K/AR DATING OF BUKIT ASAM AND BUKIT KENDI INTRUSIONS RELATED TO AGE OF MATURITY AND INCREASING OF COAL QUALITY IN TANJUNG ENIM AREA, SOUTH-SUMATERA

HARRY UTOYO
Geological Survey Centre,
Jl. Diponegoro 57 Bandung, Indonesia, Ph (022) 7203205
E mail: harryutoyo@grdc.esdm.go.id

Received: 08 June 2007, first revision : 16 August 2007, second revision : 24 August 2007, accepted : 22 October 2007

ABSTRACT

Coal bearing Muara Enim Formation is widely spread in Muara Enim, especially in Tanjung Enim District, South-Sumatera Province. Field observations display increasing maturity and quality towards Bukit Asam and Bukit Kendi intrusions. Potassium argons age analysis revealed that Bukit Asam is 0,9203 ± 0,26 million years in age and Bukit Kendi is 1,1472 ± 0,29 million years in age respectively, while Bukit Serilo displays negative age. These K/Ar ages result revealed that increasing maturity and quality of coal of the Bukit Asam and Bukit Kendi have taken place since 1,14 million years.

Keywords: K/Ar dating, coal, age of maturity, quality

1. INTRODUCTION

Coal deposit in the South Sumatera Basin laying in the Muara Enim Formation that precipitated in Miocene-Pliocene, is widely spread and part of them have been explored since the colonialism era till today. The coal deposit, in some location, has been intruded by andesite, and it made them matured and developed in its quality. In this case, the exact age, when the intrusion happened, and the range of intrusion of intrusion result, is not studied yet.

The studied area is based on geological condition of the South Sumatera Basin and the coal deposit especially in Muara Enim Formation that is widely spread.

The purpose of this paper is to carry out any research for K/Ar (Potassium-Argon) dating of Bukit Asam and Bukit Kendi intrusions, related to the age of the maturity and increasing of coal quality in the Tanjung Enim area, South-Sumatera.

The goal is to find out any relationship among (especially) intrusive rocks, its maturity and increasing quality of coal. The studied is situated in range at the coordinate of 103°30'00" - 103°52'30" East Longitude and 3°37'30" - 4°00'00" South Latitude, especially in the region of Bukit Asam and Bukit Kendi, Tanjung Enim and the surroundings, Regency of Muara Enim, South Sumatra (Figure 1). The region can be achieved by air to Palembang then continued in land by car as long as 200 km to Tanjung Enim. The purpose of it is in obtaining geological data like: petrology, geochronology, stratigraphy, micro- and macro-structures, geomorphology, and metamorphic indications on sediment contact and hard rocks. The data are expected to illustrate the geological features and metamorphic process and the maturity of coal.

The South Sumatera Basin, especially at Bukit Asam region and the surrounding had been studied by previous researchers, among others: Tobler (1906), Mannhardt (1918), Roeslan (1984), Santoso and Daulay (2006). Generally they

Content

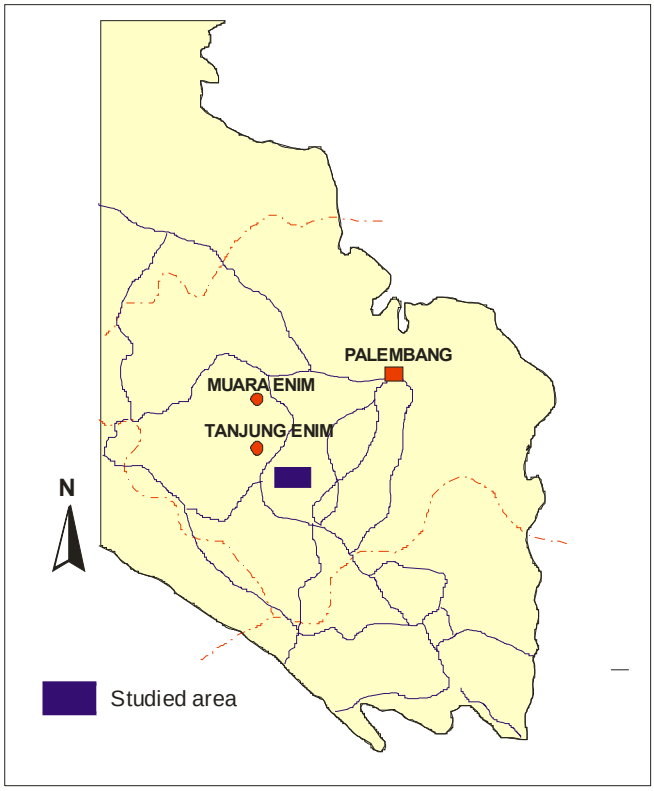


Figure 1. Locality of the studied area

stressed on the coal lays in Muara Enim Formation, which is divided into three sections:

1. Lower part coal, it is called Merapi coal seam (Merapi laag), because of its characteristic is the same as coal located in Desa Merapi, near Air Lematang stream; whereas in Bukit Asam region, the coal seam is not revealed, but in Bukit Kendi region (approximately 10 km to the south) the coal seam D is clearly revealed.

