36th Annual Convention of the Indonesian Petroleum Association 2012

Working Together to Meet Indonesia's Energy Needs

Jakarta, Indonesia
23-25 May 2012

Volume 1 of 2

ISBN: 978-1-62276-939-1

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Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571

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PROCEEDINGS, INDONESIAN PETROLEUM ASSOCIATION
Thirty-Sixth Annual Convention &Exhibition, May 2012

Rock Physics Propertiesof Coal Bed Methane Reservoir Rock: Case Study of MuaraEnim Coal

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ROCK PHYSICS STUDY OF COAL BED METHANE RESERVOIR ROCK: CASE STUDIES OF MUARA ENIM COAL

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ABSTRACT

MuaraEnim is located in South Sumatera, one of largest energy resources in Indonesia. Many formations in South Sumatera contain coal which may act as reservoir of methane. To study the characteristics of coal as methane reservoir, some samples of coal were collected in MuaraEnim to be analyzed in Rock Physics laboratory.

Some studies were carried out on MuaraEnim coal samples. These samples contain many types of porosity, i.e.: fracture porosity and matrix porosity. Coal's fracture porosity has wide range in size and also unique. Porosity of coal can be seen clearly without microscope but some micro fractures still can be observed in Nano scale using SEM (Scanning Electron Microscope). This phenomena show that porosity of coal is unique, and has different characteristic compared to the porosity of sand. Fracture pattern and pore structures study of coal reservoirs are very important, because it is directly related to the storage mechanism of gas in CBM reservoir, therefore this is very important parameter for calculating of CBM reserve. The porosity is still detected in matrix of cleat coal itself. This phenomenon causes the larger porosity content of CBM than conventional sandstone reservoirs. It is because matrix still contains smaller pores.

Seismic wave parameter plays very important role in characterization of coal bed methane reservoir. Samples of MuaraEnim coal were measured in various seismic wave parameters and various reservoir conditions, i.e.: Vp, Vs, density in various pore fluid and pressure. Coal samples were measured using Seiscore physical modeling, it is for modeling the relationships among Vp, Vs and density in various pressure of reservoir, i.e.: pore pressure and overburden pressure. Almost all of elastic wave parameter of coal as CBM reservoir is modeled in various fluids, overburden pressures and pore pressures.

Pore pressure is one of most important parameter in CBM exploration to check whether pore pressure is still original or not. By means rock physics data from Seiscore physical modeling, relationship among pore pressures and AVO parameters can be produced, result of modeling shows that the parameter of AVO can differentiate the variation of pore pressures. The orientation of coal's cleat gives also influences to seismic wave parameter of P and S wave.

Keywords: CBM, Seismic Rock Physics, Pore Pressure, Porosity

INTRODUCTION

Coalbed methane (CBM) or coalbed natural gas (CBNG) is natural gas produced from underground, unmined coal beds. Although the modern CBM industry is only about 30 years old, it has become a significant source of natural gas produced in the United States (Lamarre, 2006).

During 2004, the CBM industry produced an average of 4.7 Bcf per day, for a total of 1.72 Tcf from more than 20,000 wells. CBM currently contributes approximately 9% of the total dry gas produced in the U.S. Thirteen Tcf of CBM have already been produced, and proved CBM reserves are 18.7 Tcf, or 10% of the total U.S. natural gas reserve base. Total CBM resources in the U.S. are a staggering 703 Tcf.

The U.S. is far ahead of the remainder of the world in production of CBM (Lamarre, 2006). Indonesia have huge coal resources, therefore the possibility to find CBM reservoir is also promising.

Coalbed methane is an unconventional resource because coal is the source, reservoir, trap and seal. Gas is generated from organic matter in swamps during the coalification process that converts peat into coal. Gas is adsorbed onto the internal surfaces of the coal in a layer one molecule thick. Hydrostatic pressure of the water trapped within the coal holds the gas in place.

Coal characterization can be characterized by seismic reflection or using tomography (Nurhandoko et. al, 2009), other author also investigated limitation of AVO in CBM characterization (Peng et. all, 2006). In this paper, we would like to show CBM reservoir characterization methodology, from the pore structure, fracture and their effect of fluid saturation in seismic wave parameter includes AVO modeling using Rock Physics physical modeling for characterizing fluid saturation and pore pressure.

