JURNAL
GEOSAINS DAN TEKNOLOGI
Volume 5 Nomer 3, November 2022

Palynostratigraphy Subang, Kaliwangu, And Citalang Formation, From Cikandung River Passage, Sumedang Regency, West Java

Rizki Satria Rachman*, Winantris

Geological Engineering, Faculty of Geological Engineering, Universitas Padjadjaran

Abstrak

Formasi Subang, Kaliwangu, dan Citalang merupakan bagian penting dari Cekungan Bogor belum banyak dilakukan penelitian terutama dari studi palinostratigrafi. Oleh karena itu, penelitian ini bertujuan untuk melakukan studi palinostratigrafi pada ketiga formasi tersebut yang tersingkap baik di wilayah Sungai Cikandung, Kabupaten Sumedang, Jawa Barat. Metode yang dilakukan pada penelitian ini meliputi beberapa tahapan yaitu pengambilan sampel dengan spot sampling; preparasi palinomorf dan palinodebris dengan metode hidrogen peroksida dan metode asam; identifikasi sampel menggunakan mikroskop CX-22; serta analisis dan interpretasi data menggunakan statistik dasar penelitian. Hasilnya, daerah penelitian terbagi kedalam tiga kelompok. Kelompok pertama (sampel W.9 – W.10) berkorelasi dengan Formasi Subang yang memiliki litologi berupa batulempung dominan dengan umur Miosen Tengah dan lingkungan laut dangkal. Kelompok ini berada pada posisi cekungan proksimal dengan kondisi *dysoxic*. Kelompok kedua (sampel W.5 – W.8) berkorelasi dengan Formasi Kaliwangu yang memiliki litologi perselingan batupasir dan batulempung dengan umur lebih muda dari Miosen Tengah dan lingkungan transisi. Kelompok ini berada pada posisi cekungan proksimal dengan kondisi *dysoxic-anoxic*. Kelompok ketiga (sampel W.1 – W.4) berkorelasi dengan Formasi Citalang yang memiliki litologi batupasir dan konglomerat dengan umur lebih muda dari Miosen Tengah (Formasi Kaliwangu) dan lingkungan terestrial. Kelompok ini berada pada posisi cekungan proksimal dan kondisi *anoxic*. Secara umum dari sisi palinodebris, kehadiran material tumbuhan (palinomorf, cuticle, dan wood) berkorelasi negatif terhadap AOM dan fragmen batuan lainnya. Sedangkan dari sisi palinomorf, kehadiran foraminifera lining test berkorelasi negatif terhadap palinomorf terestrial lain terutama dari jenis *Florschuetzia*.

Kata kunci: Formasi batuan; palinodebris; palinomorf; palinostratigrafi; Sungai Cikandung

Abstract

The Subang, Kaliwangu, and Citalang Formation which are important parts of the Bogor Basin have not been studied, especially from the palynostratigraphic aspect. Therefore, this study aims to conduct palynostratigraphic study of these three formations that are well exposed in the Cikandung River area, Sumedang Regency, West Java. Method used in this research is divided into several stages including sampling by spot sampling; preparation of palynomorphs and palynodebris by hydrogen peroxide and acid methods; identification of samples using CX-22 microscope; analysis and interpretation of data using basic research statistics. Result, the research area was divided into three groups. The first group (sample W.9 – W.10) correlates with the Subang Formation which has predominantly claystone lithology with Middle Miocene age and shallow marine environment. This group is in proximal basin position with dysoxic conditions. The second group (sample W.5 – W.8) correlates with the Kaliwangu Formation which has alternating lithology between sandstone and claystone with younger age than the Middle Miocene and transitional environment. This group is in proximal basin position with dysoxic-anoxic conditions. The third group (sample W.1 – W.4) correlates with the Citalang Formation which has sandstone and conglomerate lithology with younger age than the Middle Miocene (Kaliwangu Formation) and terrestrial environment. This group is in proximal basin position and anoxic conditions.

*) Korespondensi: rizkisatriarachman@gmail.com
Diajukan : 23 Januari 2022
Diterima : 18 November 2022
Diterbitkan : 24 Januari 2023

In general, when viewed from palynodebris, the presence of plant material (palynomorph, cuticle, and wood) is negatively correlated with AOM and other rock fragments. On the other hand, in terms of palynomorphs, the presence of foraminifera lining test has negative correlation with other terrestrial palynomorphs, especially those of the Florschuetzia species.

Keywords: *Rock formation; palynodebris,; palynomorph; palynostratigraphy; Cikandung River*

INTRODUCTION

Stratigraphy is branch of geology that talks about the characteristics of rock layers from various aspects that explain the evolution of the formation of these rocks in geological time scales (Nichols, 2009; Boggs, 2014). Lately, there has been the development of science from stratigraphy which is known as the study of palynostratigraphy. Palynostratigraphy is science that studies the content of palynomorphs (organic microfossils with 5–500 μm that are resistant to acid conditions) which are related to the age and depositional environment of rocks and can be developed to identify other aspects (Ibrahim et al., 2001; Dino et al., 2012; Cirilli, 2014; Stephenson, 2018; Yulianto et al., 2019). In Indonesia, the study of palinostratigraphy is still rarely discussed because its preservation can only occur in certain rocks, especially in the terrestrial environment (Elsik, 1976; Bruno et al., 2011; Soares et al., 2017). Therefore, this palinostratigraphic study is aimed at rock formations deposited in terrestrial environment.

The Bogor Basin is one of important basins on the Java Island. This basin shows that the evolution of this island was formed predominantly in the marine environment compared to the terrestrial environment (Satyana et al., 2002; Martodjojo, 2003; Aswan et al., 2008; Muljana & Watanabe, 2012). The presence of rocks formed in the terrestrial environment only occurs in few old formations such as the Bayah, Batuasih, and Jatibarang Formation as well as some younger formations such as the Subang, Kaliwangu, Citalang, and several formations resulting from volcanic activity (Sujatmiko, 1972; Silitonga, 1973; Sujatmiko, & Santosa, 1992; Effendi et al., 1998; Martodjojo, 2003). The stratigraphy of Bayah, Batuasih, and Jatibarang formation has been widely discussed by previous researchers using various aspects, including radioactive age, macrofossils, and microfossils such as palynomorphs, foraminifera, and nanofossils (Sujatmiko, & Santosa, 1992; Effendi et al., 1998; Martodjojo, 2003). while in the Subang, Kaliwangu, and Citalang Formation, research on the stratigraphy of these formation has not been analyzed further, especially from the palynostratigraphic aspect.

