

# Major Oxide Geochemistry Of Bayah Coal Formation, Bayah District, Indonesia

Johanes Hutabarat, Ahmad Helman Hamdani, Faisal Muhamadsyah, Agung Mulyo

**Abstract:** This research investigates the geochemistry of major elements of coal found in the Bayah District, Banten Province, Indonesia. To find out the provenance, tectonic conditions, and weathering levels of coal deposited in the Bayah Formation, major oxides—dominant oxides such as  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and  $\text{Fe}_2\text{O}_3$  and minor oxides such as  $\text{MnO}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{TiO}_2$ , and  $\text{P}_2\text{O}_5$ —were identified from eight coal samples. The high concentration of  $\text{Al}_2\text{O}_3$  and  $\text{CaO}$  demonstrates the most striking aspect of the geochemistry of the coal deposit in Bayah Formation:  $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MnO}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{TiO}_2$ , and  $\text{P}_2\text{O}_5$  had been depleted in the samples. The graph plotting  $\text{Al}_2\text{O}_3$  vs  $\text{TiO}_2$  suggested that felsic to intermediate rock were sources for the coal. The plotting of  $\text{SiO}_2/\text{Al}_2\text{O}_3$  vs  $\text{K}_2\text{O}/\text{Na}_2\text{O}$  indicated, tectonically, that the provenance of the source rock comes from the active continental margin. All rock samples have a high Chemical Index of Alteration (CIA) and Plagioclase Index of Alteration (PIA) values close to 100; this indicates that the level of chemical weathering is very strong. The Index Compositional Value (ICV) was low, which suggested the presence of mature sediment, rich in clay minerals (especially kaolinite).

**Keywords:** active continental margin, Bayah Formation, coal, major oxide, provenance.

## 1 INTRODUCTION

Coal is composed of organic material, minerals, and inorganic components. Organic material, which is often referred to as “maceral,” is the main constituent of coal (about 75%). Minerals and inorganic materials, which are present in smaller quantities, are defined as “mineral matter” [1] which consists of three groups: (1) minerals in discrete and crystalline particles, (2) elements or compounds that usually exclude elements such as nitrogen and sulfur, and (3) soluble inorganic compounds in coal pore water and coal surface water. Mineral matter in coal can either be sourced from coal-forming plants (inherent minerals), or derived from the weathering of source rocks carried by the wind or water (extraneous minerals) [2,3]. These minerals can be formed both in the final syngenetic phase and in the epigenetic phase [4]. Inherent impurities in the combustion process leave ash in the form of oxides from  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{TiO}_2$ ,  $\text{Mn}_3\text{O}_4$ ,  $\text{CaO}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{P}_2\text{O}_5$ . The gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ),  $\text{CaSO}_4$ , pyrite ( $\text{FeS}_2$ ), silica ( $\text{SiO}_2$ ) can also be inherent impurities. Geologically, the Bayah area is located on the front slopes of the Southern Mountains of Java, facing the Indian Ocean which is, tectonically, an area of the Ocean Plate. During its development, the Ocean Plate moved towards the Eurasian Continent Plate, and some of the oceanic mass infiltrated the continent [5]. The sedimentary rocks in the Bayah area are the result of deformation and sedimentation of continental-type igneous rocks. This, however, does not rule out the possibility that oceanic crust-type rocks can be a source of material for sediment, including coal formation [6]

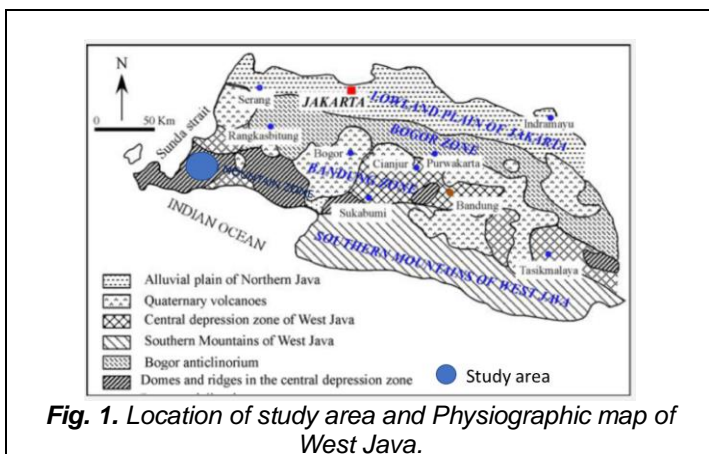
In Bayah Area, there has been a lot of research on coal related to the maceral composition, coal depositional environment, coal stratigraphy; however, research on major oxide in coal has not been widely carried out. Although present in small amounts, the presence of major oxide elements in coal plays an important role in reconstructing geological evolution such as provenance, tectonic, paleoclimate, and weathering levels in the source area. Consequently, a study of the major elements’ geochemistry of the coal in the Bayah area is conducted. The aim of this research is to identify the major oxides within coal and use the abundance and ratio of each major oxide to determine the provenance, tectonic setting, and degree of ancient weathering of the coal formation source.

