SCA2003-65: EXAMINATION OF UNCONSOLIDATED CORE BY NUCLEAR-MAGNETIC RESONANCE METHOD

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INTRODUCTION

In Russia there are some territories where hydrocarbon reserves are associated with reservoirs formed of poorly cemented or even absolutely unconsolidated sand and clay sediments. A substantial share of the world's hydrocarbon reserves is located in Cenomanian sediments of West Siberia, adjacent Arctic Ocean offshore, Miocenic sediments of Sakhalin offshore, as well as in several other areas.

Recently a low temperature technology (core freezing in liquid nitrogen) has been introduced to study unconsolidated sands in Russia. It should be noted that western oil companies have already been using this technology for quite a long time and achieved a good progress. Nevertheless, the effect of freezing at T = -196°? on the permeation and storage properties of the rock is still not absolutely clear. Some companies such as Exxon propose pressing out specimen by a plunger. However, it cannot be used for various grain size sands since individual coarse grains of the rock - when pressed out by the plunger – contact the plunger’s cutting edge butt-end and deteriorate the specimen making it unusable for the further investigation. So, the authors have carried out a series of experiments to elucidate the problem of possible low temperature impact on the permeation and storage properties of the unconsolidated rock, and cleared up some aspects of this problem.

PROCEDURES

The low temperature technology yields petrophysical parameters of unconsolidated core specimen with their intact pore space structure formed in the sediment origination. Experiments were performed to establish this fact. Miocenic core from a Sakhalin offshore well was taken by two methods: with the help of the plunger (pressing out) without freezing, and then – in parallel – using the liquid nitrogen technology. Porosity and permeability were evaluated in both cases. The comparison between the measurements (Fig. 1) showed that the permeation and storage properties of the rock retrieved at the low temperature were not changed.

Pressing out as a procedure to obtain standard specimen cannot be used routinely since the rock of the sediments under consideration includes coarse fractions (gravel), often contains pebble, which leads to the mechanical destruction of the specimen and especially of the adjacent material.

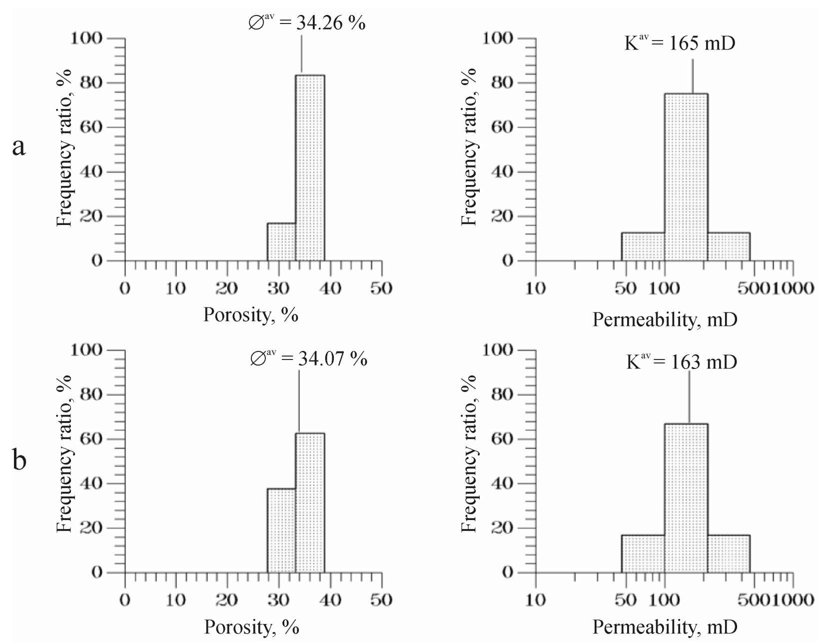

Fig. 1. Investigation of permeation and storage properties of the unconsolidated core specimen produced: a – with a plunger at the ambient temperature (total number of samples are equal to 20), b – using the low temperature technology (total number of samples are equal to 20)

Petrography of transparent slices prepared before and after applying the low temperature liquid nitrogen technology showed that the pore space structure remains intact; no grain shift or shatter was found. Nuclear magnetic resonance studies with CoreSpec-1000 NMR-spectrometer turned out a convincing proof of the intact structure and texture of the rock under investigation. Poorly cemented core of different saturations were selected for the experiment, their relaxation curves before and after liquid nitrogen freezing were obtained.

