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# Mineralogy and quality of Banti Coal, Baraka District, Enrekang Regency, South Sulawesi Province, Indonesia.

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**Abstract.** Coal deposits in Banti Village, Enrekang Regency, South Sulawesi Province, Indonesia are geographically located at coordinates: 03°27'59.72" south latitude and 119°51'34.35" east longitude and are categorized as medium coal quality. This is evidenced by the results of several analysis that have been carried out. Microscopic analysis showed that there were three dominant minerals such as quartz, pyrite and clay. While the results of mineralogical analysis using X-ray diffraction (XRD) coal in Banti Village show the contents of minerals such as quartz, illite, kaolinite, pyrite, and hematite. Proximate and total sulfur analysis of Banti coal was carried out in 3 samples, namely; sample ENRE-1A, ENRE-1C, ENRE-1D. Banti coal samples shows the average value of total moisture 2.29%, 13.79% ash content, 28.77% volatile matter, 55.83% fixed carbon, and 1.16% total sulfur content. ENRE-1A coal sample shows total moisture 3.20%, ash content 13.72%, volatile matter 27.57%, fixed carbon 55.52%, and total sulfur content 1.84%. ENRE-1C coal sample contains the lowest total moisture which is 1.68%, the highest ash content is 16.9%, volatile matter is 27.79%, fixed carbon is 53.76%, and total sulfur content is 0.92%. ENRE-1D coal sample showed total moisture content of 1.98%, ash content of 10.76%, volatile matter of 31.06%, fixed carbon of 65.2%, and total sulfur content of 0.70%. Analysis of calorific value of Banti coal samples respectively shows 6,785 kcal/kg for sample ENRE-1A, 6,794 kcal/kg for sample ENRE-1C, and 7,229 kcal/kg for sample ENRE-1D. Analyses of the three coal samples were carried out based on ASTM 1981. The presence of quartz, illite, kaolinite, pyrite, and hematite minerals in the coal samples affects the high ash content in Banti coal. The sulfur content present on Banti coal is mainly due to the presence of pyrite. In general, the ash and sulfur content of Banti coal is classified as medium coal category. Banti coal has good quality for further study, especially coal seam ENRE-1D (coal seam contain high calorific value and low total sulfur content).

## 1. Introduction

Coal is a versatile fossil fuel that has long been used for a variety of domestic and industrial purposes [1]. Coal is composed of moisture, macerale and minerals [2]. The composition of moisture, macerale, and minerals will affect the quality of coal, especially ash content, sulfur and calorific value. There are several regions in Indonesia, especially in South Sulawesi that have coal reserves, but the quality of coal do not



meet the standards. The analysis was carried out to study the characteristics of the South Sulawesi coal especially in the Banti Village.

Some regions in Indonesia, especially in South Sulawesi, have coal reserves that do not meet the standards for utilization as direct fuel or indirect fuel. Previous studies have provided information on the quality and characteristics of South Sulawesi [3–6] addition to South Sulawesi coal, East Kalimantan coal has also been conducted research related to sulfur content and coal characteristics [7,8]. This research was conducted to study the characteristics of coal in other areas found in Banti Village, Enrekang Regency, South Sulawesi Province, Indonesia.

Besides in Indonesia, studies on the presence of sulfur, mineralogy, and quality of coal in various parts of the world have been carried out by previous researchers [9–13] mineralogical data, quality, and characteristics of coal of this study are expected to provide quality information and opportunities for the proper utilization and processing of Banti coal in Enrekang Regency, South Sulawesi Province, Indonesia.

## 2. Methods.

The study began with the sampling of coal samples located in the Banti Village of Enrekang Regency, South Sulawesi Province, Indonesia. Astronomically, coal sampling locations are located at position of 03°27 '59.72 "south latitude and 119°51 '34.35" east longitude.

### 2.1. Sampling

Field data collection was carried out on coal outcrops in Banti Village, Enrekang Regency, South Sulawesi Province. Coal sampling is conducted using channel sampling method, which is taking from the floor to the roof of coal seam. Samples were taken manually using a crowbar and a geological hammer. Field data collection was also carried out in the form of the coordinates of the sampling area, photographs that could support the final study project, and other supporting data.

*2.1.1. Sample Preparation.* Sample preparation is carried out before entering the analysis phase which is useful for preparing samples according to the parameters used. The stages of the preparation process carried out in this study include cleaning, quartering, sample size reduction, and sieving. The process of sample preparation was carried out at the Mineral Analysis and Processing Laboratory, Mining Engineering Departement, Hasanuddin University.

