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THE USE OF X-RAY MICROTOMOGRAPHY TO ASSESS CHANGES IN THE VOIDS STRUCTURE OF ROCKS

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ABSTRACT

The oil and gas industry is developing rapidly. Based on this, it is necessary to determine new methods of productive prospecting of mineral deposits. One of the most high-tech and perspective methods is computer X-ray microtomography. For this stage, this method is widely used for the different fields of geology and geophysics. The main advantage is the ability to study the sample without destruction, which is especially important in the process of working with the kern material. In this paper, the method of computerized X-ray microtomography is highlighted. A comparative analysis of the voids structure of an oil source rock before and after exposure to microwave fields using the standard DataViewer software is clarified. As a result of this analysis, an increase in the diameter of a sample of a cylindrical shape after treatment with microwave fields was established, and the formation of microcracks was also established. Based on the results obtained, assumptions were made about the formation of hydrocarbon deposits. In other words, the paper discusses in detail the method that allows fixing changes in the structure of the void space of rocks as a result of oil and gas generation flowing under the influence of wave fields.

Keywords: *X-ray microtomography, oil shale, digital petrophysics, oil generation, Bazhenov suite.*

1. INTRODUCTION

Currently, there is an epoch of transition from traditional (exhaustible) energy resources, most of which are various types of hydrocarbon compounds concentrated in the subsoil, to renewable energy sources: atomic, solar and wind energy. This is due to natural, technological progress.

However, the problem lies in the fact that technological progress has not yet provided people with the necessary amount of renewable energy, and hydrocarbon reserves concentrated in standard deposits are decreasing every year. These data indicate the need to develop an innovative type of technology that is capable of extracting oil from clay-bitumen oil source deposits on the one hand and, on the other hand, to ensure a smooth transition from traditional energy sources (hydrocarbons) to alternative (thermonuclear fusion, superconductors).

In this paper, the author will discuss a particular case of studying radical reactions caused by the nuclear-electron interaction of isotopes with an angular electron magnetic effect [1-3]. In other words, a method will be highlighted in the paper that allows one to record changes in the structure of the oil source rock voids as a result of oil and gas generation occurring under the influence of wave fields, in this case, electromagnetic waves of ultrahigh-frequency (microwaves). The methodical part of the work will consist in the approach of the comparative analysis of the data on the structure of the rock structure obtained on the X-ray computer microtomograph SkyScan 1172 before and after the treatment with microwaves. The principles of scanning, reconstruction,and analysis of tomographic data will be clarified in detail, and the conclusions will be made on the basis of the results obtained about the processes occurring during the formation of hydrocarbon deposits.

2. MATERIALS AND METHODS

The object of research is the change in the structure of a sample of an oil source rock, in this case, the black mudstone of the Bazhenov suite (Russia, Western Siberia) as a result of radical reactions in dispersed organic matter (kerogen) [4-9]. As a consequence of microwave treatment, oil and gas generation processes occur, with a natural increase in the volume of hydrocarbons during the transition from a solid state (kerogen) to a liquid (oil) and gaseous (gas). During this process, the structure of the voids changes due to the cracking of the rock under the action of the high pressure of newly formed fluids.

Based on these data, an assumption was made that the existence of oil and gas generation processes or radical reactions in dispersed organic matter can be assessed not only by geochemical methods of comparative analysis, for example, by Rock-Eval or by chromatographic analysis of the composition of the bitumen, but also by computer X-ray microtomography with a resolution of samples shooting of about 3 micrometers per pixel. The experimental technique consists in a comparative analysis of the structure of the voids of a sample in its natural state (without thermal and wave processing) and the modified structure of the voids of a sample subjected to microwave treatment (thermal and wave processing).

Comparative analysis is carried out objectively, due to the excellent function of the software of the SkyScan microtomographs. The DataViewer program makes it possible to accurately overlap tomographic slices of samples before and after microwave treatment [10].

The duration of the microwave treatment of the sample was 8 minutes, with a marked increase in the sample temperature.

The method of computer X-ray microtomography is based on obtaining a set of shadow projections of the sample from different sides, after which these shadow projections using specialized software, in this case, the NRecon program, are reconstructed into tomographic sections, usually presented in 8-bit format with the graduation of the X-ray density of the sample in grayscale from black to white or vice versa [11].