## 2 METHODS AND SAMPLING

### 2.1 Site Description

The coal samples for this study were collected from coal Paleogene outcrop samples at Bayah Area, Banten, Indonesia. A total of 8 coal samples were taken from the location. All coals exhibit the following physical characteristics, brownish-black in color, dull-glass lustre, brown-black streak, tight cleats up to several cm, brittle, with pyrite and iron oxide impurity minerals. The proximate analysis of coal samples in Bayah Formation shows a moisture content (TM: 4.47 – 4.63%), inherent moisture, ash content (IM: 2.87%), volatile matter (VM : 39.72-41.45% ), and fixed carbon (FC : 51.55-51.97%). The calorific value of coal (ar) ranges between 7,288 – 7,510 Cal/gr. According to ASTM standards then the coal in the Bayah area can be classified as High volatile B Bituminous coal Physiographical, the study area was located in The Bayah Mountain Zone, extensional from Bandung zone, consist of Paleogene to Pliocene Sediment, and Quaternary Volcanic rocks (Fig. 1)

- Dr. Johanes Hutabarat MT., Associate Professor, Dept of Geology, University Padjadajaran, Indonesia., E-mail: j.hutabarat@unpad.ac.id
- Prof. Dr. A. H. Hamdani, MSi., Professor, Department of Geology, University Padjadajaran, Indonesia., E-mail: ahmad.helman@unpad.ac.id
- Dr. Faisal Muhamadsyah, MT. Lecturer, Dept of Geology, University Padjadajaran, Indonesia., E-mail: Faizal.muhamadsyah@unpad.ac.id
- Dr. Agung Mulyo, MT., Lecturer, Dept of Geology, University Padjadajaran, Indonesia., E-mail: agung.mulyo@unpad.ac.id.
- Correspondence Author : ahmad.helman@unpad.ac.id



Geologically, the Bayah area is located on the slopes of the front of the Southern Mountains of Java, facing the Indian Ocean which is tectonically an area of the Ocean Plate. During its development, the Ocean Plate moves towards the Eurasian Continent Plate, and some of the oceanic mass infiltrates the continent [5]. Thus the sedimentary rocks in the Bayah area are the result of deformation and sedimentation of continental type igneous rocks, but it does not rule out the possibility. oceanic crust type rocks can be a source of material for sediment; including coals [6]

## 2.2 Analytical Analysis

The procedures, preparation, and bagging used for the coal study are according to the ASTM Standard [7]. The coal is wrapped in aluminum foil and put in a plastic bag to avoid it from weathering and contamination. Then, the samples were dried and ground to fine size to pass a 200-mesh sieve; then divided into representative amount for chemical analysis. Acid solution mixture in the form of  $\text{HNO}_3$ :  $\text{HCl}$ :  $\text{HF}$  (3: 1: 1) is used for acid-digested coal powder. Furthermore, separation of the ash concentration was carried out by heating to a temperature of  $815^\circ\text{C}$  following the ASTM standard procedure [7], then the ash obtained is analyzed using XRF to determine the composition of the major elements. were analyzed by X-ray fluorescence (XRF) spectrometry to determine the concentrations of major elements.

### 2.2.1 Determination of Ash Content

The ASTM D2013 standard is used as a guide in determining the ash content in coal.

#### Materials and Equipment

Muffle furnace, silica dish, analytical balance to the accuracy of 0.1 mg, desiccator, aluminum metal plate and clamp pliers, coal.

#### Experimental

The dish filled with coal (1.0 gram) is placed in a cold muffle furnace at temperature room; then. temperature is gradually increased over a period of 4 hours to  $4500^\circ\text{C}$ . The temperature is raised until it reaches to  $8150^\circ\text{C}$ . To make the coal sample completely asphalted, the temperature must be maintained.. The ash obtained is then weighed and the percentage of ash in the sample is determined. Then the ash is moved to a suitable place for XRF analysis..

## 2.2.2 Determination of Oxide by XRF spectrometry

#### Materials and Equipment

Ash, XRF equipment ( Bruker S8 Tiger, Germany),

#### Experimental

In a 20 ml platinum dish, a mixture of 0.800 g of coal ash was placed with a flux mixture of 43%  $\text{Li}_2\text{B}_4\text{O}_7$ , 55%  $\text{Na}_2\text{B}_4\text{O}_7$ , and 2%  $\text{NaBr}$ . To make it easier to move the solidified button,  $\text{NaBr}$  is added. The concentration of major oxides such as:  $\text{SiO}_2$ ,  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MnO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{P}_2\text{O}_5$ . The LOI is determined by the weight lost during heating 2.3 g of sample at  $10500^\circ\text{C}$  for 60 minutes. The repeatability and reproducibility limits for various elemental oxides in coal and coal ash have been followed according to ASTM D 6349.