*2.1.2. Sample Cleaning.* Coal samples that taken from the coal site must be cleaned by brushing the coal samples, so that the impurities (such as mud, clay, and other materials) can be released from the coal samples.

*2.1.3. Sample reduction.* Sample reduction aims to minimize sample size according to the standard used without reducing sample mass by using a jaw crusher and roll crusher for smaller sizes.

*2.1.4. Quartering.* Quartering aims to divide coal sample into test samples with backup (reserve) samples. The test sample is the sample that will be used for analysis while the backup sample is an archive that if at any time an error occurs will be a substitute for the test sample. In the quartering process the sample is divided into four parts which are then stacked again in the order A + D + C + B. Then quartering is repeated many times on the pile so that the coal sample is truly homogeneous.

2.1.5. *Grinding.* After reducing the size of the coal sample, it is then grinded using agate mortar up to a size of 65 mesh and 200 mesh where the size is in accordance with laboratory analysis standards [20].

2.1.6. *Sieving.* Sieving was carried out on the grinded sample with the aim of obtaining samples of uniform size. This process is carried out manually by using a 65 mesh sieve for the total sulfur, proximate, and the heating value of coal as well as 200 mesh for XRD samples. Samples that pass through the sieve (undersize) will be stored in a sample bag while samples that do not pass through the sieve (oversize) will be crushed again to be sieved to the size according to the required size.

## 2.2. Mineral characteristics and coal quality analysis

2.2.1. *Microscopic analysis.* Microscopic analysis is only done for the initial sample that has not been sifted into a cylindrical polished section with a diameter of 3 cm and a thickness of about 5 cm. The sample is then polished with a polishing device until the surface is flat so that the constituent minerals can be clearly observed under microscopes.

2.2.2. *X-Ray Diffraction (XRD).* Sample preparation for mineralogical analysis is done by grinding first, until it becomes a very fine powder or passes the 200 mesh sieve. Grinding the sample is done using agate mortar then placed in the holder and then pressed and flattened, then scanned using an X-Ray diffractometer. The XRD scan results are then analyzed using the Impact Match Software program, and combined with x-ray diffraction pattern tables produced by certain minerals, to identify the mineral species contained in the sample. Data from mineralogical analysis using the XRD method is a diffractogram consisting of an angle value of  $2\theta$  ( $^{\circ}$ ) and an intensity value. From this diffractogram qualitative mineral data can be obtained such as the crystal type and quantitative data such as mineral species abundance.

2.2.3. *Proximate analysis.* Proximate analysis was conducted with Yamamoto furnace at the Ore Analysis and Processing Laboratory of the Hasanuddin University. This method includes the determination of moisture, volatile matter, ash content and the calculation of fixed carbon in coal and coke samples.

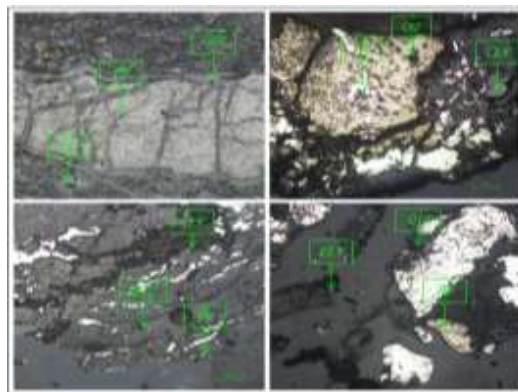
2.2.4. *Calorific value.* An instrument used to measure heat changes is called a Bomb Calorimeter. Bomb Calorimeter consists of a thick steel tube with an airtight lid. Samples to be tested are placed in platinum plates and an "iron coil" of known weight (which will also be burned) is also placed on platinum plates so that they stick to the substance to be tested. Bomb calorimeter is then closed and the lid is tightened. After that the "bomb" filled with  $O_2$  until the pressure reaches 25 atm. Then the "bomb" is put into a calorimeter filled with water. After everything is arranged, the electricity is flowed into an iron wire and after a fire occurs, the temperature rise is measured.

## 3. Results and discussions

### 3.1. Microscopic analysis

Microscopic analysis is an analysis of material that cannot be seen directly. Therefore, tools are needed so that we can see the material. Microscopes are one of the tools used in conducting microscopic analysis. Photomicrograph of Banti coal are shown in figure 1. Pyrite mineral under microscope appears yellow bronze, the intensity of the reflected light is very high and grain sizes ranging from 0.1 to 0.3 mm are formed singenetically. This type of pyrite was formed during the peatification process.