2. Middle part coal, consisting of Petai coal (C), Suban (B) and Mangus (A). The three seams are clearly revealed in Bukit Asam, but in Bukit Kendi is incompletely revealed. There is only one (B) seam in Suban, two seams in Bukit Asam, B1 and B2, Mangus seam is only one seam (A2), and in Bukit Asam is two seams, A1 and A2; otherwise, Petai coal seam (C) in Bukit Kendi consists of two seams, C1 and C2, whereas in Bukit Asam there is one seam C.

3. Upper part coal, consisting of six seams, whereas in Bukit Kendi there are twelve seams that is called Gantung seam, which is clearly revealed in Air Liku, Air Endikat and around Bukit Kendi.

2. GEOLOGICAL SETTING

2.1 Regional Geology

The studied region is part of Lahat sheet and South Sumatra Basin that was formed in Tertiary epoch (Figure 2). At the initially forming of the region, there is Pendopo plateau that spreads out to the northwest – southeast. The South Sumatra Basin is divided in two deposit group in Cenozoic era, namely Telisa and Palembang Groups.The lithological sequences of the Telisa Groups were deposited in a flooded marine environment (transgression), whereas the Palembang Group was in a dried marine environment (regression).

The Telisa Group consists of Lahat, Talangakar, Baturaja and Gumai Formations; while the Palembang Group consists of Air Benakat, Muara Enim, and Kasai Formations. In Quarternary epoch the sediment from volcanic material is the main rocks that formed in the Lahat sheet.

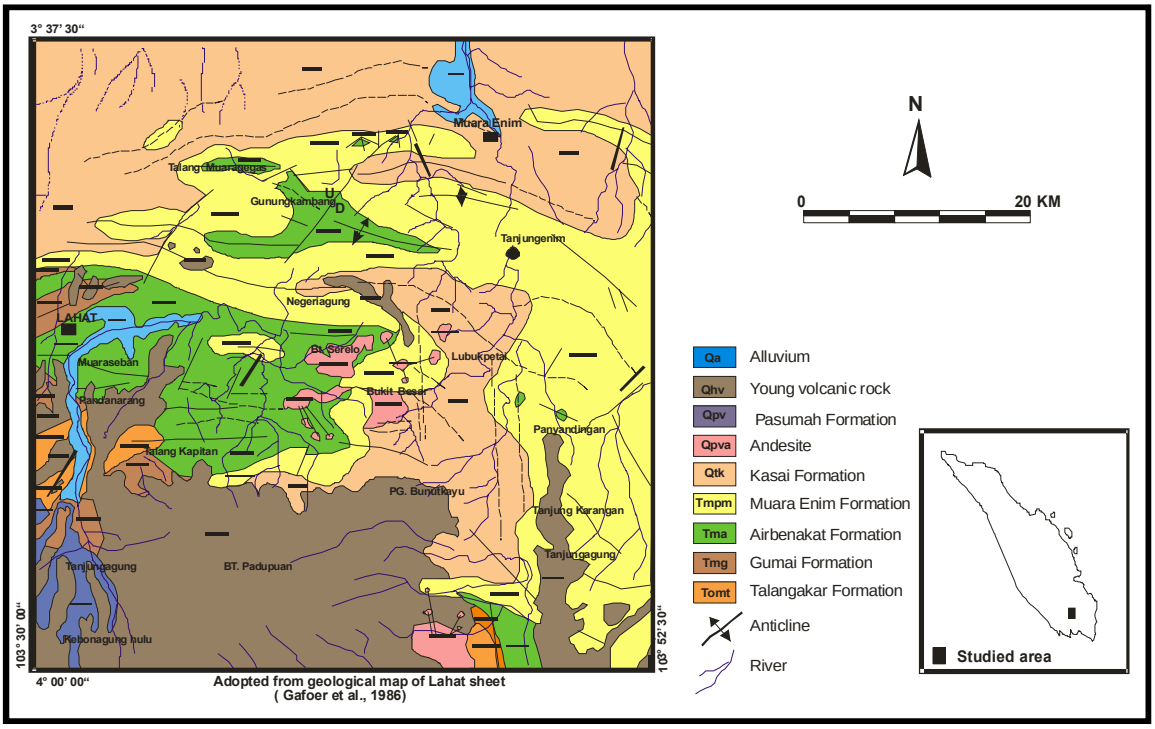


Figure 2. Geological Map of Tanjung Enim, South-Sumatera

Regionally, the west of Indonesian archipelago can be divided into three substances of tectonic structures (Koesoemadinata, 1976), they are:

1. Stable Area (*Sundaland*)
   This area is well known as *Paparan Sunda* (Sundaland), where since Tertiary epoch (± 60 million years ago) the land had been stable. The area includes Bangka, Belitung, West Kalimantan, Malaya peninsula, Jawa Sea area, and partly in Lampung area to the north direction until South China Sea.

