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Usage of computer X-ray microtomography method for core analyses from deposits with scavenger reserves

In order to identify the productive and perspective perforation in the deposits with scavenger reserves, one often faces a number of problems that prevent the selection of the most perspective intervals. One can add to these intervals the misinterpretation of geophysical well logging, as a result of drill mud colmatation into the formation or technogenic disturbances in the core of rocks that occur during lifting, sample preparation and analysis by classical petrophysical methods. In this regard, the authors of this article present a method of computer x-ray microtomography in order to develop criteria for the prospects of intervals in deposits with scavenger reserves.

The article underlines the prospects of the computer x-ray microtomography method: 3D modelling, calculation of porosity and clay coefficients, volume fraction of heavy minerals, estimation of pore distribution by size and depth of drilling mud penetration of the core, as well as experimental output with recommendations for the usage of method during experiments before and after any impact.

In accordance with the research results, we concluded that the method of computer x-ray microtomography under the study of core material can help in the development of effective criteria in order to identify the promising intervals for perforation in the section of a well with deposits with scavenger reserves of hydrocarbon. One can do this if there is a sufficient test and information sampling in relation to the test results under study.

Keywords: *The scavenger reserves of hydrocarbon, computer x-ray microtomography, interval prospect criteria, drill mud colmatation, modelling of hydrocarbon generation, SkyScan 1172.*

1.0 Introduction

In order to identify the perspective intervals for perforation and study in relation to the petrophysical properties of rocks that represent deposits with scavenger reserves, there are a number of factors that prevent acquisition of objective information about the intervals prospects [1]. These factors include: the presence of technology-related changes in the core after its drilling and lifting to the surface (the effect of drill mud colmatation) [2, 3], technology-related changes after or during sample preparation for the analysis (crack formation, core crumbiness) and as a result, incorrect interpretation of data from geophysical well logging [4-6]. In this regard, we propose to use a non-invasive method of computer-generated x-ray microtomography in combination with standard petrophysical core analyses in order to improve the foundation of decision-making during the test of individual intervals.

The key advantage of this method is the ability to assess technology-related changes in the structure of the voids, as well as to identify intervals that are at risk of drill mud colmatation into the formation. In addition, one can use this method to evaluate changes in properties within the experiments before and after any impact on rock formations. The potential of the method allow you to obtain a digital model of the sample before the impact, as well as a digital model after the impact – with the subsequent combination of digital models with the selection and characterization of areas that are subject to changes. It is important to note that the disadvantages of such method include: a limitation in the footage accuracy grade, the complexity of segmentation in relation to rock minerals of similar x-ray density, and the lack of an adequate mathematical apparatus for the accurate calculation of petrophysical properties.

In this regard, in this paper, we consider possible options for identification of criteria for the tests of intervals in accordance with computer x-ray microtomography, as well as an example of its usage within the experiments before and after any impact. The potential of the computer x-ray microtomography method and specialized software allow you to obtain the following information about the objects of study: the structure of the sample, the structure of the voids, the type of cement, the modal distribution of pore diameters, the coefficient of open and closed porosity, partially qualitative and quantitative information about the mineral

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composition of rocks, the distribution of any minerals or voids in both 3D and 2D by the depth of the sample etc. etc..

2.0 Materials and methods

In the course of the study, we applied to the material and technical base of the core facilities centre "Center for advanced research and innovative development" of the Industrial University of Tyumen.

The object of research refers to rocks of the West Siberian oil and gas basin: black mudstones of the Bazhenov formation and light gray sandstones of Jurassic deposits. In order to review the potential of the computer x-ray microtomography method, we divided the experimental part of the research into two parts: (1) study of poroperm properties in order to assess the presence of drilling mud heaver, and the depth of clay material penetration into the core; (2) study of changes in the voids structure of oil source rock before and after thermal action.