Subang Formation is a formation that has lithology of marl and limestone at the bottom which turns into claystone at the top. This formation has Late Miocene age and was formed in shallow marine environment that turned into transition (brackish water) at the top (Martodjojo, 2003; Sadisun et al., 2005). Kaliwangu Formation has lithology of alternating between claystone and sandstone with coal insertion at several locations. In addition, this formation is characterized by the abundance of nodules and molluscs in claystone. Kaliwangu Formation has Early Pliocene age with transitional environment, precisely in the tidal part of the sea (Martodjojo, 2003; Aswan, 2013; Ilmi et al., 2019). Last, Citalang Formation has lithology of sandstone and conglomerate with tuff content in some parts. This formation has Late Pliocene age with terrestrial depositional environment, precisely in the fluvial depositional environment (Martodjojo, 2003; Alam et al., 2019).

These three formations are very well exposed in the Cikandung River area, Sumedang Regency, West Java (Figure 1b) which is affected by one main fault, namely the baribis fault. (Haryanto et al., 2020). However, research on these three formations, especially from palynostratigraphic aspect, has not been recorded. Therefore, this study aims to see how the Subang, Kaliwangu, and Citalang Formation are viewed from palynostratigraphic aspect. This palynostratigraphic aspect includes the interpretation of age; the interpretation of the depositional environment and its conditions; and the interpretation of relationship between each palynological aspect in each sample formation.

METHODOLOGY

This research was conducted through several stages starting from sampling, sample preparation, sample identification, and ended

with research data analysis. In each of these stages there is a different method which is explained further in the next section.

Rock Sampling

Field samples were taken by spot sampling method with the aim of obtaining rocks that represent the Subang, Kaliwangu, and Citalang formations. In one sampling spot, sample are taken based on lithological changes or rock layer changes. Meanwhile, if the rock has very thick layer, the number of samples taken is adjusted to the thickness of rock obtained at the sampling spot (Bellian et al., 2005; Fedorko & Skema, 2013; Yasin et al., 2017).

Sample Preparation

Rock samples were prepared in the paleontology and micropaleontology laboratory at Padjadjaran University. Rock samples were selected based on the characteristics of rock which has finer grain size, this is done because finer sedimentary rocks have higher potential to contain palynomorphs (Evans et al., 2020). Samples were prepared using combination of the hydrogen peroxide method and the acid method (Modification from Traverse, 2007).

Sample Identification

The prepared samples were then identified. The samples were observed using CX-22 binocular microscope with magnification up to 1000 times. When making observations, searches were carried out to find palynomorphs along with other materials known as palynodebris. The material is then described, identified, and determined to obtain the abundance of palynomorph and palynodebris in rock samples (Winantris et al., 2012).

Sample Analysis and Interpretation

Palynomorph and palynodebris data were analyzed using several methods. Biostratigraphic analysis using palynomorph markers was performed to determine age. Palynomorph abundance analysis was carried out to determine the depositional environment. Statistical analysis using cluster analysis, ternary diagrams, and

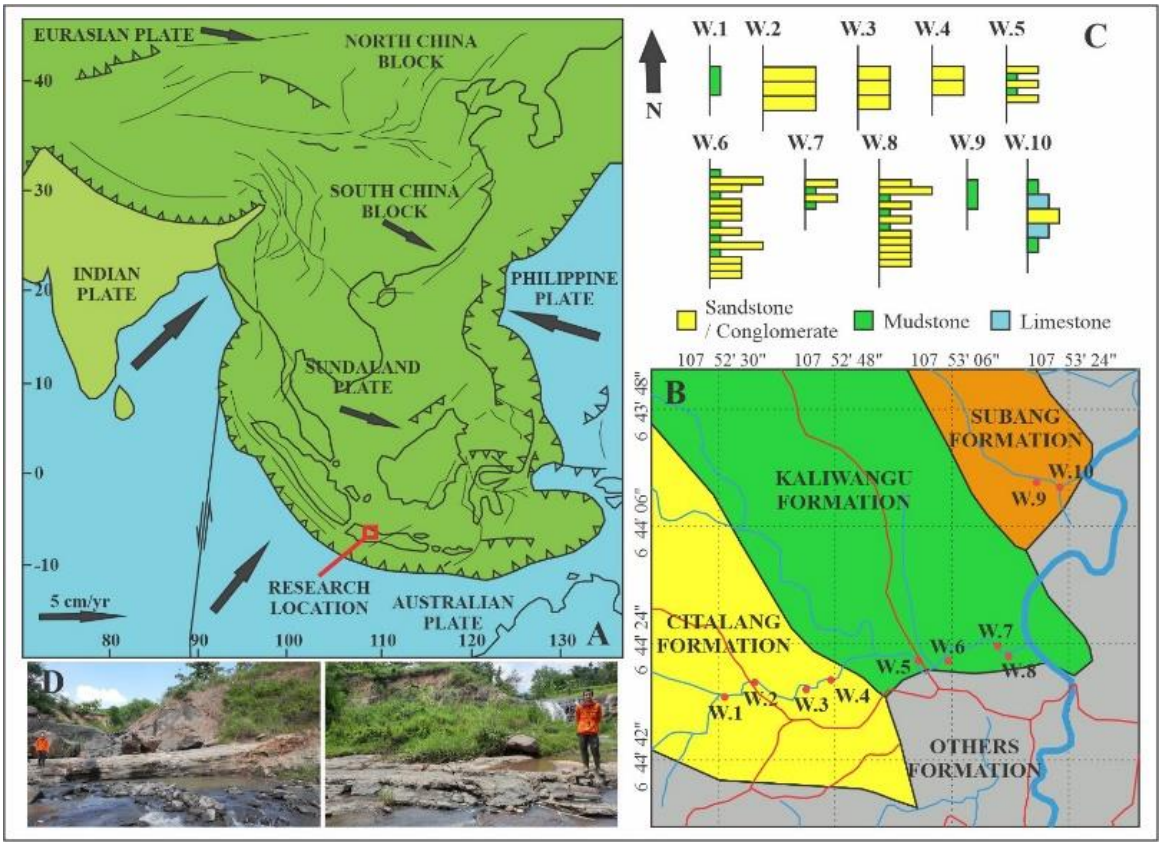

Figure 1. Location of research area; (a) Research location in relation to Sundaland tectonic setting (Modification from Metcalfe, 2017); (b) Research location in relation to geological map; (c) Stratigraphic cross-section of research location; (d) Field photo from research location.

principal component analysis (PCA) was carried out to see how the palynostratigraphy of study area. In addition, this was also done to confirm the age and depositional environment of Subang, Kaliwangu and Citalang Formation in the Cikandung River area, Sumedang Regency, West Java.