SEISMIC WAVE PROPAGATION

Propagation of seismic wave can be longitudinal and transversal, where longitudinal seismic is defined as pressure wave or P wave. The transversal seismic wave is defined whether SV wave or SH wave, S indicates shear, V indicates vertical and H indicates horizontal.

The propagation of P wave obeys the wave equation (see equation 1)

$$\frac{{}^{2}\ u}{t^{2}} \qquad {}^{2} \quad u \qquad (1)$$

Where denotes divergence of strain u (u). Therefore the P wave is also interpreted as pressure wave. The shear wave can be formulated by following equation, where the curl xu indicates how particle oscillates during wave propagation.

$$\frac{{}^{2}\ xu}{t^{2}} \qquad {}^{2} \quad xu \qquad (2)$$

Shear wave only depends on modulus of rigidity ( ), and the other hand pressure (P) wave depends on both modulus rigidity ( ) and Lame constant ( ). Therefore, shear wave is sensitive for matrix characterization, and P wave is sensitive on both matrix and also pore fluid. The cell diagram of rock is illustrated in Figure 1. Joint analysis of P and S wave derivation will result on how to characterize the fluid content of pore.

NANO TO MICRO PORE OF CBM RESERVOIR

The gas is adsorbed onto the internal surfaces of the coal in a layer one molecule thick. When the pressure of pore is decreased, this is initiated from macro fracture or micro fracture, then CBM gas can release from nano to micro pore. Fracture of coal can be from macro cleat, micro cleat or micro fracture. Figure 2.a shows the natural fracture as called as cleats, this fracture is formed during coalification process, from peat to coal. Figure 2.a shows fractures phenomena in bituminous sample, where the phenomena of fractures in lignite sample is shown in Figure 2.b. Figure 2 shows clearly the characteristics of fracture in bituminous coal and lignite, lignite coal is more fractured than bituminous coal.

Figure 3 shows the image of SEM (scanning electron microscope) of coal which collected from PTBA MuaraEnimwith magnifying 1000 times. Some micro cleats are identified, but they are not quite dominant.

The tens nano meter of cleat or pore are identified dominantly in magnifying 30.000 times (Figure 4), these pore type are responsible in absorbing gas of CBM. Nano scale of ‘fractures’ can be identified clearly in coal, these fracture-pore are probably the most responsible conduit for flowing the gas of CBM.

ROCK PHYSICS PHYSICAL MODELING

Coal seismic parameter including their velocity and density in different area of the world could be different. So that when conduct coal bed methane characterization, ideally, approximation using character of their original core sample taken from study area is quite necessary.By doing this, the expected result will be close to actual condition suitable with their reservoir condition. Therefore, the characterization of CBM reservoir results more accurate parameter and methodology of characterization.

In this study, seismic rock physic measurement for coal core sample is performed using SEISCORE ™ equipment. This procedure is done by applying the variation of overburden pressure as close as their depth, pore pressure,temperature and some anisotropyeffect which will be measured in gas and brine saturated condition. This process will produce seismic wave response and some other parameter (such as strain and density change of each measurement parameter change).

Seismic wave response will produce first arrival time which can be converted to their velocity, either P-wave or S-wave velocity. By combining their velocity and density change, almost all of elastic parameter can be derived (Acoustic Impedance, shear impedance, Lame’ Coefficient, Shear Modulus, Young Modulus, bulk Modulus, Poisson ratio, Lambda-rho, Mu-Rho, etc). In addition Vp-Vs relationshipcan be done in various overburden and pore pressure effect modeling and pore fluid saturated effect. By some modification of measurement, we can analyze theeffect of AVOanisotropy.

The rock physics modeling is done using SEISCORE™ and processed using Geo-Symphony™Seiscorefor analyzing and purifying P and S wave, it is for resulting hi accurate either P and S wave measurement in various reservoir condition.

The coal sample is loaded into the vessel of rock physics physical modeling (SEISCORE™) and then the modeling in various reservoir condition are done, i,e: various overburden pressure, various pore pressure and various pore fluid.

Figure 7 shows the effect of anisotropy in various cleat orientation and overburden pressure in various fluid saturation (gas and brine saturated condition). In gas saturation condition, S-wave is relatively similar in both of vertical (SV) and horizontal cleat orientation.In low overburden pressure under brine saturation, the anisotropy is clearly identified, the velocity of VTI (horizontal cleat) is generally low, but in hi overburden pressure (more than 30 Bar) there is violation phenomenonwhich may be caused by collapsing of pore or micro structure.

