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CLUSTER IMAGE PROCESSING TECHNIQUE FOR POROSITY ESTIMATION OF CARBONATE ROCKS

N. D. Nurgalieva[1] and N. G. Nurgalieva[2]
[1]Department of General and Applied Physics, The Moscow Institute of Physics and Technology, Russia
[2]The Kazan Federal University, Insitute of Geology and Oil & Gas Technologies, Russia
E-Mail: nurlit@yandex.ru

ABSTRACT

It is known that the exact value of rocks porosity is difficult to measure. In present paper it is proposed using Cluster Image processing technique which is considered as cost-effective alternative direct method for estimating 2D-porosity from thin sections images of carbonate rocks on base of core samples picked out from carbonate reservoir rocks of Tournasian age in well, situated on southern slope of South-Tatarian Arch (Volga-Ural region, Russia).

Keywords: porosity, carbonate rocks, Cluster Image processing system.

1. INTRODUCTION

In paper [1] MultiSpec system was used to estimate porosity of carbonate rocks. It includes cluster data using either a single pass or an iterative (ISODATA) clustering algorithm; saves the results for display as a thematic map. Cluster statistics can also be saved as class statistics. Use of clustering followed by ECHO spectral/spatial classification provides an effective multivariate scene segmentation scheme [2]. To get started with an image stored in JPEG, it is necessary to convert it to the format TIFF, which can be accomplished by, for example, program XnConvert. By downloading the image in MultiSpec, the process of clustering can be initiated.

To process clustering ISODATA algorithm is preferred because it is iterative and more accurate. It is necessary to specify the number of clusters, the percentage of their convergence and the minimum size of one cluster (in pixels).

Elementary operation of the program can be described as following. Pixels are divided into separate groups (or the image is divided into sections) on the basis of similarity of color and painted in one of the bright spectral colors. The total number of colors is given by the number of clusters. The convergence specifies accuracy rate within the range of spectral colors. The minimum size of the cluster allows adjusting the total number of pixels of the same color spectrum, without making it too small (to expand the range of pixels location). Since the pores in the photo are black, the program can recognize them as a separate group.

It was obtained the desired image in the spectral colors. The spectral color, which marked the pores, is red. It is the set of pixels of third cluster.

The output text is the final clustering statistics, which reports the number of pixels that correspond to each spectral color, as well as the number of pixels which in one way or another are not included in the classification of the percentage of convergence.

Porosity is determined by the ratio of pore area to the total area of the image, i.e. the ratio of the number of pixels corresponding to pores to the total number of pixels.

However, it should be noted that the pixel portion corresponding to pores cannot fall into the classification and remain unrecorded. Therefore, to calculate the total number of pixels of the third cluster we take the estimated percentage of unclassified pixels (average value of the porosity of studied rocks according to geophysics ~ 0.1).

Thus, to calculate the porosity of the rock from information provided by the program MultiSpec, the following formula was used:

$$\text{Porosity (total)} = (a + 0.1 * b) / c$$

where
a = number of pixels of the third class,
b = the number of unclassified pixels,
c = the total number of pixels.

In present paper we used program Cluster Image which was created in Java especially to process thin section of carbonate rock with to estimate its porosity on image of any format and with a strong color contrast between the mineral part and pores in thin sections under polarized light.

2. SAMPLE CHARACTERISTICS

For the experiment the images of samples from [3] were used. The 3D of interconnected porosity by liquid injection porosimetry and 2D porosity by MultiSpec processing technique have been already probed for these samples from Tournesian carbonate rocks [1]. From bottom to top carbonate section is interpreted as progradational sedimentary sequence of limestones from wackstones to grainstones. The limestones consist of low-magnesium calcite. A characteristic features are the absence of clay minerals in the rocks and micrite decreasing upward in the section. The biogenic component is represented by the forams, bryozoans, algae fossils. Samples are also characterized by vugs, fractures, stylolites, secondary calcite are non-conforming to primary structure of rocks. The absence of clay components, good contrast between the carbonate component (light colored areas) and pores (black areas) in

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thin sections under polarized light allow to take images of samples in order to test Cluster Image program for 2D porosity evaluation.

