

LOW-INVASION CORING IN WEST SIBERIA, DIRECT ESTIMATION OF CORE FLUID SATURATION

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INTRODUCTION

During the recent years drilling of wells using oil-base muds has been facing a strong counteraction of “the greens” and is considered as ineffective due to its high cost. In this connection, in Russia the low-invasion coring has become quite popular lately. The low-invasion coring on a semi-commercial level has been carried out in the fields within the Surgut dome area – the main region of OJSC “Surgutneftegas”’s activities.

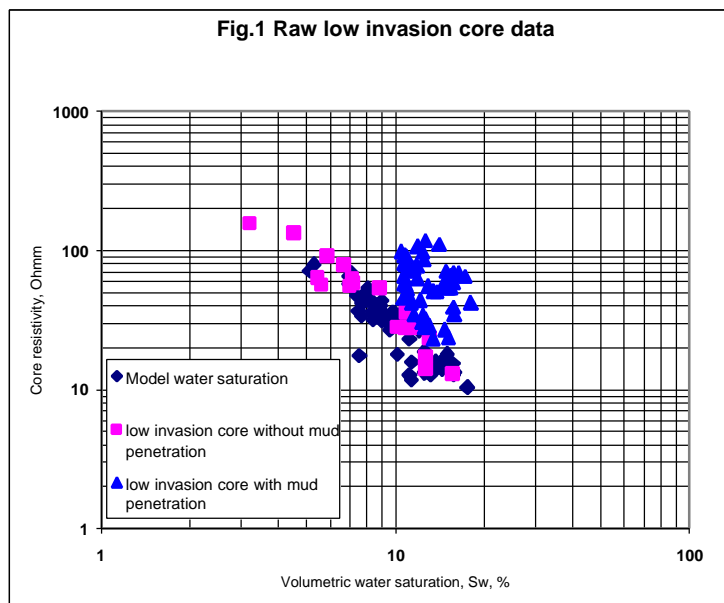
In the central part of West Siberia in a number of the Surgut dome oil fields the core was obtained by both, the low-invasion coring and oil based mud coring. This paper presents the short analysis of the results of studies of low-invasion and oil based mud core. This allowed for a direct comparison of the different core analysis results with the basic petrophysical relationships.

EXPERIMENTAL WORK

A preservation of a reservoir fluid saturation in the low-invasion core has a number of limitations both, geological ones and technological ones. Geological limitations relate to the reservoir properties, the type and characteristics of the saturating fluid. The geological factors limit a wide use of the low-invasion coring technique include a high permeability of terrigenous rocks with intergranular porosity and the intervals of rocks with cavernous-fractured type of porosity. In West Siberia the terrigenous sand deposits with an intergranular porosity are the main type of a reservoir. Therefore, the rocks permeability has the main effect on a quality of the in-place water saturation preservation in a core. Technological limitation is a rate of penetration during coring. The drilling technological parameters and the drilling mud properties also have a significant influence on a core quality. The low-invasion technique requires a thorough observation of a number of rigid technological requirements. However, if these requirements are met a high quality of the low-invasion core is ensured, which is confirmed by the comparability of the results of the low-invasion and oil-base mud core analysis. Moreover, the tested model of a laboratory analysis of the low-invasion core makes it possible to identify the core samples with distorted in-place water saturation.

Lets briefly discuss a procedure of the core analysis results processing and the criteria for determination of the analyses quality. One of the basic petrophysical equations used in determination of the reservoirs petroleum content in West Siberia is a relationship of the electric resistivity vs the rocks volumetric water saturation. For a number of oil fields such relationships were obtained for an oil-base mud core. The use of the low-invasion core analysis results allows us to obtain such relationships for the recently discovered fields and deposits. That is why a special attention at a core analysis was paid to a preservation of the core’s in-place water saturation and interstitial water mineral content.

A drilling mud filtrate invasion control in the core was made by a direct method included a use of a tracing agent added to the drilling mud. At present, during the low-invasion coring the three types of tracers have been tested, each has its own limitations and advantages. In this paper the authors do not consider in detail a problem of tracers choosing, though a proper choice has a great importance at the results analysis. In the laboratory on the specially selected core samples a displacement of interstitial water with non-polar oil was run. On the samples with the displaced water a resistivity of the pore waters and their chemical composition were determined. For each sample selected for a direct analysis of water saturation the resistivity was measured. All this allowed for a generation of the required basis for a detailed analysis of the preservation of waters in the low-invasion core withdrawn to the surface. The samples with a high filtrate invasion determined by a tracer and the samples with a low total mineral content were recognized as not corresponding to the reservoirs values. The non-representative results differ very much from the representative results on the plot (Fig. 1). For a number of samples for which no data were obtained for the tracer and pore water displacement a rejection of samples was made on the basis of this dependence. For samples poorly diluted with a filtrate a correction for water saturation is possible. The



correction was made with the account for the tracer concentration in the drilling mud and in the pore water of the sample. Such correction is acceptable, as the experience shows, at dilution of pore water with a filtrate but not more than by 30%. A higher dilution is accompanied with a partial displacement of the initial pore water out of the core with its substitution by the filtrate. At this, a reliable determination of the initial water saturation does not seem possible.

