A depositional setting variation and its effect to the coal quality of Warukin formation in Satui Area, South Kalimantan: Insight from maceral, biostratigraphy, electrofacies and lithofacies analyses

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Abstract. Warukin Formation is one of the coal bearing formation in Kalimantan that has significant coal resource. The formation as Middle Miocene Age and deposited in generally regression stage. In addition to coal, it is composed of mudstone and sandstone with siderite nodule, with some coal seams also have parting of carbonaceous mudstone. Coal from Warukin has various quality that possibly related to the changes in depositional environment. This study attempted to understand the relation between depositional environment and the coal quality. To do that, coal is sampled from coal seams that can be found in study area. After collected, the sample then analyzed using lithofacies, electrofacies, biostratigraphy, and maceral analysis. These various analyses would uncover the slight variation on depositional setting between each seam in study area. Later, the result then correlated with the coal quality analyses that have been done before. From the study, it is concluded that some coal sample has higher Sulphur content that related with deposition with more seawater influence. Biostratigraphy analyses indicate that the interburden deposited in shallow marine setting, thus indicate that the depositional interchanged between transitional setting to shallow marine. Electrofacies also indicate that there were progradation and retrogradation process in the depositional activities. Maceral studies also indicate different type of maceral component that reflect the depositional variation within the seam.

Keywords: Depositional environment, coal, sulphur, warukin formation, maceral

1. Introduction
Depositional environment can be known by analyzing geological data. Geological data that used is lithology and gamma ray log. Lithology data can be accessed by field works and observation. Sample of lithology then analyzed using lithofacies, preparation for maceral analysis and biostratigraphy analysis. The results of lithofacies analysis, maceral, and biostratigraphy can be used for determination of depositional environment. Gamma ray log then interpreted their shape based on eletrofacies shape and that shape can be used for determination process of sedimentation and their depositional environment.

Research area were located in Satui Area, Tanah Bumbu Regency, South Kalimantan Province which inside of purple box in figure 1. In Satui area include of Warukin Formation that contains coal,
mudstone, sandstone and sandstone with sideritic nodule. Warukin Formation produces coal with various quality, especially of total Sulphur contents [1]. Because of different quality of coal can related with process of depositional environment. So, we can reconstruct the process of sedimentation and depositional environment which is makes coal with variation quality. And understand the relation between depositional environment and the coal quality [2-5].

2. Experimental
Methods that used in this research are field works, laboratory analysis and studio analysis.

2.1. Field works
As the first method, field works is used to collect field data like lithology, structure and sampling of coal and their interburden sediment addition such as mudstone and sandstone. Field works at the open pit that have permissions. Sampling and observation do at high wall and channel sampling. Then sample can be used for laboratory analysis.

2.2. Laboratory analysis
After field works, sample of coal analyzed coal quality and maceral analysis and their interburden analyzed biostratigraphy analysis.

2.2.1. Coal quality. Sample of coal are analyzed by proximate and ultimate analysis to get value of moisture, total sulphur, ash, volatile matter, fixed carbon, contents of carbon, hydrogen, oxygen and nitrogen.

Figure 1. Location of research area in map from PT. Arutmin Indonesia.
2.2.2. Maceral analysis. Sample of coal are prepared into polish section and we determination presentation of their maceral based on shape and their genesis (table 1). After that we count value of tissue preservation index and gelification index to get depositional environment (figure 2).

\[
\text{Tissue Preservation Index} = \frac{(\text{Telovitrinite} + \text{telo} - \text{inertinite})}{(\text{Detro} - \text{gelovitrinite} + \text{detro} - \text{gelo} - \text{inertinite})} \quad (1)
\]

\[
\text{Gelification Index} = \frac{(\text{Vitrinite} + \text{telo} - \text{inertinite})}{(\text{telo} - \text{inertinite} + \text{detro} - \text{inertinite})} \quad (2)
\]

2.2.3. Biostratigraphy analysis. Sample of interburden sediment such as mudstone and sandstone from overburden of coal seams we prepared to find out small foraminifera include benthic and planktonic. Small foraminifera indicate depositional environment are influence by seawater and shallow marine environment.

| Maceral groups | Macerals subgroup | Macerals                  |
|----------------|-------------------|---------------------------|
| Vitrinite      | Telovitrinite     | Telinite, telocolinite    |
|                | Detrovitrinite    | Desmocolinite, vitrodetrinite |
|                | Gelovitrinite     | Gelocolinite, corpogelnite|
|                | Telo-inertinite   | Fusinite, semifusinite    |
| Inertinite     | Detro inertinite  | Inertodetrinite, micrinite|
|                | Gelo-inertinite   | Micrinite                 |
| Liptinite      |                   | Resinite, cutinite, sporinite, alginate, suberinit, and liptodetrinite |

Figure 2. Diagram of TPI X GI
2.3. Studio analysis

2.3.1. Lithofacies analysis. Lithology that have from field works can we identify of their sedimentation structure that indicates condition and process of sedimentation settling.