3. THIN SECTION IMAGE ANALYSIS

Cluster Image program was created in Java. Cluster Image does picture clustering with parameters given by user. After opening the program the picture should be downloaded and parameters should be chosen (Figure-1).

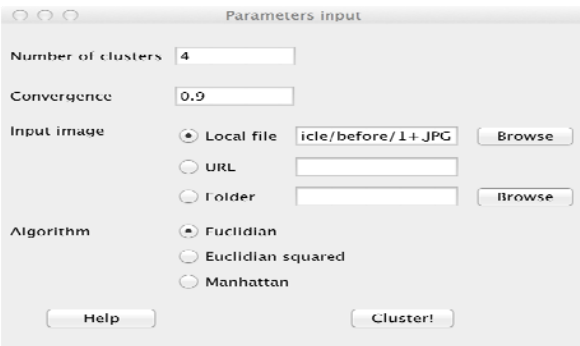

Figure-1.

The picture (for example thin section photo in polarized light – Figure-2) can be downloaded in any format; also a folder or an URL address containing pictures can be chosen as a material for clustering. It is necessary to specify the number of clusters (in our case number of clusters is 4), the percentage of their convergence (0.9 = 90%) and algorithm which estimates the distance between pixels (euclidian distance).

Figure-2. Photo of the thin section is loaded in Cluster Image. Photo is obtained under polarized light. Mineral part is light colored area and porosity is dark colored area (sample No 58).

Clustering algorithm repeats ISODATA. To process clustering ISODATA algorithm is preferred because it is iterative and more accurate [2]. It is necessary to specify the number of clusters, the percentage of their convergence and the minimum size of one cluster (in pixels).

Each pixel's color can be represented as vector of three components in RGB basis. As a result, the picture is a set of vectors which have to be divided into separate groups according to their coordinates. The total number of groups is given by the number of clusters, while the convergence specifies the accuracy rate within the group and bounds the number of algorithm iterations. The distance algorithm can also be changed; each of this algorithms (Euclidian, Euclidian squared, Manhattan) makes the pixels' contribution a bit different.

The program creates a completely new image in which pixels of a particular group are all colored in average color of the group. Since the pores in the photo are black, the program can recognize them as a separate group (Figure-3).

Figure-3. Received image from thin section photo of sample No 58 (Figure-2): pores are black.

If needed, the input image can be displayed to compare it with the clustered one.

Also the diagram can be built, on which each cluster's contribution percentage is shown. Thus, the estimated porosity is determined by the contribution of a cluster which color is the closest to black - the color of pores (Figure-4). In our case, the porosity value estimated by the program is 14%.

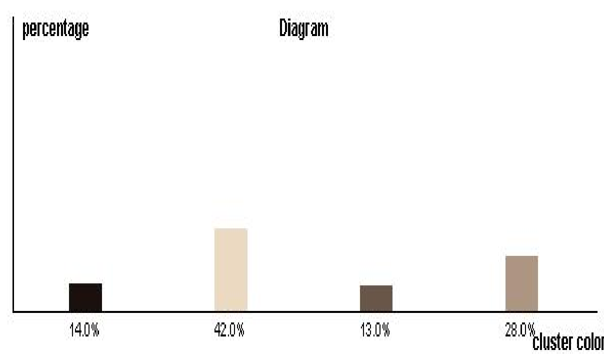

Figure-4. Cluster's contribution percentage for image from thin section photo of sample No 58. Porosity value estimation is 14%.

4. RESULTS AND DISCUSSIONS

Figure-5 shows the results of typical thin sections imaging using Cluster Image processing system. On Figure-6 one can see the change of 2D-porosity after Cluster Image using in comparing with results received by Multi Spec program and liquid injection method [1].

All types of porosity estimation variations reflect the presence of two porous zones. Upper zone (1947-1953 m) and lower zone (1953-1959 m) are characterized more and less oil saturation respectively (Figure-6).