Clay minerals that appear are kaolinite and illite with grain sizes ranging from 0.1 to 1.9  $\mu\text{m}$ . Kaolinite has physical characteristics that are slightly whitish ash, have a triclinic crystal system, a radial crystal class, weak pleochroism is not visible, is formed with syngenetics. Whereas illite is mostly found in coal with a whitish roof coating, has a monoclinic crystal system, prismatic crystal class, weak pleochroism, has a low surface relief. Minerals with physical characteristics are black gray, low intensity of reflected light, and grain size range from 0.1 to 0.5  $\mu\text{m}$ . Quartz is also formed syngenetically and is rarely found as epigenetic [2].

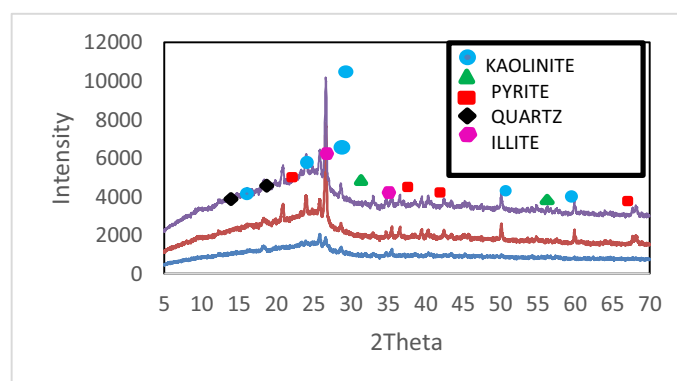


**Figure 1.** Photomicrograph shows some mineral in Banti Coal

Based on the results of microscopic analysis, the coal samples show that the dominant minerals in the Banti Village of Enrekang Regency are 3 types, namely Pyrite (Py), Clay (Cly), and Quartz (Qtz). The existence of these minerals can be seen in microscopic observations with samples that have been used as polish section. All minerals are formed by a syngenetic process. Syngenetics mean that the mineral is formed relatively simultaneously with the formation of coal (peatification stage), and is part of a series of rock stratigraphy.

### 3.2. X-Ray Diffraction (XRD)

This technique is used to identify the crystalline phase in the material by determining the lattice structure parameters and to get the particle size.



**Figure 2.** Difraktogram of Banti coal sample.

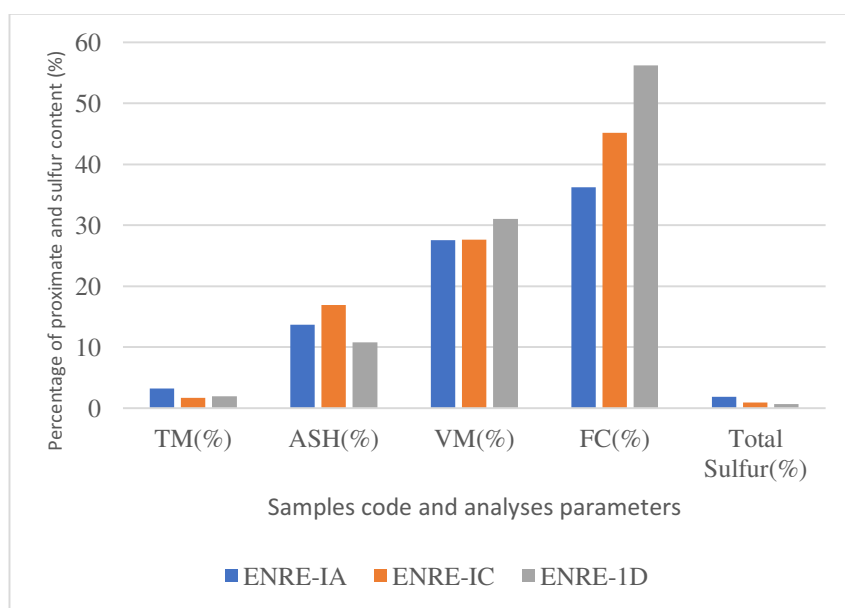
The most dominant mineral group found in coal is around 60-80% of the total mineral matter. Common minerals found in coal are clay, quartz, carbonate, sulfide and sulfate minerals. Specifically for Banti coal, some mineral are found such as quartz, illite, kaolint, pyrite, and hematite.

