THE IMPACT OF PERMEABILITY AND WELL SPACING ON WELL PRODUCTIVITY IN A COALBED METHANE RESERVOIR

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ABSTRACT

The production mechanism of gas from coalbed methane (CBM) reservoir is considered as complex and difficult to analyze. The gas is adsorbed in inner surface of the coal matrix (seam) and usually contain water its fracture. In CBM reservoir, permeability and well spacing are parameters affecting the response of coal-seams reservoirs. Higher permeability will increase fluid flow in coal cleat (fracture), while smaller well spacing may increase the pressure decline of the reservoir. The two phenomena accelerate the gas desorption time from the coal-seams. This paper presents a simulation experiment, intended to study the impact of permeability on gas and water production in coalbed methane reservoir. The results show that the permeability have a significant effect on initial water rate, cumulative gas and water produced. While the well spacing has no effect on initial rate and a little effect on peak gas rate.

Keywords: coalbed methane, permeability, well spacing.

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1. INTRODUCTION

Most CBM reservoirs contain water in cleats (fracture system) but also contain a small amount of free gas in the cleats. Most of the gas is stored in the matrix. The production rate in a CBM reservoir is affected combination of reservoir and geological parameters such as dual porosity, anisotropic permeability, relative permeability, desorption time, nonlinear Langmuir sorption isotherm, and water saturation.

To produce gas, the cleats must be dewatered to provide a pathway for the gas to the well. As the water has flowed out of the reservoir, the reservoir pressure declines, the relative permeability to water decreases, and the water flow rate decreases. After the saturation pressure has been reached, the coal will start to release gas. This gas will diffuse from the matrix and desorbs into the cleats. The amount of gas released will follow the sorption
isotherm. Gas flow rate in the cleats will increase to a maximum value as the relative permeability to gas improves which is resulted from the dewatering process. When reduction of the reservoir pressure is significant, the gas rate declines.

The number of production well in the reservoir as well as the drainage area of a well a considerable contribution to the depletion of the reservoir pressure. Accordingly, the parameters affect production of a CBM well. The objective of this paper is to analyze the impact of well interference on well productivity. This field-based study uses reservoir data from a field located on South Sumatra (Indonesia).

1.1. Geological review
According to geological, South Sumatera Basin is estimated to have the most potential coalbed methane reservoir in Indonesia. The gas potential in the area is predicted about 183 TCF. in the South Sumatra basin. The basin is bounded to the northeast by Tiga Puluh high and to the southwest by pre-Tertiary basement in the uplifted Barisan Mountain. While to the northeast it wedges out onto the Sunda Craton and to the south and east it is bounded by Garba mountain, Lampung high, and a high which is parallel with the east beach of Sumatra. South Sumatra basin can be divided into four sub-basins.

The South Sumatra Basin is filled with several formations as shown in Figure 1 the pre-tertiary, Lahat, Talang Akar, and Baturaja formations were deposited during the transgressive phase. But after that the Gumai, Air Benakat, Muara Enim, and Kasai formations were deposited within the regressive phase. Within the Muara Enim Formation shale is dominated with an alternation of sandstones and coal seam. The formation deposited on the land to shallow marine environments varies in age from late Miocene to early Pliocene. The thickness of the formation varies from 450 to 750 meters. According to [7] this formation contains five main coal seams.

2. METHOD
The Eclipse software was used to generate numerical gas forecasts for the coalbed methane reservoir. The model wells located in a rectangular shaped reservoir with homogeneous characteristics. To simulate the cleat and matrix system of coalbed reservoir, dual permeability model was applied.

The reservoir model with wells was constructed properties from field data. The wells were in 1, 3, 5, 7, and 9 spot patterns as illustrated in Figure 2. The numerical simulation method used to study the impact of neighbor wells interference on the well located the center. The software handles interference between wells even when they on production at different times. The variables studied were permeability and well spacing.

Data Subancoal seam are given in Table 1. To study the effect of the variable mentioned above, the sensitivity of each variable was. The permeability, thickness, and well spacing were varied from 1 to 10 mD, 16 to 32 ft, and 80 to 250 acres, respectively.