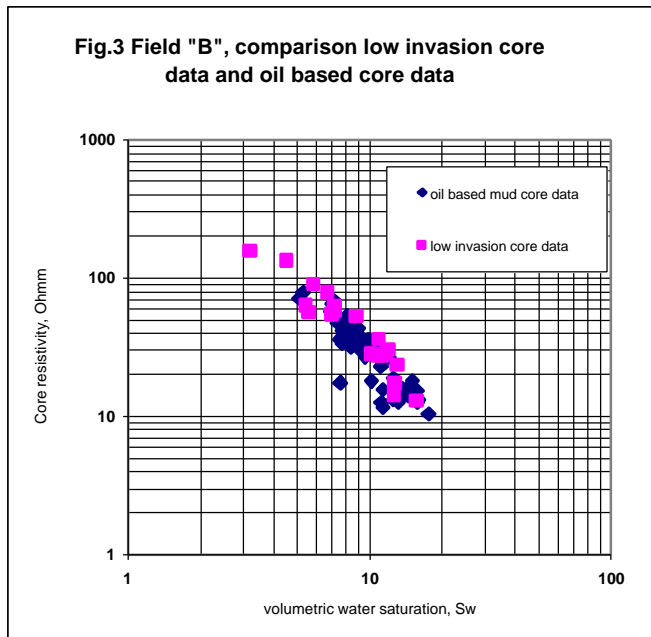
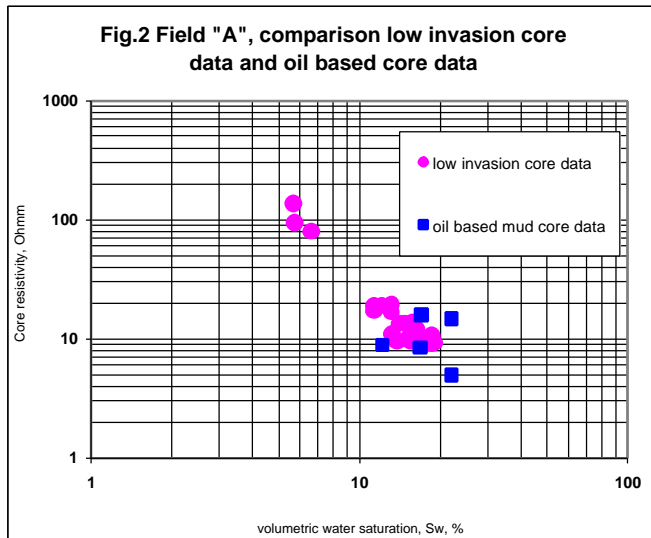
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RESULTS

Taking into account of the reservoir parameters and reservoir fluids properties as well as an observation of the technology requirements will make it possible to achieve a high quality of coring using the low-invasion coring technology in the oil reservoirs of the Surgut dome for the crudes with a low GOR. As an example of obtaining the correct results the three fields with different geology within this area were chosen.

Example No. 1. The studied bed in the field “A” is located within the depths range 2000-2100 m. The rocks are presented by medium-grained sandstones with permeability from 0.5 to 2.0 Darcy and porosity of 25-30%. The core collection using the low-invasion technique was performed in two wells, earlier in one oil-based mud well a core was obtained from the same formation. In the low-invasion core it became possible to