2.3.2. Electrofacies analysis. From gamma ray log of four drill hole we determine shape of curve and interpreted their process sedimentation and depositional environment. Every shape refers to process sedimentation as in figure 3 [5].

3. Results and discussion

3.1. Lithofacies
From field work there are 4 coal seam which are DL 1, EU 1, EU 2 and EU 3 (figure 4). DL1 has massive coal and EU has parting and lenses of Sulphur. Carbonaceous parting shows more supply of sediment when deposition of coal or the occurrence of flood events carrying sediments. Where sulfur lenses indicate two different depositional currents, but the influence of seawater is more dominant that it can reduce sulfate to sulfur. Overburden (OB) and Interburden (IB) are claystone with sediment structure parallel lamination. The parallel laminate sediment structure shows deposits occurs in low energy [6-8].

3.2. Electrofacies
From gamma ray data all of drill hole have all type of eletrofacies and indicates retrogradation, progradation and aggradation phase. There are 4 wells, named is Selatan for the south well, Utara for the north well, Barat for the west well, and Timur for the east well. Of the four wells shows various electrofacies shapes, such as cylindrical shape, bell shape, funnel shape, symmetrical shape, and serrated shape. It shows that research area was deposited in the transition zones between land and sea where sedimentation process is strongly influenced by the presence of a sea level change phase (retrogradation, progradation and aggradation phase). South and east drill holes have more complicated type electrofacies than north and west drill holes (refers to figure 5).

Figure 3. Shape of electrofacies
Figure 4. Lithofacies of 4 seams. From top to bottom: DL1, EU1, EU2 and EU3.

Figure 5. Electrofacies from drill holes

The thickness of north well is 45 m and with the thickness of coal seam is about 1 m to 10 m, south well is 114 m and with the thickness of coal seam is about less than 1 m, west well is 75 m and with the thickness of coal seam is about 50 cm to 4 m, also east well is 100 m with the thickness of coal seam is about 50 cm to 4 m.

3.3. Coal quality
From coal quality data EU 2 seam, EU 1 floor seam, and EU 3 floor seam have high content of total sulphur. That indicates there are effect of marine while depositional, which is marine can reduce sulphate from the origin vegetation into Sulphur (table 2 and table 3) [9, 10].

3.4. Maceral
Maceral data shows that DL 1 seam. EU 1 seam. EU 2 seam was deposited in Upper Delta Plain Fluvial and EU 3 Seam was deposited in Backbarrier (figure 6). And it refers from EU 3 until DL 1 has occurred regression phase. The result of maceral analysis shown at table 4 and figure 6. There are sample of maceral’s shape in figure 7 [11, 12].
### Table 2. Coal quality data from PT. Arutmin Indonesia.

| Sample Code | M % adb | A % adb | TS % adb | CV % adb |
|-------------|---------|---------|----------|----------|
| CR DL 1     | 16.2    | 10.0    | 0.2      | 5150     |
| CB DL 1     | 18.8    | 2.6     | 0.2      | 5479     |
| CF DL 1     | 17.6    | 3.3     | 0.3      | 5569     |
| CR EU 1     | 25.4    | 4.1     | 0.12     | 4.7      |
| CB EU 1     | 21.9    | 2.7     | 0.2      | 5.1      |
| CF EU 1     | 19.8    | 3.6     | 0.8      | 5367     |
| CR EU 2U    | 21.9    | 7.5     | 2.3      | 4749     |
| CB EU 2U    | 24.7    | 3.9     | 1.7      | 4944     |
| CF EU 2U    | 19.2    | 15.8    | 0.9      | 4552     |
| CR EU 2L    | 20.5    | 9.3     | 2.1      | 5163     |
| CB EU 2L    | 24.5    | 5.8     | 0.8      | 4877     |
| CF EU 2L    | 19.4    | 13.1    | 0.8      | 4937     |
| CR EU 3     | 22.6    | 5.0     | 0.3      | 4.9      |
| CB EU 3     | 23.6    | 9.6     | 0.5      | 4.6      |
| CF EU 3     | 19.9    | 7.9     | 0.3      | 5.2      |