Before the research, we prepared the samples for analysis – we designed the cylinders from the rocks with a diameter of 8-10 mm, and the footage accuracy grade constituted approximately 4-15 microns/pixel in accordance with the task. We maintained the research by a computer x-ray microtomograph SkyScan 1172, and we used professional software Nrecon, CTan, CTvox, and DataViewer for reconstruction and analysis of tomographic output. In order to maintain the quantitative calculations in 3D, to fasten the analysis process, we selected the most significant areas from digital models of samples in the form of cubes with an edge of 1-2 mm.

Within the study if there are rock properties, we applied to the following parameters (within the scope of the footage accuracy grade): porosity and clay coefficients, volume percentage of heavy minerals, modal equivalent-pore diameter, depth of drill mud penetration into the core, presence of assessment of the drilling mud heaver (barite, as a rule) on the surface of the core material.

Within the study of changes in the rocks void structure of the Bazhenov formation before and after thermal action, we put the samples under the temperature of 100-200-300-400-500 degrees of Celsius in a muffle furnace, after which we obtained the digital models of samples by the method of computer x-ray microtomography and we analyzed the changes in the structure of the voids (porosity coefficient, modal equivalent-pore diameters). We made a record of the temperature by an industrial thermometer. Within the experiment at a temperature of 370°C, one sample exploded, and the other at a temperature of 480°C started to burn. Photos of samples after thermal action are shown in Fig.1.

2.1 Results

The research results of light gray sandstones by computer x-ray micro-tomography are indicated in Figs.2 to 4.

Fig.1 Experimental samples after heat treatment from left to right 100-200-300-400-500°C, respectively.

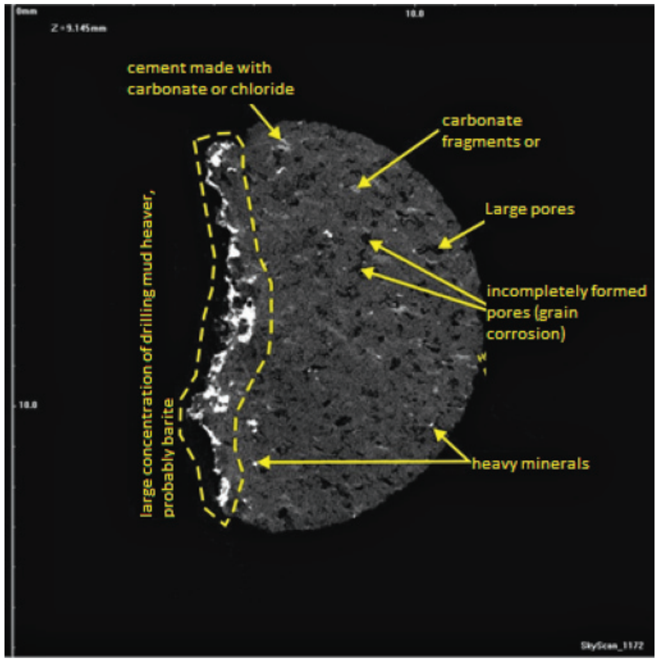

Fig.2 Description of the x-ray microtomographic section (resolution 4 microns/pixel).

Types of cement: incomplete pore; continuous uneven; film, corrosion - there is frequent replacement of clastic grains with clay material. We noted the presence of a drilling mud heaver, probably, barite has representation characteristics of the mineral. One observes no fracture, and the structure of the void is pore.

The porosity coefficient constituted 17.6%, the clay coefficient - 25.4%, and the volume content of heavy minerals - 0.06%. Most often, the size of pore channels corresponds to values of 12-20 microns, the maximum equivalent diameter- 142 microns.