The principle of operation of the method of microtomography (see Figure 1) is the same with medical tomography or tomography for a full-sized core. It is important to note the geometrical dimensions of the sample – the smaller the sample, the higher the resolution and less noise (typical of the SkyScan 1172 microtomograph). In this case, the golden mean was chosen: the sample diameter was 12 mm, and the shooting resolution was 3.3 μm/pixel. Also, when conducting high-resolution sampling, it is necessary to select the correct parameters: the type of filter, the scan step and the number of frames. In this case, the following parameters were selected from the microtomograph experience: filter – aluminum + copper (standard), scanning step – 0.3 degrees, number of frames – 5, number of random frames – 30, scanning was performed at 360 degrees. Choosing the right number of random frames and scanning at 360 degrees helps to avoid ring artifacts.

After the tomographic projections of the sample were obtained, they were reconstructed with the following parameters: Smoothing=3; Smoothing kernel=0 (Asymmetrical boxcar); Ring Artifact Correction=20; Object Bigger than FOV=ON; Filter cutoff relative to Nyquist frequency=100; Filter type=0; Filter type description=Hamming (Alpha=0.54); Undersampling factor=1; Threshold for defect pixel mask (%)=0; Beam Hardening Correction (%)=46; Minimum for CS to Image Conversion=0.000000; Maximum for CS to Image Conversion=0.100000. An example of the obtained qualitative tomographic slice is shown in Figure 2.

After carrying out experiments and obtaining digital models of core samples before and after treatment with microwave waves, the samples were processed using the capabilities of the DataViewer program. A logical "difference image" operation was performed between digital models – the difference is an image; a more detailed algorithm of the operation is presented in the guidelines of the device manufacturer [12].

3. RESULTS AND DISCUSSION:

As a result of the research, the following materials were obtained, see Figure 3. The yellow arrows indicate the fracturing resulting from those radical reactions and oil and gas generation processes. An increase in the diameter of the sample is also clearly observed; this is indicated by the light line along the contour of the sample (for convenience, it is outlined nearby with green). Numerous black dots, next to which white dots are combined, indicate the impossibility of joining heavy mineral inclusions of the sample. In the end, most of the image is grey; it indicates the successfully combined parts of the sample.

In general, the literary analysis showed that the cracking of organic matter significantly changes the structure of the voids [13-16]. As a rule, the degree of change in the structure of the voids depends on many factors: the degree of maturity of organic matter (kerogen), the rate of thermal effects on the rock, volume fraction of kerogen and others [17]. However, an important feature of this study is a systematic explanation of the essential features of the X-ray microtomography method, which make it possible to reasonably use comparative analysis before and after conducting an experiment on a test sample.

Based on the data obtained, it can be noted:

Indirectly, the computerized X-ray microtomography method can be used to assess the progress of the distribution of kerogen (the approach works in the absence of carbonate inclusions in the sample).

As is well known, cracks propagate along the path of least resistance; objectively, it should be noted that in this experiment most of the cracks formed only in the marginal parts, and the cracks are practically not observed in the central part. This may be a confirmation of the ideas of Nesterov that pressure inhibits chemical reactions, and in order to overcome the energy barrier, it is necessary to carry out pressure relief [18]. Perhaps as a result of microwave treatment and thermal heating, radical reactions proceeded more actively in the edge parts of the sample than in the central part. In this case, these studies can help explain the abnormally high pressures in low-permeability reservoirs – Achimov deposits, and will also be consistent with the presence of fracture on the wings of deposits.

There are many opinions about the processes of formation of hydrocarbon deposits. The most common is the opinion on thermobaric conditions, i.e., upon reaching specific temperatures (about 300 degrees Celsius) and pressure, the dispersed organic matter begins to generate liquid and gaseous hydrocarbons. This is all confirmed by numerous laboratory experiments, but for some reason, everyone forgets that there are no such temperatures in oil source rocks and there have never been. In this regard, it is possible to agree with the opinion of the correspondent member of the Russian Academy of Sciences I.I. Nesterov that the processes of petroleum generation proceed discretely and most likely the most important role is played by isotopes with an angular electron magnetic effect, on which Anatoly Leonidovich Buchachenko has devoted many works. [19, 20]

4. CONCLUSIONS

The technique of using a comparative analysis of the results of the computerized X-ray microtomography method of the core was used to identify the qualitative characteristics in the structure of the voids of the samples before and after exposure to microwave waves. The obtained results were interpreted and backed up by the judgments of the leading Russian scientists Nesterov and Buchachenko.