## 3 RESULT AND DISCUSSION

### 3.1. Major Oxide Composition in Coals

The Major oxide geochemistry data of the eight samples are given in Tables 1. Without entering LOI data, all major oxide abundances are recalculated as shown in Table 1. For the determination of provenance, tectonic setting, and weathering degree of the source rock, the major oxides and the ratio of each oxide to the other is used in the form of a two-variable (bivariate) graph or three-variable (ternary) plot

**TABLE 1**

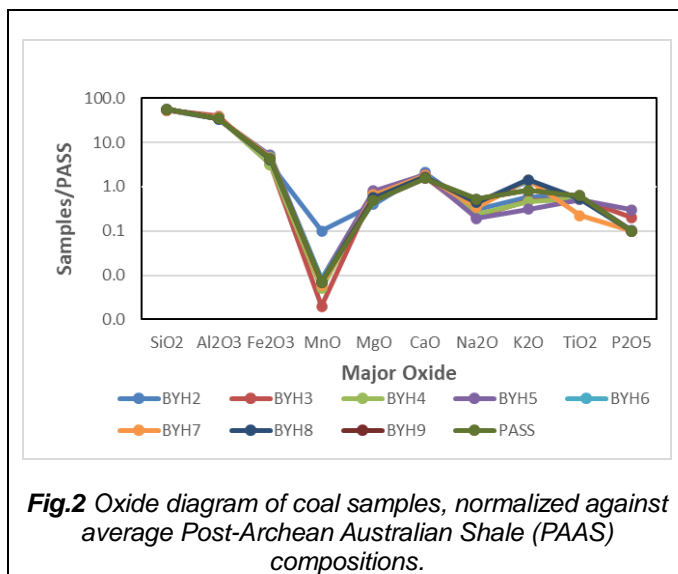
MAJOR OXIDE COMPOSITIONS (WT.%), OXIDE RATIOS AND WEATHERING INDICES VALUES OF BAYAH COAL

Oxides.	BYH2	BYH3	BYH4	BYH5	BYH6	BYH7	BYH8	BYH9	Average	PASS
$\text{SiO}_2$	55.0	53.91	55.19	53.84	55.21	53.21	55.81	56.26	54.80	62.8
$\text{Al}_2\text{O}_3$	37.5	38.92	36.62	35.12	34.2	36.14	34.11	34.81	35.93	19.0
$\text{Fe}_2\text{O}_3$	3.3	3.21	3.17	5.21	4.62	4.51	4.12	4.31	4.06	6.5
$\text{MnO}$	0.1	0.002	0.005	0.008	0.008	0.006	0.007	0.007	0.02	0.1
$\text{MgO}$	0.4	0.7	0.72	0.81	0.46	0.65	0.56	0.48	0.60	2.2
$\text{CaO}$	2.1	1.71	1.82	1.89	1.68	1.81	1.68	1.54	1.78	1.3
$\text{Na}_2\text{O}$	0.3	0.21	0.24	0.19	0.44	0.34	0.44	0.52	0.34	1.2
$\text{K}_2\text{O}$	0.6	0.49	0.46	0.31	1.34	1.42	1.44	0.82	0.86	1.7
$\text{TiO}_2$	0.6	0.52	0.56	0.51	0.54	0.22	0.53	0.62	0.51	1.00
$\text{P}_2\text{O}_5$	0.1	0.2	0.1	0.3	0.1	0.1	0.1	0.1	0.14	0.20
Total	100.0	100	99	98	99	98	99	99		
$\text{Na}_2\text{O}/\text{K}_2\text{O}$	0.50	0.43	0.52	0.61	0.33	0.24	0.31	0.63	0.45	0.3
$\text{K}_2\text{O}/\text{Na}_2\text{O}$	2.00	2.33	1.92	1.63	3.05	4.18	3.27	1.58	2.49	3.2
$\text{SiO}_2/\text{Al}_2\text{O}_3$	1.47	1.39	1.51	1.53	1.61	1.47	1.64	1.62	1.53	3.3
$\text{Al}_2\text{O}_3/\text{SiO}_2$	0.68	0.72	0.66	0.65	0.62	0.68	0.61	0.62	0.66	0.3
$\text{Fe}_2\text{O}_3/\text{K}_2\text{O}$	5.50	6.55	6.89	16.81	3.45	3.18	2.86	5.26	6.31	1.5
$\text{Fe}_2\text{O}_3+\text{MgO}$	3.7	3.91	3.89	6.02	5.08	5.16	4.68	4.79	4.65	8.7
$\text{CaO}+\text{Na}_2\text{O}$	2.4	1.92	2.06	2.08	2.12	2.15	2.12	2.06	2.11	2.9
$\text{Al}_2\text{O}_3/\text{TiO}_2$	63.62	74.85	65.39	68.86	63.33	164.27	64.36	56.15	77.60	18.9
$\text{Al}_2\text{O}_3/\text{Na}_2\text{O}$	125.00	185.33	152.58	184.84	77.73	106.29	77.52	66.94	122.03	15.8
$\text{Fe}_2\text{O}_3/\text{SiO}_2$	0.06	0.06	0.06	0.10	0.08	0.08	0.07	0.08	0.07	0.1
$\text{K}_2\text{O}/\text{Al}_2\text{O}_3$	0.02	0.01	0.01	0.01	0.04	0.04	0.04	0.02	0.02	0.02
CIA	96.90	97.72	97.50	98.07	93.90	94.51	93.63	94.93	95.89	75
PIA	98.40	98.92	98.69	98.92	97.39	98.08	97.38	97.03	98.10	86
ICV	0.19	0.18	0.19	0.25	0.27	0.25	0.26	0.24		0.8
CIW	99.21	99.46	99.35	99.46	98.73	99.07	98.73	98.53	99.07	-