RESULTS

The research was conducted on the Cikandung River which is located at 6º44'26.6" S – 107º53'5.28" E to 6º43'59.83" S – 107º53'22.56" E. From the field work, 10 outcrops were obtained (W.1 – W.10) consisting of 55 samples. Next, 38 samples were prepared to determine the content of palynomorph and palynodebris in each sample (Figure 1a & 1b). Result, 19 samples did not contain palynomorph, 11 samples contained few palynomorphs (<10 individuals), and 7 samples contained large number of palynomorphs (>10 individuals). This means that in general the research area in Cikandung River trajectory has low palynomorph preservation because it is difficult to find palynomorphs in this rock formation (Figure 3).

Geological Setting

Overall, the rock lithology in study area has strike dip ranging between N 180ºE/10º which has westward slope. If refers to the regional geological map, this area is included into 3 rock formations, namely the Citalang, Kaliwangu, and Subang Formation. The results from field activities confirm the existence of these three formations when viewed from the lithological changes. The lithology of research area can be grouped into 3 sections from old to young by stratigraphy, including (Figure 1):

Section 1 which correlates with the Subang Formation (Samples W9 – W10)

In the first part, which is correlated with the Subang Formation, rocks are found in form of an alternation between carbonated claystone and limestone at the bottom. When getting up in this section, the limestone seems to disappear so that only massive claystone that is carbonate is found. If the lithological changes were further traced from the first section to the second section, firm contacts indicating formation boundaries were not found. The change from Subang Formation to Kaliwangu Formation can be seen with the claystone becoming non-carbonated and alternation between claystone and sandstone was found.

Section 2 which correlates with the Kaliwangu Formation (Samples W5 – W8)

In the second part, which is correlated with the Kaliwangu Formation, rocks are found in form of an alternation between sandstone and claystone. This claystone in some parts has strong carbonaceous properties so that it is darker and is close to black in color. In addition, in some parts of this claystone contains very abundant mollusk fossils. If the lithological changes were further traced from the second section to the third section, firm contacts indicating formation boundaries were not found due to the limited outcrop in Citalang Formation. The change is obtained suddenly from the alternation between sandstone and claystone to become conglomerate in the third section.

Section 3 which correlates with the Citalang Formation (Samples W1 – W4)

In the third section, which is correlated with the Citalang Formation, rocks were found in form of massive sandstone which in some parts developed into polymic conglomerates. The rock in this third section has very high level of oxidation so that the rock has reddish color compared to other rock formation.

Palynostratigraphy

Palynostratigraphic analysis performed on the study sample contained various palynomorphs and palynodebris. At least 219 individuals divided into 14 palynomorph species and 7 palynodebris groups were identified for further analysis. The result, *Acrostichum sp* and *Inaperturopollenites sp* became the dominant palynomorphs in the study sample, while the most dominant palynodebris came from the presence of other fragments that mostly came from the rest of rock fragments (Figure 2).

If the palynomorph analysis is correlated with the rock formation, the Subang Formation contains a large number of palynomorphs to be identified, the Kaliwangu Formation has very few palynomorphs to be identified, while the Citalang Formation does not have any palynomorphs in the rock sample to be identified (Figure 3). Palynomorph content is indeed strongly

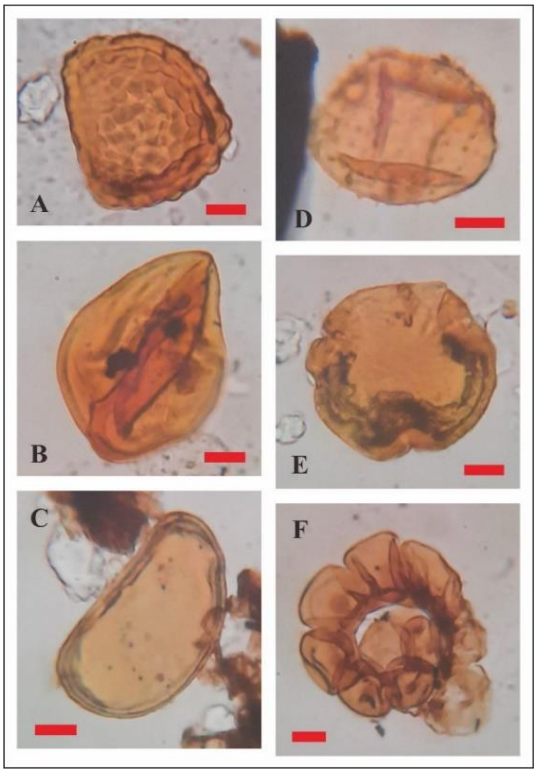

Figure 2. Palynomorph from research sample; (a) *Verrucatosporites usmensis*; (b) *Florschuetzia trilobata*; (c) *Laevigatosporites*; (d) *Echiitriporites schootenoides*; (e) *Lanagiopollis nanggulanensis*; (f) *Foraminifera lining test.*

influenced by various aspects of rock samples including lithological characteristics, rock conditions, or the process of formation of these rocks. Therefore, even though the Citalang Formation has terrestrial depositional environment that should have preserved a lot of palynomorphs, because the rocks have coarse grain sizes (conglomerates and sandstones) and are driven by rock conditions in a strong oxidation state, the rocks in this formation cannot properly preserve palynomorphs. This also occurs in the Kaliwangu Formation which contains very few palynomorph. So that the analysis of palynostratigraphy can not be separated from the condition of preservation of palynomorphs because rock samples contain different amounts of palynomorph.