We designed the percentage graphs of the clay material content distribution in relation to pore, pore sum and clay material (in cross-section) in accordance with the depth of the

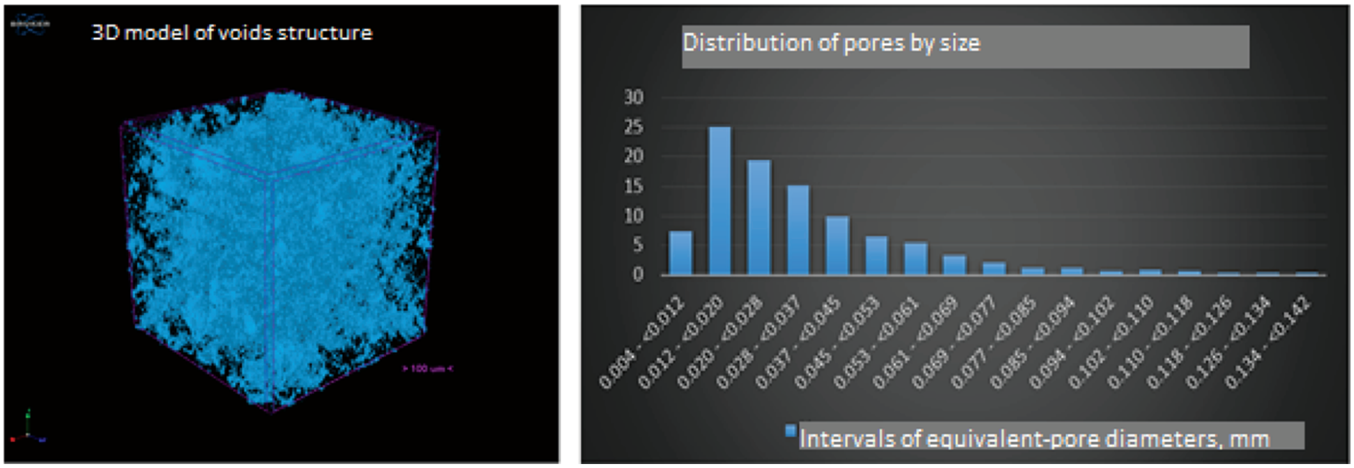

Fig.3 3D model of the void structure and results of analysis of the pore distribution by the size of slice (resolution of 4 microns/pixel)

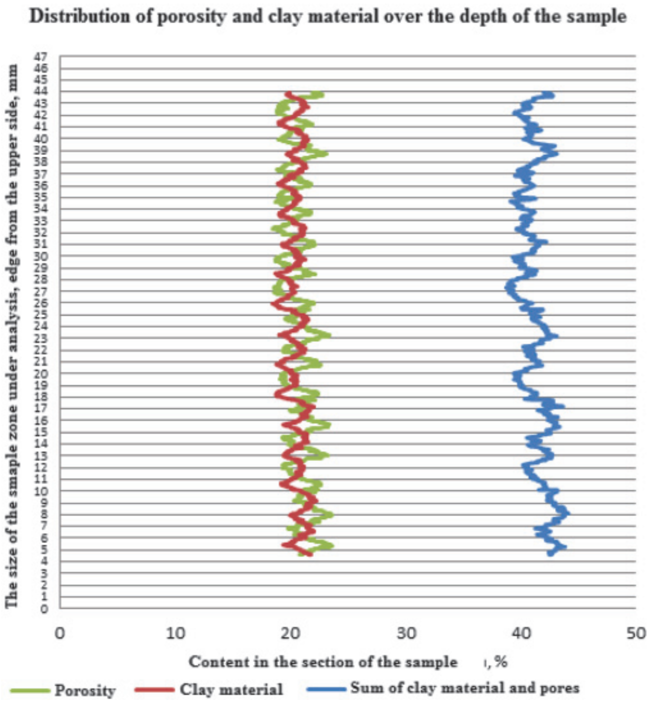

Fig.4 The distribution of porosity and clay material over the depth of the sample in accordance with 2D analysis (footage accuracy grade of 15 microns/pixel).