All data have been hydroxide normalized.

CIA—Chemical Index of Alteration, PIA—Plagioclase Index of Alteration, CIW—Chemical Index of Weathering, ICV: Index Compositional Variability To find out whether there is an enrichment or depletion in the oxide compound composition, the average value of each oxide compound or the ratio of the oxide compounds according to the Post-Archean Australian Shale (PAAS) [8] is compared with the average value in the sample. A similar narrow range with  $\text{SiO}_2$  content is also found in  $\text{Al}_2\text{O}_3$  contents (34.11–38.92 wt.%; average 35.93 wt.%). The range of  $\text{Fe}_2\text{O}_3$  abundances in the samples is 3.17–5.21 wt.%, and average 4.06 wt.%. The low concentrations of  $\text{MnO}$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ , and  $\text{K}_2\text{O}$  are similar; i.e., 0.1–0.002 wt.% (average 0.02 wt.%), 0.40–0.81 wt.% (average 0.60 wt.%), 1.54–2.1 wt.% (average 1.78 wt.%), and 0.19–0.52 wt.%

(average 0.34 wt.%), 0.31–1.44 wt.% (average 0.86 wt.%), respectively. The abundances of  $TiO_2$  vary considerably (0.22–0.81 wt.%, and the average 0.57 wt.%). The  $P_2O_5$  abundances are 0.1–0.3 wt.%, and average 0.14 wt.%. The abundance of  $SiO_2$  for each sample or its average value, is smaller than the Post-Archean Australian Shale (PAAS) value. However, the  $Al_2O_3$  in coal is higher than the PAAS. Other major oxides like  $Fe_2O_3$ ,  $MnO$ ,  $MgO$ ,  $CaO$ ,  $Na_2O$ ,  $K_2O$ ,  $TiO_2$ , and  $P_2O_5$  are depleted relative to the PAAS (Figure 2). The lower abundance of  $Na_2O$  and  $K_2O$ , when compared to the PAAS value, indicates that chemical weathering has occurred, which results in the loss of feldspar minerals. A depletion in abundance of  $SiO_2$  along with other oxides such as  $MnO$ ,  $MgO$ ,  $CaO$ ,  $Na_2O$ ,  $K_2O$ ,  $TiO_2$ , and  $P_2O_5$ , followed by increasing  $Al_2O_3$  indicates that the source rock from which the coal was formed has weathered. Enrichment of  $Al_2O_3$  is ascribed to the high content of clay minerals which is related to the weathering of feldspar at the source area.