CBM reservoir needs pore pressure information to identify whether the pore pressure of reservoir is original (virgin) – or pressurized or has been relieved, AVO response is one of tools to identify the originality (pressurized zone) of CBM reservoir. Figure 7 clarifies the effect of pore pressure to the seismic wave (Vp and Vs). Generally, both Vp and Vs decrease with increasing pore pressure. Figure 8 shows the of the effect of pore pressure in AVO. We can identify and discriminate the fluid type of fluid saturator of coal, brine or gas, the figure 8 show the effect of fluid , the gas saturated tends to left-down of AVO quadrant.

CONCLUSIONS

CBM reservoir contains some porosity types, i.e: macro fracture, micro fracture, tens nano scale of fracture which caused by nano cleats orientation, and also nano scale porosity. This porosity phenomena makes the storage mechanism of CBM reservoir becomes complex and non-conventional like in sandstone reservoir. The matrix of coal from SEM image seems very tiny (in nano meter scale), it causes storage mechanism of CBM becoming unique.

Generally the overburden pressure tends to increase the velocity of P and S wave. The orientation of cleat influences the seismic wave parameter, but in high overburden pressure there is a violation of seismic wave velocity. It may be caused by collapsing macro and micro meter scale of fracture or porosity. The pore pressure gives also effect in AVO parameter, this phenomena is very important because, CBM reservoir need pore pressure imaging to check whether the reservoir is pressurized or no pressurized (leaking).

REFERENCES

1. Lamarre, R.A., 2006, CoalbedMethane:ACompendium of Influential Papers, AAPG.
2. Bossie-codreanu, D., Wolf, A. and Ephraim, R., 2004, A new characterization method for coal bed methane, GeologicaBelgica, 7/3-4: 137-145
3. Ramos, A. and Davisz, T., 1997, 3-D AVO analysis and modeling applied to fracture detection in coalbed methane reservoirs , GEOPHYSICS, VOL. 62, NO. 6, P. 1683–1695.
4. Peng, S., Chen, H., Yang, R., Gao, Y., and Chen, X., 2006, Factors facilitating or limiting the use of AVO for coal-bed methane, Geophysics, Vol. 71, no. 4, p. c 49 – c 56
5. Nurhandoko, B. E., Mubarok, S., Sukmana, I., Sulistyanto, B., Rudiyanto, H., Wiyanto, Y., and Ambia, F., 2009, Subsurface coal seam characterization using seismic tomography: a case study in MuaraEnim South Sumatera, Proceeding Asian Physics Symposium 2009.