RESULTS AND DISCUSSION

The core pore space structure study by NMR in a strong magnetic field shows quite reliable differences both in the structure and mineral skeleton surface properties. The occurrence or lack of the above on the relaxation curves allows discussing the changes due to the low temperature effect on the structural characteristics and permeation and storage properties of the rock. Figure 2 (a, b) shows the initial relaxation curves and decoded into differential and integral porosity curves. The differential and integral curves characterising the pore space structure show no substantial changes. The storage properties evaluations fall within the experimental error limits. The above experimental data shows no significant changes in clays porosity, capillary bound water and effective porosity. Thus, one can conclude that the low temperatures did not distort the structural proportions in the rock.

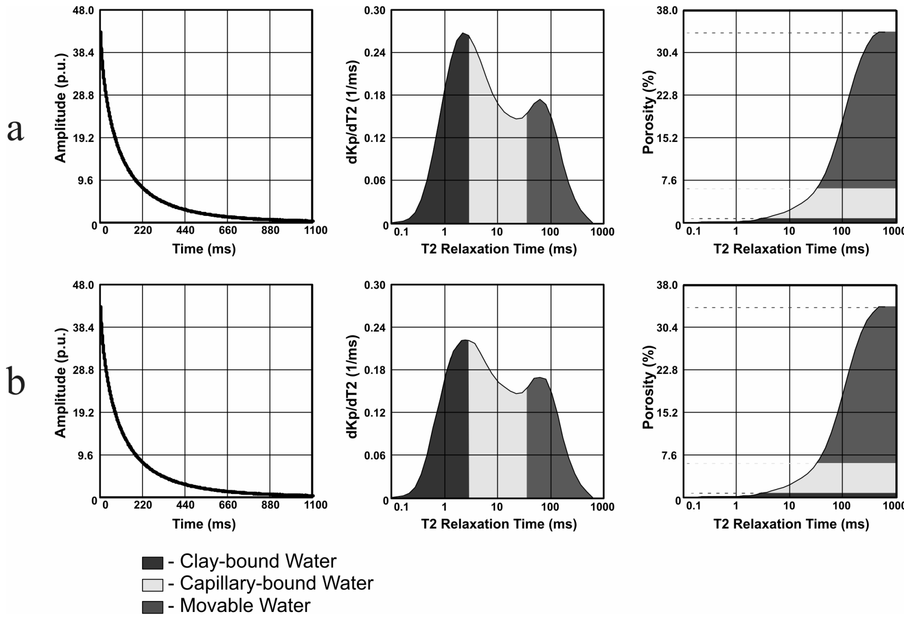

Fig. 2. Relaxation curves (CPMG measurements with NE = 2200, TE = 0.5 ms, TW = 3000 ms) and T_2 distributions: a – before deep freezing; b – after deep freezing. Poorly cemented Miocenic sand from the Sakhalin island

The procedural and technological problems of evaluating the state of the specimen under study and pore space structure disturbances measure proved out to be harder. Finally these very problems are criteria of the values really measured at the laboratory.

One of the main arguments of the opponents to the low temperature technology suggests that - from a physical point of view – freezing must change the core pore structure if its volume (pore space in this case) is filled up completely with water. When freezing, the water will crystallise and increase its volume. In turn, such situation should have deteriorated the contacts between individual grains and therefore should have led to the softening of the rock. The changes should have been seen on the NMR relaxation curves, but the authors did not notice any substantial characteristic changes in the course of the experiments.