**Fig.2** Oxide diagram of coal samples, normalized against average Post-Archean Australian Shale (PAAS) compositions.

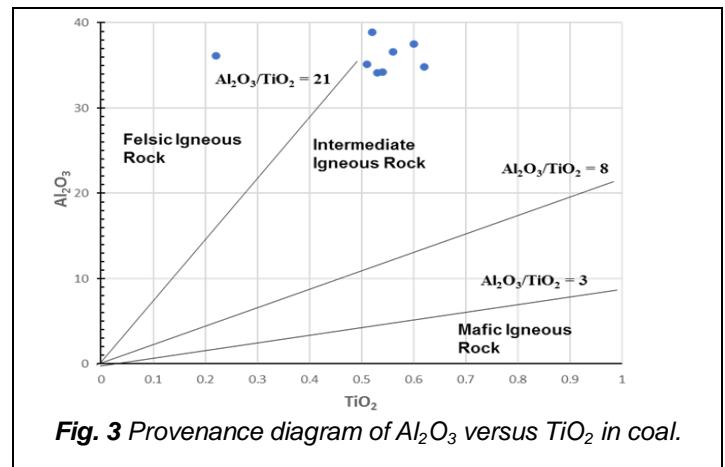
The three major oxides were  $SiO_2$ ;  $Al_2O_3$  and  $Fe_2O_3$  were dominated in coals. Quartz, clay and pyrite minerals are thought to be carriers of these elements.[9]. The dominance of  $SiO_2$  and low percentage K-feldspar related oxide ( $K_2O$ ,  $MnO$ ) in samples indicated that the source area was exposed to long-term weathering. The indication of Ti element in the intermediate rock is reflected by the high  $TiO_2$ . The  $Al_2O_3/TiO_2$  range of 56.15–164.27 wt.% (average 77.60 wt.%) was reflected relationship with the felsic sources [9]. The low value of  $MgO$  in sediment was supported the interpretation. The high ratio of  $Al_2O_3$  (34.11–38.92 wt.%; average 35.93 wt.%); reflects during the coal formation process the influence of very large clay minerals; possibly related to the high weathering of feldspar minerals. The other major oxide ratio in coals; have  $K_2O/Na_2O$  ratio (1.58–4.18 wt.%, average 2.49 wt.%) (Table 1), suggested that materials sources from quartz rich sediments. The relative abundance of alkali feldspar over plagioclase and clay minerals in sediment can be interpreted can be predicted using  $K_2O/Al_2O_3$  ratio. Cox [10] mentioned that a significant quantity of alkali feldspar relative to other aluminosilicates is indicated by the  $K_2O/Al_2O_3$  ratio >0.5; while,  $K_2O/Al_2O_3$  ratios <0.4 indicated that sediment contain a rare of alkali feldspar. The average  $K_2O/Al_2O_3$  ratio within coal samples of 0.02 wt.% (0.01–0.04 wt.%); suggested that the

source materials were lack of feldspar. The  $SiO_2/Al_2O_3$  ratio most of coals were low (3.85–5.37 wt.%; average 4.74 wt.%); shows that tectonics during coal deposition is relatively weak, basin subsidence is also slow, causing coal deposition to take place stably. [11]

## 4 DISCUSSION

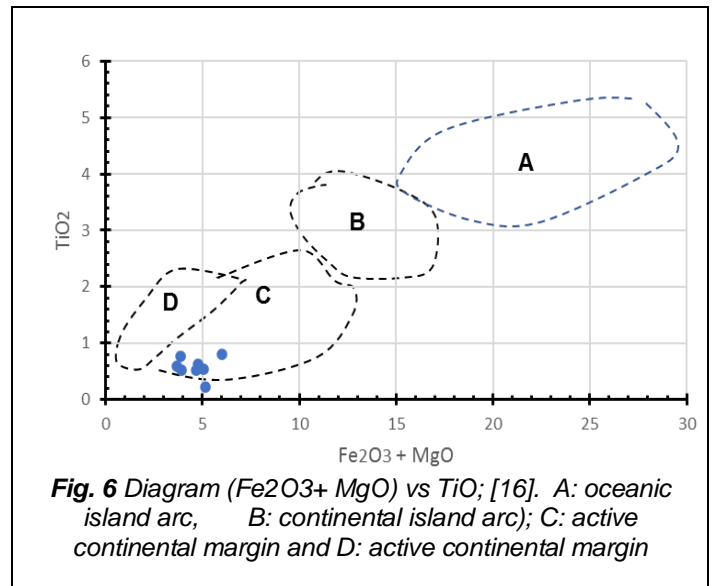
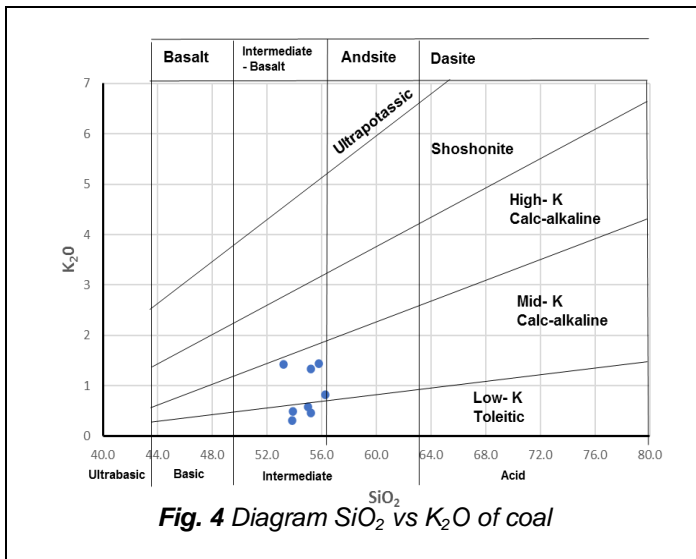
### 4.1. PROVENANCE

