

Thin Sections Images Processing Technique for the Porosity Estimation in Carbonate Rocks

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Abstract. In present paper we used program Cluster Image which was created in Java to process thin section image of carbonate rock 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. For the experiment the images of thin sections of carbonate rocks of the Carboniferous age were used. Cluster Image does picture clustering with parameters given by user. After opening the program, the picture should be downloaded and parameters should be chosen. A thin section photo in polarized light 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. To process clustering ISODATA algorithm is preferred because it is iterative and accurate. 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 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. Digital estimation of porosity was made for cores from two wells in comparison with liquid injection method of porosity measuring. The features of digital porosity were explained by porosity genesis.

1 Introduction

Digital estimation of porosity of carbonate rocks 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 (Nurgalieva et al. 2014; 2015; 2016).

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) (Nurgalieva et al. 2016).

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.

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).

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.

Carbonate rocks are characterized by voids of different genesis (Mazzullo 2004; Nurgalieva 2012; Nurgalieva et al. 2016).

Porosity of carbonate rocks is composed of primary and mostly secondary pores because the primary porosity reduced by cementation and compaction during post-depositional burial. Tournaisian carbonate reservoirs in Southern slope of South-Tatar Arc (Republic of Tatarstan, Russia) lay beneath unconformity (Nurgalieva 2012; Nurgalieva et al. 2015). 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. Regularities and differences in 2D and 3D porosity distribution are caused by complicated combination of primary and secondary porosity.

In this paper we continue to study these features of Tournaisian carbonate rocks of Southern slope of South-Tatar Arc on example of new log.

2 Object of Research

The carbonate section of Tournaisian rocks was probed in interval of Kizelian horizon. In common it is a progradational sedimentary sequence bottom-up from wackestones to grainstones. 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. 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, calcitization, fracturing and stylolization process. Leaching occurs primarily on the aragonite and low-magnesia calcite, metasomatically replaced with calcite. The leaching processes and calcite mineralization are likely to occur from the beginning of diagenesis with regime change pH. Fractures and movement joints, non-conformal primary biogenic and sediment bioclastic structure and cross elements leaching and calcite mineralization are likely to dominate at the later stages of diagenesis 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, supported with benthic foraminifera, bryozoans, molluscs, green algae. This version of contribution is properties of the carbonate grade.

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 Method

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

The photo of thin section in cross nicols is downloaded in Cluster Image (e.g. photo A on Fig. 1). 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 (Nurgalieva et al. 2015).

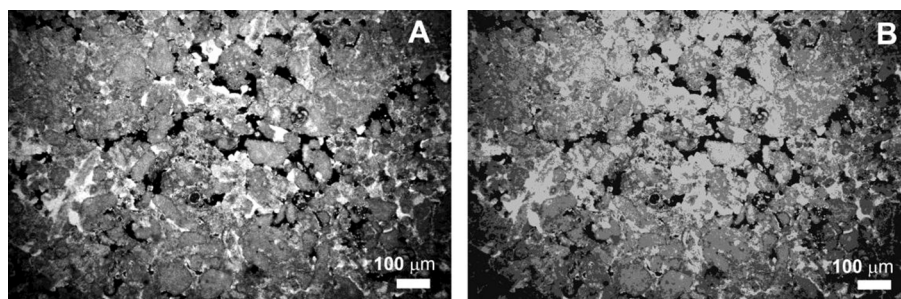


Fig. 1. The images of thin section of carbonate rock (depth 1205,8 m): A – before processing; B – after processing

The program creates a new image, wherein pixels in each range are colored the mean color (photo B on Fig. 1). With respect to that, the pores in the picture are black; the software can specify them as part of a particular range.

The image is accompanied by a diagram which shows the contribution of each cluster, e.g. porous space, group in the image (Nurgalieva et al. 2015).

4 Research Results and Discussion

Figure 2 demonstrates the variation of 2D porosity evaluation based on Cluster Image and 3D porosity evaluation according to the method of fluid saturation. Variations of 2D porosity can be considered as reflecting more or less 3D porosity. The difference

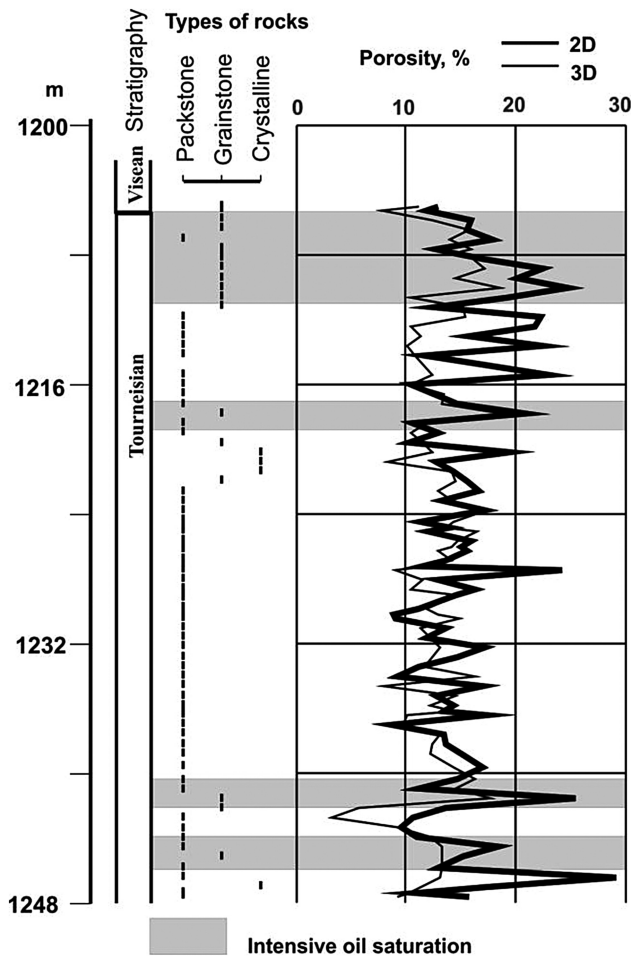


Fig. 2. The well section: comparing of porosity estimation by method of liquid saturation (3D porosity) and Cluster Image processing (2D porosity)

between two types of porosity associates both with the methodological features used according to the methods for measurement the porosity and the nature of the void space. The method of fluid saturation estimates only open porosity in large pores. Digital 2D method permits to estimate all porous space. The difference between these types of estimation depends from types of carbonate rocks (e.g., grainstones, packstones or crystalline rock). In grainstones this difference is less than in packstones and crystalline rocks. Oil saturation zones are also characterized by less deviation of 2D porosity from 3D porosity. It points on higher reservoir properties in rocks with structural type of porous space in comparing with non-structural type of this one.

The Tournaisian limestone lithogenesis was controlled by sedimentation and diagenesis due by supersaturated solutions. In the studied section, secondary porosity was probably to be formed in a multiphase way by both models of multimineral and stabilized limestones, wherein porosity distribution in the section 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. The erosion boundary between the Tournaisian limestone and the Visean clay is hardly expressed by the influence of supergene meteoric agents (Nurgalieva et al. 2015, 2016). Particle selective pores, vugs and caverns formed in these rocks. Regularities and differences in 2D and 3D porosity distribution are caused by complicated combination of primary and secondary porosity.

5 Conclusion

The program Cluster Image helps to differ 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 photos of thin sections of carbonate reservoir rocks with reliably established voids in the image.

According to the estimation of the porosity of carbonate rocks using Cluster Image it is identified specific variations of the indicated capacitive parameter of the well 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 rocks in the east of the Russian Plate.

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