2. Volcanic Inner Arc
   This area is mobile mountain zone, which shows volcanic and tectonic activities. The zone spreads from west of Sumatra island, it is ridge of Bukit Barisan mountain and continues to the ridge of Southern Jawa mountain and ended in Nusa Tenggara islands.

3. Non-Volcanic Outer Arc
   The area is located at the outer part of west shore of Sumatra island through the islands of Singkil, Nias, Melawai and Enggano and continues to south of Jawa Sea.

The South Sumatra Basin is a Tertiary sediment concave, where is parted in the north by Pegunungan Tigapuluh, in the east is bordered on Paparan Sunda, in the west is by Bukit Barisan and in the south is by Lampung plateau.

2.2 Geology of the studied area

The Muara Enim Formation had been observed by some former researchers, such as Tobler in 1906 and Hartmann in 1918 in Bunian and Sukamerinda areas. These observations concluded that the coal of Muara Enim Formation was formed in allochthonous way at marine environment, because the authors found local marine fossil in Air Litaan, Bunian and Sukamerinda. Then, Manhardt in 1918, found that the coal of Muara Enim Formation was deposited in autochthonous way at non-marine environment. The formation consists of claystone and sandstone with its special characteristic of the widespread coal sediment availability, including into Palembang Group. The formation in some places is intruded by andesitic rocks. The morphology of studied area is part of South Sumatra Basin. The study was conducted in Tanjung Enim area and surroundings, especially in Bukit Kendi and Bukit Asam areas.

The studied area can be divided into 2 units of

Content

morphology based on its topography; steep and flat hills. The morphologic unit of the steep hill is identified by The density of contour interval and the straightness of river streams. This area covers Bukit Asam with 283 meters in height, Bukit Lengkuas 255 meters in height, Bukit Tapuan with 223 meters in height, Bukit Kendi with 371 meters in height, Bukit Cepadang with 250 meters in height, and some other lower hills with morphology that is steep enough. This morphologic unit is formed by andesitic rocks that spreads covering 10% of the studied area.

Flat hills morphology is relatively slope, generally spreading out around Air Enim big river stream to the boundary confine of steep morphology around the intrusive area as mentioned before. Also, there are puddles in this area and they are caused by former explorations. This morphologic unit is structured with sediment such as sandstone, siltstone, claystone, coal, tuff, alluvial pebble and gravel covering about 90% of studied field.

The pattern of river stream at the andesitic intrusive location is generally small and radial, ended at estuaries of Air Lawai and partly to Air Enim. The rivers around hilly region are commonly straight streams, vertical erosion that is strong enough. The bigger rivers are Air Lawai and Air Enim, which are located further from the intrusive area. They formed meandering where horizontal erosion is stronger than the vertical one.

2.3 Stratigraphy of the Studied Area

Sedimentation process in Bukit Kendi area had occured since Upper Miocene until now, shifting from shallow marine to non-marine. Stratigraphy in the region started with the forming of Air Benakat Formation that is deposited in a shallow marine environment. The type of rock consists of yellow-brownish glauconite sandstone, fine medium grain, lamination of sediment; symmetrical at upper part, and massive form at lower part and well sorted. The thickness of the formation is greater than 250 meters, spreading in Bukit Kendi area. Mio-Pliocene sediments are deposited in Muara Enim Formation, and the formation can be divided into 2 units, which is in lower part, and upper part (Table 1).

The lower part is sandstone unit with intercalated siltstone, claystone and coal. This unit is characterized by 5 seams of coal, i.e.: D, C1, C2, B and A2 seam, which are interbedded with grey siltstone intercalated claystone. The sediment structure of grey claystone is symmetrical, wavy and well sorted, yellow-greyish sandstone. The thickness of this unit is approximately 100 to 200 meter, and they are widely spread.

Tuffaceous sandstone unit is present in upper part with intercalated tuffaceous siltstone, tuffaceous claystone and coal. This unit is identified by 12 seams of Gantung coal. The coal is black-brownish, hard and compact. Besides, there is conglomerate of tuffaceous sandstone that is well sorted and consists of sediment, feldspar also quartz fragments with the shape of sub-rounded. The structure is finer than upper part, symmetrical to wavy lamination. The tuffaceous sandstone is yellow-white, well sorted and cross-bedded sediment structure. The siltstone is bright grey, carbonate, tuffaceous and symmetrical lamination of sediment structure. The tuffaceous claystone is light grey interbedded oxidized claystone (clay ironstone), brown-reddish, hard, sub-rounded shape. This unit is widely spread with the thickness around 250-550 meters.

