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Influence of nanomirelal phases on development processes of oil reservoirs in Volga-Ural region

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The optimisation of oil-field development by enhancing oil recovery is the most important target in further improvement of oil production processes. The resulting economic benefits often exceed those from discoveries of new fields, especially in hard-to-reach regions. Despite the wide use of enhanced oil recovery methods, their efficiency is in many cases not as high as expected. For instance, in terrigenous reservoirs of the Volga-Ural region oil recovery rarely exceeds 0.4, and in carbonate reservoirs with the complex structure, variability and high oil viscosity it can be as low as 0.15-0.20. In natural bitumen fields, the recovery factor is even lower.

Analysis of the conducted EOR optimisation operations indicates that EOR methods mainly aim to change the hydrodynamic conditions in the reservoir under development or the physicochemical properties of oil, – for instance, to decrease its viscosity or to change its lyophilic behaviour. The impact of EOR methods on the reservoir's mineral component remains largely unstudied. It is generally believed that the mineral component of the reservoir, its matrix, is inert and remains unaffected by EOR methods. However, the analysis of oil-field development processes and the available studies allow the conclusion that natural hydrocarbon reservoirs are sensitive to any impact on both the near-wellbore zone and the whole reservoir.

The authors' research in the reservoir's mineral phase dynamics has permitted the conclusion that the reservoir's fluid phases (including hydrocarbons) and the reservoir itself form a lithogeochemical system that remains in unstable equilibrium. Any external impact, such as the reservoir penetration or the use of EOR methods, disturbs this equilibrium and changes the filtration characteristics of the reservoir, the fluid chemistry and the reaction of the reservoir's mineral component to the impact. In order to characterise the processes in the reservoir in the course of its development, the authors have worked out the concept of lithogeochemical equilibrium in the oil-reservoir system. According to this concept, the reservoir-fluid system contains inert and active mineral phases. Clastic grains in terrigenous reservoirs and carbonate accumulations in carbonate reservoirs represent the inert phases that do not react to reservoir stimulations. The active mineral phases are generally represented by finely dispersed, nano-sized minerals that form an unstable mineral assemblage, rapidly changing its form and orientation within pores and voids and crystallising in them in the course of the reservoir stimulation. The active nanomineral component is represented by clay minerals, finely dispersed carbonate material, finely dispersed sulphide minerals (pyrite), finely dispersed hydroxides, finely dispersed quartz and rare minerals.

The dynamic analysis of nanomineral phases in pore channels of the oil reservoir allows the prediction of the reservoir reaction to a specific EOR method, the selection of reservoir stimulation methods and the optimisation of oil recovery.

In accordance with the authors' instructions, the reservoir properties, areal distribution and spatial concentration of active nanomineral phases as well as their reaction to the physicochemical impact have been recorded in the course of the lithotechnological mapping in some oil fields of the Volga-Ural province. Such lithotechnological maps allow the selection of optimal reservoir stimulation methods with consideration for the lithological and mineralogical characteristics of the reservoir, including its particular regions, and for their reaction to the stimulation.