The Occurrence of Acid Mine Drainage in Tanjung Formation, South Kalimantan – Indonesia “The Correlation with Clay Minerals Genesis, Reviewed from Sedimentary Process, with Geochemical Aspect”

by Basuki Rahmad

The Occurrence of Acid Mine Drainage in Tanjung Formation, South Kalimantan – Indonesia "The Correlation with Clay Minerals Genesis, Reviewed from Sedimentary Process, with Geochemical Aspect"

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ABSTRACT

Tanjung Formation has a lot potential as a coal-bearing formation in South Kalimantan. However, most of mining activities have a serious risk concerning the coal-bearing strata have high enough level of acidity and greatly affects the coal's quality. The purposes of this research are to understand lithology characteristic, the type of clay minerals, and the influence of clay genesis in the formation of acid mine drainage. To understand the occurrence of acid mine drainage, the methods used in this research are surface geological mapping supported by PIMA and maceral analysis. Based on the surface geological mapping and analysis on the depositional environment, there are three rock units in this area; from the oldest to youngest Pitanak andesite, Tanjung sandstone, Tanjung claystone, and alluvial deposit. Tanjung claystone was deposited in Transitional Lower Delta Plain – Back-barrier which is influenced by seawater or marine environment; and its coals were deposited in dome/ridge-shaped Marsh (Bog) in different states, limnic and telmatic state, influenced by groundwater level (trangression – regression, rainy and dry season). Thus, produced framboidal pyrite and gypsum as it potential acid forming material. Besides that, the coal mine activity (excavation or moving the overburden material) causing the exposure of sulfide to the air; and in this condition, sulfide minerals will be oxidized, dissolved by meteoric water and then forming the acid mine drainage in the research area.

Keywords: *Tanjung Formation, Tanjung claystone, Lower Delta Plain, acid mine drainage, clay minerals, gypsum, framboidal pyrite.*

INTRODUCTION

Barito Basin is a basin that consist various coal-bearing formations. One of its coal-bearing formations is Tanjung Formation, which is until now the target of coal exploration by many companies in South Kalimantan. However, the relatively high-level acidity of total sulfur could be a hindrance to the activity of mining production, one of them is acid mine drainage which will have serious impacts on the environment. Therefore, it is necessary to analyze the depositional environment and clay minerals to understand their relationship with the formation of acid mine drainage.

Depositional environment analysis is supported by PIMA analysis to determine the type of clay minerals. Clay minerals are the main factor of ion carrier which have been decomposed due to the acid and mixed with coal-overburden material. The purposes of this research are to understand lithology characteristic, the type of clay minerals, and the influence of clay genesis in the formation of acid mine drainage.

DATA AND METHODS

The research was conducted to determine the occurrences of acid mine drainage at the Tanjung Formation coal mines. The research methods used are detailed surface geological mapping, stratigraphic measuring section, and rocks sampling used for various analyses in laboratorium.

The methods used in this research are coal petrography and Portable Infrared Mineral Analyzer (PIMA) analysis. Coal petrography analysis is performed to determine the coal facies and its origin. PIMA analysis is performed to determine the type of clay minerals which have potential acid forming. Based on both analyses, the authors can understand and determine which coal-bearing depositional environment that could support the material distribution to form the acid mine drainage.

GEOLOGICAL FRAMEWORK

The research area is located in southeast of Barito Basin, which is one of the Tertiary basins in South Kalimantan. In the northern part, Barito Basin is separated from Kutai Basin by Adang Fault; whereas in the eastern part, it was separated from Asam-asam Basin by Meratus Complex that extends from southwest to northeast; the basin has a narrow opening to the south towards the Java Sea; and the basin is an asymmetric basin, formed a foredeep in the eastern part and a platform approaching the Schwaner Complex towards the west. In general, the geomorphology of research area are undulating hills with 148 m.a.s.l.