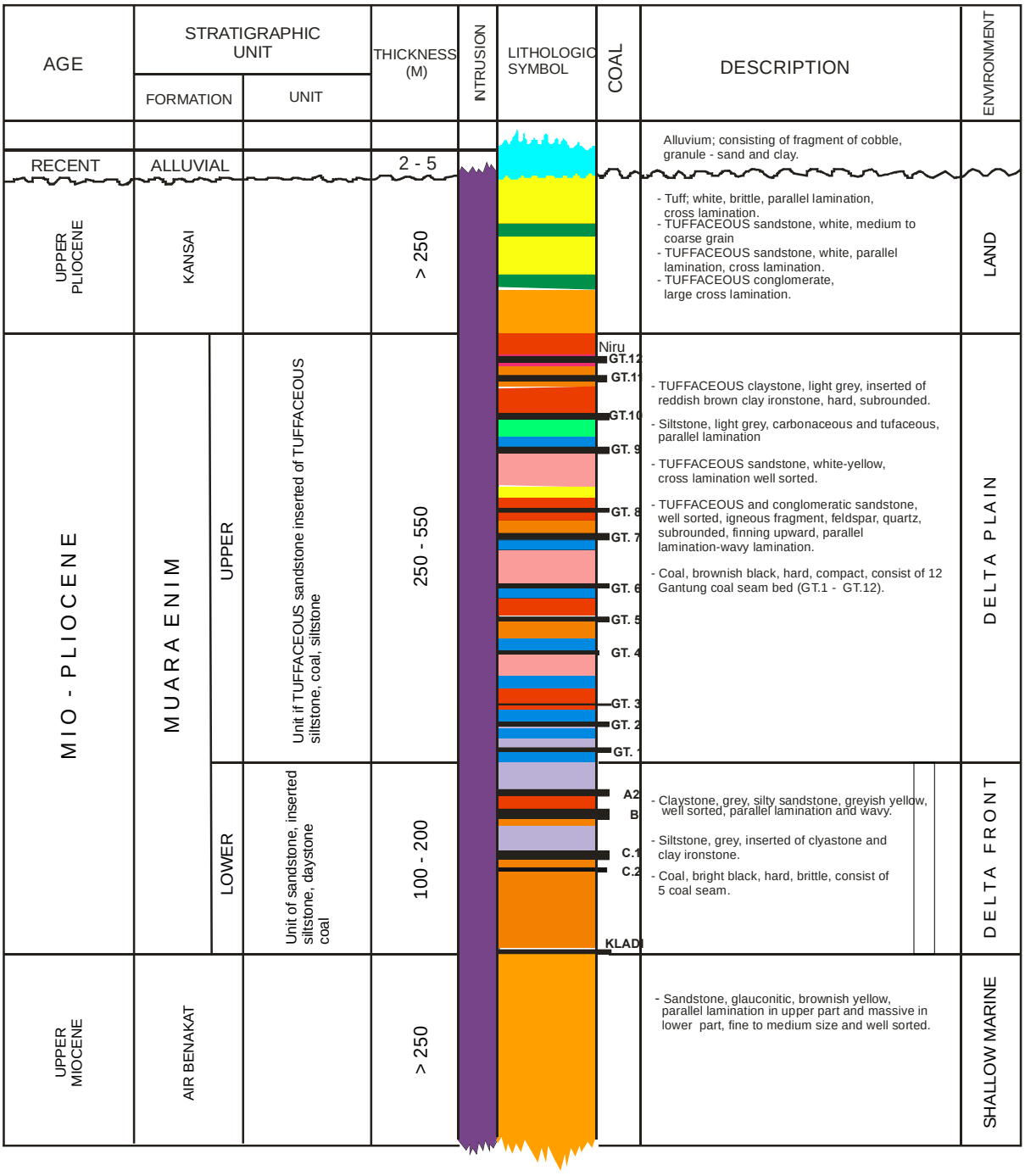
Upper Pliocene Kasai Formation is deposited in a non-marine environment. The rock consists of cross-bedded tuffaceous conglomerate in a large scale. These are:

- Tuffaceous siltstone, white, with symmetrical lamination and minor cross-bedded of sediment structure;
- Tuffaceous sandstone, white and the size is coarse to medium;
- White tuff, easily kneaded with symmetrical lamination and cross-bedded of sediment structure. The thickness is greater than 250 meters.