The difference between 2D and 3D porosity is predominantly positive that depends on type of rock and porous space and methodical differences. Liquid injection method gives insufficient results in case of (connected) porosity measurement in the cavernous and fractured samples. In thin sections the total two-dimensional porosity is measured. Therefore it should be expected a significant excess of 2D evaluation of porosity on the 3D evaluation of porosity in the samples with caverns and fractures, as well as in samples with a high proportion of isolated and (or) small pores. In investigated case exceeding is mainly due to the vugs, caverns and fractures [1]. 2D porosity by Cluster Image technique is characterized by higher values in comparing with 2D porosity by MultiSpec technique. It can be explained by fact that the pixel portion corresponding to pores cannot fall into the classification and remain unrecorded in case of Multi Spec technique. If the 2D evaluation of porosity below the 3D evaluation of porosity, it can indicate not only on methodical features, but also a significant difference rock fragments analyzed by liquid injection method and method of thin sections imaging. However, in common, all estimates indicate increased porosity of upper carbonate zone as compared to lower.

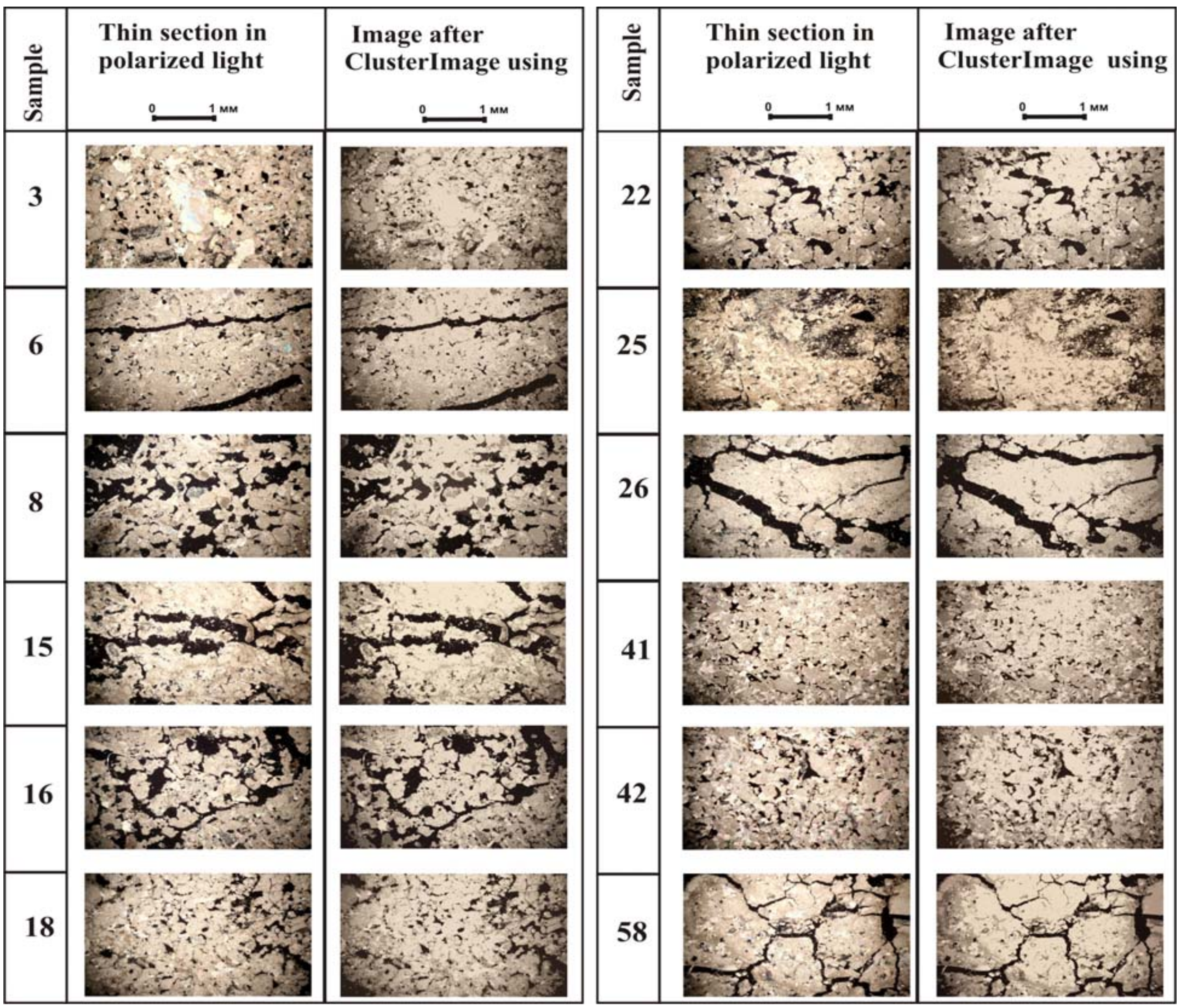

Figure-5. Demonstration of typical samples of Tournasian carbonate section (see Fgure-6).

The geological nature of these zones has been already explained in [1]. Porosity of investigated carbonate rocks is composed of primary and mostly secondary pores because the primary porosity reduced by cementation and compaction during post-depositional burial. Investigated carbonate reservoirs lay beneath unconformity. The porosity values are higher in zone