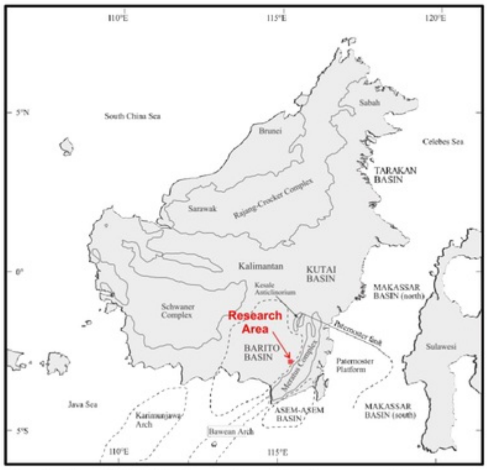

Fig. 1 Simplified physiography of Kalimantan (Witts et al., 2012)

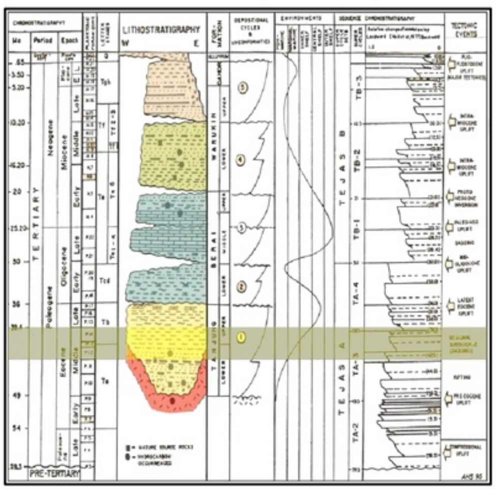

Fig. 2 Tectonostratigraphy of Barito Basin (Satyana, 1995). Stratigraphy of research area is marked yellow.

Based on the surface geological mapping, there are three rock units in this area, from the oldest is Pitanak andesite (Late Cretaceous), Tanjung sandstone (Eocene), Tanjung Claystone (Eocene), and alluvial deposit (Holocene).

Pitanak andesite is the basement of this area and only consisted of andesite (locally); and the base of this unit is Late Cretaceous based on dating performed by previous researcher (Sikumbang & Heryanto, 1994; Witts et al., 2012) . Tanjung sandstone is consisted of domination of sandstone with intercalation or interbedded siltstone, claystone, carbonceous claystone, and locally coal seam with its thickness is 0,42 meters; this unit deposited in Transtional – Lower Delta Plain. Tanjung claystone is consisted of domination of claystone and carbonaceous claystone, with intercalation or interbedded of siltstone, sandstone, carbonaceous shale, and nine coal seams (including shaly coal) with its thickness ranging from 0,25 to 1 meter; this unit deposited in Lower Delta Plain – Back-barrier. Both of Tanjung sandstone's and claystone's age were determined by pollen fossils; *Verrucatosporites* sp., *Verrucatosporites usmensis*, *Dicolpopollis* sp., *Discoidites* sp., *Striatricolpites* sp., *Laevigatosporites*, *Poligonum*, *Gleicheniidites* sp., *Retistephanocolpites williamsi*, *Flourschuetzia trilobata*, *Proxapertites operculatus*, *Palmae* type, *Selaginella* type, *Durio* type, and *Arenga*; which are indicated Eocene and deposited in fresh water swamp.

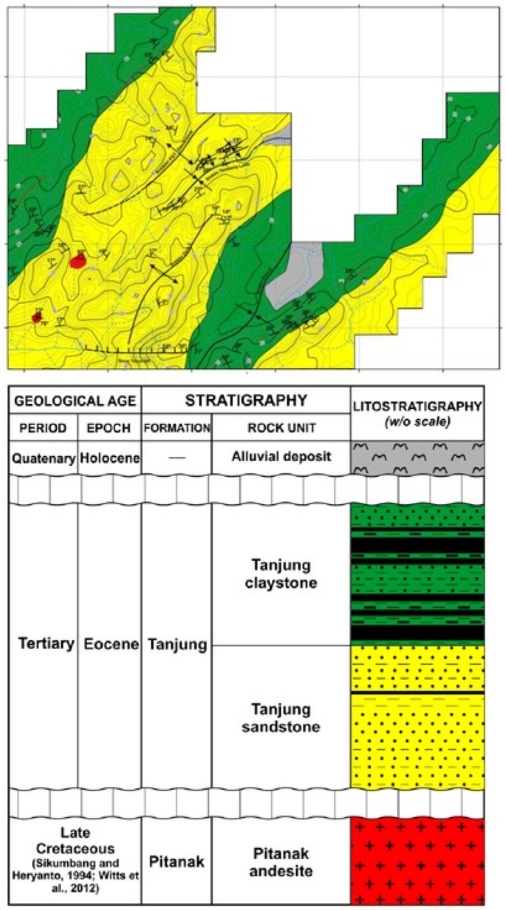

Fig. 3 Geological map and stratigraphy of Pengaron area and its adjacent area.