Various approaches are used with geochemical data—one of which is using oxide compounds to determine coal provenance in the study area. The evidence regarding the conditions of sediment provenance as well as other sedimentary processes, i.e., weathering and sorting, is identifiable from the compound oxide [12], [13]. The four main rock sources in provenances of sedimentary rock—namely mafic igneous, intermediate igneous, felsic igneous, and quartzose sedimentary recycled within the quartzose detritus field—can best be recognized by the composition, abundance, and ratio of the oxide compounds. The unmovable properties of titanium (Ti) and aluminum (Al) in an environment, which qualify them as representative tools to determine the provenance of sedimentary rock [13], coal [14], and oil shale [15]. Figure 3 showing the bivariate plot of  $Al_2O_3$  against  $TiO_2$  from Hayashi et al. [16] for identified provenance



**Fig. 3** Provenance diagram of  $Al_2O_3$  versus  $TiO_2$  in coal.

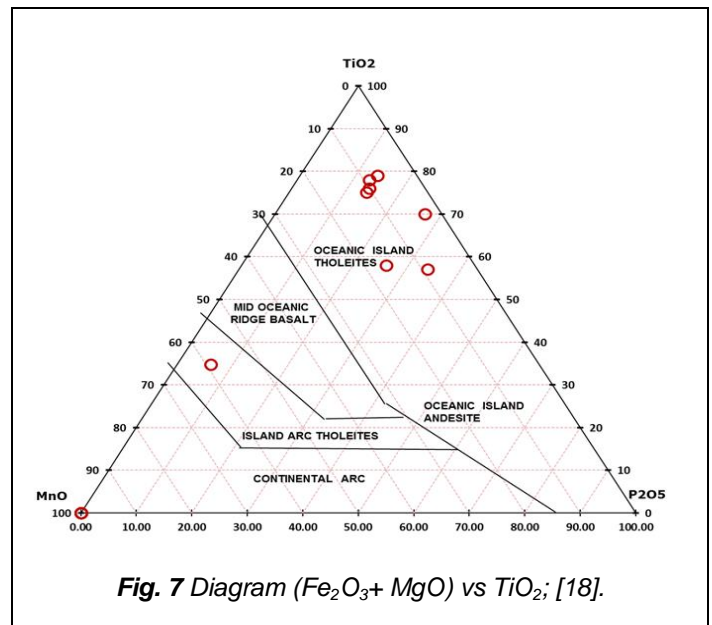
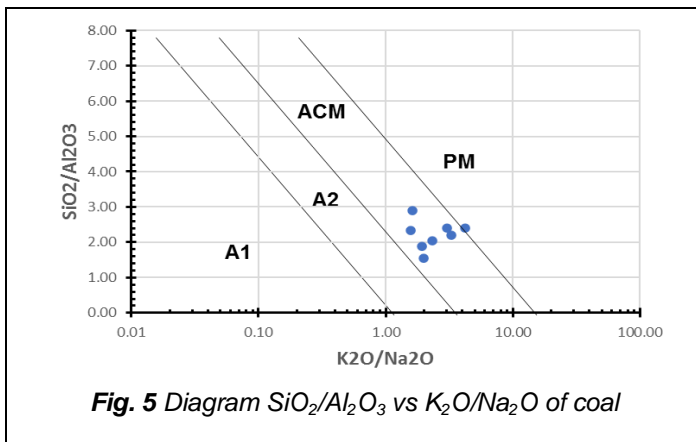
Hayashi et al., [16] has divided the provenance of sedimentary rock based on  $Al_2O_3/TiO_2$  ratios into rock derived from mafic ( $Al_2O_3/TiO_2$  ratio 3–8), intermediate (ratio 8–21), and felsic ( $Al_2O_3/TiO_2$  ratio 21–70). The coal provenance in Bayah Area is sourced from felsic to intermediate rock, which is indicated by a high ratio value of  $Al_2O_3/TiO_2$  (56.15–164.27 wt.% and average 77.60 wt.%). The  $SiO_2$  against  $K_2O$  diagram [17] indicates that the source material is from magma series Low K- Tholeiitic to calc-alkaline medium (Figure 4)



**4.2. TECTONIC SETTING**

The abundances and ratio of major oxides in sedimentary rocks reflects the diversity of tectonic arrangements in which these sedimentary rocks are formed which to specific tectonic environments [18]. By using a log graph  $(K_2O/Na_2O)$  vs  $SiO_2$ , the tectonic setting of sedimentary rocks can be determined. Roser and Korsch [11] grouped it into A1: arc setting, basaltic, and andesitic detritus; A2: evolved arc setting, felsic-plutonic detritus; PM: passive margin; and ACM: active continental margin. In this diagram, all samples are located in the active continental margin field (Figure 5).

Referring to the graph  $SiO_2$  vs  $K_2O$  (Figure 4), graph of  $SiO_2/Al_2O_3$  vs  $K_2O/Na_2O$  (Figure 5), and graph of  $(Fe_2O_3 + MgO)$  vs  $TiO_2$  (Figure 5); it can be stated that the tectonic setting of source material for forming coal is the active continental margin which was related with subduction oceanic crust beneath the continental crust [19]. The plot the major oxide in a triangle diagram  $TiO_2-10MnO - P_2O_5$  [20]; further emphasize that mostly of coal were form in tectonic setting of Oceanic Island Tholeiites; except one sample (BYH2) has a source coming from Island Arc Tholeiites (Figure 7).