The limitations of palynomorph preservation affect the interpretation of age for these three formations. The rocks from Subang Formation are interpreted as having Middle Miocene age, this is drawn by the presence *of Florschuetzia trilobata* and *Echiitriporites schootenoides* fossils. *Florschuetzia trilobata* fossil indicates that this rock formation was not younger than Middle Miocene because it was extinct at this age. Meanwhile, *Echiitriporites schootenoides* fossil shows that the Subang Formation rock was not formed older than Miocene age because this fossil only appeared at this age. Second, the rocks in the Kaliwangu Formation are interpreted to be younger than the Middle Miocene, this is drawn by the presence of fewer fossils of *Florschuetzia trilobata* and the appearance of *Florschuetzia sp*. *Florschuetzia sp* fossil found in the research sample show characteristics that are close to *Florschuetzia levipoli*. However, this fossil does not show any verrucate ornamentation on the equatorial part. Therefore, the age of *Florschuetzia sp* interpreted as younger than *Florschuetzia trilobata*. Last, Citalang Formation is interpreted as having younger age than the Middle Miocene. Since palynomorphs were not found in this formation, the age of this rock was drawn based on the stratigraphic position of the rock which shows that the Citalang Formation is younger than the Kaliwangu Formation (Figure 3).

Depositional environment from the Subang Formation to the Citalang Formation has slightly changed from shallow marine environment to terrestrial environment (Figure 3). Subang Formation is interpreted as being formed in shallow marine environment, this can be seen by the presence of many foraminifera lining test that are not found in other rock formations. On the other hand, indeed in the Subang Formation there are many palynomorphs of terrestrial origin. However, considering the high level of palynomorphs preservation in Subang Formation, these others pollen and spores originating from land in this sample are the result of long-distance transport. This interpretation is also confirmed by the variety of palynodebris found in Subang Formation, the diversity of palynodebris indicates that this formation was formed in the accumulation area of transport results, both lithic fragments, organic fragments, and amorphous organic matter.

Furthermore, the Kaliwangu Formation is interpreted as being formed in transitional environment, this can be seen by the disappearance of the foraminifera lining test and the presence of palynomorphs originating from mangrove, back-mangrove to freshwater swamp.

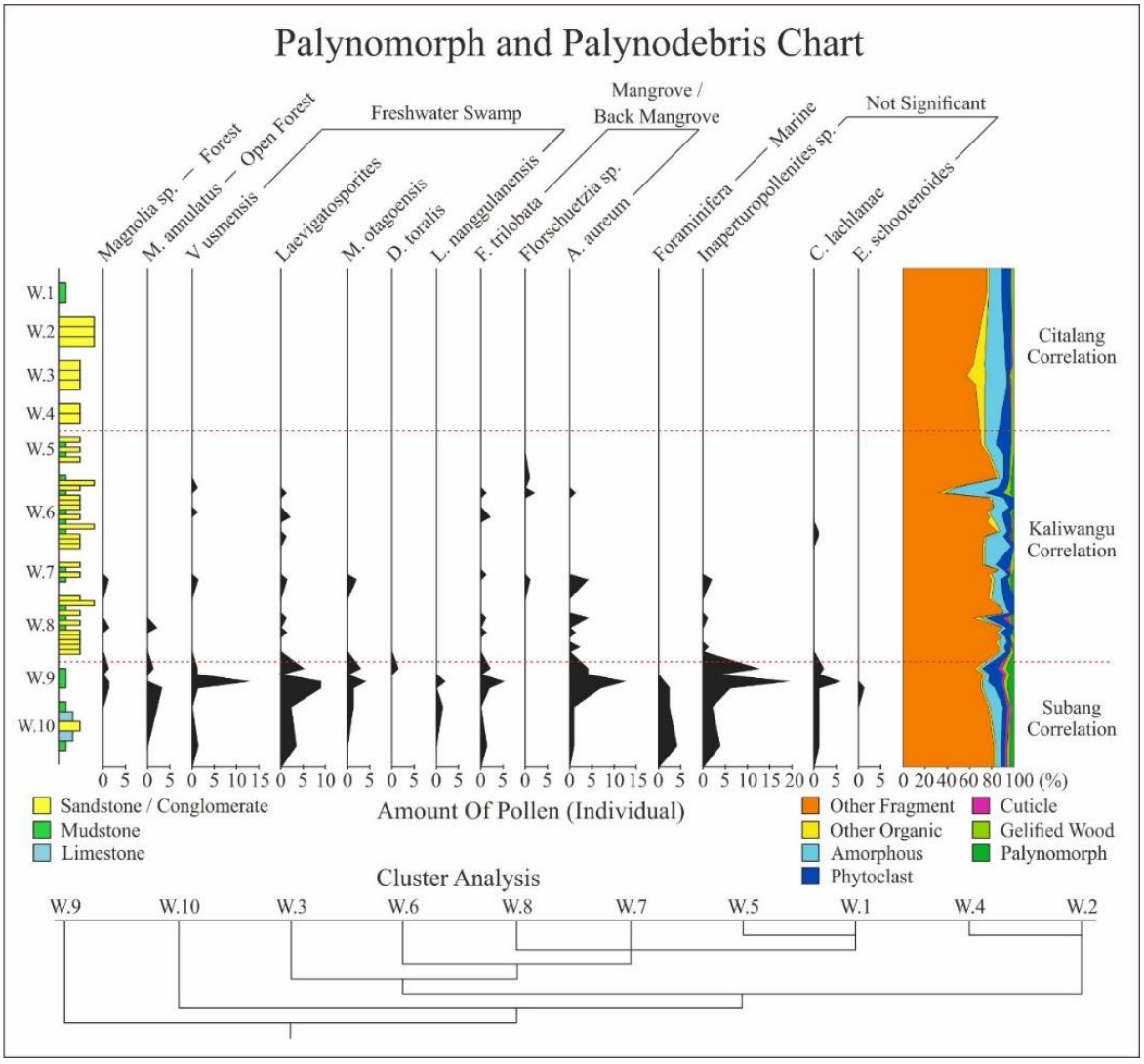

Figure 3. Palynomorph and palynodebris diagrams and the cluster analysis results of research sample.

The fossils that characterize this transitional environment include *Florschuetzia sp*, *Florschuetzia trilobata*, and *Verrucatosporites usmensis*. In addition, the diversity of palynodebris in this formation has decreased which indicates high energy at the time this formation was formed. Thus, others palynomorphs and palynodebris tend not to be deposited well in this formation.