CLAY MINERALS ASSOCIATION

Clay minerals are common weathering products, and act as a secondary mineral. These minerals were formed on the surface where air and water interacted with silicate minerals, which break it down into clay minerals and other products. Clay minerals are one of the main factors as the carrier of acidic compounds that break down and mixed with the coal overburden.

40% of research area is Tanjung claystone with most of it has iron oxide as its matrix. This shows that the Tanjung claystone is affected by heavy weathering due to the exposure of mining activity, and potentially to form acid mine drainage.

Sample Code	Mineral Association
AGM-S1	Kaolinite
	Halloysite
	Gypsum
KCM-S1	Kaolinite
	Halloysite
	Siderite
	Gypsum

Kaolinite Mineral Group
Carbonate Mineral Group
Sulfate (secondary) Mineral Group

Table 1 Clay minerals association in Tanjung Formation.

Based on PIMA analysis, the clay minerals that existed in research area are kaolinite and halloysite which included in kaolinite mineral group (Bailey, 1980). These minerals were formed from intensive chemical weathering of acidic volcanic rocks; and in this case, these minerals were assumpted from the basement in this area or from the Meratus Complex in the southeast of research area. Siderite was included in carbonate mineral group; this mineral was formed in the reduction or closed environment (non-marine), and in this case it was formed in swamp. The gypsum is included in sulfate (secondary) mineral group (Bailey, 1980); this mineral was formed from the oxidation of sulfide minerals (pyrite) when exposed and influenced by seawater.

COAL MACERALS

Tanjung Formation's coal was observed in *PKP2B* of PT. Kadya Caraka Mulia and PT. Antang Gunung Meratus with its thickness ranging from 0,25 to 1 meters. Coal macerals were used in this research to understand the influence of the water level in peat evolution and sedimentary process as well as to determine what type of pyrite that was formed.

Those coals were analyzed with organic petrography method, and the results were converted to TPI (Tissue Preservation Index), GI (Gelification Index), GWI (Groundwater Index), dan VI (Vegetation Index). The converted results were plotted to TPI vs GI (Diessel, 1986; Lamberson et al., 1991; **Fig. 5** and **6)** and GWI vs VI facies diagram (Calder et al., 1991; **Fig. 7**).

Based on the observation, the formed pyrite was pyrite framboidal. This type of pyrite indicated that these peats were influenced by seawater .

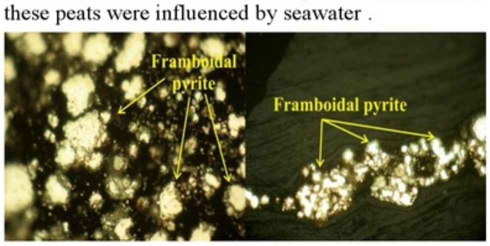

Fig. 4 Framboidal pyrite, indicated that the peats were influenced by seawater.

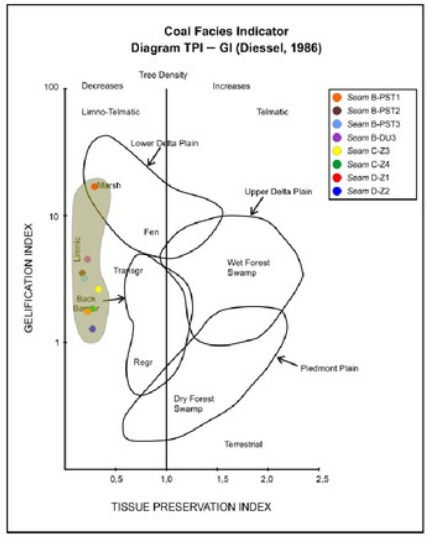

Fig. 5 Coal facies (according to Diessel, 1986) in Tanjung coal. The coal was deposited in Marsh in limnic state (low moor).