Figures

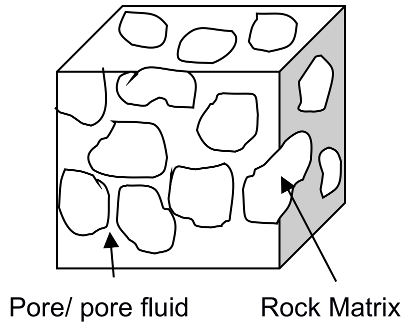


Figure 1. Illustration of rock matrix and pore

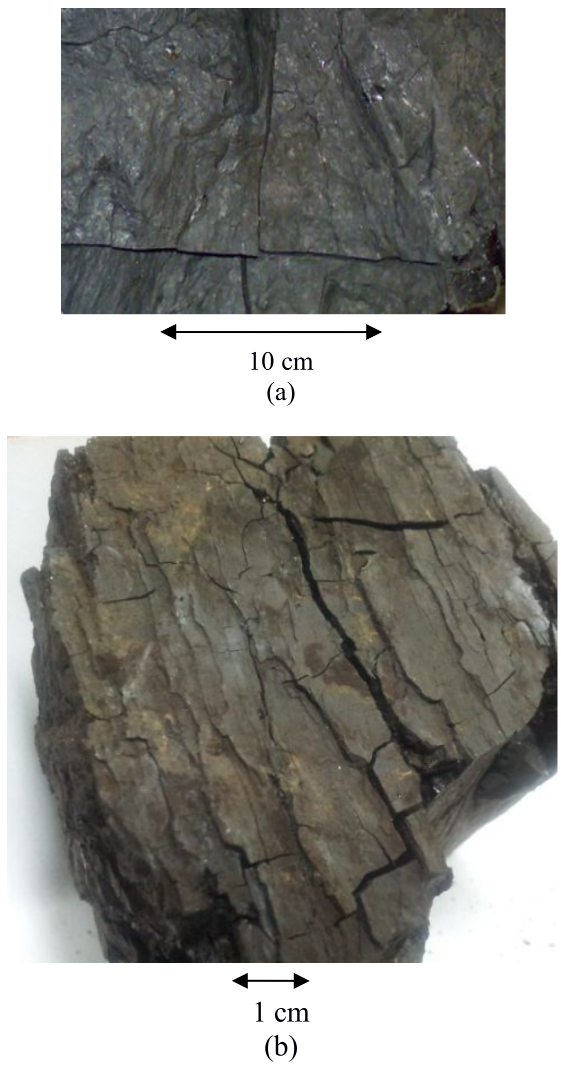


Figure 2.Nature of coal's fracture or macro cleat of coal. (a) fracture or cleat of bituminous coal, (b) fracture or cleat of lignite coal.

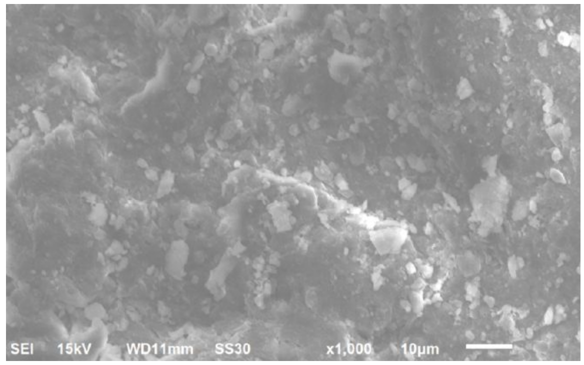


Figure 3.Micro meter fracture in coal. 1000 times magnification. Sample was collected from MuaraEnim PTBA.

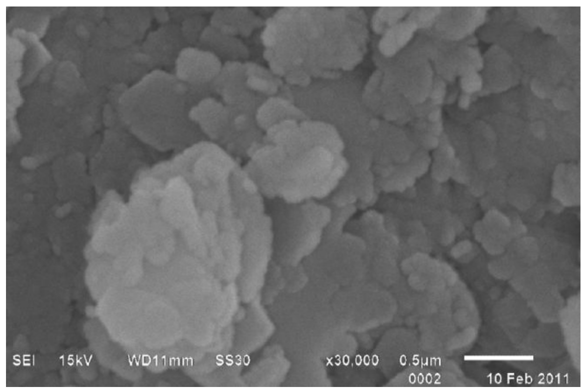


Figure 4.Tens nano meter cleats of coal. Coal sample was collected from MuaraEnim PTBA.

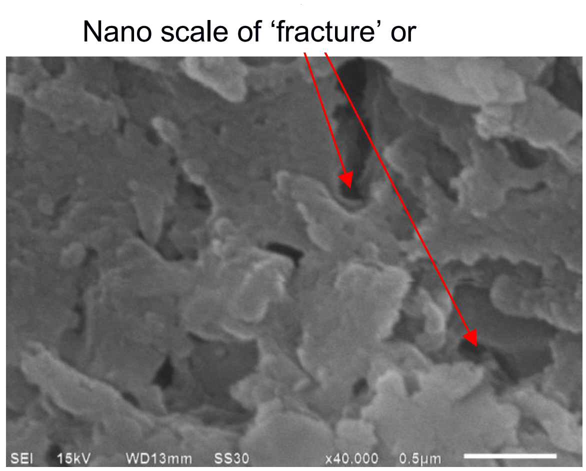


Figure 5. Nano meter scale of ‘fracture’ or pore in coal. Coal sample was collected from MuaraEnim PTBA.

