USE OF LOW-INVASION CORING TECHNIQUE FOR ESTIMATION OF RESERVES DEPLETION IN THE FIELD SAMOTLOR

Vladimir .V. Fedortsov, SSC "Sibcore"
Bulat Y. Hairullin, SPE "Sibburmash"
Vener G. Mamyashev, SPC "Tyumenngeofisica"
I.S. Jaffarov, Chingiskhan I. Khalikov, "Tyumen Oil Company"

The oil field Samotlor has been under development for more than 30 years. Currently, the main producing formations, AV_{2-3}, AV_{4-3} and BV_8, are characterized by a high degree of oil reserves depletion and water production. In this connection, the technologies to identify poorly drained zones having oil saturation close to the initial values are very important today.

Determination of oil saturation of the producing formations intensively exploited by conventional geophysical surveying is very complicated due to uncertainty of the formation waters salinity. This parameter and residual water content undergo significant changes in the process of water injection into the formation to maintain the reservoir pressure.

A direct estimation of current oil saturation (So) can be provided by a core, collected with preserved in-place water saturation. The use of the technique for core collection with oil-base drilling mud is not welcomed because S_o in the flushed zones may be erroneous due to the penetration of oil-base mud filtrate into the core pore space. Therefore, the geological department of the Tyumen Oil Company made a decision to perform coring by the low-invasion coring method using water-base mud. This technique was described in detail in the earlier publications [1].

The scientific-production company SibBurMash was invited to perform coring because it is specialized in designing and manufacturing the equipment for coring and provides the engineering supervision of operations. The main task put forward to the core investigators was a direct estimation of the current oil saturation in the developed formations by a core. At present, similar estimations have been made on a core collected in three wells in different areas of the field. In this paper the results of the low-invasion core extraction and study are described for one of the wells.

The difficulties to ensure a proper application of the low-invasion coring technique in this well were caused by water entry from the water-bearing deposits overlaying the cap of the formations AV, which were not shut-off by the casing string. In the process of coring a number of significant problems occurred with maintaining the drilling mud designed parameters and an increase of carving, which resulted in a reduction of the core recovery from the separate intervals.

To maintain the tracer concentration in the drilling mud at a constant level in these conditions became a serious problem. The concentration of fluoresceine and sodium nitrite, used as tracers, in the drilling mud during one run varied significantly, and this created difficulties in estimation of a degree of the oil-base drilling mud filtrate invasion in the

back to contents

core. The conventional technique of the core quality control by tracers was found as ineffective, therefore, the evaluation of oil-base mud filtrate invasion in the core and the rocks fluid saturation condition was made with the account for a determination of the pore water mineral content and chemical composition in the studied samples. For this the procedures of aqueous extract and driving the interstitial water out of the core by injecting a non-polar oil were used. On the basis of these procedures results a rejection of core samples invaded with water-based mud filtrate was made and the intervals by-passed in the process of development were distinguished.

The core samples selection was performed at the well-site with a preliminary visual inspection of the mud aqueous phase invasion into the core by luminescence of the tracer added to the mud in the UV light. To maintain the core natural fluid saturation the samples were cut out of the core center at liquid nitrogen temperature. The core studies included direct measurements of the core water- and oil saturation, its electrical resistivity in preserved state and a combination of routine studies of rocks filtration-capacitance characteristics and their bulk and mineral density. Additionally, a simulation was performed of the rocks electric resistivity at their various water saturation and at a various salinity of the formation water model corresponding to both, the initial in-place salinity and the salinity of injected waters. The lower limit of salt content in the injected water produced with oil is 14g/l, the initial formation waters salinity is 26 g/l. For these values the theoretical curves were drawn (Fig.1). The theoretical relationships between the electric resistance ρ_i and volumetric water saturation (W = Ǿ*Sw, where Ǿ is a porosity coefficient, Sw is a water saturation factor) were compared with the those measured on the low-invasion core conditioned samples with the preserved water saturation as well as with the data of the core collected with the hydrocarbon-base drilling mud (Fig.1) obtained at the early stage of the Samotlor AV layers development.

The comparison of the theoretical relationships $\rho_i = f(W)$ with the actual data makes it possible to determine the error in the water saturation estimation at salt content changing from 14 to 26g/l by the electric resistance.

Thus, the maximum error in the estimate of Sw based on the relation $\rho_i = f(W)$ at the electric resistivity equal to 6 Ohm and Ǿ=30% (modal value) does not exceed 15%. In the region of high resistances the error becomes less.

Water retaining capacity (S_w^0) is a parameter of a fast estimation of the reservoir quality, which has been in use for more that 20 years in West Siberia oil industry. According to the definition it is a water saturation obtained by centrifuging at normal conditions (ensuring a capillary pressure in the system air-water of 2.4 atm.). Taking into account that in the Samotlor AV layers the homogeneous reservoirs are predominant the relation S_w^0 – Ǿ is very close (Fig.2). The relationship of the relative water saturation change, determined by the formula $Rw = (Sw - S_w^0)/ S_w^0 * 100$, over the bed elevation above the OWC allows for an estimation of the initial water saturation at any point for the conditions of the homogeneous layer (Fig.3).

Algorithm of identification of intervals with initial water saturation and water saturation changed in the process of the development was as follows:

1. Assessment of Ǿ according to logging has been made in the beds crossing.
2. Assessment of the reservoir quality S_w^0 by the relation S_w^0=f (Ǿ).
3. Assessment of initial water saturation by the relation Rw=f(h).
4. Assessment of current water saturation by the relation ρ_t = f (W).
5. Comparison of initial and current water saturations. If the discrepancy does not exceed the assessments error then the interval may be referred to the poorly drained ones (i.e. not covered by development). If the discrepancy exceeds 15-10% (depending on the electric resistivity and Ǿ) then the interval may be treated as watered).

