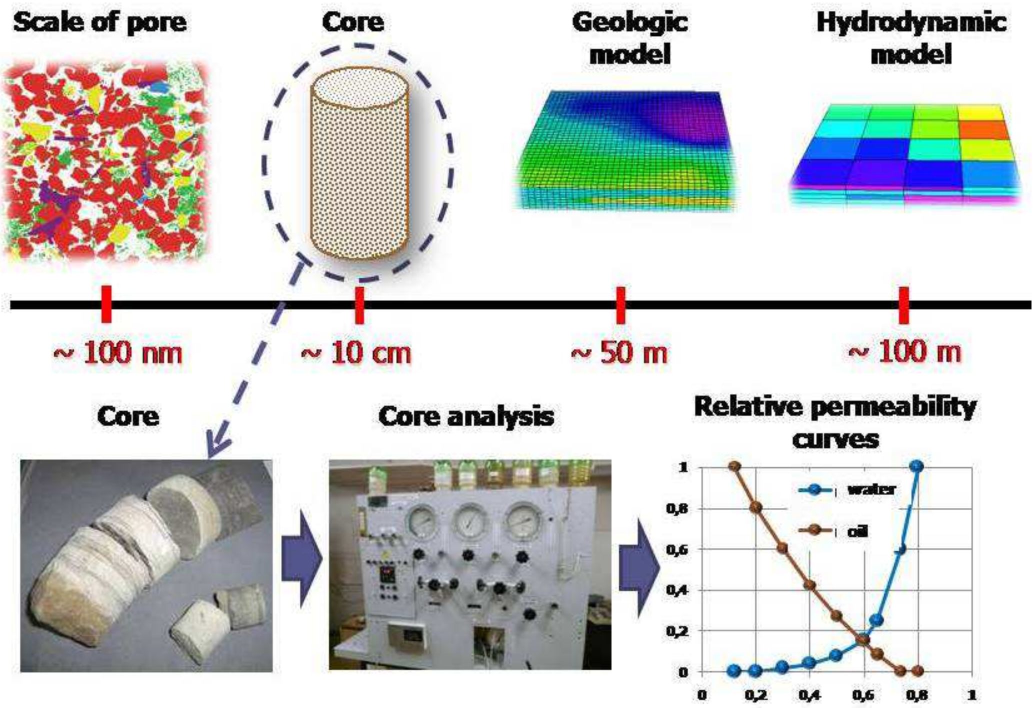

Figure 2. Scales of different objects

The laboratory experiments on a core can give us a pore size distribution. If we use percolation theory, we can model flow of fluids in microscale. Averaging of different numerical experiments give opportunity to calculate the phase relative permeability for current pore size distribution. In this context a percolation model is a random net of small capillaries (fig. 3), where we solve equations of flow. For more information of this calculation methods of phase relative permeability from pore size distribution one may read [4], [5].

