QUANTITATIVE CHARACTERIZATION OF CARBONATE PORE SYSTEMS ON JONGGRANGAN FORMATION USING DIGITAL IMAGE ANALYSIS (DIA)

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ABSTRACT

Jonggrangan Formation is characterized by major occurrence of reef limestone and small portion of bioclastic limestone that were well exposed at Samigaluh Area, Kulon Progo Regency, Daerah Istimewa Yogyakarta Province. These carbonates have a wide variety of pore systems that imprint different petrophysical properties, which are more difficult to predict than in siliciclastics. Digital Image Analysis (DIA) can be applied to respond the carbonates complexity by calculating pore value and also characterizing the pore shape in digital form. The method is based on images from rock thin sections taken under an optical microscope (OM) and also core analysis results to be compared. Sixteen rock thin section samples have been analyzed with several observation representatively in order to mitigate the effect of area selection problems. Blue-dyed liquid also has been added to those thin section samples, so the pore could be identified clearly. Based on further examination, both primary and secondary pore systems are well developed. There are six pore shapes are identified within different pore values. Crossplots of pore values indicate the pore variety depends on several rock parameters. In summary, understanding characterization of carbonate pore system on Jonggrangan Formation by using DIA method is fast and accurate, useful to encourage and enrich carbonate petrophysical analysis concept.

I. INTRODUCTION

The carbonates are influenced greatly by sea level fluctuation which recorded on rock textures. Pore system in carbonate is much more complex than siliciclastics, as a result of overwhelming biological origin of carbonate sediments that reflected by the occurrence of porosity within grains, growth framework porosity within reefs, and the common development of secondary porosity due to pervasive diagenetic processes (Choquette and Pray, 1970). In addition to traditional descriptive and qualitative porosity evaluations, there exists a need for quantitative methods that characterize the various aspects of pore space and enable a quantitative assessment of the distribution of porosity and other physical properties (Anselmetti et al., 1998). This Paper discusses about evaluating pore characteristic quantitatively on carbonates using digital image analysis (DIA) which well-established method of quantifying pore space from images of thin sections. Numerous researches were conducted over time to classify pore structure. Anselmetti et al. (1998) quantified the pore shape in carbonates from digital images obtained by optical microscope and Scanning electron microscope. Castro (2013) determined Gamma parameter (ratio between pore perimeter and area) and correlated it with permeability measurements. In this study, authors try to enlight about relationship several parameters toward carbonate facies and pore type based on thin section and supported by core analysis.

Jonggrangan Formation is one of many carbonate facies that well exposed in Indonesia, particularly in Java island, has been elected to be analyzed. Carbonate reef on Jonggrangan Formation may lead us to understand more about the development of carbonate pore system.

II. REGIONAL GEOLOGY

The study area belongs to Kulonprogo Sub-basin, the eastern part of South Central Java Basin. This basin is located on the southern
portion of modern Java Volcanic Range and could be identified as well as Basin lies on Magmatic Arc. Volcanic activity which is occurred was the result of subduction beneath the Hindia Ocean. Thus, this basin is classified as fore arc basin since it’s location is in front of Java Volcanic mountain range. The oldest Formation in this area is Middle Eosen Nanggulan Fm. which is well exposed on Nanggulan Village. This Formation is typified by the occurrence of intercalation of sandstone, shale, claystone and lignit which is deposited on paralic depositional environment. Lies conformably above Nanggulan Formation is Kaligesing Fm. consisted of volcanic breccia and intrusion. Since no fossil could be attained from this formation, it is assumed as Oligosen Age formation. Another formation which is deposited on the approximate same time with this formation is the polymict breccia Dukuh Fm. Dukuh Formation consists of polymict calcareous breccia with interbedded sandstone and claystone, interpreted as shallow marine sediments. Dukuh Formation and Kaligesing Formation has interfingering stratigraphic relation. Lies unconformably above Kaligesing Formation are two distinctive carbonate formation, Sentolo Fm. and Jonggrangan Fm. Sentolo Fm, typified as clastic carbonate formation, consist of intercalation of calcarenite, calcilutite, and marl. The abundant fossil content in this formation allowed a firm depositional environment interpretation of this formation, as well as the Age of this formation. Sentolo Formation deposited on Neritic-upper Bathyal environment. On the other hand Jonggrangan Fm., the focus of this study is characterized by the occurrence of reefal limestone which depict various carbonate facies. Jonggrangan Fm. is interpreted as a patch reef deposited on shelf area. Sentolo and Jonggrangan have interfingering relation. (Pringgoprawiro and Riyanto, 1968).