Furthermore, the rocks in recent alluvial deposit are small material like cobble, pebble, sandstone gravel and claystone, with the thickness around 2 to 5 meter. Based on the field observation, the coal seam in Muara Enim Formation can be divided into 3 sections: lower, middle and upper parts. The lower part characterized by the availability of the lowest coal seam, that is Merapi seam, located at village of Merapi, the Bukit Asam coal mine known as D seam (8-10 meter). The middle part consists of 3 groups of seam: Petai (C), the thickness of 5-8 meters; Suban (B1 and B2), the thickness of 3-8 meters; and Mangus (A1 and A2) seam, each thickness is 7 meters. The upper part is called Gantung seam; and Bukit Kendi consists of 12 seams, Bukit Asam consists of 6

Content

Table 1. Stratigraphic coloumn of Bukit Kendi area



seams, where the lowest seam is called Burung seam, the next upper part are Benaung, Kebon, Enim, Lematang and Niru (Pujobroto and Hutton, 2000). At Bukit Kendi, the Petai seam consists of 2 seams that are C1 and C2 with the thickness of 6-7 meters each; otherwise B seam only consists of one B2 seam with the thickness around 4-8 meters, where A2 seam parted by Suban marker seam that is thin coal seam as thick as 30 to 50 cm that is widely spread, so it can be a marker seam between the two coal seams.

2.4 Structure of the Studied Field

It is assumed that geological structure of studied field occuring since Plio-Pleistocene, formed fold-

Content

ing structure and thrust fault. Because of intrusive, they formed flat fold and normal faults indicates of north-south.

The folding at Bukit Kendi area formed anticline and syncline with the dip of around 60°. It is assumed that the intrusive is stronger than that of at Bukit Asam and the sediment is quite steep.

2.5 Intrusive Rocks

Tobler (1906) characterized the hard rock located in the south of Muara Enim into Serillo Group, and divided into 3 sections, namely:

1. Sub-Group of Bukit Besar;
2. Sub-Group of Bukit Punggur;
3. Sub-Group of Bukit Asam.

The intrusive in the studied area is grouped into Sub-Group Bukit Asam. At Bukit Asam coal mining, the intrusive is dyke that forms hills of Asam, Tapuan, Lengkuas; whereas intrusive in the shape of sill could be found at Suban. Intrusive in the shape of dykes that found at Bukit Kendi mining formed Bukit Kendi and Bukit Cepadang is Furthermore, at the south mining, between Bukit Kendi and Bukit Cepadang, also found intrusive in the shape of sill. The intrusive is assumed to have occured after the folding in Plio-Pleistocene.

3. METHODS

The used methods are field study with laboratory analysis. The field observation was conducted based on the geological map of Lahat sheet in scale 1:250,000 by Gafoer et al., 1986 (Figure 2), issued by Geological Research and Development Centre, Bandung. The usage of topographic map is topography in scale 1:100,000 and 1:250,000 from Geological Research and Development Center; and 1:50,000 from Bakosurtanal Bogor. Geological data collection from the field was conducted by making a geological cross-section with global positioning system (GPS), especially on sediment rocks, coal, hard rocks and so on. Completing the result of observation from the studied area, some analyses were conducted in the laboratory of Geological Survey Centre Bandung including petrography and potassium-argon (K-Ar) analysis. From the field, 81 samples were collected, consisting of andesitic intrusive, coal and sedimentary rocks. To obtain common information about intrusive formation and its temperature, it was prepared 34 rocks samples for the purpose of petrography analysis. Besides, 4 samples of intrusive rocks and 1 sample of glauconitic sandstone were selected and prepared for the purpose of K-Ar analysis. Each is related to a method of dating intrusive and coal deposit. To find out the effect of intrusive and tectonic to the development of coal quality, 15 samples of coal were selected for the purpose of petrography and chemical analysis. From the analysis, it is expected to find out the effect of tectonic and intrusive, and when, or the age, the maturity or development of coal quality in the studied field.

4. RESULT AND DISCUSSION

4.1 Petrographic Analysis

The Bukit Asam intrusion (Figure 3) is recognized with the colour of dark grey, porphyritic texture with medium to fine phenocryst and the matrix dominated by plagioclase and minor hornblende in very fine size, location (01 H06). Phenocryst is dominated by plagioclase and minor hornblende that commonly had been turned into chlorite (green). Besides, there are also minor fracture filled by carbonate (white). The Bukit Tapuan intrusion is characterized by the colour of bright grey, porphyritic texture, and there is minor fine grained scoria structure. The specific characteristic of this intrusion is coarse grained phenocryst hornblende, until 2 cm. The Bukit Tapuan intrusion is predicted to have contact to the Bukit Lengkuas intrusion. There is a possibility that the Bukit Tapuan intrusion intruded Bukit Lengkuas or vice versa. The Bukit Lengkuas intrusion is characterized by dark grey, weak porphyritic texture and fine grained, almost 90% is composed of plagioclase, minor content of magnetite and Q-eyes. Hornblende is found in a small numbers and it turned into chlorite (green).