As a result of the research, one can draw the following conclusions:

1. The method of computer microtomography is recommended for use in tasks related to the study of the voids of rock samples.
2. It is recommended to conduct additional research in this direction since information is presented only for one experimental sample.
3. The fact of an increase in the diameter of a sample of a cylindrical form of black mudstone of the Bazhenov suite as a result of 8-minute treatment with microwave radiation was recorded.

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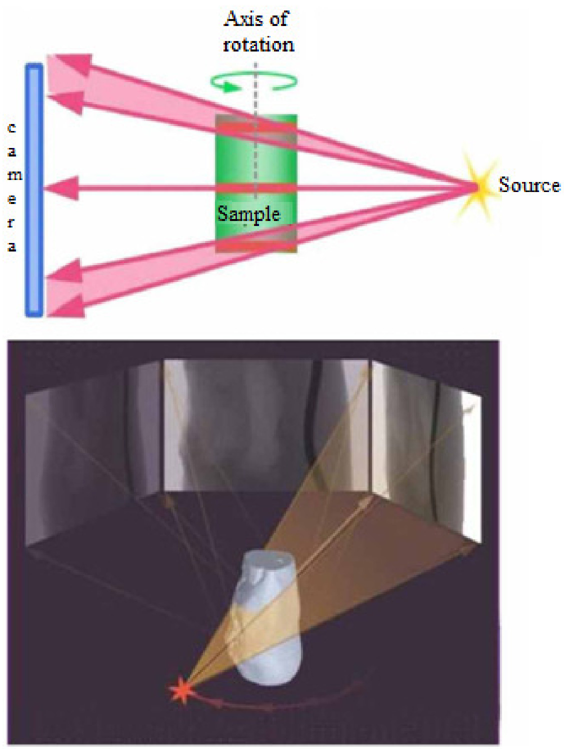