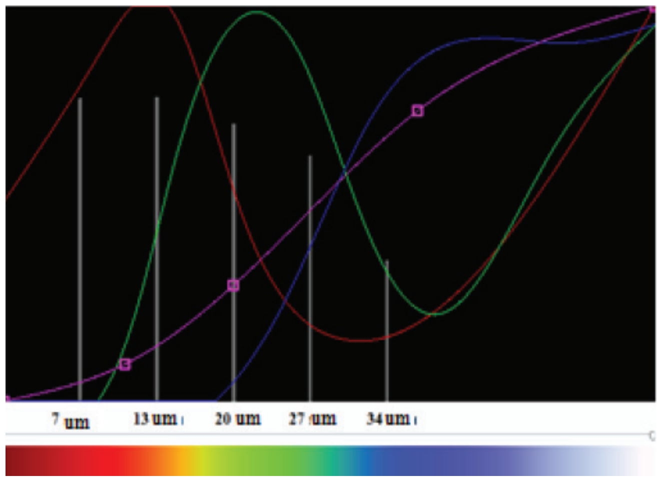

Fig.5 Colour scheme for pores of different sizes on 3D models of the voids structure from the CTvox program

sample. One assumes that with movement from the edge of the sample to the center (full-size core), the porosity will increase, and the amount of clay material will decrease. After these graphs reached the "asymptote" (i.e., a stable zone of values variability) in relation to the depth of the sample under analysis, we concluded that the contamination of the void stops from the very start of this zone. In this case, there is no technology-related contamination of the voids with clay material of the drill mud, but in accordance with the output of the high-resolution footage, we note the presence of a drilling mud heaver – it may influence on the indicators of the geophysical well logging equipment.

Research results by computer x-ray microtomography of changes in the voids structure of oil source rock before and after thermal action.

After we put the samples of black mudstones of the Bazhenov formation under the heat treatment, we conducted the further research by computer x-ray microtomography. After that, in digital models of the sample, we selected the cubes with an edge of 1 mm for 3D modelling of the voids with a pore size distribution for ease of analysis (Figs.5 and 6).

As a result of thermal actions on black mudstones of the Bazhenov formation we did not observe any significant changes within the temperature range up to 200°C in the structure of the voids; within the temperature range of 200-300°C, we observed an increase in pore size in 20-27 µm; within the temperature range of 300-400°C we observed a progressive increase of the pore size in 34 microns, within the temperature range 400-500°C we observed the significant changes.

