Distribution model, depositional environment and facies of coal in the AE field, Kutai Kartanegara area, East Kalimantan

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Abstract. The AE field is a planned coal mining area in Kutai Kartanegara, East Kalimantan. A preliminary analysis of coal and non-coal lithology conditions, which act as constituents of the AE Field, must be carried out to determine the next step in the mining business. The physical properties of several coal seams in the AE Field are different, so characterization is necessary. The purpose of this study is to characterize coal and non-coal lithology in the study area, while the aim is to determine the facies analysis and depositional environment of coal. The research method used is surface and subsurface mapping (drilling). The results showed that the AE Field has four coal seams, namely seams-1, 2, 3, 4A, and 4B, which dip to the northeast. The coal formed in the lower delta plain transitional depositional environment, in the swamp, crevasse splay, channel, levee, and inter-distributary bay facies.

1 Introduction

Coal is one of the natural resources found in Indonesia and is used as a vital energy raw material. Global coal demand is still high, so coal mining and exploration operations in Indonesia must also be prepared to face the conditions of increasing coal demand globally. The coal demand as an energy source is increasing, therefore to determine the existence of accurate coal deposit potential, it is necessary to conduct comprehensive and thorough exploration, one of which is by modeling the distribution or geometry of coal and analysis of facies and deposition environment.

The AE field is a planned coal mining that located in Kutai Kartanegara, East Kalimantan (Figure 1). Prior to the mining process, it is necessary to conduct an initial analysis of the lithological conditions of coal and non-coal, which act as constituents of the field, so that initial steps can be determined at a later stage related to pen pit modelling, calculation of

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reserves and stripping ratios and determination of mining units. At first glance, the condition of some of the coal in the AE Field looks pale, which indicates poor quality, but in several locations, the color of the coal is blacker, shiny, and denser. The variations in physical characteristics certainly have implications for the quality of coal in the research area, so it is necessary to characterize the quality of the coal. In connection with the thickness and quality of coal, the facies and depositional environment are quite influential in influencing whether or not the quality of the coal is high. Based on this, researchers need to analyze the facies and depositional environment of the coal.

This study aims to characterize coal and non-coal lithology in the study area. This study aims to determine coal's distribution, depositional environment, and facies. This research can provide an overview of coal quality and assist in determining the mining unit that will be applied to exploitation activities.

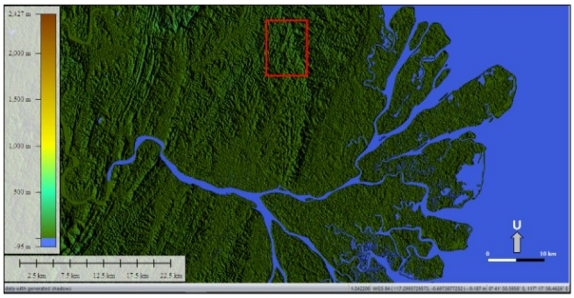

Fig. 1. Location of the study area (red box).

2 Geology of the research area

The AE field is part of the Kutai Basin [1]. This basin is located on the eastern edge of the Sunda Shelf, which was produced due to extension forces on the southern part of the Eurasian Plate [2]. The tectonic framework of this basin is influenced by regional tectonic developments involving interactions between the Pacific, India-Australian, and Eurasian plates. It is also influenced by regional tectonics in southeastern Asia [3].

Referring to the Samarinda Regional Geological Map [4], the study area comprises the Balikpapan Group and the Kampung Baru Formation, both coal-bearing formations in the study area. The lowest Balikpapan group is composed of clastic rocks of the Mentawir Formation, composed of massive sandstones with fine-medium grain sizes interspersed with claystone, siltstone, shale, and coal. The unit is growing 540 m thick in Balikpapan but is flaking offshore. The Gelingseh Formation was deposited along the Middle Miocene, consisting of claystone, siltstone, and sandstone. This formation is deposited in harmony with the Klandasan Formation. The three formations above are the Balikpapan Group which were deposited during the Middle-Late Miocene.

The Kampung Baru Formation comprises coal-rich sandstone, siltstone, and shale. Coarser clastic sedimentary units develop at the bottom of this formation with a thickness of 30 - 120 m, and to the east, the sandstone facies change to shale units. The Kampung Baru Formation was deposited during the Pliocene with unaligned contacts with the Balikpapan Group.

3 Research methods

The research method used is a surface geological survey and shallow drilling to obtain subsurface data. This research is qualitative in nature, in which lithology data and their

distribution in the field are then analyzed to determine the facies and depositional environment of the coal.