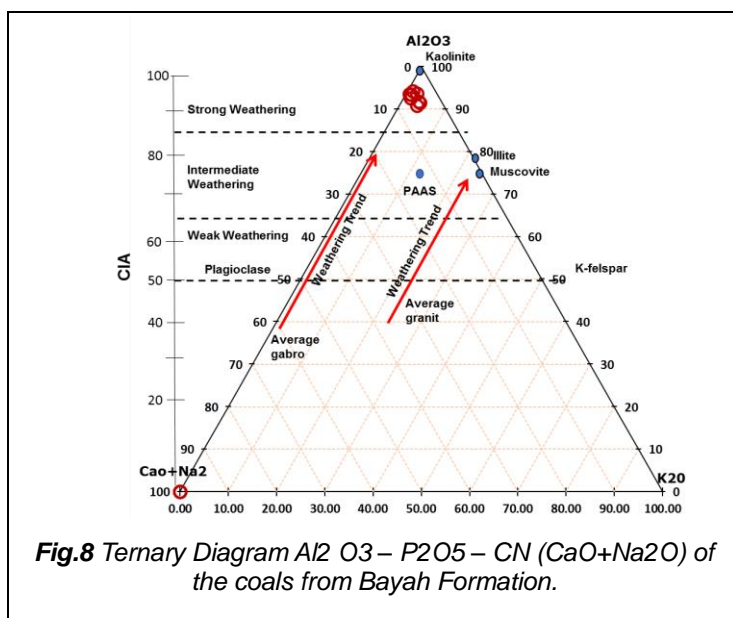


The  $(Fe_2O_3 + MgO)$  versus  $TiO_2$  diagram corresponded to the graph plotting  $(K_2O/Na_2O)$  vs  $TiO_2$ , which shows that tectonic settings are similar in an active continental margin field (Figure 6)

**4.3 Level of Source Area Weathering**

In principle, the abundance of major elements can reflect the original composition of the source rock; however, the proportion of this abundance can change with the weathering process which affects the source rock and the changes that occur after deposition. This causes in several ways; the major abundances cannot be used as an indicator of source rock origin. The Chemical Index of Alteration ; CIA [21] and Plagioclase Index of Alteration ; PIA [22] were applied to

identified the level of intensity weathering. Due to an approximate feldspar and volcanic glass made of 75% labile mineral in upper crust; the CIA and PIA should be used as a paleo-weathering indicator [23]. The alteration of major minerals such as heavy minerals, feldspar and volcanic glass into clay minerals is reflected in the CIA value. The calculated weathering indicator such as CIA, PIA, and CIW values (Table 1) range from 93.63 to 98.07 wt. % (average 95.89 wt. %), from 97.03 wt. % to 98.92 wt.% with an average 98.10 wt. %, and from 98.53 to 99.46 wt. % with an average 99.07 wt. % respectively. All coal samples fall within a strong weathering degree. The high CIA value in coal (more than 85) indicates that the sediment is at a mature level and contains feldspar minerals with high weathering rates from tectonically active sources. The labile cations, such as Ca, Na, and K, tended to be removed, compared to the stable elements of Al and Ti. The  $Al_2O_3$  content is above the average PAAS, indicating that the high intensity of weathering causes alkaline elements and rare earth elements to be released from the sediment. All types of coal have CIA values falling near the kaolinite field, suggesting the dominance of clay minerals in the sources of coal (Figure 8).



## 5 CONCLUSION

Geochemical studies of major oxides in coal sediments from the Bayah Formation in Banten, Indonesia were conducted to determine their provenance, tectonic setting, and level of source area weathering in which the coals were deposited. The research demonstrates that the coal was derived from felsic to intermediate source material in an active continental margin.; which are not only associated with continental type rocks but also with oceanic rocks. The high CIA and PIA values suggested a strong degree of weathering in the source rocks.

## Acknowledgment

The authors are grateful to the funding from the University Padjadjaran Research Programme of the Academic Leadership Grant (ALG) of the year 2020. The authors also would like to acknowledge the Dean of Faculty of Geology for their support to establish this article.

