PROSPECTING MIOCENE CARBONATE HARDGROUND AS CAPROCK, CASE STUDY IN OYO FORMATION, GUNUNGKIDUL, DAERAH ISTIMEWA YOGYAKARTA

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ABSTRAK. Oyo Formation is located in Gading, Playen, Gunungkidul Regency, Province of Daerah Istimewa Yogyakarta. It has stratigraphic record that representative for study about carbonate hardground as caprocks in petroleum system because the hardground is well expose. This research is focused on study of carbonate hardground role as caprocks in petroleum system based on the characteristic of pore type, cement type and strength. The objective of the research is to identify Miocene carbonate hardground ability to be a caprock. The methods used in this research are measuring section to integrate stratigraphic record to reconstruct the sedimentation and diagenetic model in the depositional environment, petrography to reconstruct diagenesis model, and point load compressive strength test to assesses the maximum force of hardground can take as a caprock before it breaks. Result shows there are many hardground beds formed intercalated with limestones. Hardground is recrystallized and the pore and permeability are reduced due to aragonitic cementation in low energy environment. Result shows the maximum pressure hardground can hold is 2,737 MPa (UCS) and if situated as hydraulic seal, it will break in the depth greater than 279,514 meters. In conclusion, Miocene carbonate hardground with case study in Oyo Formation is not capable to be a good caprock in petroleum system.

Kata kunci: hardground, permeability, caprock, UCS, carbonate

I. INTRODUCTION

This research is conducted to study characteristic of limestone hardground especially pore type, cement type, and strength. The study is also integrated with stratigraphic record to reconstruct the sedimentation and diagenetic model in the deposition environment. The research is set to analogously study limestone in term of petroleum system. The objective of the research is to identify Miocene carbonate hardground ability to be a caprock. Oyo Formation of regional stratigraphic Southern Mountain Zone has carbonate lithology which aged Middle Miocene. Carbonate lithology of that formation consist of muddy allochom limestone intercalated with tuffaceous sandstone at lower and foraminiferal lime packstone and foraminiferal lime wackstone at upper. Those lithology

II. DATA AND METHOD
The methods used in this research are study from past literature about field observation, petrography, and point load compressive strength test. Field observation conducted to observe hardground in the natural condition, petrography assesses composition including cement to reconstruct diagenesis model. Compressive strength test assesses the maximum force of hardground can take as a caprock before it breaks.

The methods of this research consist of 3 step, that is past literature study, field sampling data and laboratory analysis. Past literature study encompasses geological regional study of Oyo River in Surakarta - Giritontro Geologi Regional Map (Surono, dkk 1992) and reviewing past researches like Melati Mahardheany (2015) about stratigraphic and sedimentation process mix carbonate - siliclastic rock also Rubiarto (2005) concern in deposition environment of Oyo Formation in Widoro - Oyo - Giringsing River, Playen, Gunungkidul Regency, Province of Daerah Istimewa Yogyakarta.

Field sampling data involve measuring section scale 1 : 10 where total thickness is 9,2 m. The average of dip bedding is 9 degree. For additional, petrology description, observe of hardground bedding and trace fossil also do in this step. Furthermore, hardground is selective sampling with width approximately 10 - 15 cm for laboratory analysis. The last step is laboratorium analysis encompasses petrographic analysis through plane polarization and cross polarization to know the composition and diagenesis interpretation result. Point load compressive strength test took place in Laboratorium Geologi Tata Lingkungan, Departemen Teknik Geologi, Universitas Gadjah Mada as a way to get the value of uniaxial compressive strength (UCS).

III. RESULT AND DISCUSSION

1. Measured section

Measured stratigraphy in Oyo River geographically in 449888, 9127485 UTM until 449842, 9127421 UTM. This measuring is conducted by vertically stratigraphy. Based on the measuring section which can be seen in figure 1, it can be divided into four lithofacies, which is Tuffaceous parkstone facies (TPF), Wackestone facies (WF), Rudstone facies (RF), and Packstone facies (PF). The classification of the limestone based on Embry & Klovan (1971), it has similar composition like mud, calcite, fragments, and other material carbonate in different size.

2. Petrography Analysis

From the petrography observation, the composition of hardground are allochem (skeletal fragments), micrite, and sparite. the percentage of each composition and porosity can be seen in the table 1.