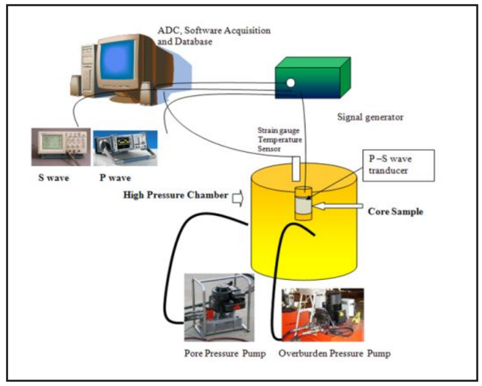
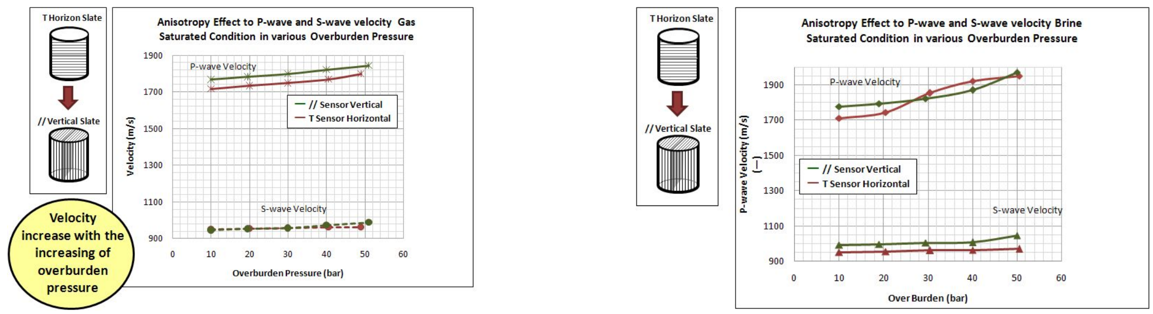
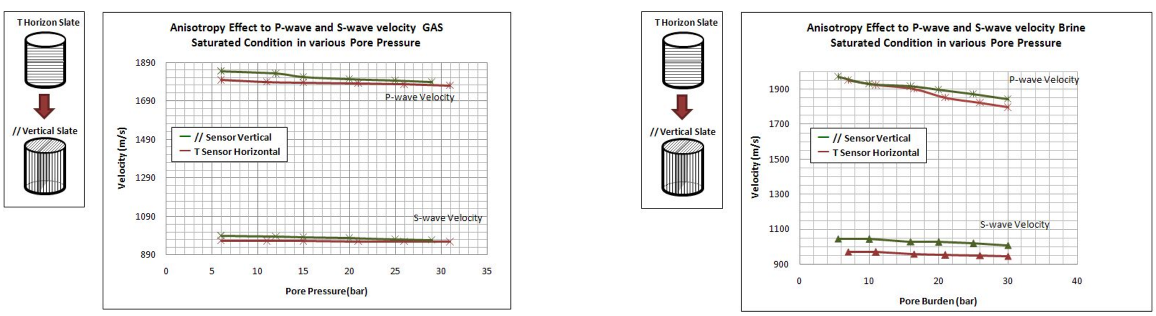


Figure 6. SEISCORE^{TM}module for seismic rock physics analysis (Courtesy of Rock Fluid Imaging Lab)



(a) (b)

Figure 6. Effect of anisotropy of cleat and overburden in seismic velocity of P and S wave in various fluid saturation;a) measurement under gas saturation; b) measurement brine saturated condition.



(a) (b)

Figure 7. Effect of anisotropy of cleat and pore pressure in seismic velocity of P and S wave in various fluid saturation; a) measurement under gas saturation; b) measurement brine saturated condition.

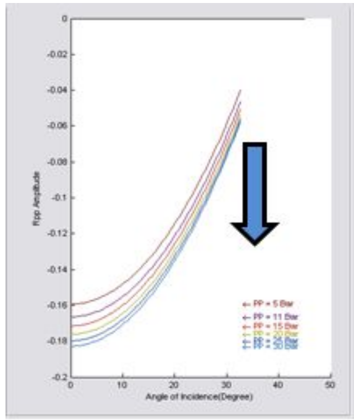


Figure 8. Effect of pore pressure in AVO

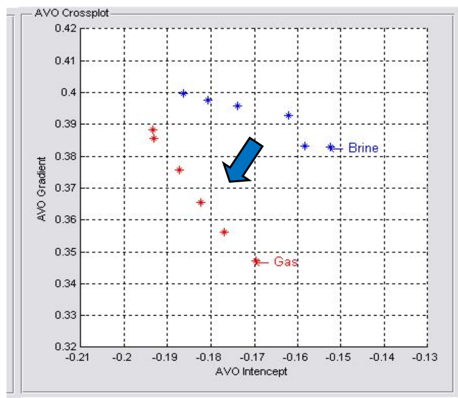


Figure 9. AVO Crossplotfor coal under brine saturated and under gas saturated.