The Bukit Kendi intrusion (Figure 4) is characterized by grey, fine grained porphyritic texture, minor scoria about 1 mm that is filled by carbonate (white), and content of magnetite. Partly, the horndlende had turned into chlorite. This intrusion presumably is older than coal forming; the fact, sedimentary rocks position containing of coal seam is located only several meters from the intrusion body and the dip is quite sharp (32° to 64) to the direction of Bukit Kendi. By the position of

Content

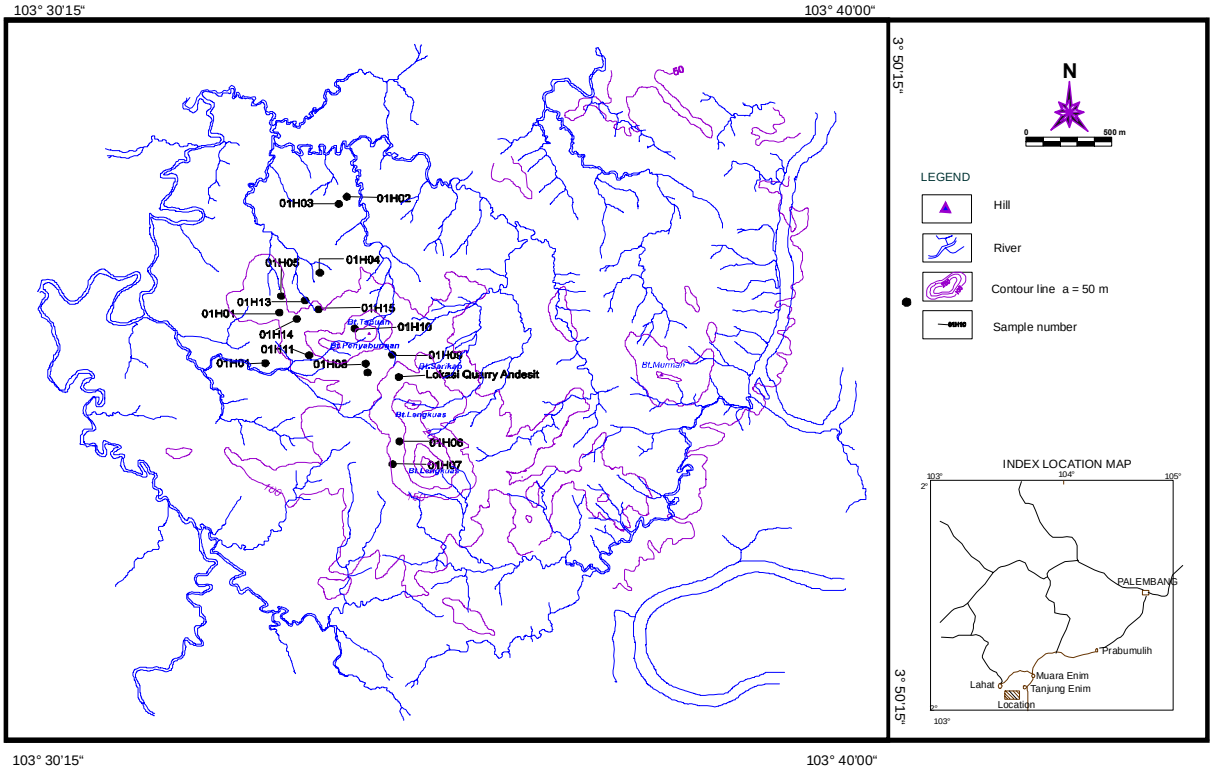


Figure 3. Map of rock and coal location Bukit Asam Area, Tanjung Enim, South-Sumatera