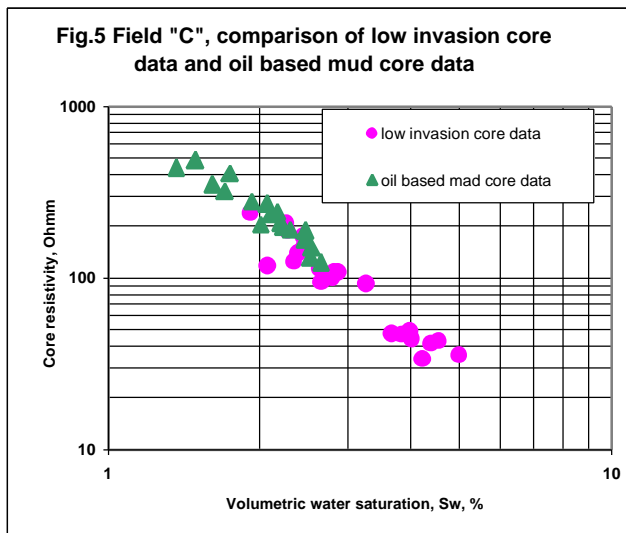
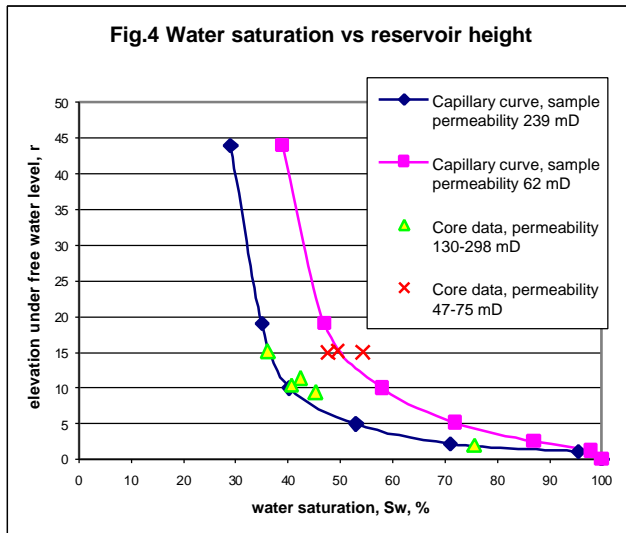
successfully preserve the in-situ water saturation and pore water salinity. In Fig.2



relationships between the electric resistivity and the volumetric water saturation for this formation are shown, which were obtained on the oil-based mud and low-invasion core. These relationships agree very well and practically coincide. Only two samples of the preserved state (low-invasion) core were discarded. A preservation of the in-place water saturation in the low-invasion core was achieved thanks to a proper selection of the cutting tool ensuring a high penetration rate during coring and the drilling mud composition providing a low fluid loss.

Example No.2. In the field “B” the core collection was performed from the formations interval 2200-2300 m. The pool is of a sheet-roof type with a small elevation above WOC. A major portion of the field is located within the zone of the non-maximum oil saturation, where water saturation is higher than irreducible water saturation. The reservoirs are presented by the two main types of rocks: fine-grain sandstones with porosity of 20-25% and permeability of 200-400 mD and by coarse-grain aleurolites with porosity of 18-22% and permeability of 5-50 mD. During preparation and performance of works all steps defined in the

works program were fulfilled, However, about 30% of the core were invaded to a large degree by the drilling mud filtrate. The analysis allowed for an identification of non-reproducing in-situ conditions values of water saturation and electric resistivity. The relationship obtained on the low-invasion core between the electric resistivity and volumetric water saturation agrees well with the generalized relationship for the oil-base mud core (Fig.3). The values received for water saturation exceed the values of irreducible water saturation of rocks, which were obtained by the semi-permeable membrane method and on ultracentrifuge. This is explained by a small elevation of the coring interval above WOC. The height of the transition zone under the free water level according to the capillary pressure curves is from 5 to 25 m for the reservoir rocks with various filtration-



capacitance characteristics. However, a good agreement is observed between the water saturation obtained by the direct method on the isolated core and that one calculated by capillary pressure curves (Fig. 4).

Example No.3. The field "C". The core collection was performed from the depths interval 2700-2800 m. The formation is characterized by poor reservoir properties and oil wettability of the grains surfaces. The reservoirs are presented by heavily compacted sandstones and aleurolites with porosity of 10-18% and permeability 1-20 mD. At such low filtration-capacitance properties the rocks are characterized by low values of water saturation, which can be less than 20%. The core collection was performed at the exploration stage from the three wells drilled with oil-based muds. At one development well there was proved a low-invasion coring. Not any drilling mud filtrate invasion in the core was registered. The dependence of the electric resistivity on the volumetric water saturation in the low-invasion core agrees very close with the one obtained for the core collected with oil-base

drilling mud (Fig. 5).

CONCLUSION

Thus, the low-invasion coring proved to be effective for the formations with various geological conditions and various reservoirs surface wettability. The proper planning and arrangement of operations in a well and in a laboratory makes it possible to obtain the results providing a petrophysical base for determination of reservoir oil saturation using geophysical survey data. However, carrying out of jobs for collection of low-invasion cores demands a thorough preliminary planning and monitoring of work at a drill-site. More rigid technology requirements towards the low-invasion coring procedure entirely prove their value in view of economics at comparison with the cost of oil-based mud core. This allows for an optimistic forecast with regard to the application of the low-invasion core collection method in West Siberia.