Primary data was obtained directly in the field from 4 drilled wells, where some of the data was analyzed in the laboratory and then processed and interpreted. The drill points of the wells (AE-1, AE-2, AE-3, and AE-4) are aligned in a relatively northeast-southwest direction to adjust the position of the coal seams, which are tilted relative to the northeast. Secondary data is taken from related literature that is relevant to research topics locally and regionally.

The analysis of the depositional environment was carried out by considering the depositional environment models in the transition area. The coal depositional environment can control the lateral spread, thickness, composition, and quality of coal. This environment can occur in coastal areas (paralic) or swamps (limnic). The depositional model used in this study refers to the model of Horne [5], which suggests that five primary depositional environments form coal. The environment includes the upper delta plain, transitional, lower delta plain, back barrier, and barrier. Each depositional environment has rock associations and produces different coal characters.

4 Results and discussion

4.1 Coal distribution

Coal in the Kalimantan area is generally associated with other sedimentary rocks, such as claystone, shale, and sandstone [6,7]. The description of the model of coal deposits and non-coal layers needs to be modeled to understand the pattern of coal distribution. Geological modeling in this study has a vital role in providing an overview of the interpretation of the shape of coal deposits. The modeling results are a coal geology model displayed in roof and floor contours and sub-crops of coal seams. Based on data analysis results from found outcrop data and drilling data, four main coal seams can be modeled, namely seams-1, 2, 3, 4A, and 4B, with their distribution showing a dip of 10° - 12° to the northeast. (Figure 2).

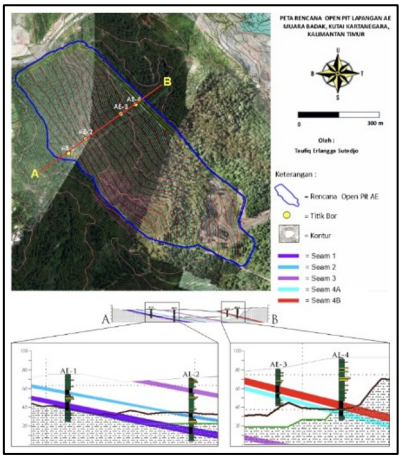

Fig. 2. Modelling of coal distribution in the AE field.

4.2 Facies and depositional environment

The interpretation of the coal facies and depositional environment in the AE field is based on physical characteristics, lithological composition, and their associations. The research area is physiographically included in the Kutai Basin zone, which has the Old Mahakam Delta system, so that facies and depositional environment analysis follow the delta system, according to Horne [5].

Analysis of drilling data AE-1 to AE-4 (Figure 2) shows that the AE Field is composed of claystone lithology (predominantly), sandstone, siltstone, coal, carbonaceous claystone, carbonaceous siltstone, and shale. The entire lithology forms several facies associations, which include channel, swamp, crevasse splay, inter-distributary bay, and levee.

The AE-1 well has a depth of 50 meters with two coal seams (seam-1 and seam-2). The two seams are associated with inter-distributary bay, channel, and levee facies. This group of facies associations is interpreted to have been deposited in a transitional lower delta plain environment. Coal in seam 1 has a thickness of approximately 11 meters, while in seam 2, the thickness is around 7 meters.

Three seams of coal were found in well AE-2 (Figure 2); seam-1 and seam-2 are interpreted as a continuation of coal in well AE-1. The thickness of the coal in this well is relatively similar to AE-1 but slightly thinner. In stratigraphic position, seam-3 coal is found on top of seam-2 coal with slightly different physical characteristics, whereas seam-3 coal is slightly paler with a thickness of approximately 6 meters. In well AE-2, coal is associated with swamp, channel, crevasse splay, inter-distributary bay, and levee facies. All of these facies associations are interpreted to have been deposited in the transitional area of the lower delta plain.

The AE-2 well is the deepest well, so it provides quite complete geological information. The variation of facies association in this well indicates three coal seams. The exciting thing about this well is that a thickened channel facies association is not found in wells AE-3 and well AE-4. It is used as rock correlation because a key bed can be interpreted as continuity.

Wells AE-3 and AE-4 (Figure 2) have different characteristics from wells AE-1 and AE-2. In well AE-3, several facies associations were found, such as interdistributary bay and swamp,, while in well AE-4, facies associations were found, such as interdistributary bay, crevasse splay, and swamp. Some of these facies associations are interpreted to have formed in the transitional environment of the lower Delta plain.

