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New Digital Methods of Estimation of Porosity of Carbonate Rocks

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Abstract

Carbonate stones consist of about 60% of the global reserves of hydrocarbons. The structure of pore space of carbonate rocks considerably differs morphologically and genetically from such one in clastic stones. In the carbonate rocks interconnected and unconnected voids can be equally important. There exists 3D estimation of porosity by the method of liquid saturation, mainly, aimed at interconnected void volume. Digital methods of thin section estimation of porosity make it possible to fix both types of voids and reveal the importance of one or another type in formation of reservoir properties of rocks. It is considered the possibilities of using the program Cluster Image as alternative and express way for estimation of 2D advantages from thin areas of carbonate stones reservoirs by example of Tournasian oil-bearing deposits, penetrated by the well in the southern slope of the South Tatar crest. The program Cluster Image allows avoiding application of estimated percentage of unclassified pixels in the process of estimating photographs of thin porosity carbonate reservoir rocks with significantly lockable voids in the image. It has been determined the specific variations of porosity by well profile depending on lithotypical rocks and structure of void volume. These variations correspond to the zonal structure of natural carbonate oil-saturated reservoir.

Keywords: Carbonate Rocks, Porosity, The Program Cluster Image

1. Introduction

In the carbonate rocks there it is contained ~60% of the world reserves of hydrocarbons[1]. From the point of view of void volume the carbonate rocks are characterized by more complex lithologic structure in comparison with the clastic stones. This complication is specified by the impact of chemical, biochemical, biological and hydrodynamic conditions of settlement. The system producing the carbonate substance has strong chemical and physical influence on formation of pore volume and matrix in carbonate sinter that can cover the influence of gravitational factor. Pore structure in the carbonate stones differs from pore formation in the sand rocks being regulated, mainly, by gravitational layering of fragmental substance that leads to formation of rocks reservoirs of granular type.

Genetic form and heterogeneity of carbonate stones are defined, in instance, in distribution of pore space[2]. Both open and closed pores prevail in the carbonate rocks. The formation of pores, to considerable extend isolated ones, is influenced on algae, brachiopods, mollusks, echinodermata and the other organisms.

Thus, the pore space of carbonate rocks reservoirs is a compound object for genetic reconstruction and quantitative assessment.

There exist 3D estimations of porosity from cylindrical core samples, costly and time-taking (for example, estimation of open porosity by fluid saturation), but 2D estimations of porosity from thin sections (inexpensive and express) also proved to be rather good[3-5]. Let us immediately note that estimations of porosity in these approaches will differ due to primary identification of porosity in 3D method and formation of general porosity in the 2D figure of the thin area.

It is founded of works on the use of software on digital

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fine section photography processing for the purpose of express 2D estimation of porosity of carbonate rocks reservoirs[3,5,6].

In the article[7] we have shown the program MultiSpec feasibilities for fulfillment of the indicated problem.

MultiSpec clusters the user-defined images with parameters[8]. To begin operation with an image saved in JPEG format, it needs to be converted into TIFF, which is possible to do by means of, for example, the program XnConvert. After having downloaded the image to MultiSpec, one can begin the process of clusterization.

Software work can be expressed as: points are divided into different groups according to color and turn one of the bright spectral colors. All of such colors depend on a number of clusters, and convergence sets accuracy of hitting in the range of spectral colors. Minimal dimension of the group lets to adjust all of pixels of one color range without reducing it. The minimum dimension of a range lets you to adjust all of the pixels of the same color range without making it tiny (for expanding the spectrum of hitting pixel). Since the voids of the picture are black, the software should know them as a different range.

The porosity is defined by the scale of pore section to the section of the whole picture, i.e. by the scale of the number of pixels related to pores to the all of pixels.

But, it can be said that the share of pixels related to pores can not remain in the distribution and stay unaccounted. So, all of pixels of the 3th range are taken evaluated share of undistributed pixels (the mean amount of the void scale of the studied sediments based on borehole geophysics ~0.1).

The present paper shows the results of using the program Cluster Image[9] to estimate porosity carbonate reservoir rocks, which avoids the use of the evaluated share of undistributed pixels.

2. The Object of Research

To assess the porosity of thin sections, it was taken the oil-saturated core instances, selected from the well on the southern grade of the Tatar crest from deposits of Kizel horizon of Tournasian tier overlapping with Bobrikovsky clays of the Visean. The carbonate section of Kizel horizon bottom-up is a progradational sedimentary sequence from wackestones to grain stones[7,9]. A characteristic feature of the selected microfacies is the lack of clay materials in the rock composition and the content of micrite component, zoning respectively, decreases up the section[9]. Biogenic components are remnants of the shells of foraminifera, pelecypods, bryozoans, remnants of green algae. Dominating postsedimentary processes expressed in thin sections are the leaching, calcitation, fracturing and stylolization process. Leaching occurs primarily on the aragonite and low-magnesia calcite, metasomatically replaced with calcite. The leaching processes and calcitation are likely to occur already at the stages of diagenesis and early catagenesis with regime change pH. Fractures and movement joints, non-conformal primary biogenic and sediment bioclastic structure and cross elements leaching and calcitation are likely to dominate at the later stages of catagenesis and at the later stages of the species at activation of geodynamic regime. The absence of clay minerals in the rock composition indicates primary pure lime sludge, life-supported with benthic foraminifera, bryozoans, molluscs, green algae. This version of contribution is properties of the carbonate grade[10,11].