Simulations were conducted for all cases and run for 30 years. Each case was run five times with different spot pattern as depicted in Fig.2. The results of the cases were grouped and compared to analyze the effects of the parameters studied as well as that of number of neighbor wells.
Figure 1 Stratigraphic Column for the South Sumatra Basin

Figure 2 Schema centered well surrounded by various numbers of neighborwells.
3. RESULT AND DISCUSSION

results of simulations described in the preceding section are analysed. Figure 3 to 9 shows the effect of the number of neighbor wells and permeability on the center well productivity cumulative gas produced, cumulative water produced, initial water rate, gas rate, and time of gas rate, respectively. The effects of the four variables are discussed as follows.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Field Unit</th>
<th>SI Unit</th>
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<tbody>
<tr>
<td>Depth</td>
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<td>433.12 m</td>
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<tr>
<td>Thickness</td>
<td>106.0ft</td>
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<tr>
<td>Fracture Porosity, $\phi_f$</td>
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<td>Fracture Permeability, $k_f$, mD</td>
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<td>Desorption Time</td>
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<td>2E+02 m$^2$/sec</td>
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<tr>
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<td>0.010 m</td>
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<td>Langmuir Pressure (PL)</td>
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<td>Gas Content</td>
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3.1. The Effect of Permeability and Number of Neighbor Wells on Gas Production

The drainage area of a well is limited by that of its neighbor wells. This means that the maximum recovery per well is reduced as the number of neighbor wells increase as depicted by curve of Figure 3. The other curves of lower permeability, however, do not follow the correlation. This may be wells not produce the gas its irreducible saturation in the drainage area.
Furthermore, the curve of permeability of 1 mD shows a contrary relationship where the cumulative gas produced the center well increases as the number of neighbor wells increase too. Most of gas in coal seam is adsorbed in the matrix. The desorption of the gas occurs after the pressure declines below desorption. Therefore, coalbed methane production depend on reduce overall pressure within the reservoir by producing the formation water. Higher number of neighbor production wells may increase the rate of the reservoir pressure decline throughout the drainage area of the central well. Accordingly, more gas is desorbed and produced through the well as the pressure decline increase. This means that, interference effects of neighbor wells would accelerate the gas production.

In general Figure 3 indicates that the cumulative gas produced of the central well increases as the fracture permeability of coal seam increase. The permeability is a significant parameter which props up the productivity of the well. The effect of the permeability decreases as the number of neighbor wells increases. The presence of neighbor wells restricts the drainage area of the central well. Therefore, as the number of the neighbor increases, the cumulative gas product is controlled by limitation of the drainage area. In the absence of the neighbor wells, the increment of cumulative gas was 14850 MSCF or 252 % as the permeability was varied from 1 to 10 mD.

Figure 4 shows profile of gas and water rate for 80 acres well spacing, permeability of 10 mD, and 8 neighbor wells. During initial production stage, the gas rate will increase until it achieves its peak. After such peak, the rate profile will decline as shown in fig. The peak of gas rate is achieved within two years and after that the rate declines as the reservoir pressure continues to decrease.

**Figure 3** The effect of permeability and number of neighbor wells on cumulative gas product.

**Figure 4** Gas and Water Profiles for the 80 acres well spacing, 10 mD, and 8 neighbor wells
The impact of permeability and well spacing on well productivity in a coalbed methane reservoir

The peak gas rate is affected by the permeability and well spacing (drainage area permeability and well spacing have a contrary effect on peak gas rate. The increment of peak was up to 18.41 MSCFD or 220.6\% as the permeability was changed from 3 to 9 mD. While the fig shows that the initial peak gas rate tends to be lower larger well spacing. The decline of peak was only up to 6.1\% the well spacing was changed from 80 to 250 acres. It can be concluded that the effect of permeability on the peak rate is more significant than that of the well spacing.

Figure 6 illustrates that the permeability and the well spacing have again a contrary effect on the time required to peak gas rate. The increase of permeability time to peak, while the increase of well spacing results in longer time too. The increase of time was 15 years or 240\% as the well spacing was changed from 80 to 250 acres at the permeability of 3 mD. Time required to the production peak as well as the increase of gas rate during the early production stage and the decline of gas rate during the late production stage is related pressure decline. The effect of reservoir pressure is more significant in larger drainage area; the pressure decline during production stages is related with the depletion level of the gas reserve the reservoir. On the other hand, the permeability parameter is proportional to the production rate which accelerates the pressure decline and time to peak production rate as well. The decrease of time was 16.6 years or 90\% as the permeability was changed from 1 to 9 mD at well spacing of 80 acres.

