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Effect of convective transport in porous media on the conditions of organic matter maturation and generation of hydrocarbons in trap rocks complexes

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Abstract

By analyze of catalysis processes of hydrocarbons and oil in the medium with the oil source rocks usually it is used the approximation about homogeneous medium and homogeneous PT- conditions in it. But the oil source rocks are porous medium, the slow flows in which are influenced by convection, which leads to significant heterogeneities of the structure of PT-conditions of oil source matter ripening. These structures can be either stationary or no stationary. In that paper we developed results of numerical modeling of convection in homogeneous medium and in the medium that contains heterogeneous for permeability 2D and 3D inclusions for detection and quantitative estimation the convection influence on the volume oil source rocks estimation in which the oil catalysis conditions are realized. It is showed that the amount of oil forming significantly depends from the convection intensity.

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Keywords: Oil deposit, convection in the porous medium, stationary state.

1. Introduction

By investigation of the oil deposit the most interest is the oil volume and oil quality. The oil quality depends from the content of oil source rocks and conditions of the thermal influence on its matter maturation. The last features

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depend from the distribution of the heat sources and conditions of the heat-mass transfer of the oil source matter inside the porous rock. Therefore it is very important to consider new effects and new models for analyze and estimating the process of oil forming and saturating inside the oil source porous medium.

2. Model and equations

For receiving the simplest qualitative estimations of oil resources usually it is used the one dimensional medium model [1]. In that case the process of heat transfer is described by one heat transfer equation and it allows for the forms of the oil layers use the horizontal layered structures. However such model cannot be used for the porous medium after a free convection of viscous fluid occurring which is the oil component in the porous medium [2]. This model becomes not only rough, but yet it becomes incorrect. First of all from that follows that the induced as the result of convection the flows structure does not stay constant and one dimensional. By convection occurring there are forming 2D or 3D flows of viscous fluids [2 3] and this means that by constant one dimensional distributions of thermal conductivity values of the rocks and oil matter for describing the process of heat transfer inside the viscous porous medium it is needed to use a system of equations for the impulse and temperature. If the velocity of the flow inside the porous medium can be considered as a sufficiently small value, usually it is used the approximation of Darcy and the convective movement of a viscous incompressible one component fluid inside the porous medium can be described by a system equations as follows [2,3]:

$$\mathbf{u} = \frac{K}{\nu}\left(-\frac{\nabla p}{\rho_0} + g\alpha T\mathbf{e}_z\right)$$

$$(\rho c_p)_c \frac{\partial T}{\partial t} + (\rho c_p)_f \mathbf{u}\cdot\nabla T = \lambda_c \nabla^2 T$$

$$\nabla\cdot\mathbf{u} = 0 \qquad (1)$$

where $\mathbf{u} = \eta\,\mathbf{v}$ –velocity Darcy for filtration inside the porous medium, η – porosity of the medium, $\mathbf{v}$ – average velocity of the fluid inside the pores, p – pressure, g – acceleration of gravity, ν – kinematic viscosity of the fluid, K – permeability, T – temperature, λ_c – thermal conductivity, $(\rho c_p)_c$ – heat capacity of the fluid saturated medium, $(\rho c_p)_f$ – heat capacity of the fluid.

For numerical modeling of that problem we shall formulate the system (1) in dimensionless form. Let us take as units: for the length – the thickness of the permeable layer H; for filtration velocityc – κ_{ef}/H; time – bH^2/κ_{ef}; pressure – $\rho_0\nu\kappa_{ef}/K$, where $\kappa_{ef}=\lambda_c/(\rho c_p)_f$ – effective coefficient of thermal conductivity of the medium, $b=(\rho c_p)_c/(\rho c_p)_f$ – ratio of thermal capacities of the medium and fluid. The system of dimensionless free thermal convection in the porous medium inside the permeable area is as follows:

$$\mathbf{u} = -\nabla p + Rd\,\theta\mathbf{e}_z$$

$$\frac{\partial\theta}{\partial t} + \mathbf{u}\cdot\nabla\theta = \nabla^2\theta$$

$$\nabla\cdot\mathbf{u} = 0 \qquad (2)$$

where $\theta=(T-T_0)/\Delta T_H$ – dimensionless temperature, T_0 – temperature at the upper cold boundary of the layer, ΔT_H – vertical difference of temperatures inside the layer with a thickness H, α – coefficient of thermal fluid expansion. The dimensionless temperature θ changes from $\theta_0=0$ at the upper boundary up to $\theta_1=c=\Delta T/\Delta T_H$ at the lower, where ΔT – difference of temperatures between the isothermal horizontal boundaries of the including area. The values of the parameter c are fitted in each case related to the angle of incline of the permeable layer. The convection intensity is determined by the number of Raleigh-Darcy [2,3]:

$$Rd = \frac{\alpha g H \Delta T_H K}{\nu\kappa_{ef}} \qquad (3)$$