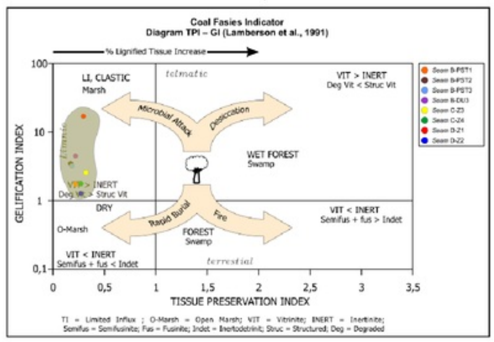

Fig. 6 Coal facies (according to Lamberson et. al, 1991) in Tanjung coal. The coal was deposited in Marsh in limnic state (low moor) and dominated by microbial attack process.

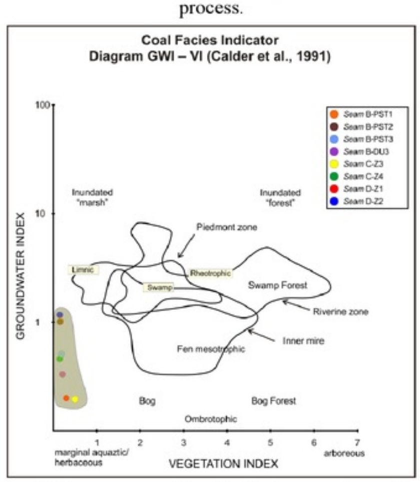

Fig. 7 The peat type of coal in Tanjung coal was Bog (ombrotrophic peat, high moor)

Based on depositional environment and coal facies analysis by using Diessel's (1986) and Lamberson et al.'s (1991) concept, the peats were deposited in Marsh environment in limnic state (low moor) which is contradicted with the result from Calder et al.'s concept, that shown the peats were deposited in telmatic state (high moor).

If these results are integrated, we can conclude that the peat swamps were dome-shaped/ridge-shaped Marsh (Bog) in limnic state (low moor) and telmatic state (high moor). These peat swamps' environment were located in tropical climate with two seasons (dry and rainy seasons), which were highly contributed to peat accumulation, especially the peat's water level fluctuation as a primary control in peat accumulation (Dehmer, 1993 in Rahmad, 2013).

The changes in peat swamps' water level caused the maceral in Tanjung Formation's coals weren't homogeneous. When in limnic state (rainy season, seasonal flooding, or transgression phase), maceral vitrinite and liptinite were well-preserved due to peats were submerged below groundwater level (anoxic). But, when in telmatic state (dry season or regession phase), the peat swamps weren't completely submerged below groundwater level, which caused the peat's top parts in dry state (oxic state). In oxic state, the top part were oxidized and change the maceral into inertinite, the same thing that caused some of the forest fire in several places and turned the plants into charcoal (Cook and Kantsler, 1982). Sclerotinite are present abundantly in inertinite group, convincing our state that the peats were in telmatic state, when the groundwater receded, the top parts were in humid state and the sclerotinite (fungus) would grew and created oxic environment which is contributed in oxidation process to the other macerals. While in the rainy season, the peat swamps would receive intense water from rain and seasonal flood, caused the other sedimentary material mixed into the peat swamps (limited influx clastic), and as a result, the content of mineral matter in Tanjung Fm.'s coal are generally high. In addition, the transgression phase in research area also contributed to cause the content of mineral matter, including pyrite, in coal became high.

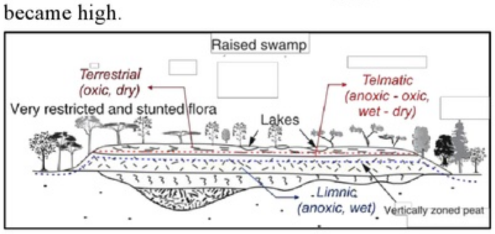

Fig. 8 Peat swamp environment model approaching in research area (modified from McCabe, 1984 in Thomas, 2013).