The results received at this approach demonstrate a feasibility of estimation of the current water saturation of the developed bed rocks by electrometry methods.

Another interesting moment revealed at the analysis of the current oil saturation in the developed field on a core was a recognition of non-working interval over the section. It was found out that in all AV group layers under development the interlayers with permeability less than 80-100 mD actually were not involved in the depletion process. In the layer AV_{4-5} as more homogenous in structure the boundary value of permeability for the non-working intervals was 80 mD, and for more disintegrated formations AV_1, AV_{2-3} the interlayers with permeability less than 100 mD are not involved in the development.

Thus, the complex of the studies performed made it possible to determine the reservoirs current oil saturation by a direct method and to reveal the regularities of the reserves depletion depending on the reservoir properties of the formations.

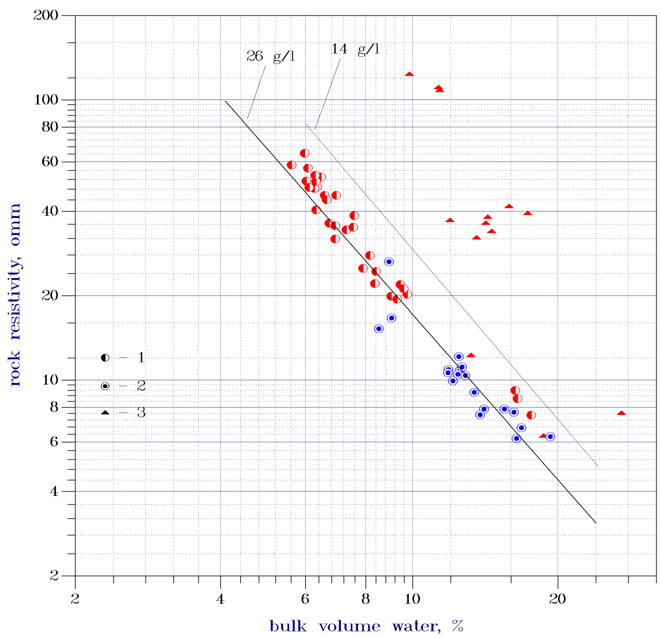

Fig.1 Comparison of rock resistivity of low-invasion core and oil-base core
1 - rocks with initial bed salinity (data of oil-base mud core)
2 - rocks with salinity of pore water more then 16 g/l (penetration of injected water)
3 - rocks with salinity of pore water less then 10 g/l (penetration of water-base mud during drilling)
Dotted line is theoretical curve for injected water, m≈n=2.0, for a brine resistivity equal to that 14 g/l NaCl
Solid line is theoretical curve for connate water, m≈n=2.0, for a brine resistivity equal to that of 26 g/l NaCl

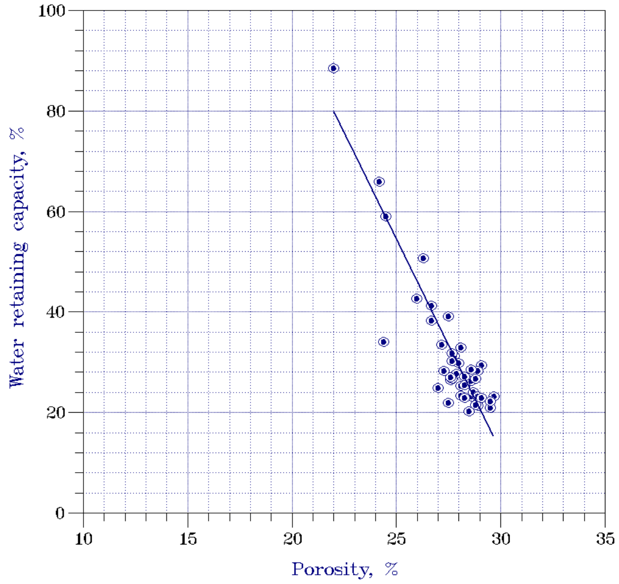

Fig.2 Relation between water retaining capacity and porosity for AV formation Samotlor field.

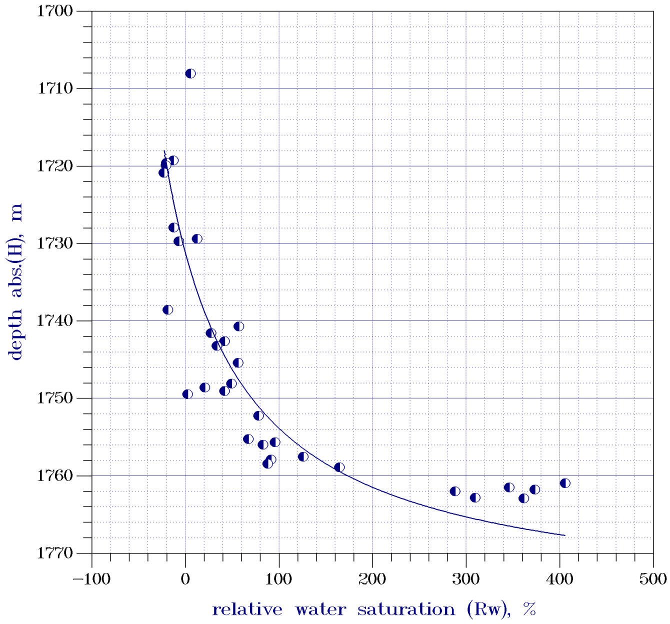

Fig.3 Change of relative water saturation Rw vs the height of formations AV at Samotlor field

REFERENCES

1. B.Khairullin and other, “Low-invasion core technology”, SCAL FORUM, Abu-Dhabi, 1998.

back to contents