## References

- [1] C. R. Ward, Review of Mineral Matter in Coal, Australian Coal Geology, Geol. Soc. of Australia, vol. 6, pp. 87-107. 1986
- [2] R. B Finkelman, Trace and Minor Elements in Coal, In Organic Geochemistry (Engel, M.H & Macko, S.A) Plenum Press, New York, pp. 299-318, 1993
- [3] H. L. Zhao, C. R. Ward, D. French and I. T. Graham. Major and Trace Element Geochemistry of Coals and Intra-Seam Claystones from the Songzao Coalfield, SW China, Minerals, vol. 5, pp. 870–893. 2015
- [4] C. F. K. Diesel. Coal Bearing Depositional System, Springer Verlag, Berlin, pp. 137-158. 1982
- [5] T. O. Simandjuntak, and A. J Barber., Contrasting Tectonic Styles in the Neogene Orogenic Belt of Indonesia. In Hall, R. and Blundel, D.J. (eds), Tectonic Evolution of Southeast Asia. The Geological Society Special Publication 106, London: pp.185-201. 1996
- [6] U. Ediar and K. Udaya. Environment and Tectonic Evolution of Rock and Sediment Based on Major Elements in Bayah waers AND Adjacent Area of Banten Province. Jurnal Geologi Kelautan, vol. 12, No.3, pp. 125-133. 2014
- [7] American Society for Testing and Material (ASTM) Standards, Petroleum products, lubricants and fossil fuels, gaseous fuels; coal and coke, USA, 650 p. 2002.
- [8] R. L. Rudnick, S. Gao., Composition of the continental crust. In The Crust Treatise on Geochemistry; Rudnick, R.L., Ed.; Elsevier-Pergamon: Oxford, UK. 2003
- [9] M. Mishra, S. Sen. Provenance, tectonic setting and source-area weathering of Mesoproterozoic Kaimur Group, Vindhyan Supergroup, Central India. Geol.Acta. vol. 10, pp. 283–293. 2012
- [10] R. Cox, D. R. Lowe, R/ L. Cullers, The influence of sediment recycling and basement composition on evolution of mudrock chemistry in South Western, United States. Geochim. Cosmochim. Acta vol. 59, pp. 2919–2940. 1995
- [11] B. P. Roser, R. J. Korsch. Determination of tectonic setting of sandstone mudstone suites using  $SiO_2$  and  $K_2O/Na_2O$  ratio. J. Geol., vol. 94, pp. 635–650. 1986
- [12] M. Yossifova, C. Lerouge, Y. Deschamps. Mineral matter and trace elements in the Vulche pole coal, Bulgaria. Geolines, vol. 22, pp. 89–94. 2009
- [13] B. P. Roser, R. J. Korsch., Provenance signatures of sandstone-mudstone suites determined using discrimination function analysis of major-element data. Chem. Geol. Vol. 94, pp. 67, 119–139. 1988
- [14] S. Dai., R. B. Finkelman, Coal as a promising source of critical elements: Progress and future prospects. Int. J. Coal Geol. Vol. 186, pp. 155–164. 2018
- [15] S. M. McLennan, S. Hemming, D. K. McDaniel, G. N. Hanson, M. J. Johnsson, Basu. A Geochemical approaches to sedimentation, provenance, and tectonics. Processes Controlling the Composition of Clastic Sediments. Spec. Papers-Geol. Soc. Am., vol. 284, pp. 21–40. 1993
- [16] K. Hayashi, H. Fujisawa, H. Holland, H. Ohmoto. Geochemistry of approx. 1.9 Ga sedimentary rocks from northeastern Labrador, Canada. Geochim Cosmochim Acta. Vol. 61 no. 19, pp. 4115–4137. 1997.
- [17] A. Peccerillo., and S. R. Taylor, Geochemistry of Eocene Calc-alkaline Volcanic Rocks from the Kastamonu Area, Northern Turkey. Contribution of Mineral Petrology. Vo.;

58, pp. 63-81. 1976

- [18] M. R. Bhatia, K.A. W. Crook, Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins. *Contrib. Miner. Petrol.*, vol. 92, pp. 181–193. 1982
- [19] A. Miyashiro, Volcanic Rock Series in Island Arc and Active Continental Margin. *American Journal of Science*. Vol. 274, pp. 321-355. 1974.
- [20] E. D. Mullen. 1983, MnO/TiO<sub>2</sub>/P<sub>2</sub>O<sub>5</sub>: a minor element discriminant for basaltic rocks of oceanic environments and its implications for petrogenesis, *Earth and Planetary Science Letters*, vol. 62.No. 1, pp. 53-62. 1983
- [21] Nesbitt, H.W., 1985, Young, G.M. Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic consideration. *Geochim. Cosmochim. Acta*, 48, 1523–1534.
- [22] Fedo, C.M.; Nesbitt, H.W.; Young, G.M., 1995 Unraveling the effects of potassium metasomatism in sedimentary rocks and paleosols, with implications for paleoweathering conditions and provenance. *Geology*, 23, 921–924.
- [23] Nath BN, Kunzendorf H, Pluger WL 2000. Influence of provenance, weathering and sedimentary processes on the elemental ratio of the fine-grained fraction of the bed load sediments from the Vembanad Lake and the adjoining continental shelf, southwest Coast of India. *J Sed Res* 70, 1081-1094