ROCK QUALITY GROUPING IN SANDSTONE FORMATION USING A CRITICAL POROSITY APPROACH AT FORMATION PRESSURE CONDITIONS

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ABSTRACT

The methods of grouping reservoir rock types based on the physical properties of rocks that have been studied by previous researchers still have a relatively large value of uncertainty. This uncertainty arises in conditions where rock type grouping is carried out in wells that do not have core sample data. Where we know that in the oil and gas field, not all wells in the field are subjected to rock sampling, either routine core analysis or special core analysis. From these problems, the authors feel the need to carry out this study to create a method for classifying reservoir rock types based on the physical properties of rocks that can be used in wells that do not have core sample data. The rock types in the wells that do not have core samples will be grouped based on the critical porosity value of the rock obtained from the vp value in the acoustic log data owned by these wells. By making an approach model through the critical porosity of rocks from wells that have core sample data, wells that only have acoustic log data can be grouped by using the critical porosity approach which is generated from the vp value of the acoustic log.

Keywords: acoustic log, core sample data, critical porosity, rock physic, and rock type grouping,

INTRODUCTION

Each rock has different geometric characteristics and pore structures between one rock and another. The different characteristics of each rock can be grouped into rock groups that have similar rock quality. Previous researchers have conducted a lot of research in terms of grouping rock quality, such as Guo, G. et al. (2005) who proves that the geological process of rock deposition will affect the physical properties of rocks, (Guo, G. Et al, 2005) then Amafule (1993) made a hydraulic flow unit equation that classifies rock types against their hydrolic flow unit (HFU), each HFU has a proximity flow zone indicator (FZI). (Amafule, 1993). Wibowo and Permadi (2013) made a rock grouping approach to the pore structure and pore geometry of rocks, (Wibowo and Permadi, 2013) and there are several other researchers who grouped rock types with different methods, such as Gomes, J.S. et al (2008), Permadi& Wibowo (2009), Wibowo & Permadi (2013).

The approach to grouping rock types that has been studied by previous researchers still has quite high uncertainty. The uncertainty in this approach occurs in wells that do not have core rock analysis data. To reduce uncertainty in wells that do not have core rock analysis data, researchers feel the need to conduct this research. This study focuses on obtaining an approach method for grouping rock types in wells that do not have core rock analysis data but have acoustic log data which has a value of P wave propagation velocity (Vp). With the Vp value, it will be possible to calculate the critical porosity value of the rocks in the well. The critical porosity value is used to make an approach so that the rocks can be grouped. each rock group having the same pore geometry character and pore structure will different critical have porosity values (Prakoso, S. Et al, 2017).

The author will do rock type through a critical porosity approach to pore geometry and pore structure so that rock types will be formed that have critical porosity values that are different from each rock type.

METHODOLOGY

The maximum porosity value of the rock into a suspension can be the definition of

critical porosity (Prakoso, S. Et al, 2017).

The data used in this research are routine core analysis data, special core analysis data, and log data from the sand stone formation KutaiBasin, the equipment used in conducting this research is a set of computers in a computer laboratory and software from the Department of Petroleum Engineering, Trisakti University, which has Petrel software installed. inside it.

The method used in conducting this research is Wibowo and Permadi method in analyzing pore geometry and pore structure of each core rock sample data with the following formula (Wibowo, A.S, 2014):

$$(k/\emptyset)^{0.5} = \emptyset \times (k/\emptyset^3)^{0.5}$$
 (II.1)

With $(k / \phi) 0.5 =$ the pore geometry and $k / \phi 3 =$ the pore structure.

The value of critical porosity can be determined using the method of nur et al. by estimating using the parameters of the porosity and bulk modulus of each routine core and special core sample data. The formulas that can be used are as follows (Nur, A. Et al, 1995):

$$B = \left(1 - \frac{\phi}{\phi_c}\right) B_m \tag{II.2}$$

With B = bulk modulus (Gpa), ϕ = porosity (frac), ϕ c= critical porosity (frac), and Bm= bulk modulus mineral (Gpa)

MetodeHashinShtrikman used for analysis mineral bulk modulus, In sandstone there are two dominant minerals, namely clay minerals and quartz, because there is more than one dominant mineral in the rock, calculations are carried out using this method, the following formula (Hashin, Z. and Shtrikman, S., 1963):

$$B_{hs} = B_1 + \frac{f_2}{\frac{1}{(B_1 - B_2)} + \frac{f_1}{(B_1 + 4/3\,\mu_1)}}$$
(II.3)

With Bhs = bulk modulus of HashinShtrikman (Gpa) minerals, f1 = mineral fraction 1, and f2 = mineral fractions 2.

The bulk modulus value can be obtained from data P wave velocity (Vp) and S wave velocity (Vs) obtained from core sample measurement data using a sonic viewer. So that from the values of Vp and Vs can be obtained shear modulus and bulk modulus

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values that can be determined using the rock elasticity method with the following formula (Mavko, G., et al, 2009):

$$Vs = \sqrt{\frac{\mu}{\rho}} \tag{II.4}$$

$$Vp = \sqrt{\frac{B + \frac{4}{3}\mu}{\rho}} \tag{II.5}$$

With Vs as Velocity S (m / s), μ as shear modulus (Gpa), and ρ as density (gr / cc).

The stages in conducting this research can be seen in the flow diagram of Figure 1 as follows:



Figure 1. Research Flow Chart

RESULT AND DISCUSSION

Determination of critical porosity values can be carried out in surface pressure dry conditions using the equation Nur et al. after analysis of volume of clay (Vcl) from each rock sample using a regression equation which can be seen in Figure 2.