RELATIONSHIP BETWEEN SULFUR PRESENCES WITH DEPOSITIONAL ENVIRONMENT

Each of every coal overburden deposit has various depositional environment characteristic. It depends on the condition where the sediment was deposited to distinguish the sub-depositional environment specifically; and based on detailed profile analysis, the sediments in the area were deposited in (older to younger) distal bar then regressed into distributary mouth bar (Transitional – Lower Delta Plain; Tanjung sandstone) and gradually became interdistributary bay and there's a local storm wash-over deposit (Lower Delta Plain – Back-barrier; Tanjung claystone).

Regionally, the sulfur content is influenced by depositional environment. The sulfur content in Lower Delta Plain will be higher than in Transitional Lower Delta Plain; because if the coalification in process and the interdistributary deposit overlain the peat deposit, the existed bacteria in the peat would be dead; one of the reason why the sulfur content is concentrated at the roof or floor of coal seam, each of them has a sulfur content of its own. The sulfur will be bounded with the minerals that derived from the sub-depositional environment.

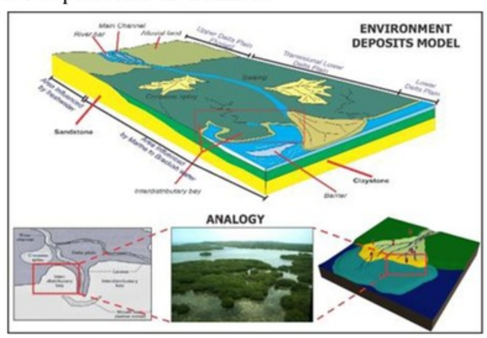

Fig. 9 Tanjung depositional environment model, focused on the Tanjung claystone's coal, interdistributary bay of Lower Delta Plain.

The impact from depositional environment to the overburden deposit is the content of chemical aspect causes enrichment of sulfide, which potentially act as one of the compounds that forms acid mine drainage.

In the research area, the transgression phase has the higher sulfur content, reviewed from claystone and siltstone as its lithology and featuring iron nodule, pyrite and clay minerals that associated with marine environment or affected by seawater.

THE FORMATION OF ACID MINE DRAINAGE

Acid mine drainage (AMD) is formed when certain sulfide minerals in the rock influenced by oxidation. In the coal mines, iron sulfide usually dominated by pyrite, and sulfide minerals are in the form of a bound between the sulfur and metal that found scattered in the nature.

The coal mine activity (excavation or moving the overburden material) causing the exposure of sulfide to the air. In this condition, sulfide minerals will be oxidized, dissolved and then forming the acid mine drainage. Acid mine drainage has a potential to dissolve the metal that passed through it and forming streams of hazardous or toxic substances, thus will degrading the environtment's quality.

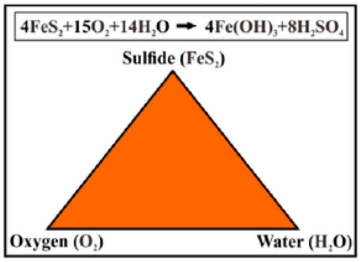

Fig. 10 Formation of acid drainage

In the research area, although the PIMA analyses result in all of them are potential acid forming (PAF) materials, only one of them that has most potential producing the AMD, which is gypsum. This is because the gypsum was formed by the influenced of seawater which will reducted to sulfide in closed environment. The other clay minerals, kaolinite and carbonate group are not the main PAF; this was due to the pyrite's type is framboidal pyrite, a sulfat pyrite that was produced from the influence of seawater or marine environement.

CONCLUSION

Tanjung Formation, especially Tanjung claystone, in research area was deposited in Lower Delta Plain – Back-barrier, where the environment was influenced by seawater or marine environment; this was caused by the transgression – regression cycle in the research area. The influence of seawater produced framboidal pyrite (sulfate pyrite) and gypsum as a clay mineral; thus make them as the most potential materials that will produce acid mine drainage.

The coal mine activity (excavation or moving the overburden material) causing the exposure of sulfide to the air. In this condition, sulfide minerals will be oxidized, dissolved by meteoric water and then forming the acid mine drainage in the research area.

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