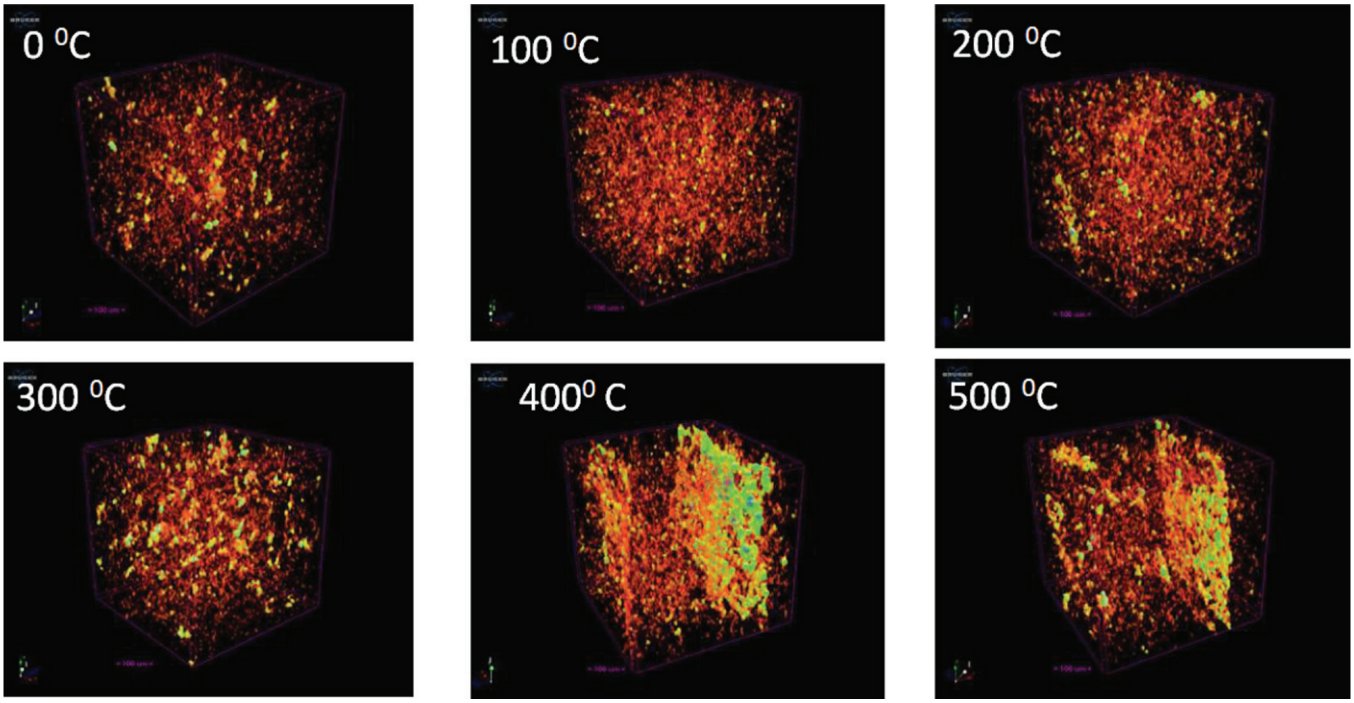

Fig.6 3D models in the voids structure of oil source rock before and after thermal action with the selection of pores with different sizes by a certain color from the CTvox programme

3.0 Conclusions

As a research results by computer x-ray microtomography method in relation to the rocks, we examined the potential of such method in order to identify the perspective intervals for perforation, as well as the possibilities of this method for the comparative analysis before or after any impact. As an example, we studied the properties of light gray sandstones and black mudstones.

We can state that in order to identify perspective test intervals for the well section, the computer x-ray microtomography can provide the following information in order to improve the argumentativeness of decision-making: (1). Porosity coefficient (within the resolution), (2) Modal equivalent-pore diameter (within resolution), (3) Presence of a drilling mud heaver, (4) Depth of drill mud penetration into the core, (5) The presence of technology-related changes in the core. In accordance with the data of quantitative and qualitative characteristics, one can develop criteria for selection of perspective intervals for tests. For this purpose, it is necessary to develop a statistical database and compare it with the results of well tests in order to make recommendations on untested intervals in the future.

Also, in accordance with the research results, one can state that computer x-ray microtomography is a convenient tool for a comprehensive assessment of changes in the properties of rock before and after any impact. One can use it as methods of planning in order to increase reservoir recovery rate, as well as for the modelling of the oil generation processes in accordance with this paper. One should note that as a result of thermal action on black mudstones of the Bazhenov formation there is an increase in the equivalent diameter of pores as a consequence of auto-fluidized rock burst (transition of organic matter from solid to liquid and gas as a result of cracking) – it suggests that petroleum generation potential of the Bazhenov formation is yet-to-spend. In this regard, one can state that this method in experimental studies that relate to heating and modelling of oil generation processes can carry information about the oil and gas generation potential, so the team of authors recommends to use this method, as well as for the basin modelling, in particular, for the hydrolysis of rock formations.

Acknowledgments

In the course of the study, the authors applied to the material and technical base of the core facilities centre "Center for advanced research and innovative development" of the Industrial University of Tyumen. The team of authors express gratitude.

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Printed by Pradip Kumar Chanda at The Indian Press Pvt. Ltd. 93A Lenin Sarani, Kolkata 700 013 and published by him for Books & Journals Pvt. Ltd. from 62 Lenin Sarani, Kolkata 700 013.