Cement type of all sample is blocky which composed by aragonite and it has fibrous shape . Petrographic analysis is done by observing 4 main component which is allochem, micrite, sparite, and porosity. Allochem consist of algae, planktonic, bentonic and large foraminifera. The main issue of petrographic analysis is porosity. The porosity can not be seen clearly because the sample is a hardground which is the main composition of the rock had been transformed into mineral carbonate crystal. Type of the
porosity which dominated the rock is intercrystalline with some part of interparticle or intraparticle. As hydrocarbon reservoir, especially in carbonate rock, this samples are include in bad rock. This is because the crystalline rock conditions cause a reduction in rock porosity due to cementation and compaction processes. The type of cement found in the sample is mesh of needles, which composed of aragonite mineral. The form of cement is fibrous or needle. The type of carbonate cement shows the diagenesis environment of the rock sample is Phreatic Marine Zone (figure 3). In addition, the percentage between the presence of micrite and cement also shows that samples include in the marine phreatic diagenesis environment which associated with few water circulation. The presence of micrite in the sample is very abundant in the foraminifera shell which means it is a microbial micritization product.

3. Depositional Environment

Based on stratigraphy measurement and petrography analysis, there are four facies which compose the study area. Four facies produce similar limestone with the grain size from fine sand to pebble, thick limestone lamination, and also the lateral and vertical distribution has large geometry. Deposition environment from Wilson Belt (1975) modified by Flugel is used in this study as a model and given the conclusion that the deposition environment is slope-toe of slope.

4. Geological Reconstruction

The field observation shows there are many hardground beds intercalated with limestone. Petrographic analysis shows hardground is recrystallized and the pore is reduced due to cementation as well as the permeability. This hardground is interpreted to be formed in the low energy environment. Rubiarto (2005) research in Oyo formation shows that deposition occurs in bathymetry of bathyal (deeper marine). Bathyal zone has range of 200 - 2000 in depth below sea level. Interpreting that Oyo Formation was formed near the volcano flank which has the high slope in depositional environment. Assuming the carbonate factory was located in the shallow marine (neritic, 0 - 200 m), the carbonate materials transported to depositional environment through the volcano slope with turbiditic mechanism.

Hardground was formed in the low energy time when sediment supply from the carbonate factory is low. The water with carbonate ions circulated in the upper bed of deposited limestone. The circulation of the water caused the cementation in the upper bed with Aragonite in mineralogical composition of the cement. During this low energy time, organisms lived in the upper part of the bed with the primary direction is lateral. When another sediment package came, the trace of the organism is preserved and forming ichnofossil with horizontal pattern recorded in the hardground. The presence of horizontal ichnofossil strengthen the hypothesis of very low sedimentation rate or non depositional phase when hardgorund was being formed.

5. Compressive Strength Test

Five samples are tested under point load test and the result can be seen in table. There are variations among the pressure test samples, ranging from 2kN - 6 kN. Based on the test, HG 2 and HG 6 has the biggest result which is 6 kN, while the smallest result is
HG 4 with 2 kN. Sequentially HG 1, HG 7 has 3 kN and 5 kN. The result of point load test then convert into uniaxial compressive strength (UCS), so the UCS value for HG 1 is 1,314 Mpa, HG 2 is 2,474 Mpa, HG 4 is 0,876 Mpa, HG 6 is 2,737 Mpa, and HG 7 is 2,230 Mpa.

Variation of UCS values are very on the composition, grain size, sorting, and packing of the rock itself. Stronger the sample/rock, bigger stress that the rock can hold, and weaker the sample/rock, less stress the rock can hold. Value of UCS could be applied in caprock (seal) analysis.

Caprock could fail in maintaining the accumulated hydrocarbon in reservoir. If it happens, hydrocarbon could leak to surface as tertiary migration. Gluyas and Swarbrick (2004) divided caprock into two groups based on how fluid could break through the caprock: membrane seal and hydraulic seal. Limestone, as studied in this research belongs to hydraulic seal, Limestone is rigid or less ductile. Fluid could pass through fractures in the rock that caused by pore pressure that exceed the strength of the rock (Gluyas and Swarbrick, 2004). Pore pressure gradient of rock with freshwater fluid is 9,792 kPa/m (Schlumberger, online)

With simple calculation with data of pore pressure gradient and UCS value from each sample, the maximum depth before caprock (limestone in this study) being fractured by pore pressure calculated as follows (table 2):

\[ H = \frac{\text{UCS}}{\text{Pore pressure Gradient}} \]

From the depth calculation in the table, depth range is 89,461 - 279,514 m. Maximum depth from the test shows relatively shallow compared to caprock depth which covers oil and gas reservoirs and may reach hundreds to thousands meters. Based on this study, hardground could not be a good caprock.