The lack of clay parts, a well contrast among the carbonate part (dark section) and pores (black section) in fine areas under crossed Nicols let to take picture of the considered instances for 2D estimation of porosity.

3. Research Methods

The program Cluster Image is created in the programming language Java. The developed program performs clustering of images using the parameters, specified by the user. After opening the program, the image is loaded on the selected parameters shown in Figure1.

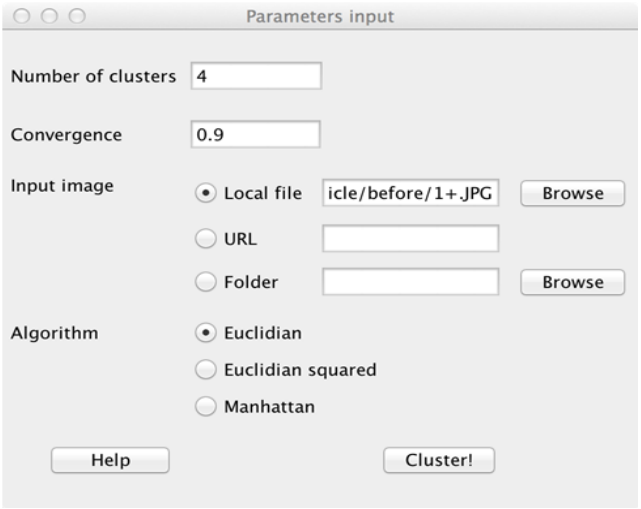

Figure 1. Determination of input parameters in the program cluster image.

It is vital to determine the number of ranges (in this case, it is equal to 4), the convergence rate (in this case, 0.9 = 90%), and also to select an algorithm for estimating the distance between pixels (it is usually the method of the Euclidean distance).

The clustering is based on the algorithm ISODATA, which is preferable due to the iterative properties and higher accuracy[12,13]. It is vital to determine the number of ranges, percent of convergence and smallest cluster dimension in pixels.

Figure 2 shows the photo of the section, downloaded in Cluster Image. The picture was taken with crossed Nicols. The mineral part is colored in light tones, with black pores being stood out-circular VUG on the left and in-mold void in the remnants of foraminifera right are well identified (arr. 124 wells. 1706-b).

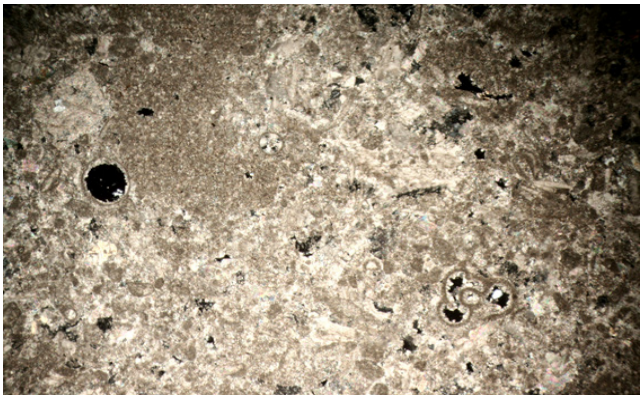

Figure 2. The photo of the section, downloaded in Cluster Image. The picture was taken with crossed Nicols. The mineral part is colored in light tones, with black pores being stood out - circular vug on the left and in-mold void in the remnants of foraminifera right are well identified (arr. 124 wells. 1706-b).

The color of each pixel can be represented as a vector in the RGB three component bases. The result is an image as a group of vectors, which may be classified into sections based on their orientation. The total number of groups is defined by the number of clusters, and the convergence determines the degree of precision in the group and specifies the number of repetitive in the approach.

The program creates a new image, wherein pixels in each range are colored the mean color. With respect to that, the pores in the picture are black; the software can specifies them as part of a particular range shown in Figure 3.

The image is accompanied by a diagram which shows the contribution of each cluster group in the image. Thus, the porosity is measured. In our case it is 7% shown in Figure 4.

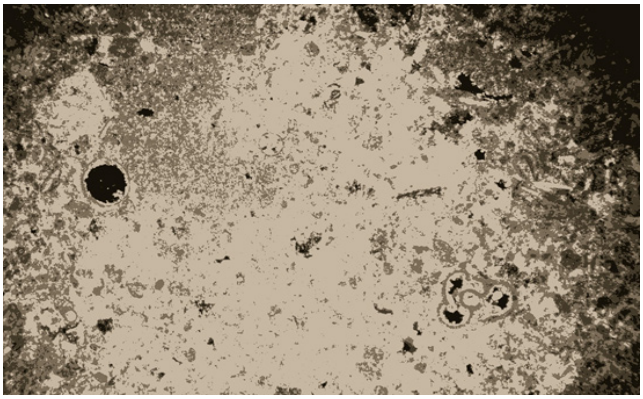

Figure 3. The photo arr. 124, obtained in Cluster Image: black-pores.