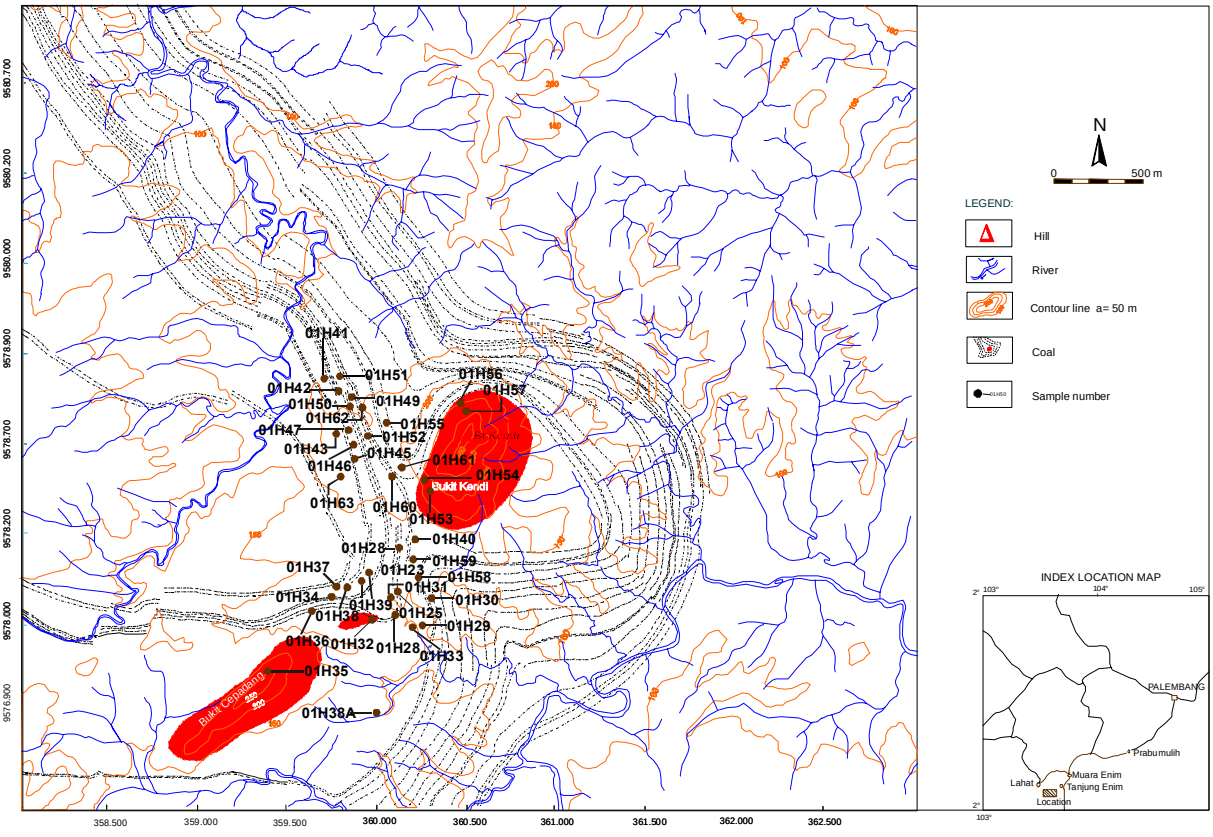


Figure 4. Map of rock and coal location in Bukit Kendi Area, Tanjung Enim, South Sumatera

Content

intrusion, it is presumably that the intrusion of Bukit Kendi intrusion has no effect directly to the developing of coal quality in the area.

The Bukit Cepadang intrusion is characterized by grey; there is minor orifices structure less than 1 mm (<1%) and containing magnetite about 5%. The correlation with coal cannot be found yet because there are not any direct contact. However, the intrusion of Bukit Cepadang presumably has genetic correlation with the sill intrusion located at south mining (quarry) less than 100 meter from this intrusion.

Sill-shaped intrusion is identified by dark grey, porphyritic texture, egg-shaped orifice structure and many smooth fractures filled by carbonate. Phenocryst is dominated by plagioclase about 1 mm having minor long and coarse prismatic shape of hornblende (1.75-3.5 mm). Around location 01H32 (Figure 4), in the north edge of the intrusion, the rocks is fractured and brecciated. Sill-shaped intrusion is located above A seam and parted by interbedded sandstone, siltstone and claystone silicified with thickness more than 4 meter. Coal seams A and B are located at lower part, megascopically characterized with metallic luster and the shine is lessened and tend to be a candle luster from the intrusive body. At the location where is far enough from the intrusion body, the shine becomes dull, indeed, the structure originated from wood is frequently revealed.

4.2 Potassium Analysis

So many methods can be used to find out content of potassium in rocks and mineral. The methods are gravimetric, Flame Photometry and Atomic Adsorption Spectroscopy (AAS). Physical method is X-ray fluorescence, isotope dilutions and neutron activation for appearance. In the research, potassium content was analyzed by flame photometry type M7D. This instrument has capability to measure potassium concentrate accurately, by using liquid gas (LPG), and additional standard of lithium. The result of measurement can be viewed on Table 2.

4.3 Argon Analysis

Argon analysis consists of 2 parts:

1. separation and purity of argon from rock and mineral;

2. measurement of the sum of radiometry argon (^{40}Ar) in extracted gassy sample Argon is extracted from rock/mineral by burning in a very high vacuum system. Isotope of argon measured by using mass spectrometer VG 3600 Isotech, the result can be viewed in Table 2.