Figure 2 The relationship between porosity and Vcl

In Figure 2 the regression equation Vcl = $0.475\phi + 0.1505$, the regression equation is needed in determining the amount of Vcl content found in rock samples that do not have XRD analysis data from 314 samples used in this study.

The value of Vcl content in rocks will affect the size or bulk of the rock matrix modulus which is calculated using the HashinShtrikman model (Bhs.), Bhs value is needed to calculate the critical value of rock porosity.

So that by obtaining critical porosity values from each rock sample in dry conditions surface pressure can be calcified rock quality into several groups based on the pore geometry approach and the pore structure on critical porosity which can be seen in Figure 3.



Figure 3 Classification of Rock Quality using the Geometry and Pore Structures Approach to Critical Porosity (Rahmawan, S., et al, 2019)

In figure 3, it can be seen that the relation of geometry and pore structure to critical porosity can produce a classification of rock

quality into 10 rock types. Each rock group has pore geometry, pore structure and critical porosity that are different from other rock

groups. The formation of different rock groups is also influenced by differences in the range of critical porosity values of each rock type, the range of critical porosity values of each rock type can be seen in table 1.

Table 1. Range of Critical Porosity Value of Each Rock Type (Rahmawan, S., et al, 2019)

фc	Rock Type
>0.263	1
0.215-0.265	2
0.183-0.215	3
0.153-0.183	4
0.134-0.153	5
0.120-0.134	6
0.101-0.120	7
0.085-0.101	8
0.073-0.085	9
< 0.073	10

The classification of rock quality based on the critical porosity approach to geometry and pore structure can be verified against the results of rock quality grouping using the pore geometry approach and pore structure which can be seen in Figure 4.



Figure 4. A. Approach to Pore Geometry and Pore Structure, B. Approach to Geometry and Pore Structures Against Critical Porosity

In Figure 4 it can be seen that the results of a verification the geometry approach and the pore structure on critical porosity with the pore geometry approach and the pore structure have groupings similar to 10 rock types, so it can be said that critical porosity can be used to determine rock quality groupings. Will dry and pressurized rock conditions must be converted into wet conditions and formation pressures so that any interior that does not have rock samples can be grouped into rock quality using acoustic log data.

Condition conversion is done by converting P wave velocity (Vp) to resemble the acoustic

log conditions at formation pressure. To be able to convert the P wave propagation state to rock samples that have log data measured at the state of surface pressure into a formation pressure state with the Pore Space Stiffness method which can be seen in Figure 5.



Figure 5. (A) Graphs (Bhs / Bdry) -1 vs & Wells D-107, (B) Vpcore Validation @ PLog with Vplog



Figure 6. (A) Graphs (Bhs / Bdry) -1 vs & Wells J-95, (B) Vpcore Validation @ PLog with Vplog

In Figure 5 and 6 it can be seen that the more of pore space stiffness graph line results from the condition of the core data coinciding with the pore space stiffness line from the log data, will make the core Vp data converted to formation pressure close to the acoustic log Vp. The pore space stiffness constant value is generated from 1 / Pore Bulk modulus ($B\phi$) taken from the slope constant of the log data pore space stiffness line. The magnitude of the

pore space stiffness value constant of each well is different as in table 2.

Table2. Pore Space Stiffness Values From		
Each Well		

Well	t
D-107	0.022187
D-109	0.017653
D-117	0.035581
D-120	0.055021
D-129	0.042010

D-139	0.036315
D-47	0.044322
J-95	0.063355
S-21	0.046514

Vp value of core data that has been converted into formation pressure will affect the value of critical porosity which will determine rock quality grouping under formation pressure conditions using a geometry and pore structure on critical porosity approach. The classification of rock quality which based on the geometry approach and pore structure on critical porosity under the conditions of formation pressure can be seen in Figure 7.



Figure 7. Relationship of Geometry Pore vs. Pore Structure vs ¢c for Each Rock Type @ PLog

Limitation of critical porosity values on rock quality grouping of formation pressure conditions (@Plog) after a condition conversion has a difference to the boundary of critical porosity values still in the surface pressure condition (@Ps) which can be seen in table 3

Table 3. Comparison of the Range of Critical Porosity Values

Rock Type	$\phi c @Ps$	¢c@Plog
1	>0.263	≥0.3
2	0.215-0.265	0.225-0.3
3	0.183-0.215	0.181-0.225
4	0.153-0.183	0.167-0.181
5	0.134-0.153	0.140-0.167
6	0.120-0.134	0.121-0.140
7	0.101-0.120	0.099-0.121
8	0.085-0.101	0.080-0.099
9	0.073-0.085	0.070-0.80
10	< 0.073	≤ 0.070

The depth of log data that does not have core sample data can be grouped into rock quality that has been converted into formation pressure conditions using critical porosity values to be generated from acoustic logs and

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entered into groups of critical porosity values generated from core samples that have been converted into formation pressure conditions, grouping rock quality at uncored intervals can be seen in figure 8.



Figure 8. Examples of Rock Type Calcification Using Log Data on D-117 Wells

CONCLUSIONS

- 1. Pore geometry and pore structure have a related relationship to P and S wave velocity and critical porosity. This relationship proves that the value of critical porosity can be easily and simply used to estimate rock types. Where Vp and Vs are influenced by the conditions when measuring the value.
- 2. One rock type has a unique geometry and pore structure relationship that is characterized by certain critical porosity values.
- 3. From the results of rock type formation analysis using the approach of pore geometry and pore structure to critical porosity, the quality of rock type is strongly influenced by the limitation of critical porosity values of stress-affected rocks, where the influence of pressure on this analysis is the condition when measuring core data and log data.
- 4. Grouping rock types in wells that do not have core sample data can be done using the critical prosity approach, which can be obtained from the Vp value in the acoustic log data of wells that do not have core sample data.

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