- M: Moisture
- VM: Volatile
- C: Carbon
- A: Ash
- FC: Carbon
- H: Hydrogen
- O: Oxygen
- N: Nitrogen
- TS: Sulphur

### Table 3. Coal quality data from Puslitbang Tekmira.

| Sample | Proximate analysis | Ultimate analysis |
|--------|--------------------|-------------------|
|        | M % adb | A % adb | VM % adb | FC % adb | C % adb | H % adb | N % adb | TS % adb | O % adb |        |
| DL1    | 15.7    | 3.4     | 42.3     | 38.6     | 57.2    | 5.9     | 0.9     | 0.3     | 32.3    |
| EU1    | 15.5    | 2.5     | 40.9     | 40.9     | 57.7    | 5.8     | 0.9     | 0.3     | 32.6    |
| EU2U   | 14.5    | 6.7     | 40.8     | 38.0     | 55.1    | 5.5     | 0.7     | 2.2     | 29.7    |
| EU2L   | 14.8    | 3.8     | 41.7     | 39.7     | 57.9    | 5.9     | 0.8     | 1.0     | 30.6    |
| EU3U   | 11.2    | 3.7     | 53.5     | 31.6     | 62.9    | 6.8     | 0.7     | 0.5     | 25.7    |
| EU3L   | 14.0    | 7.2     | 42.7     | 36.1     | 56.5    | 6.1     | 0.8     | 0.9     | 28.5    |

### Table 4. Result of maceral analysis

| Sample | Tl | Dt | Gt | V | Re | Al | Sb | F | SF | Sc | Ma | I | Py | TPI | GI | IED | Rank |
|--------|----|----|----|---|----|----|----|---|----|----|----|---|----|-----|----|-----|------|
| DL1    | 27.6 | 39 | -  | 66.6 | 1 | 1.6 | 3.6 | 6.2 | 5.6 | 20 | -  | 25.6 | 1.6  | 1.36 | 3.60 | UDP  |
| EU1    | 41.4 | 35.4 | -  | 76.8 | -  | 1.6 | 1.6 | 2.2 | 16.4 | 2.6 | 21.2 | 0.4 | 1.58 | 5.13 | UDP  |
| EU2U   | 40.6 | 27.4 | -  | 68 | 0.4 | 0.4 | 1   | 1.8 | 10 | 15 | 2.2 | 27.2 | 3    | 2.22 | 3.72 | WFS  |
| EU2L   | 43   | 36.2 | -  | 79.2 | 0.6 | 0.4 | 1   | 2  | 13 | 5.4 | 0.4 | 18.8 | -    | 1.68 | 5.30 | UDP  |
| EU3U   | 29.6 | 51.6 | 0.6 | 81.8 | -  | 1   | 1   | 9.6 | 5  | -  | 14.6 | 2.6  | 0.8  | 6.59 | BB   |
| EU3L   | 32.4 | 51.4 | -  | 83.8 | -  | -   | -   | 0  | 6.6 | 6.6 | -  | 13.2 | 3    | 0.89 | 7.35 | BB   |

- Tl, Dt, Gt: Macerals
- V: Total Volatile
- Re: Total Residual
- Al, Sb: Alumina and Selenium
- F, SF: Fluorine and Sulphur
- Sc, Ma: Silicon and Magnesium
- I: Iron
- Py: Pyrites
- TPI, GI, IED: Rank indicators
- UDP, BB: Lignite and Bituminous coal
3.5. Biostratigraphy
Overburden EU 1 and overburden EU3 have contents foraminifera indicates marine environment. Sample of foraminifera are shown at figure 8.

![Figure 6. Results depositional environment of plotting maceral data.](image)

![Figure 7. Maceral in sample](image)

![Figure 8. Sample of overburden with foraminifera. Top is overburden EU 1 seam and bottom is EU 3 seam.](image)
3.6. Reconstruction of depositional history

Based on data analysis of lithofacies, electrofacies, maceral, and biostratigraphy, it was found that the deposition of the four seams interchange in depositional environment which showed the regression phase (figure 9) [13, 14]

4. Conclusion

Coal seam that deposited by the influence of sea water has a high content of sulphur. Differences characteristic of seam indicates depositional interchanged between transitional settings to shallow marine. The depositional environment of coal affected by seawater will increase the total Sulphur content which will reduce the quality of coal.

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