### 3.3. Proximate Analysis

Proximate analysis of coal is intended to determine the characteristics and quality of coal in relation to the use of the coal, namely to determine the relative amount of total moisture (TM), volatiel matter (VM), fixed carbon (FC), and ash content (ASH), that contained in coal. This proximate analysis is the most basic test in determining the quality of coal. Table 1 shows proximate data of Banti coal, Enrekang Regency, South Sulawesi.

**Table 1.** Results of Proximate Analysis of Banti coal.

Samples code	Proximate Analysis (% Adb)				Remarks
	TM	ASH	VM	FC	
Enre-IA	3.20	13.72	27.57	55.52	Coal
Enre-IC	1.68	16.90	27.67	55.76	Coal
Enre-ID	1.98	10.76	31.06	56.20	Coal
<b>Average</b>	<b>2,29</b>	<b>13,79</b>	<b>28,77</b>	<b>55,83</b>	<b>Coal</b>



**Figure 3.** Results of proximate and total sulfur content analyses of Banti coal.

The results of the Total moisture (TM) analysis can be seen in Table 1 which shows that the coal seam of ENRE-1C is 1.68% and ENRE-1D is 1.98%. According to ASTM D2974-87 [14], Banti Coal is classified as coal with low total moisture (TM) content. The Banti coal ash content of ENRE-1A 34.25% is classified as medium ash coal. The results of the volatile matter (VM) analysis can be seen at the lowest percentage found in ENRE-IA with a percentage of 27.57% and the highest percentage found in ENRE-ID with a percentage of 31.06%. So that, if averaged, the percentage of volatile matter (VM) of Banti coal is 26.76% and is included in the medium category. Classified as coal with high fixed carbon.

Coal which has a total sulfur content of 3% or more is referred to as coal with a high sulfur content while coal which has a total sulfur content of between 1% -3% is referred to as coal with a medium sulfur content and coal which has a total sulfur content less of 1% referred to as coal with low sulfur content [12].

**Table 2 .** Results of total sulfur analyses.

Samples Code	Total Sulfur (% Adb)	Remarks
Enre-IA	1.84	Coal
Enre-IC	0.92	Coal
Enre-ID	0.70	Coal
<b>Average</b>	<b>1.16</b>	<b>Coal</b>

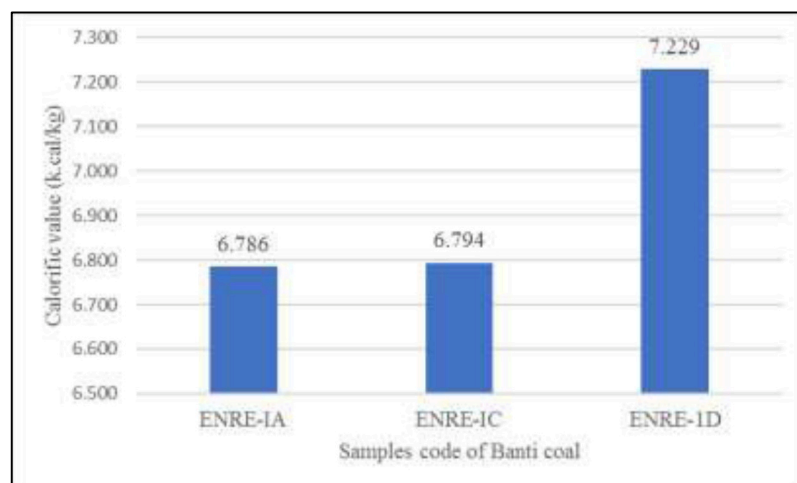
The results of the analysis of total sulfur content can be seen in Table 2, the lowest total sulfur content of the three analyzed samples contained in the ENRE-ID sample with a value of 0.70% and the highest total sulfur content in the ENRE-IA sample with a value of 1.84%. From the total sulfur grouping data obtained from the test results showed the average total sulfur was 1.15 including the medium sulfur content category.

#### 3.4. Calorific Value Analysis

Calorie value of coal depends on the rank of coal. The higher the rank of coal will be followed by the higher of calorific value. In the same coal the caloric value can be influenced by water and also ash content. The higher the water or ash, the smaller the calorific value. Table 3 and figure 4 are the results of the calorific value analysis of the Banti coal, Enrekang Regency, South Sulawesi Province.