III. SAMPLE AND RESEARCH METHOD

Sixteen rock thin section samples have been analyzed with several observations representatively in order to mitigate the effect of area selection problems. Blue-dyed liquid also has been added to those thin section samples, so the pore could be identified clearly. The DIA (digital image analysis) method is based on images from rock thin sections taken under an optical microscope (OM) and also core analysis results to be compared. The method comprises of three steps: image acquisition, segmentation, and calculation of pore parameters. Image acquisition takes approximately 10 – 15 minutes per sample, with additional time needed for image analyses and statistical evaluations. The segmentation process is the separation of a specific feature from the background and it was performed on colored digital images acquired in standard RGB (red-green-blue) which were converted to a binary 8-bit BW (black and white) format to identify respectively, the pore and the matrix/cement. In this study, the object feature of segmentation was the rock pore that was quantified and its geometry parameterized. In addition, the image analyses program authors used (Image J) is freely available as public domain software. Then calculation process uses mathematical programs in order to create crossplots for several parameters.

IV. DATA AND ANALYSIS

Several parameters defined in the DIA to quantify pore space. Two DIA parameters, Dominant pore size (DOM) and Perimeter over area (PoA), are proved to best describe several aspects of pore system, namely facies, pore type, porosity (Φ) and permeability (K). Theoretically, dominant pore size (DOM) is determined as the upper boundary of pore sizes of which 50% of the porosity on a thin section composed. Half of the pore space of an area is composed of pores as big as or
smaller than the DOM. Whereas, Perimeter over area (PoA) is the ratio of the sum of total perimeter of the pores and total pore area identified in the thin section. It describes how complex is the porous system independent of total porosity.

Based on further examination from outcrop, core (polished slab) and thin section data, eight lithofacies have been determined (Figure 1 &2). Six pore types also have been observed which are Vuggy, Moldic, Intraparticle, Interparticle, Channel, and Growth-Framework. The quantitative results show that visible porosity (Φ) varied between 1.87 – 34.7 % and permeability (K) varied between 44.68 – 151.68 md (Table 1). Based on crossplot both visible and measured porosity vs perm, there is no relationship between these parameters.

DOM varied between 157 - 1100 µm². Crossplot of porosity vs permeability with according to DOM values in figure 3 shows that for a given porosity, the high DOM values indicate the presence of large pores in the thin section as observed in Figure 4.A, where a grainstone facies with vuggy pore type displays DOM 1100 µm². At the same porosity, the smaller value DOM, smaller pore size is and the larger number, larger the pore size is.

The PoA varied between 75.5 - 166 mm⁻¹. Figure 5 shows crossplot of porosity vs permeability with according to PoA values. Figure 4.B shows the high PoA value, 139.5 mm⁻¹, for a thin section of a framestone facies with growth-framework porosity. At the same porosity, the smaller PoA, the simpler pore geometry is and the larger number, the more intricate pore geometry.

V. DISCUSSION

Linkage of measured pore with visible pore

Both visible porosity and measured porosity show the different values on several samples (Figure 6). It is result of the effect of area selection for 2 cm x 2 cm thin section samples, does not represent the whole porosity characteristic of carbonate rock. The difference value is a possibility, because on carbonate facies, the secondary porosity (eg: vuggy, moldic, and channel) are subsequently well developed on Jonggrangan Formation. Simply put, scale of observation and area selection take an important play.