Last, the Citalang Formation is interpreted as being formed in terrestrial environment, this can be seen by the rock lithology which has become significantly coarser. The lithology of these rocks shows that the palynomorphs cannot be preserved in these rocks. When viewed from the palynodebris, this formation has quite a lot of organic matter compared to other formations, it confirms that this formation was formed in terrestrial environment. However, very high energy and oxidation condition caused the palynomorphs to not be preserved in this formation.

Cluster analysis showed a tendency for the samples to form 5 groups which correlated with the rock formations in study area. The first cluster (W.2 and W.4) is a cluster with no preserved palynomorph content in the rock. This cluster correlates with the Citalang Formation in the study area. The second cluster (W.1, W.5, W.7, W.8, and W.6) is a cluster that is taken with a few palynomorph content and similar palynodebris content in these samples. This cluster correlates with the Kaliwangu Formation in the study area. However, sample W.1 has a high closeness to the second cluster, this happens because of the very high similarity when viewed from the palynodebris aspect, even though this sample does not contain a palynomorph. The third cluster

(W.3) is a cluster in study area that does not contain palynomorphs, but has palynodebris differences in the form of increased organic matter content compared to the previous cluster. So it is still correlated with the Citalang Formation. The fourth and fifth clusters (W.9 and W.10) were the highest clusters containing palynomorphs with a fairly similar palinodebris diversity. Thus, these two clusters are correlated with the Subang Formation in the study area (Figure 3).

DISCUSSION

In general, the results of this study are correlated with previous studies when viewed from other aspects outside of palynostratigraphy. Samples in the Subang Formation (W.9 and W.10) have Middle Miocene age, samples in the Kaliwangu Formation (W.5 – W.8) have younger age than the Middle Miocene, and samples from the Citalang Formation (W.1 – W.4) has younger age than the Kaliwangu Formation. This results is in accordance with previous research which states that the Subang Formation has Late Miocene age which in some studies is also stated to reach Middle Miocene age. (Martodjojo, 2003; Sadisun et al., 2005). Meanwhile, due to limited palynomorph preservation in the Kaliwangu and Citalang Formation, interpretation from these formation can only be drawn to have younger age than the Middle Miocene. This result is indeed correlated with previous research which states that these two formations have Pliocene age (Martodjojo, 2003; Aswan, 2013; Ilmi et al., 2019; Alam et al., 2019).

When viewed from depositional environment aspect, this study states that the Subang Formation was deposited in shallow marine environment and changed to transition in the Kaliwangu Formation, until finally becoming terrestrial in the Citalang Formation. This is correlated with previous research which states that the Subang, Kaliwangu and Citalang Formation is a process of environmental change from shallow marine to terrestrial in the regression phase. So that shallow marine environment in the Subang Formation can turn into terrestrial environment in the Citalang Formation.

Principal component analysis is carried out to see how the variables are grouped both in terms of samples and parameters taken. The results of Palynodebris PCA showed that the sample was divided into 5 clusters (Figure 4a). First, samples W.2 and W.4 were grouped because they did not have certain predominance of palynodebris. Second, samples W.1, W.5, and W.6 were grouped because they had palynodebris with types of other organic matter that were more dominant. Third, sample W.3 was separated because basically this sample has similarities like the second cluster, but has higher dominance of other organic matter than the previous cluster. The fourth is samples W.7 and W.8 which are grouped because they contain all parameters evenly with tendency for cuticle dominance in them. Last, samples W.9 and W.10 were grouped because of the high content of plants, both in terms of palynomorph and cuticle in the sample. The PCA results also showed that the palynodebris parameters in the form of plant yields (Palynomorph, Cuticle, and Wood) had a high positive relationship. While AOM and other materials are on the other side of the PCA diagram which shows a negative relationship with plant-based materials.

Palynomorph PCA results showed that the sample was divided into 5 clusters (Figure 4b). First, samples W.1 to W.5 were grouped because they did not contain any palynomorphs at all. Second, samples W.6 and W.7 were grouped because they contained *Florschuetzia sp* which is quite high. Third, sample W.8 was separated because it did not show the dominance of certain palynomorphs in it with few palynomorph content. Fourth, sample W.9 is separated very far because it contains all of the palynomorphs that are evenly distributed with the highest number of palynomorphs compared to other samples. Fifth, sample W.10 was separated because it contains large number of palynomorphs with predominance of foraminifera in it which shows a high marine influence at this point. The PCA results also show that the parameter of palynomorph in the form of foraminifera lining test has high level of negative relationship compared to other palynomorphs, this indicates that the presence of foraminifera compared to other palynomorphs has the opposite level of presence. Although from the diagram it can be seen that in some conditions foraminifera can be found with several palynomorphs such as *Monoporites annulatus* and *Lanagiopollis nanggulaensis*.