associated with unconformity. Therefore, secondary porosity can be explained by meteoric eogenetic or telogenetic environment. Investigated carbonate rocks consist of mineralogically stabilized to low-magnesium calcite and can be correspond to late eogenetic or telogenetic freshwater exposure of older limestones. Particle selective pores, vugs and caverns formed in these rocks.

Part of secondary porosity (vugs, caverns and fractures) can form in mesogenetic environments in which most fluids are brines that typically are saturated with respect to calcium carbonate. Therefore, these fluids are not capable of dissolving carbonate rocks and creating secondary porosity. Rather, such fluids tend to form dolomite. In investigated limestones there is no dolomite. Carbonate dissolution and porosity formation in deep-burial environment can be due by hydrocarbons history. It is known that carbon dioxide, hydrogen sulfide, and organic acids are formed during maturation of organic matter to hydrocarbons in source rocks. Together these gases and acids can move long distances vertically and laterally to dissolve buried carbonates just ahead of migrating hydrocarbons.

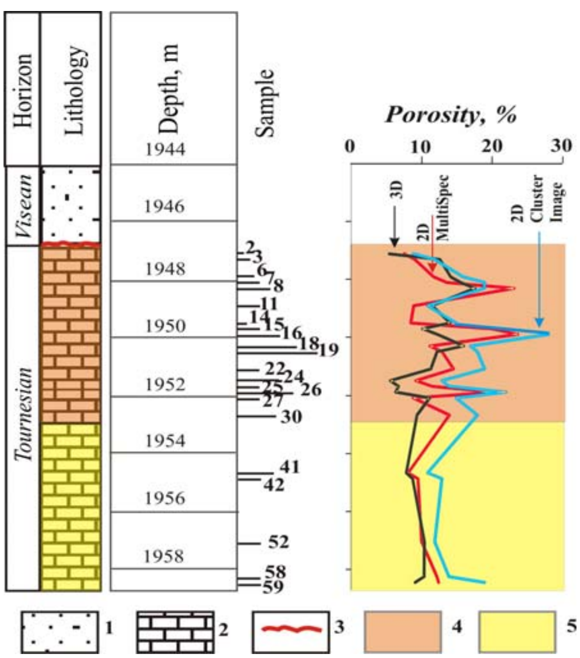

Figure-6. The geological section of well, 3D and 2D-porosity variations along the section.
Legend: 1 - sandstones, 2 - limestone, 3 - unconformity, 4 – high oil saturation, 5 – low oil-saturation.

5. CONCLUSIONS

The porosity of oil-saturated carbonate rocks with a strong color contrast between the mineral part and pores in thin sections under polarized light can be digitized and estimated using Cluster Image program. This estimation can be used to identify zoning and interpretation of porosity genesis within carbonate reservoir rocks.

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