Figure 1. *The principle of the SkyScan 1172 microtomograph operation*

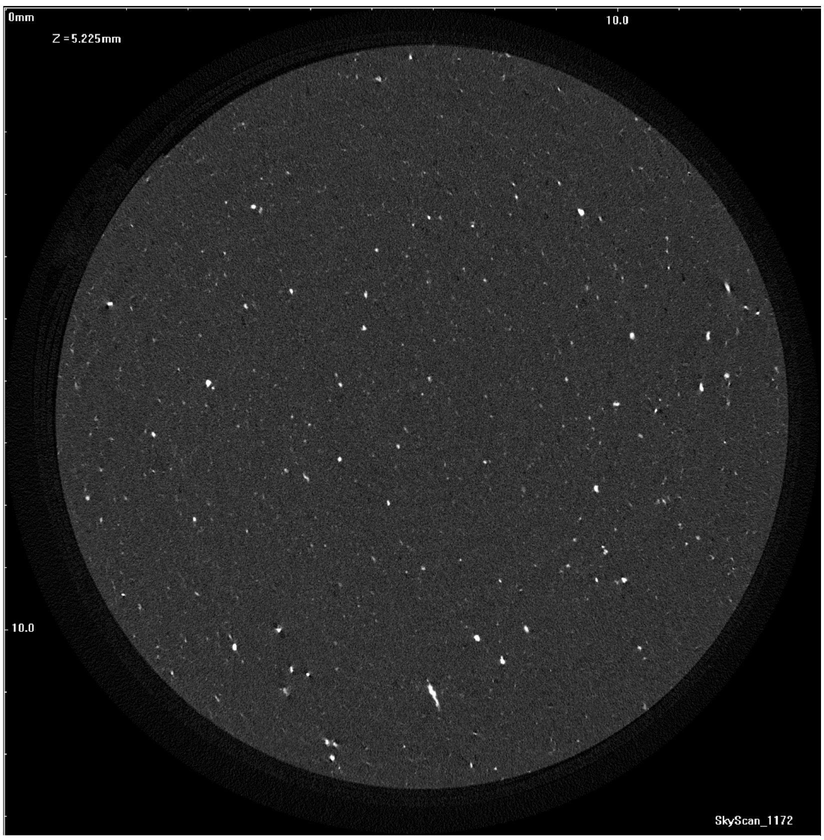

Figure 1. *An example of a qualitative tomographic slice*

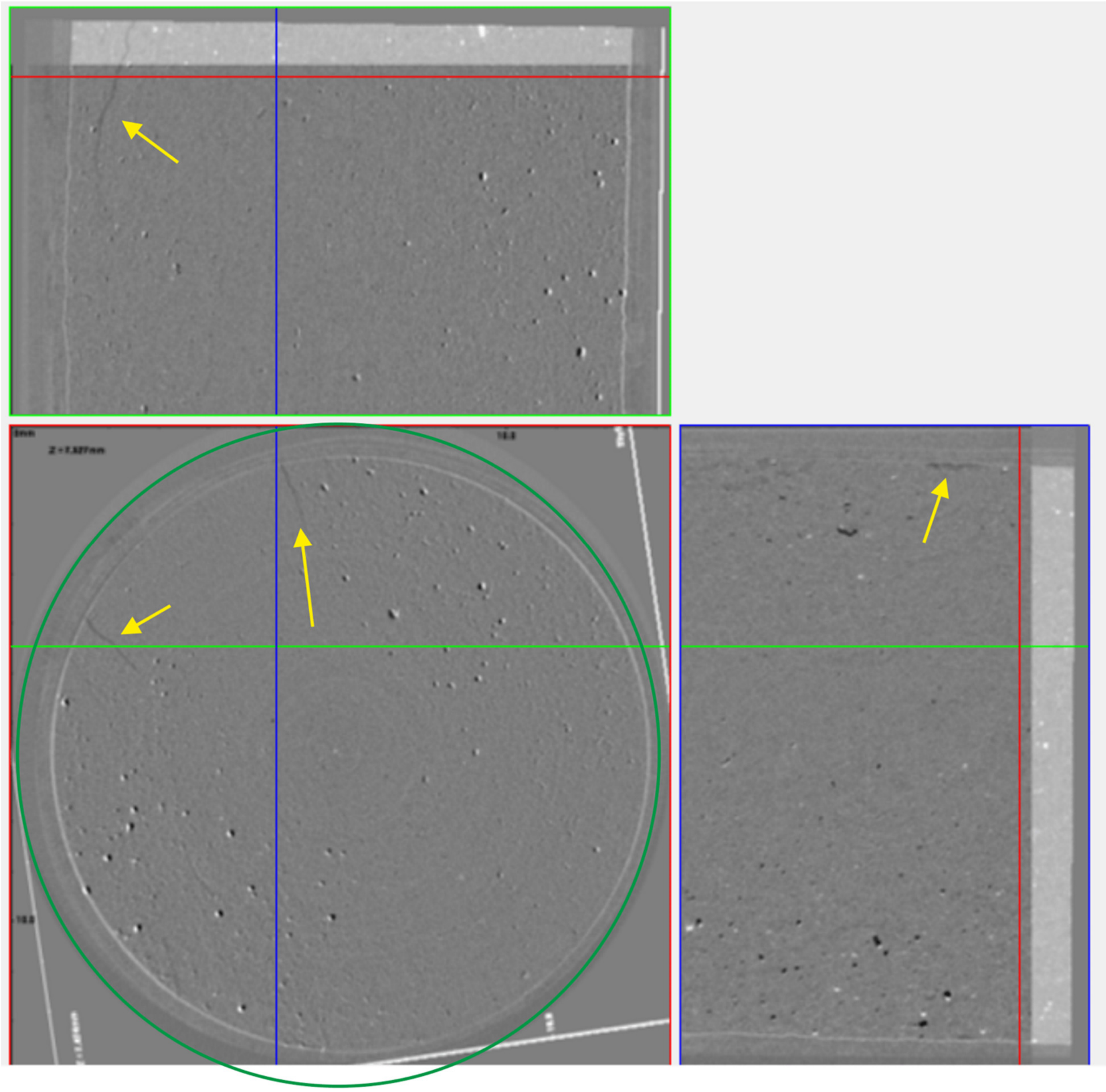

Figure 2. *Orthogonal sections of the combined digital model after performing the logical operation "difference image" (before and after exposure to microwave)*