4.4 Interpretation of the Analysis Result of K/Ar Dating

In the K/Ar analysis of Bukit Asam and Bukit Kendi areas, the determinant of mineral date is plagioclase that has good purity in between 94% to 98%. The plagioclase can be used to date K/Ar of volcanic rocks. The analysis result of K/Ar dating shows that maturity and development of coal quality in Bukit Asam and Bukit Kendi areas was since Upper Miocene to Pliocene. Bukit Cepadang was formed (7.9482 ± 0.49), while Bukit Kendi (1.1472 ± 0.29) and Bukit Asam (0.92 ± 0.26) million years ago. Whereas Bukit Serilo shows negative result, presumably its age is very young, so the radiogenic argon is not detected.

Table 2. The Analysis result of K/Ar dating andesite (plagioclase) of Bukit Asam and Bukit Kendi

No	Sample Code	Purity (%)	Potassium (%)	^{40}Ar	Age (million year)	Location
1.	01H06	96	0.5593	0.068	0.9203 ± 0.26	Bukit Asam
2.	01H56	97	0.7485	0.117	1.1472 ± 0.29	Bukit Kendi
3.	01H21	98	0.6150	0.022	Negative	Bukit Serilo
4.	01H35	94	1.3561	0.200	7.9482 ± 0.49	Bukit Cepadang

Content

5. CONCLUSION

The results from studied field can be concluded as follows:

1. The coal seam at Bukit Kendi mining area is located between 2 big intrusions that are Bukit Kendi and Bukit Cepadang. There is sill-shaped intrusion in upper seam A2 and lower Gantung coal seam between them.

2. The coal located at studied field had been struck by a strong tectonic force; it can be seen from the anticline at direction to the north-west-southeast and fault, the dip in the south wing is flatter (8°) and the dip is steeper in the north wing (about 32° to 47°).

3. Coal in the nearby area of sill intrusion and fault, has metallic luster, easily shattered, wood structure and no resin residue found. Whereas in further area from intrusive, it is characterized by candle luster to dull, and track of wood structure and brownish resin residue is commonly still identified.

4. Coal in the studied field was deposited in the closed marine environment to shallow marine characterized by the availability of pyrite and glauconite.

5. The most influential intrusion to the development of coal maturity is Bukit Asam intrusive (0,9230±0,26 million years ago); while Bukit Serilo shows negative result, presumably is very young so the age could not be detected by K/Ar method.

5. ACKNOWLEDGEMENT

The author acknowledges PT. Bukit Asam dan PT. Batubara Bukit Kendi for their supports of the research that well conducted. Appreciation to all members of the team for their cooperative teamwork.

6. REFERENCES

Gafoer, S, Amin T.C and Purnomo, J., 1986. *Geological map of Lahat, South-Sumatera Scale 1:250.000*, Geological Research and Development Centre Bandung.

Gafoer, S, Amin T.C and Purnomo, J., 1993. *Geological map of Baturaja, South-Sumatera Scale 1:250.000*, Geological Research and Development Centre Bandung.

Hartmann, Z.G., 1918: Verslag over de resultaten, v.h. Geol. Mijnbk., Onderzoek Soekamerinda en Boenian., Jarb. Mijnwezen verh II.

Koesoemadinata, R.P.,1976. Preliminary framework of the tertiary basins of Indonesia. *Proc of Third. Reg Conf. Geol Mineral Resources. Southeast Asia Bangkok*. Nov 14-18.

Mannhardt, F.G., 1918. Verslag over de resultaten, v.h Geol Mijnbk. Onderzoek der Tanjung Kolenvelden., Jaarb. *Mijnwezen. Verh. II*., p 67 – 107.

PT. Bukit Kendi, 2001. Geology of Bukit Kendi Area, South-Sumatera. *Internal report of PT. Bukit Kendi.* Unpublish.

Pujobroto, A. and Hutton, A. C., 2000.Influence of andesitic intrusions on Bukit Asam coal, South Sumatera, Indonesia. *Proceedings of South East Asian Coal Geology Conference*, Bandung.

Roeslan, K., 1984. The coal resources of Indonesia and Southeast Asia. *AGID-ILP Workshop, 7th Australian Geological Convention,* Sydney.

Santoso, B. and Daulay, B., 2006. Coalification trend in South Sumatera Basin. *Indonesian Mining Journal, vol.9 no. 06.*

Tobler, A., 1906. Topograpishe und Geologishe Beschriebung der Petroleum Geberte bei Moeara Enim (Sud Sumatera); Tijdsch. *Kom. Ned. Akad. Genotsch., Series 2, v XXXIII*, p 224 – 241.