One of the factors preserving the rock structure and pore space intact while freezing the rock is the fact that the pore space is not filled up to 100% by its fluids in the overwhelming majority of cases. While retrieving or lifting the core to the wellhead some fluids will be lost, which will be due to a liquid degassing phenomenon. There is always some amount of gas dissolved in the rock saturating fluids in situ. When the core is lifted to the wellhead, the dissolved gas begins to release and transform to its free state. Since this process has a bulk nature, some liquid fluids saturating the rock are drained out of the rock due to a swabbing action. We conducted experimental modelling of the process to find out the scale of the core fluid loss during the core lifting. The core was saturated with water and oil in different controlled proportions, then placed into gas and saturated up with the gas at the formation pressures. So, it was a complete model of formation fluid saturation. Methane CH_4 or carbon dioxide CO_2 was used as the gas phase. The gas phase surrounding the core was replaced with the drilling mud, and the process of lifting the core to the wellhead was modeled. The formation pressure was reduced from the bottomhole pressure to the atmospheric one with the same dynamic characteristic as in the actual drilling tool lift from the bottomhole. Figure 3 shows the experimental results. As seen from the given data there is a loss of rock saturating fluids in any case. We measured water loss at different proportions of the core saturating fluids. For absolute values in percentage, in the overwhelming majority of the cases the water losses always compensated for those additional volumes arising due to water crystallization while freezing. Consequently, freezing the core will not make any noticeable changes in the pore space structure because the core saturation will never reach 100% as a rule. This conclusion is confirmed by the experiments.

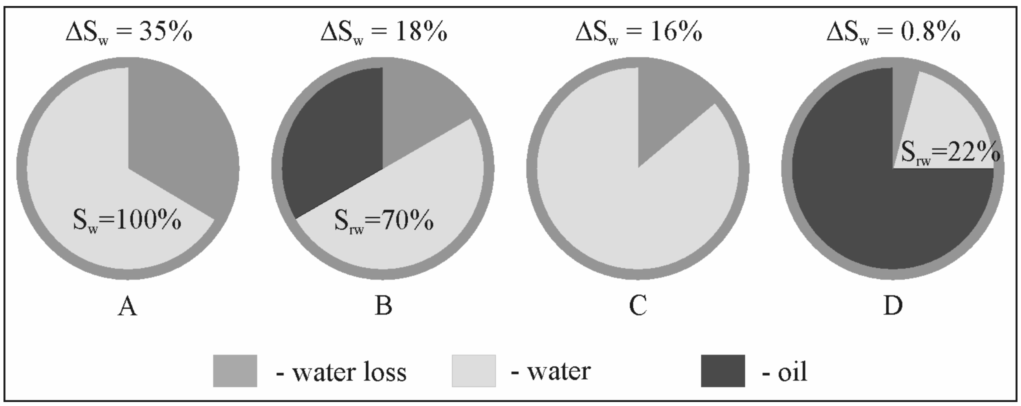

Fig. 3. A diagram of water loss from core specimen while modelling of lifting them from the bottomhole to the wellhead

A special unit for NMR experiments to study the core in conditions modelling its natural situation in situ (under the rock pressure) was developed. The core holder was made of composite radio-transparent materials. There appeared an opportunity to study the uniform pressure effect on the pore space structure of the rock by NMR. The core holder made of the composite materials was designed for the standard Russian core size (diameter of 30 mm, length of 30 to 40 mm. The rock pressure and formation pressure were modelled within the range of 0 to 50 MPa each. The initial measurements in the experiments for NMR characteristics evaluation in situ showed that there exists a substantial effect of the measurement conditions on the measured relaxation curves behaviour in the unconsolidated rocks. It is too early to make conclusions from the initial experimental data. However, the authors do hope the experiments will be continued.

CONCLUSION

Experiments on unconsolidated sand and clay reservoirs confirm that the low temperature technology (T = -196°?) for cutting out core specimen will not cause substantial changes either in the permeation and storage properties or in the pore space structure.

The NMR investigation suggests that the low temperatures have an insignificant influence and a minimum effect on the pore space structure and the surface properties of the mineral skeleton of the rock.

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