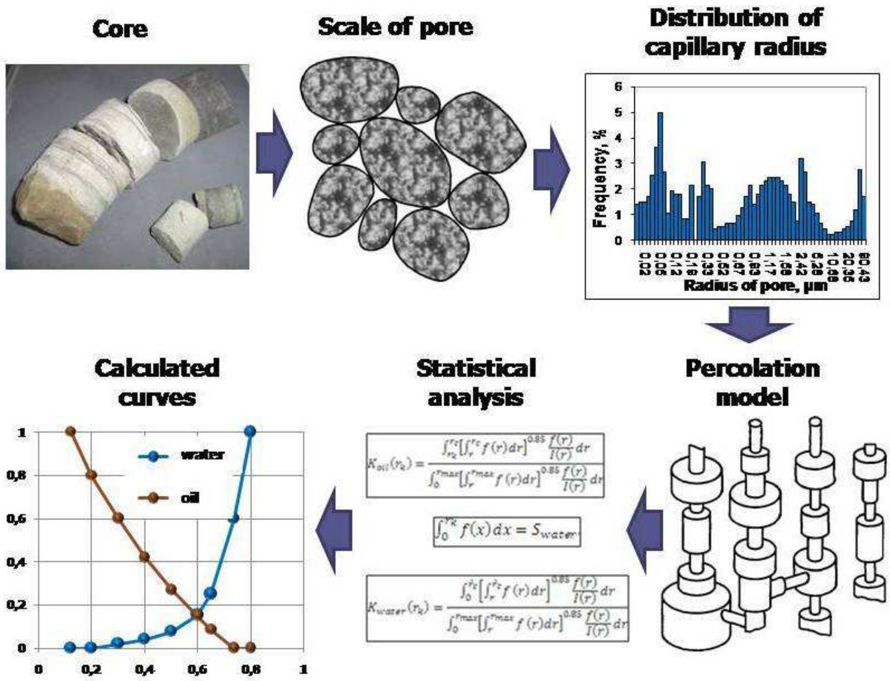

Figure 3. Statistical analysis of pore size distribution

The results of statistical averaging of all possible percolation models give us some relative permeability curves, where we try to take into account all inhomogeneity of natural reservoirs. The goal of geologic model is taking into account parameters of macroscale. But for forecast calculations this model is very difficult for fast calculations. That is why a grid of geologic model coarsens. For saving quantitative character of two-phase flow with the transition from the geologic model to the hydrodynamic model we must carry through an upscaling phase and absolute permeability. Modeling of flow into separate hydrodynamic cells with taking into account geologic grid and parameters and with different gradients of pressure and saturation (fig. 4) can give an opportunity to get data for Darcy’s law – the rate of different phases (water, oil, gas). These results are used in the calculation of permeability. This method of the upscaling of the phase relative permeability in basis of multiphase flow is called «method of Kyte and Berry» [2], [3].

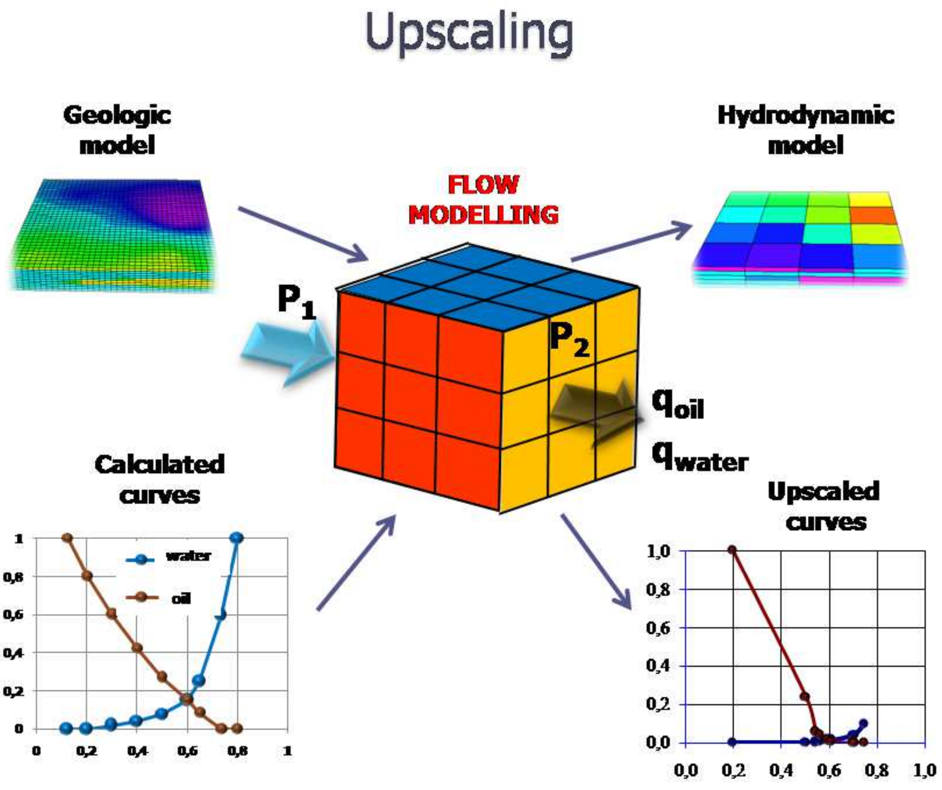

Figure 4. Scheme of upscaling of phase permeability with transition from geologic to hydrodynamic model

This way of the modeling two-phase flow may give some successful results in a history matching of hydrodynamic models:

- the calculation from the pore scale give opportunity to consider the relative permeability for farcies of geologic models without upscaling;
- the upscaling relative permeability from the geologic model to the hydrodynamic model saves two-phase flow character.

The history matching means correction of initial data of model for goal of increasing accuracy of calculated parameters (rates, water cut) with compare to a history data of wells. Correct history matching gives correct and informal forecast calculations. This information may plays role of the last step to some very important decision in a strategy of the development of oil and gas filed.

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