Figure 5 The effect of well spacing and permeability on peak of gas rate

Figure 6 The effect of well spacing and permeability on time required to the gas rate peak.
3.2. The Effect of Permeability and Number of Neighbor Wells on Water Production

The effect of the number of neighbor wells and permeability on the initial water rate and cumulative water produced of the central well, respectively. Initial water rate of the well is not affected by the number of neighbor wells is no inference of neighbor wells at initial condition. On the other hand, permeability affects the initial water rate is almost linearly proportional to the permeability. The increase of initial water rate was about 53 STB/D or 897 % as the permeability was changed from 1 to 10 mD.

Figure 8 depicts that the number of neighbor wells has an opposite effect on the cumulative water produced. The permeability is proportional to the cumulative water produced. Its effect seems reduce as the number of neighbor wells is added. The increment of cumulative water produced the permeability change from 1 to 10 mD reduces from 601% for absence of neighbor well to 158% for the presence of 8 wells. As the number of neighbor wells increase, the drainage area of each well becomes smaller. It results in a diminution of water reserve and cumulative water produced as well. As water is produced from the wellbore, the pressure reduction starts to around the wellbore. The amount of water being produced is proportional to pressure reduction from each well through its drainage area. Eventually it interfere the pressure of drainage area boundary of neighbor wells. The pressure reduction propagation to the boundary of the smaller drainage area is faster than that to the boundary of the larger one. The limitation of water reserve as well as the pressure in the drainage area restricts the cumulative water produced.

![Figure 7](image7.png)

**Figure 7** The effect of permeability and number of neighbor wells on initial rate

![Figure 8](image8.png)

**Figure 8** The effect of permeability and number of neighbor wells on water produced.
4. CONCLUSIONS

Based on the simulation results and analyses shown above, several conclusions:

1. The peak gas rate and cumulative gas rate increase with increase the permeability. The effects of the permeability were largest at the absence of neighbor wells. In the absence, the increment of cumulative gas was 14850 MSCF or 252 % as the permeability was varied from 1 to 10 mD. While the increment of peak gas rate was up to 18.4 MSCFD or 221 % the permeability was varied from 3 to 9 mD.

2. The peak gas rate is slightly lower as the well spacing is larger. The decline was only up to 6.1% as the well spacing was changed from 80 acres to 250 acres. The larger the well spacing is, the later peak gas rate is. The increase of time was 15 years or 240 % as the well spacing was varied from 80 acres to 250 acres at the permeability of 3 mD.

3. Permeability causes the time to peak gas rate smaller, while the increase of well spacing results in a longer time to peak gas rate. The increase of time to was 15 years or 240 % as the well spacing was changed from 80 acres to 250 acres at the permeability of 3 mD. The decrease of time was 16.6 years or 90 % as the permeability was changed from 1 to 9 mD at well spacing of 80 acres.

4. The permeability the initial rate of water land accelerates. The increase of initial water rate was about 53 STB/D or 897 % as the permeability was changed from 1 to 10 mD. However, the effect of the permeability reduced when decrease well spacing, since water in place decreases and the pressure decline was accelerated well spacing. The increment of cumulative water the permeability changed from 1 to 10 mD reduce from 601% for the absence of neighbor well to 158% for the presence of 8 neighbor wells.

REFERENCES


BIOGRAPHY
Asri Nugrahanti received her B.Sc. degree in Petroleum Engineering from Institut Teknologi Bandung in 1981. She received M.Sc. Degree in Material Science from Universitas Indonesia in 1993. She pursued her education in Universiti Teknologi Malaysia and received Ph.D. degree in 2007. She is currently a Vice Rector for Planning and Development at Universitas Trisakti, Indonesia. She has 34 years of teaching and research experience. Dr. Asri’s primary research interest is in formation evaluation and unconventional energy.