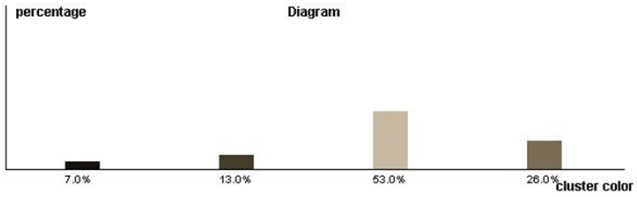

Figure 4. Distribution of cluster groups in the image, arr. 124 porosity 7%.

4. Research Results and Discussion

Figure 5 shows the variation of 2D porosity evaluation based on Cluster Image and 3D porosity evaluation according to the method of fluid saturation.

In general, variations orientation of 2D measurement of porosity correspond to the nature of 3D estimation of porosity shown in Figure 5 and reflect the presence of four porous zones where oil saturation decreases down the section of the zone A to zone D are shown in Figure 5. The difference between the values of the parameters under consideration takes a different sign, which is associated both with the methodological features used according to the methods for assessing the porosity and the nature of the void space. The method of fluid saturation gives significant errors in the measurement of open porosity and fine areas are measured by all the porosity and evaluation is two-dimensional. So, it needs that a main increment of 2D of

porosity over 3D evaluation of porosity assessment in the instances with cavities and cracks, as well as in samples with a high degree of isolated and (or) subcapillary pores. In this paper, this increasing is strongly because of the cavernous and fracturing processes shown in Figure 5. If the 2D porosity estimate is below the 3D one, it proposes not only methodical properties, also a main variation stone fragments being investigated by the approach for fluid saturation and the technique for estimating porosity in thin sections.

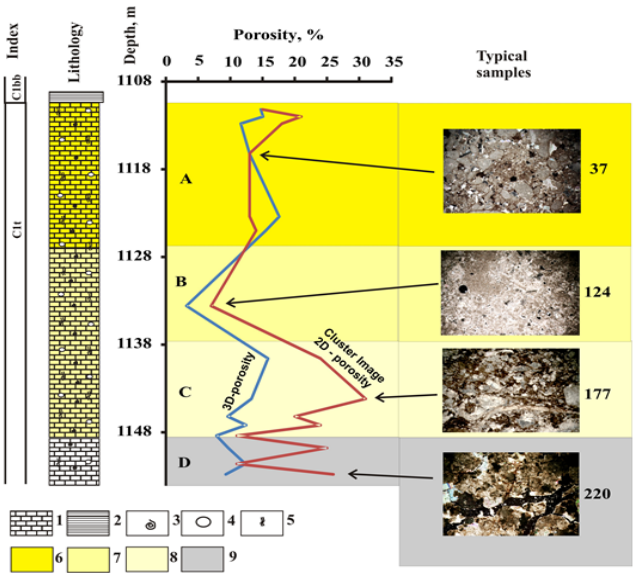

Figure 5. The section of the borehole, the variations of 3D and 2D porosity on section. Notation conventions: 1 – sandstones, 2 – limestones, 3 – fossils, 4– caverns, 5 – fractures, 6-9 – zone of decrease of intensive oil saturation (A) to absent (D).

The formation of voids under review of section of carbonate rocks is, obviously, to a greater extent due to the processes of formation of secondary porosity[10,11]. This limestone with a long history of lithogenetic already consisting of low magnesia stable calcite and lithogenesis undergone to the changes at the later stages, under the influence of supersaturated solutions. In the studied section, secondary porosity was probably to be formed in a multiphasic way by both models of multimineral and stabilized limestones, wherein porosity distribution in the section (at least four zones A-D) shows the effect of a greater degree of tectonic processes during the formation of voids. Indeed, the erosion boundary between Tournasian limestone and Bobrikovsky clay is hardly expressed and the influence of supergene meteoric agents in the formation of porosity is limited shown in Figure 5.

5. Summary

- The program Cluster Image makes it possible to capture structured and unstructured types of voids and avoid the use of unclassified estimated percentage of pixels in the process of assessing the porosity from the photographs of thin carbonate reservoir rocks with reliably established voids in the image.
- According to the evaluation of the porosity of carbonate rocks using Cluster Image it is identified specific variations of the indicated capacitive parameter of the borehole section, depending on the rock lithotype and the structure of voids. These variations correspond to the zonal structure of natural oil-saturated carbonate reservoir created by the particular lithogenetic history of Tournaisian deposits in the east of the Russian Plate.

6. Conclusion

The void fraction of oil-saturated carbonate stones with a powerful color contrast among the mineral section and void volume in fine areas under polarized light can be numbered and evaluated by utilizing Cluster Image. The results of this evaluation are utilized to specify section and explanation of the genesis of porosity of carbonate reservoir stones.

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