If the hardground samples used in this study placed in the depth of several thousand meters beneath surface, the pore pressure exceeds UCS value. Hardground will be fractured and forms secondary porosity

6. **Prospecting Hardground as Caprock**

Combining petrography analysis hardground has low porosity (making the permeability values low) because of strong cementation, but. In UCS test the strength of hardground is low. Low permeability conditions of the hardground fulfill the one requirement of caprock. Even though low permeability condition is fulfilled, but the strength of the rock could not hold the rising pore pressure with depth. This is caused by rigidity of hardgorund because composed mainly of carbonate minerals and make the hardground classified as hydraulic seal. From UCS value and conversion to depth shows the maximum depth of the hardground before it breaks is 279,514 meters. This depth is very shallow for petroleum accumulation. For comparison, petroleum (oil and gas) accumulation commonly accumulates in the depth of hundreds to thousands of meter.
IV. CONCLUSION

Hardground can be a caprock (hydraulic seal) due to intensively reduced porosity and permeability. Hardground strength (UCS) only shows maximum value of 2,737 MPa or will break if depth greater than 279,514 meters which is very shallow for hydrocarbon accumulation. Miocene carbonate hardground with case study in Oyo Formation is not capable to be a good caprock in petroleum system.

REFERENCES

Surono, B. Toha, and I. Sudarno, 1992, Geological Map of Surakarta - Giritonro, Jawa, Geological Research and Development Centre
Table 1. Data result of petrographic analysis

<table>
<thead>
<tr>
<th>Sample</th>
<th>Width</th>
<th>Allochem</th>
<th>Micrite</th>
<th>Sparite</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HG 1</td>
<td>5 cm</td>
<td>61,2 %</td>
<td>14,5 %</td>
<td>17,3 %</td>
<td>7%</td>
</tr>
<tr>
<td>HG 2</td>
<td>10 cm</td>
<td>60,8%</td>
<td>13,8%</td>
<td>11,4%</td>
<td>14%</td>
</tr>
<tr>
<td>HG 4</td>
<td>20 cm</td>
<td>50,8%</td>
<td>15%</td>
<td>20,8%</td>
<td>13,4%</td>
</tr>
<tr>
<td>HG 6</td>
<td>15 cm</td>
<td>45,8%</td>
<td>24,2%</td>
<td>19,2%</td>
<td>10,8%</td>
</tr>
<tr>
<td>HG 7</td>
<td>10 cm</td>
<td>67,5%</td>
<td>10,5%</td>
<td>11,7%</td>
<td>10,3%</td>
</tr>
</tbody>
</table>

Table 2. Data result of compressive strength test

<table>
<thead>
<tr>
<th>Sample</th>
<th>UCS (MPa)</th>
<th>Pore Pressure Gradient (KPa/m)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HG 1</td>
<td>1,314</td>
<td>9,792</td>
<td>134,191</td>
</tr>
<tr>
<td>HG 2</td>
<td>2,474</td>
<td>9,792</td>
<td>252,655</td>
</tr>
<tr>
<td>HG 4</td>
<td>0,876</td>
<td>9,792</td>
<td>89,461</td>
</tr>
<tr>
<td>HG 6</td>
<td>2,737</td>
<td>9,792</td>
<td>279,514</td>
</tr>
<tr>
<td>HG 7</td>
<td>2,230</td>
<td>9,792</td>
<td>227,737</td>
</tr>
</tbody>
</table>
Figure 2. Microphotograph of HG 7 showing larger foraminifera in micrite and sparite (under Plane Polarization)
**Figure 3.** Calcite fills void space in the sample in the process of cementation in sample HG 4 (under Plane Polarization)

**Figure 4.** Diagenesis environment of carbonate rock (Tucker and Wright, 1990)