The interesting thing found in the AE-3 and AE-4 wells was the presence of coal divided by quite thick claystone fragments. In addition, both have similar lithological arrangements. Two coal seams were found in these two wells, which still showed one formation frame, so they were named seam-4A and seam-4B. Another interesting thing is that the coal in the two wells is associated with an inter-distributary bay which is relatively more influenced by the rise and fall of the sea level so that sulfur minerals are found and are interpreted to form in the transitional environment of the lower delta plain. Coal in the lower delta area is generally characterized by continuous and thick seams [8].

Field observations and drill data analysis results show that various facies and depositional environment associations of the rocks making up the AE Field are associated with Old Mahakam deltaic depositional systems. The overall facies associations include channel, swamp, crevasse splay, levee, and inter-distributary bay. These facies associations are interpreted to form in the lower delta plain transitional area.

4.2.1 Channel facies

In the study area, this facies association is characterized by upward smooth lithological succession and also found quite thick sandstones with normal gradation depositional

structures. Most of these facies associations are composed of medium to coarse sedimentary rocks or are dominated by fine to coarse pair rocks. The nature of the sandstones in the study area smoothes upward, starting from the coarse grain size, which erodes the precipitated layers that were formed earlier.

This facies association is more towards the tidal channel with upward smooth vertical succession; the mudstone fragments at the bottom of the layer indicate that during the deposition process, there was an erosion process of the underlying layer in the form of tidal flat deposits. Vertical succession smoothing upwards indicates that the depositional currents are very fast at the bottom and weaken at the top. The presence of mudstone inserts that form wavy to lenticular sedimentary structures indicates a suspended load process caused by tidal currents that carry sediment with very fine fractions in the form of mudstone. Support for this interpretation is also the presence of glauconite minerals in sandstones which characterize the effect of seawater.

4.2.2 Swamp facies

This facies association is characterized by the relatively thick presence of coal in the AE Field. The swamp environment that forms coal in the study area is formed in the delta system of the transitional lower delta plain. It shows the effect of seawater entering during coal formation so that there is sulfur in the coal and glauconite minerals in non-coal rocks. This facies is formed due to the supply of currents from downstream rivers, which form swamps so that much peat is formed.

4.2.3 Crevasse splay facies

This facies is interpreted as a product of flood overflow that overtook the levee. This facies association is characterized by medium to coarse sandstones that tend to be rough upward; reverse gradations are also found. Increasingly finer, this facies is associated with siltstone and claystone due to water overflowing into the flood plains and throwing sedimentary material to the outer side of the river by forming separate patterns and channel systems.

4.2.4 Levee facies

This facies association is characterized by fine fraction sedimentary rocks in claystone, siltstone, and fine sandstone intercalations, which tend to be smooth towards the top or normal gradation. It is caused by the initially high depositional energy at the beginning, followed by the deposition of a suspension of clay-sized grains due to standing water that exceeds the river body (overbank). The presence of iron oxide is due to the condition of the embankment, which continues to experience repeated flooding and drying. The presence of iron oxide makes the rock more compact.

4.2.5 Interdistributary bay facies

This facies dominates the study area. This facies association is characterized by claystone interspersed with sandstone-siltstone and alternating between claystone and sandstone. These facies are interpreted as open water bodies surrounded by dikes or marshes connected to the open sea by tidal channels. The effects of these tides make the lithofacies in the study area composed of alternating inserts of claystone and sandstone because the depositional energy varies but tends to flow smoothly. Another aspect that supports the effect of sea level tides in these facies is sulfur and glauconite minerals.

Thus, based on various existing facies associations, the AE Field is generally composed of coal and non-coal lithology deposited in a transitional lower delta plain environment. Coal seam 1, seam 2, and seam 3 (wells AE-1 and AE-2) are interpreted to have formed in the upper transitional lower delta plain (Figure 3). It is supported by data showing that this well has channel facies with relatively coarse sand grains. Some lithologies contain traces of roots and tree fossils, although their abundance is small. The interpretation of the depositional environment is also supported by the presence of glauconite minerals which indicate the effect of seawater during rock formation.

In addition, wells AE-1 and AE-2 (coal seams-1, 2, and 3) are followed by channel and level facies associations, which are not found in wells AE-3 and AE-4 (coal seam-4A and 4B). It also shows the presence of more sandstone than wells AE-3 and AE-4, although claystone predominates. Based on this, the researchers interpreted that the coal in wells AE-1 and AE-2 was deposited in the upper transitional lower delta plain environment.