**Table 3.** The result of calorific value analysis of Banti coal

Samples Code	Calorific value (kcal/kg)	Remarks
Enre-IA	6,786	Bituminous
Enre-IC	6,794	Bituminous
Enre-ID	7,229	Bituminous
<b>Average</b>	<b>6,936</b>	<b>Bituminous</b>



**Figure 4.** The result of calorific value analysis of Banti Coal

The calorific value of the Banti coal results shows that in the ENRE-1A sample the calorific value is 6,786 kcal / kg, in ENRE-1C the calorific value is 6,794 kcal / kg, and the ENRE-1D sample has a calorific value of 7,229 kcal/kg (see table 3 and figure 4). This calorific value is good enough to be used as fuel and this calorific value is categorized as bituminous coal according to ASTM coal classification, 1981.

When viewed from the calorific value, the most economical to be used in various industries is coal in ENRE-1D. Determination of calorie value is a very important determination, because it is the basis of the specifications in the contract. The calorific value is used in estimating energy sources, and in some coal classification systems it is used as a parameter to classify coal according to rank.

### 3.5. Quality of Banti Coal

Based on the coal quality grouping data obtained from the test results (Tables 1, 2, and 3), the average total moisture was 2.29% including the low category, 28.76% volatile matter, 1.15% total sulfur, and Ash 13.79% the middle category, fixed carbon 55.16% included in the high category, coal calorific value of 6,936 kcal / kg. Table 1 shows that ENRE-1A sample has total moisture is higher than ENRE-1C, the decrease in moisture content as the seam is deeper is due to the increase in fixed carbon content and the decrease in volatile matter and ash content. The fixed carbon content will be proportional to the calorific value content, the greater the fixed carbon content will be followed by an increase in caloric value content. The total sulfur content is very high in ENRE-1A sample due to the abundance of plant remain ENRE-1A samples (Table 2). The content of the plant remains natural blackshale or coally shale in ENRE-1A samples can increase the total sulfur content of coal. When the decay of sulfur does not decay and remains until the formation of coal [3], the presence of plant remains in the ENRE-1A sample increases the total sulfur content.

However, the analysis of ENRE-1D samples showed higher total moisture and volatile matter, and lower ash and total sulfur content than ENRE-1A and ENRE-1C samples. So that the fixed carbon content and calorific value of the ENRE-1D sample increased (Table 3). This shows a reduction depositional environment where the sedimentation process takes place gradually and slowly. The existence of the Coally shale is directly influenced by the rising sea level which shows differences in conditions at the time of material accumulation . Rising sea water which affects peat sedimentation results in the mixing of other non-carbon material which results in unclean coal. Based on the coal rank classification, the quality of Banti coal includes bituminous coal with the characteristics of brownish black coal, very brittle, moderate sulfur content, high calorific value, low moisture content, high carbon content and low ash content.

### 3.6. Relationship of Minerals and Coal Quality

It has been mentioned earlier that in Banti coal contains several minerals such as pyrite (Py), quartz (Qtz), topaz (Tpz), kaolint (Kln), hematite (Hem) and illite (Ill). Coal basically contains three main components, namely: Moisture, Mineral matter and Coal matter. These three components greatly affect the quality or calorie content of a coal, because the three components are constituent components of coal which complement each other. If the moisture is large then coal matter and mineral matter will be low as well as apply to every other high component means other components will be low between minerals, calories and rank.

Based on the analyzes that have been done, it can be concluded that the availability of mineral matter greatly affects the quality of Banti coal. This is because the density of clay minerals such as kaolinite and illite affects the total moisture of Banti coal reaching 2.29% and the abundance of oxide minerals such as quartz and hematite which are classified as high greatly affects the ash content of Banti coal reaching 13.29%. Mineral pyrite contributes greatly to the sulfur content in coal so that the total Banti coal sulfur is 1.15%



#### 4. Conclusion

Based on the results of microscopic analysis, some dominant minerals are obtained, namely clay, quartz and pyrite, while the results of X-ray diffraction (XRD) analysis of Banti coal show mineral contents such as kaolinite, illite, quartz, and hematite. The results of the analysis of coal quality indicate that the total moisture ranges from 1.68% to 3.20%, the ash content ranges from 10.76% to 13.72%, volatile matter ranges from 27.57% to 31.06%, fixed carbon ranges from 53.76% to 56.20%, total sulfur ranges from 0.70 to 1.84%, and calorific values range from 6,786 to 7,229 kcal / kg. Based on the classification of coal according to ASTM (American Society for Testing Material), Banti coal at Enrekang Regency, South Sulawesi Province, which is best used in the industry, namely ENRE1-D coal seam. From the averaged value of proximate and calorific value, Banti coal is classified as high volatile bituminous coal. Mineral matter coal density can affect the quality of coal. Based on the ash and sulfur content analysis, Banti coal samples included in the medium coal quality category.

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