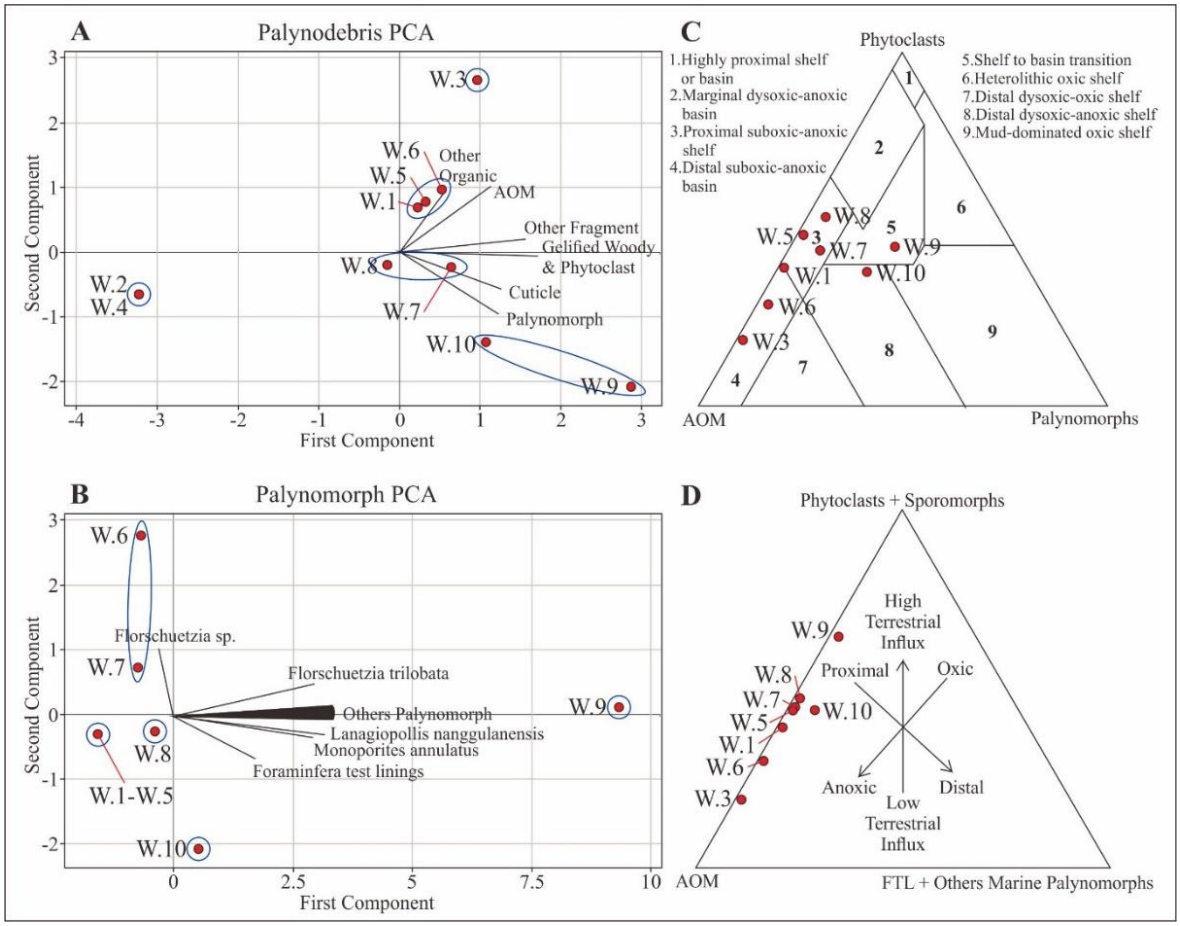

Figure 4. Results of principal component analysis (PCA) and palynofacies; (a) Palynodebris PCA; (b) Palynomorph PCA; (c and d) Palynofacies Ternary Diagram.

The results of the first palynofacies ternary diagram (Figure 4c) show that the sample belongs to 4 environmental conditions. 3 samples belong to the proximal suboxic-anoxic shelf, 3 samples belong to the distal suboxic-anoxic basin, 1 sample belongs to the shelf to basin transition, 1 sample belongs to the distal dysoxic-anoxic shelf, and 2 samples were not plotted due to data limitations. Proximal suboxic-anoxic shelf is a condition where the basin decreases which causes the preservation of AOM and phytoclasts simultaneously. Distal suboxic-anoxic basin is a condition of maximum subsidence of basin, so that the palynomorphs cannot be preserved and only produce AOM in the sample. Shelf to basin transition is a condition where the basin decreases with increasing sources of various sediments so that the presence of AOM, Phytoclast, and palynomorphs can be found. Last, distal dysoxic-anoxic shelf is a condition like shelf to basin transition but with higher AOM distribution which is thought to be due to stronger sea influence (Tyson, 1995; Gotz et al., 2008; Filho et al., 2012; Aggarwal et al., 2019).

The results of second palynofacies ternary diagram (Figure 4d) show that all research samples are in the proximal region which has tendency to be in anoxic conditions. This shows that depositional environment in these three formations is in very high terrestrial influence condition which can be seen by the large number of rock fragments and phytoclasts in the rock samples. In addition, the large number of AOM in some samples indicates that the study area is in anoxic condition that is not good for palynomorphs to be well preserved. (Tyson, 1995; Gotz et al., 2008; Tyson, 2012; Aggarwal et al., 2019).

From the results of principal components and palynofacies analysis, several interpretations can be drawn (Figure 5). The first group (W.9 – W.10) is sample with dominant content of palynomorph and other plant material with a large number of foraminifera. This sample is in the proximal position of basin that has dysoxic

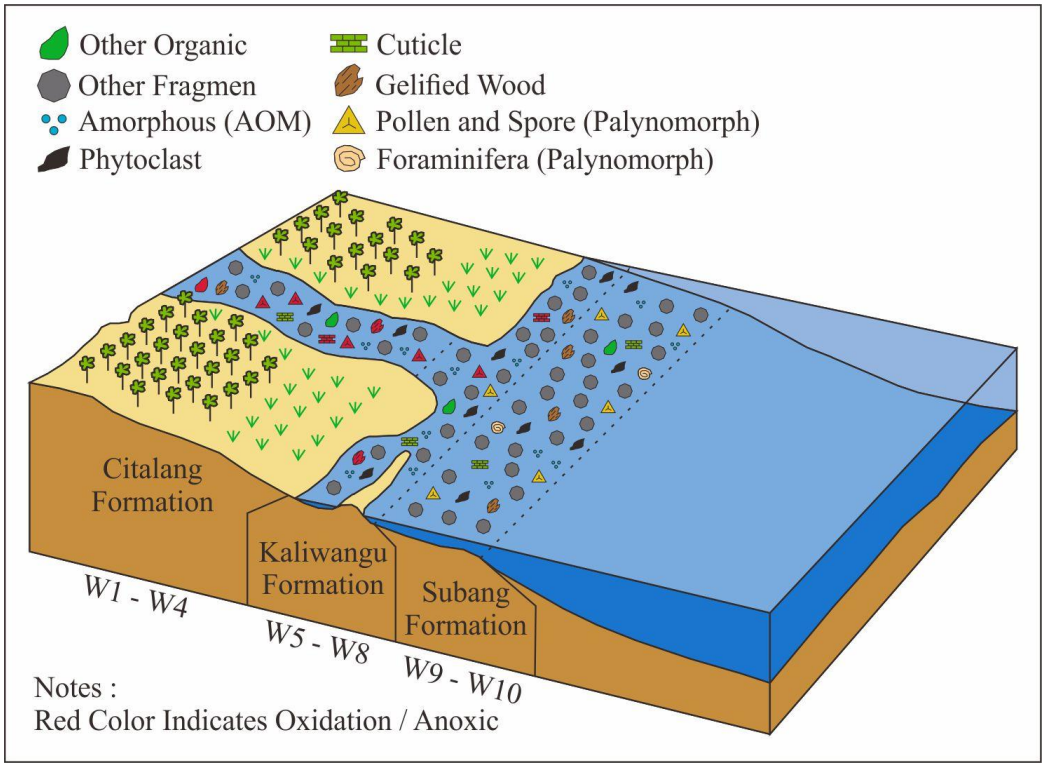

Figure 5. Modeling of rock sample content and depositional environment from the study area.

