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Tectonic Controlled of Cleats Development as Implication of Coal Bed Methane (CBM) Prospect in the Barito Basin, South B

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SUMMARY

Cleats are considered as one the important parameters in the CBM development particularly related to permeability. A complete characterization of cleat distributions and orientation may provide a better tool for indirectly estimating porosity and permeability in coal reservoirs as critical parameters for coalbed methane extraction. This paper is presented results of detail study cleats development within Miocene coal seams as part of CBM exploration and development.

Most data were collected on mine walls (cross-section view measurement). Cleats data were collected for several coal seams from 60 scan lines and 39 windows measurement locations with total 20,000 cleats were measured from outcrops. Three major cleat orientations; WNW-ESE, NNW-SSE, and NE-SW. The relationship between cleat spacing and coal rank: bright coal (vitrain) generally have smaller cleat spacings than dull coal (durain). Coals with low ash content tend to have smaller cleat spacing than coals with high ash content. Relationship between coal density and calorific value shows high calorific value with low ash content tends to have large density. This suggests that coal composition related to cleats characteristics. This cleats origin might be subjected from several processes particularly superimposed by later processes such as hydrostatic pressure and tectonic stresses.

Introduction

Coal Bed Methane (CBM) is classified as unconventional hydrocarbon generated from coal seams. Indonesia considered that CBM become one of the most important energy contributions in the future due to the decreasing resources of conventional hydrocarbon. The study area is located in the Barito Basin, South Borneo. The Barito Basin is a Tertiary basin located in the southern part of Borneo Island and it proved as one of the Indonesian prolific coal basins, which has a great CBM potential. Cleats are considered as one the important parameters in the CBM development particularly related to permeability. A complete characterization of cleat distributions and orientation may provide a better tool for indirectly estimating porosity and permeability in coal reservoirs as critical parameters for coalbed methane extraction.

Study Objectives

The main study objectives is mostly to evaluate and characterize cleats behavior in outcrop-scale including to understand cleats attributes (spacing, aperture, orientation), vertical and lateral distributions as well as to understand the influence of structure (syn& post sedimentation tectonic) to cleat development. To understand the effect of large tectonic process such as uplifted Meratus Mountain to the cleats behavior in the basin particularly their intensity. Integrating the compiled cleat characteristics with other structural information to examine variability in structural domains and thus enhance the understanding of the evolving stress regime during the Tertiary.

Method of Study

The methods used in this study includes: field survey and field data acquisition, data sorting, statistical analysis and interpretation. The field survey and field data acquisition conducts identify fractures, butt and face cleats within the layer/bed and measure the fracture attributes (spacing, height, aperture, and orientations) of each fracture and/or cleat. There are two methods of measurement used in this study. The first method is scanline method, where only data that intersects the scanline were measured. The geometry of the measured are designed to be an exposure at least 3 m wide (parallel to the bedding plane), the height is depend on the bed thickness, so the maximum height need to be set. The other method is windows sampling method, where the geometry of measured area designed to be a rectangle, ususally with 100 cm x 100 cm dimension, however there is coalbed that have only 25 cm thickness, so the measured area is confined to 0.25 m x 0.25 m dimension. All the fracture and cleats within this area were measured (**Figure 1**).

The scanline method is commonly used for cross-section view, while windows method is used for plan view exposure (e.g. top of the coal seam). These conventions are used to identify cleats: length is dimension parallel to cleat surface and parallel to bedding; height is parallel to cleat surface and perpendicular to bedding; aperture is dimension perpendicular to fracture surface; spacing is distance between two cleats and/or fractures at right angles to cleat surface (**Figure 2**). The cleats and fractures measurement were done by scanline and windows methods. More than 20000 cleats and/or fractures were measured from 60 scanline and 39 windows measurement locations.

Figure 1 (a) Sample location where scanline method measured the cleats and fractures along the line. (b) Sample location where the windows methods measured all the cleats and fractures within the 1 m x 1 m rectangle.

Statistical data analysis was accomplished by put all data into rose diagram and lower hemisphere stereographic projection. By applying an assumption cleats originally formed sub vertical in flat-lying bed, cleats and fractures in each coal seam were rotated to its original position (when the bed horizontal). This sorting technique successfully infers the cleats and/or fractures which formed during or after coalification due to tectonic stress. Data calculation was made to obtain the metrics used to characterize the relationship between cleats attributes and distance/area of measurement. Data calculation results are presented in graphical forms including charts, plots, and trend curves to display the relationship between densities, distance and cleat attributes. Using plot distributions and function forecasting, trend curve types were selected and plotted, supplemented with goodness-of-fit (R^2) values that represent the quality of the relationships. With the addition of functional and statistical analysis, geological interpretation was then applied to the data.

Figure 2 Schematic diagram showing the cleat/fracture attributes were measured: A is aperture; B-B' is the length of measurement; S is spacing between fracture/cleat; and L is the height/length of fracture/cleat (modified from Sapiie, 1998).

Cleat Analysis Results

60 scanline and 39 windows measurement locations with total ~ 20,000 cleats were measured in Barito Basin. Field data presented in this study most likely corresponding to macrocleats. Most data were collected on mine walls (cross-section view measurement). Cleats data were collected for several coal seams including Eocene Tanjung Fm. and Miocene Warukin Fm. Most data were collected from Warukin Formation which is subdivided into Lower, Middle, and Upper Warukin.