Linkage of facies with porosity and permeability

Facies is known as one factor which control petrophysical values such as porosity and permeability. However the extent of facies control on porosity is constraint by several aspects. In order to prove the hypothesse, the cross-plot of lithofacies toward porosity and permeability has been done (Figure 7). It shows that the lithofacies influence on porosity and permeability is not linear. Simply put, there are several samples of the same lithofacies type which possessed different petrophysical values. For example, grainstone (red symbol) present the lowest porosity and lowest permeability but the other grainstone present higher result with different value significantly. These condition, by far are controlled by diagenetic processes. A carbonate rock has its own sedimentation history both syn depositional or post depositional. The petrophysical values can be better when dissolution happen but it can be worst while recrystallization occur, such as porosity, will be enhance by dissolution process, while recrystalisation does the opposite.

Linkage of pore type with DOM and PoA

In general, grainstones with large secondary pores (vuggy) had high DOM and low PoA. Otherwise, fine grained facies which are packstones and wackestones supported by microporosity had high PoA and low DOM. Figure 8 shows a summary of these result, crossplot of DOM vs PoA plot for all thin sections analyzed and a few images of the sections indicating the respective PoA and DOM parameters.

VI. CONCLUSIONS

This study concludes that:
• Carbonate pore system is more complex than siliciclastics.
• Digital image analysis method is useful to encourage and enrich carbonate petrophysical analysis concept.
• The geometric DIA parameters that varied better able to quantify the differences in pore type of the thin sections study are dominant size (DOM) and perimeter of area (PoA) which could be used to identify high and low porosity.

VII. ACKNOWLEDGEMENT
Authors would like to acknowledge to Geological Engineering Department of UPN “Veteran” Yogyakarta for the support and also to Sedimentology Lab. for facilitating the laboratory analysis.

REFERENCES


TABLES

<table>
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<tr>
<th>Sample Code</th>
<th>Lithofacies</th>
<th>3D Φ (%)</th>
<th>3D Visible Φ (%)</th>
<th>Main Pore Type</th>
<th>DOM (µm²)</th>
<th>PoA (mm⁻¹)</th>
<th>Perm (md)</th>
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<tr>
<td>Ari 1</td>
<td>Wackestone</td>
<td>5,7</td>
<td>15,63</td>
<td>Vuggy</td>
<td>202</td>
<td>144</td>
<td>49,98</td>
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Φ: porosity; DOM: dominant pore size; PoA: perimeter over area; Perm: permeability.

FIGURES

Figure 1. (From left to right) Integration of outcrop, core (polished slab) and thin section data.

Figure 2. Core-plug sample and tools for measuring porosity analysis to support DIA result.
Figure 3. Crossplot of porosity vs permeability with according to DOM values. The high DOM values indicate the presence of large pore size, and lower DOM values indicate the opposite.

<table>
<thead>
<tr>
<th>Lithofacies</th>
<th>Main Pore Type</th>
<th>Avr. Porosity</th>
<th>DOM</th>
<th>PoA</th>
<th>K</th>
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<tr>
<td>Grainstone</td>
<td>Vuggy</td>
<td>34.7 %</td>
<td>1101 µm²</td>
<td>105 mm¹</td>
<td>75.43 md</td>
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<tr>
<td>Framestone</td>
<td>Growth-Framework</td>
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</tbody>
</table>
Avr. Porosity = 22.59 %
DOM = 366 µm²
PoA = 137.5 mm⁻¹
K = 69 md

Lithofacies = Packstone
DOM = 345 µm²
Main Pore Type = Channel
PoA = 139.5 mm⁻¹
Avr. Porosity = 10.74 %
K = 118.26 md

Figure 4. Photomicrographs show three samples section of pore system (left) in which porosity is shown as blue, and digital image analysist result in BW-image (right) which porosity is shown as black and matrix is white. (A) Grainstone facies, (b) Framestone facies, and (c) Packstone facies.

Figure 5. Crossplot of porosity vs permeability with according to PoA values.
Figure 6. Comparison of measured porosity values obtained from core-plug analysis and porosity values obtained from digital image analysis for various pore type. There is no linear caused by nonrepresentative observation area of view under optical microscope.

Figure 7. Crossplots of measured pore vs permeability (left) and visible pore vs permeability (right) for various facies. Both crossplots illustrate that the extent of facies control on carbonate pore system is constraint by several aspect.
Figure 8. Crossplot of dominant size (DOM) vs perimeter of area (PoA) plot for all thin sections analyzed and a few images of the sections indicating the respective DOM and PoA parameters.