condition. From this, the rocks in the first group are interpreted to be formed in shallow marine environment. This was taken because of the large number of foraminifera and other plant materials with proximal positions and dysoxic conditions, these conditions indicate the potential for palynomorphs and palynodebris that are quite diverse in these rocks. The second group (W.5 – W.8) is sample with very few palynomorph and palynodebris content and does not show any dominance other than the rest of rock fragments. This sample is in a proximal condition and dyoxic-anoxic basin. Therefore, the rocks in this second group are interpreted to have formed in transitional environment. This was taken because of the higher content of *Florschuetzia* species and the absence of other palynodebris diversity with a proximal position and more anoxic conditions, this condition indicates that AOM tends to be more developed and the palynomorph and palynodebris cannot be preserved under these conditions.

Finally, the third group (W.1 - W.4) is sample with no palynomorph content and slightly varying palinodebris. This sample is in a proximal condition and highly anoxic basin. Thus, rocks in this third group are interpreted to have formed in terrestrial environment in a deep depression. This is interpreted because the very high AOM indicates very anoxic conditions causing no palynomorphs to be preserved in this rock.

CONCLUSION

Research area is divided into three groups. The first group (samples W.9 – W.10) correlates with the Subang Formation which has lithology of claystone dominance. This group has Middle Miocene age with shallow marine environment in the proximal basin position and dysoxic conditions. The second group (sample W.5 – W.8) correlated with the Kaliwangu Formation having alternating lithology between sandstone and claystone. This group has younger age than Middle Miocene with transitional environment in the proximal basin position and dysoxic-anoxic conditions. The third group (sample W.1 – W.4) correlates with the Citalang Formation having sandstone and conglomerate lithology. This group has younger age than Middle Miocene (Kaliwangu Formation) with terrestrial environment in the proximal basin position and anoxic conditions. In general, in terms of palynodebris, the presence of plant material (palynomorph, cuticle, and wood) is negatively correlated with AOM and other rock fragments.

On the other hand, in terms of palynomorphs, the presence of foraminifera lining test has negative correlation with other terrestrial palynomorphs, especially those of the Florschuetzia species.

ACKNOWLEDGMENT

Thank you to the Chancellor of Padjadjaran University for funding research through the HIU-RKDU program, the paleontology laboratory team from Faculty of Geological Engineering Padjadjaran University, and all parties who have helped and provided encouragement in this research.

REFERENCES

Aggarwal, N., Thakur, B., Jha, N., 2019. Palaeoenvironmental changes in the Lower Gondwana succession of the Godavari Graben (South India) inferred from palynofacies. *Journal of Paleolimnology*, *61*, 329-343. https://doi.org/10.1007/s10933-018-0062-8

Alam, S., Sendjaja, Y.A., Jurnaliah, L., Gani, R. M., Fachrudin, K.A., 2019. Evidence of Pliocene-Pleistocene Unconformity in Eastern Bogor Trough, Sumedang, West Java. *Journal of Geological Sciences and Applied Geology*, *3*(1), 38-43.

Aswan, Rijani, S., Rizal, Y., 2013. Shell Bed Identification of Kaliwangu Formation and its Sedimentary Cycle Significance, Sumedang, West Java. *Indonesian Journal of Geoscience*, *8*(1), 1-11. https://doi.org/10.17014/ijog.v8i1.151

Aswan, Suparka, E., Rijani, S., Sundari, D., Patriani, E.Y., 2008. Asymmetrical condition of the Bogor Basin (West Jawa, Indonesia) during the Middle Miocene to Pliocene based on taphonomic study of shellbed and its sequence architecture. *Bulletin of the Geological Survey of Japan*, *59*(7-8), 319-325. https://doi.org/10.9795/bullgsj.59.319

Bellian, J.A., Kerans, C., Jennette, D.C., 2005. Digital Outcrop Models: Applications of Terrestrial Scanning Lidar Technology in Stratigraphic Modeling. *Journal of Sedimentary Research*, *75*(2), 166-176. https://doi.org/10.2110/jsr.2005.013

Boggs, S., 2006. *Principles of Sedimentology and Stratigraphy* (4th ed.). New Jersey: Pearson Prentice Hall.

Bruno, D.Z., Elysee, G.K., Jean-Paul, Y.N., Kouadio, A., Kizito, T.B., Raphael, Y.K., Ignace, T., 2011. Palynostratigraphy and depositional palaeoenvironment of Cretaceous-Palaeogene (K-Pg) boundary deposits on Abidjan margin (Cote d'Ivoire). *Journal of Geography and Regional Planning*, *4*(11), 644-655. https://doi.org/10.5897/JGRP.9000110

Cirilli, S., 2014. Upper Triassic-lowermost Jurassic palynology and palynostratigraphy: a review. *Geological Society, London, Special Publications*, *334*(1), 285-314. https://doi.org/10.1144/SP334.12

Dino, R., Soares, E.A., Antoniolio, L., Riccomini, C., Nogueira, A.C., 2012. Palynostratigraphy and sedimentary facies of Middle Miocene fluvial deposits of the Amazonas Basin, Brazil. *Journal of South American Earth Sciences*, *34*, 61-80. https://doi.org/10.1016/j.jsames.2011.11.008

Effendi, Kusnama, & Hermantos, 1998. *Peta Geologi Lembar Bogor, Jawa Barat, Skala 1:100.000.* Bandung: Pusat Penelitian dan Pengembangan Geologi.