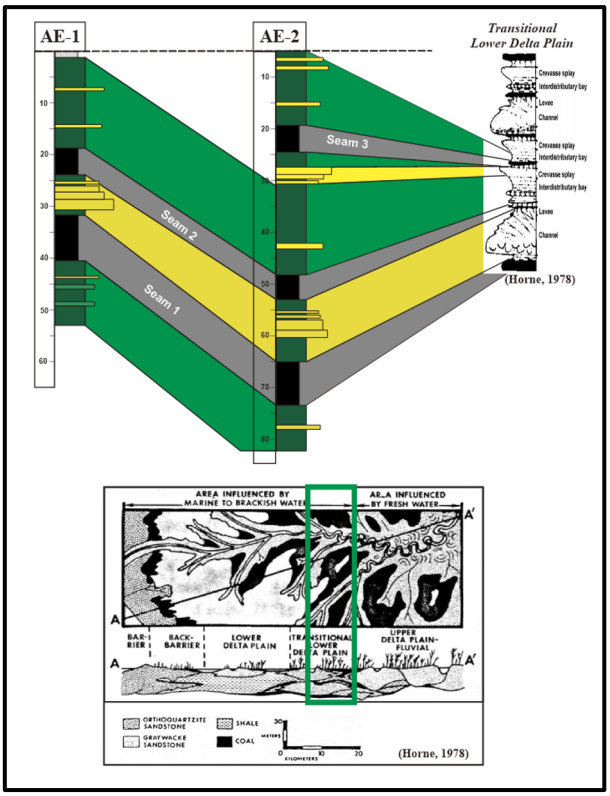

Fig. 3. The interpretation of the depositional environment of coal and non-coal lithology in wells AE-1 and AE-2.

Coal in wells AE-3 and AE-4 (seams-4A and 4B; Figure 4) is composed only of the swamp, inter-distributary bay, and crevasse splay facies, but in general, much of it is composed of inter-distributary bay facies. The presence of the dominant inter-distributary bay facies indicates a significant tidal effect of seawater. The presence of claystone in this well also dominates, so researchers interpret it to have formed in a deeper environment, namely in the lower transitional lower delta plain.

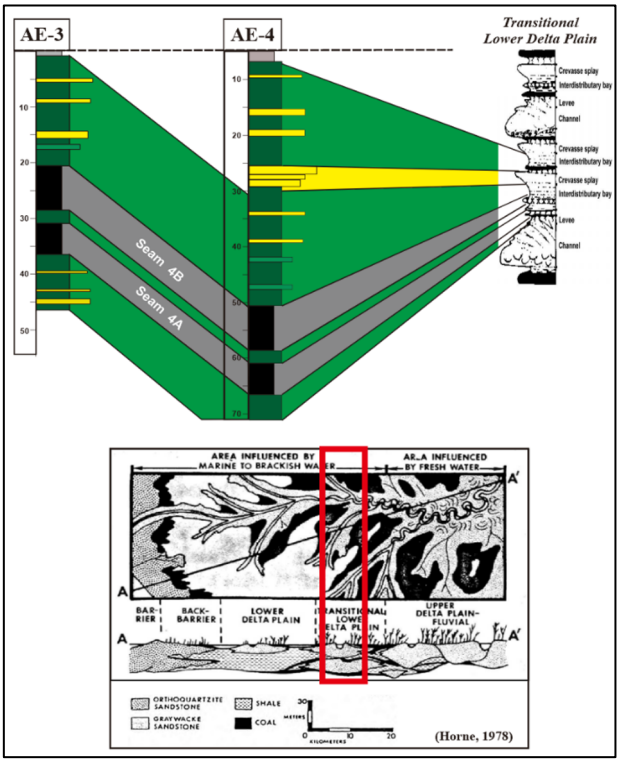

Fig. 4. The interpretation of the depositional environment of coal and non-coal lithology in wells AE-3 and AE-4.

5 Conclusion

The AE field is composed of clastic sedimentary rock lithology and coal. This field has four coal seams (seams-1, 2, 3, 4A, and 4B), with the coal distribution model having a dip of 10° - 12° to the northeast. The lithology that comprises the study area was deposited in the delta system depositional environment, namely in the lower delta plain transitional area. Coal is formed in the environment with facies associations: the swamp, crevasse splay, channel, levee, and inter-distributary bay.

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