Cleats orientation show three main orientation; WNW-ESE, NNW-SSE, and NE-SW orientations. Tanjung and Warukin Formation showing equal face cleats orientation. Face cleats orientation within Tanjung and Warukin Formation has dominantly WNW-ESE direction. Discrepancy is observed within Warukin Formation, where several locations have face cleats direction NE-SW direction differ by $\sim 90^\circ$ from other locations in the same interval. The apparent discrepancy may have resulted from structural geology associated with strike slip faults nearby which formed a secondary (tectonic) cleat system. The regional maps of cleat orientation have distinguished domains and variable cleat strike. Uniformity of cleat strikes within domains indicates that fractures responded to regionally coherent stress patterns, which could reflect plate-scale stress or stresses related to uplift or basin geometry (i.e. Laubach et al., 1998). By this mean the origin and evolution of coal (as an opening-mode fracture) can be attributed to compression, extension and other manifestation of tectonism. The control of the tectonic stresses on the cleat formation is based on the intrinsic tensile forces and fluid pressure in coal beds. The formation of cleat within Tanjung Formation might be related to the NW-SE trending rift basins were formed and followed by a prolonged period of subsidence and sedimentation extending into the Late Miocene. While, the formation of cleat in the Warukin Formation is related to the transpression along Meratus Range which produces NW-SE compressive stress. The face cleats extend along the S_H direction and the butt cleats along the direction of horizontal minimum compressive principal stress (S_h the), so regular reticular cleat pattern is formed in Barito Basin.

The cleat attributes (frequency, density, spacing, aperture, and height) are presented in the graphical chart along their distance measurement for all scanline measurements. From all comparison charts showing the frequency, density, spacing between the cleats, and the length/height of the cleats are not equal everywhere. The measurements observed at different places of the study area reveals that the cleat spacing and the length of the cleats vary from one place to another. Apertures of cleat data observed at an interval of 0.01 to 0.3 cm, where most of data are range between 0.01 - 0.05 cm.

The measure of cleat/fracture density used in this study is the summed length of all fractures within a square area, divided by the area of the rectangle. The cross plot chart between bed thickness and density shows that in thinner the coal bed, the higher cleat density (**Figure 3**). Based on the distribution of fracture density in the study area, particularly on the area with numerous observation locations showing an increases of fracture to the north and to the east towards Meratus Range. This evidence shows cleat density might be related to the structural position. Several NW-SE cross sections were made to show density variation towards Meratus. Density contour on the adjacent area of scanline location shows density increase northwards and eastwards. Density increases northward most likely due to diachronous uplift of Meratus Mountains where the northern Meratus Range is more uplifted than the southern part. In addition to see the relationship between cleat density, spacing and the steepness of the coal bed-dip showing there is no subtle relationship between those two attributes, this means cleats development is not simple; another possible explanation could be related to the coal composition and will be discussed below.

Figure 3 Diagram showing the crossplots between bed thickness/spacing and average density from all scanline locations.

Figure 4 Charts shows the density along the measured scanline with the calorific value and ash content in several interval of scanline.

Several studies indicated the relationship between cleat spacing and coal rank, spacing decreasing from lignite through medium volatile bituminous coal and increasing through antrachite coals (Law, 1993). The available data have vitrinite reflectance ranging 0.25-0.49% and classified as Lignite to Sub Bituminous C. The cross plots gives spacing range 2.84-17.08 cm. This result is comparable with the scanline results in the same interval: 2.28-13.34 cm.

The lateral coal samples from several scanline locations indicate varies calorific value and ash content related to the density value along the scanline (**Figure 4**). This laboratory results also showing the coal composition not only varies in vertical but also in horizontal. The summary chart of density with coal samples along the scanline shows the general relationship where high calorific value with low ash content tends to have large density.

Conclusions

1. Based on the characteristics of the coal thickness, the Warukin Formation can be subdivided into the Lower, Middle, and Upper Warukin. The Lower Warukin is characterized by thin (<2 m) coals and abundance of tidal and marginal marine influence. The Middle Warukin is characterized by unequal coal thickness from 2 m to ~60 m thick interbedded with fluvial facies. The Upper Warukin is characterized by a general reduction in coal abundance and thickness, and an increase in fluvial facies.
2. Three major cleat orientations; WNW-ESE, NNW-SSE, and NE-SW.
3. There might be no single process on the cleat formation, where different process may occur since cleat initially formed until now. So, the cleats which formed during coalification can be superimposed by later processes such as hydrostatic pressure and tectonic stresses.
4. Cleat and fracture data from this study indicate that a power-law distribution exists between spacing and aperture of cleats and fractures. Goodness-of-fit varies around 0.90.
5. This study summarizes relationship between cleat attributes and cleat density. They are: an inverse linear is the best fit data for the bed thickness-density relationship, an exponential relationship between average density and cleat height, a power-law relationship between average density and average spacing, and cleat density increases related to regional structural position where they increases towards Meratus.
6. Cleat spacing varies with coal type and ash content. Relationship between cleat spacing and coal rank, spacing decreasing from low to high rank coal. Relationship between cleat density with calorific value and ash content showing general relationship where high calorific value with low ash content tends to have large density.

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References

- Laubach, S.E., Tremain, C.M., Ayers, W.B. Jr. [1991] Coal fracture studies: Guides for coalbed methane exploration and development. *J. Coal Qual.* **10**, 81–88.
- Law, B.E. [1993] The relation between coal rank and cleat spacing: implications for the prediction of permeability in coal. *Proc. Int. Coalbed Methane Symp.*, II, pp. 435–442.
- Sapiie, B. [1998] *Strike-Slip Faulting Breccia Formation And Porphyry Cu-Au Mineralization In The Gunung Bijih (Ertsberg) Mining District Irian Jaya Indonesia*, Disertasi S-3, The University of Texas at Austin.