Elsik, W.C. (1976). Microscopic Fungal Remains and Cenozoic Palynostratigraphy. *Geoscience and Man*, 15(1), 115-120. https://doi.org/10.1080/00721395.1976.9989779

Evans, S.D., Dzaugis, P.W., Droser, M.L., Gehling, J.G., 2020. You can get anything you want from Alice's Restaurant Bed: exceptional preservation and an unusual fossil assemblage from a newly excavated bed (Ediacara Member, Nilpena, South Australia). *Australian Journal of Earth Sciences*, *67*(6), 873-883. https://doi.org/10.1080/08120099.2018.1470110

Fedorko, N. & Skema, V., 2013). A review of the stratigraphy and stratigraphic nomenclature of the Dunkard Group in West Virginia and Pennsylvania, USA. *International Journal of Coal Geology*, *119*, 2-20. https://doi.org/10.1016/j.coal.2013.07.016

Filho, J.G., Menezes, T.R., Mendonca, J.D., Oliveira, A.D., Silva, T.F., Rondon, N.F., Silva, F.S., 2012. Organic Facies: Palynofacies and Organic Geochemistry. In *Geochemistry - Earth's System Processes* (pp. 211-248). Rijeka: Intech.

Gotz, A.W., Feist-Burkhardt, S., Ruckwied, K., 2008. Palynofacies and sea-level changes in

the Upper Cretaceous of the Vocontian Basin, southeast France. *Cretaceous Research*, *29*(5-6), 1047-1057. https://doi.org/10.1016/j.cretres.2008.05.029

Haryanto, I., Ilmi, N.N., Hutabarat, J., Adhiperdana, B.G., Fauzielly, L., Sendjaja, Y. A., Sunardi, E., 2020. Tectonic and Geological Structures of Gunung Kromong, West Java, Indonesia. *International Journal of Geomate*, *19*(74), 185-193. https://doi.org/10.21660/2020.74.05449

Ibrahim, M.I., Ela, N.M., Kholeif, S.E., 2001. Palynostratigraphy of Jurassic to Lower Cretaceous sequences from the Eastern Desert of Egypt. *Journal of African Earth Sciences*, *32*(2), 269-297. https://doi.org/10.1016/S0899-5362(01)90007-7

Ilmi, N.N., Haryanto, I., Abdurokhim, Adhiperdana, B.G., Helmi, F., Hutabarat, J., Sunardi, E., 2019. Distribution Pattern Differences of Kaliwangu Formation in Ujungjaya dan Pasir Malati, Sumedang, West Java. *Journal of Geological Sciences and Applied Geology*, *3*(3), 42-45.

Martodjojo, S., 2003. *Evolusi Cekungan Bogor, Jawa Barat*. Bandung: Institut Teknologi Bandung.

Metcalfe, I., 2017. Tectonic evolution of Sundaland. *Bulletin of the Geological Society of Malaysia*, *63*, 27-60.

Muljana, B. & Watanabe, K., 2012. Modal and sandstone composition of the representative turbidite from the Majalengka sub-Basin, West Java Indonesia. *Journal of Geography and Geology*, *4*(1), 1-17. http://dx.doi.org/10.5539/jgg.v4n1p3

Nichols, G., 2009). *Sedimentology and Stratigraphy* (2nd ed.). United Kingdom: Wiley-Blackwell John Wiley & Sons.

Sadisun, I.A., Shimada, H., Ichinose, M., Matsui, K., 2005. Study on the physical disintegration characteristics of Subang claystone subjected to a modified slaking index test. *Geotechnical and Geological Engineering*, *23*(3), 199-218. https://doi.org/10.1007/s10706-003-6112-6

Satyana, A.H., Armandita, C., Raharjo, B., Syafri, I., 2002. New Observations on the Evolution of the Bogor Basin, West Java: Opportunities for Turbidite Hydrocarbon Play. *Buletin Geologi Institut Teknologi Bandung, Edisi Khusus*, 1-15.

Silitonga, P.H., 1973. *Peta Geologi Lembar Bandung, Jawa Barat, Skala 1:100.000*. Bandung: Pusat Penelitian dan Pengembangan Geologi.

Soares, E.A., D'apolito, C., Jaramillo, C., Harrington, G., Caputo, M.V., Barbosa, R.O., Santos, E.B.D., Dino, R., Goncalves, A.D., 2017. Sedimentology and palynostratigraphy of a Pliocene-Pleistocene (Piacenzian to Gelasian) deposit in the lower Negro River: Implications for the establishment of large rivers in Central Amazonia. *Journal of South American Earth Sciences*, *79*, 215-229. https://doi.org/10.1016/j.jsames.2017.08.008

Stephenson, M.H., 2018. Permian palynostratigraphy: a global overview. *Geological Society, London, Special Publications*, *450*(1), 321-247. https://doi.org/10.1144/SP450.2

Sujatmiko, 1972. *Peta Geologi Lembar Cianjur, Jawa Barat, Skala 1:100.000*. Bandung: Pusat Penelitian dan Pengembangan Geologi.

Sujatmiko & Santosa, 1992. *Peta Geologi Lembar Leuwidamar, Jawa Barat, Skala 1:100.000.* Bandung: Pusat Penelitian dan Pengembangan Geologi.

Traverse, A., 2007. *Paleopalynology* (2nd ed.). Netherlands: Springer.

Tyson, R.V., 1955. *Sedimentary Organic Matter, Organic Facies and Palynofacies*. London: Chapman and Hall.

Winantris, Syafri, I., Rahardjo, A.T., 2012. Oncosperma Tigillarium Merupakan Bagian Palino Karakter Delta Plain di Delta Mahakam, Kalimantan. *Bionatura - Jurnal Ilmu-ilmu Hayati dan Fisik*, *14*(3), 228-236.

Yasin, M., shahzad, A., Abbasi, N., Ijaz, U., Khattak, Z., 2017. The Use of Stratigraphic Section in Recording Quagmire of Information for the Fluvial Depositional Environment - A Worked Example in District Poonch, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Geology*, *1*(2), 1-2.

Yulianto, E., Sukapti, W.S., Setiawan, R., 2019. Palinostratigrafi, Paleoekologi dan Paleoklimatologi Plistosen Awal Berdasarkan Studi Palinologi Formasi Pucangan di Daerah Sangiran. *Jurnal Geologi dan Sumberdaya Mineral*, *20*(3), 133-141. https://doi.org/10.33332/jgsm.2019.v20.3.133-141p