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The Significance Relationship between Palynomorph Fossil Preservation and Grain Size in Rock: Case Study of Walat and Batuasih Formations, Sukabumi, West Java

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Abstract

Palynomorph is dust-sized material that is resistant to acids and can be preserved as fossils in sedimentary rocks. Fossil content in rocks is very diverse which is influenced by various factors, one of this factors is the texture of rock in form of grain size. The Walat and Batuasih Formations are sedimentary rock formations that have variety of grain sizes. This research aims to examine relationship or correlation between grain size and palynomorph preservation in rocks with case studies in the Walat and Batuasih Formations. 42 samples were taken from measured stratigraphic section and analyzed both grain size and palynomorph content. Statistical analysis with Normality Test using Shapiro Wilk and Liliefors; Homogeneity Test using Levene Test; and Non-Parametric Associative Test using Spearman Rank was conducted to see the relationship of these variables. Result, the Walat and Batuasih Formations have conglomerate, sandstone, mudstone and coal lithologies with quite variety of palynomorphs. Statistical results show that all variables have data that are not normally distributed with tendency to be non-homogeneous. Moreover, it was found that the grain size of rock had significant effect on the preservation of palynomorphs in the rock. Clay grains has positive correlation of 0.613 and sand grains has negative correlation of -0.653. This shows that the finer the grain size, the more effective the preservation of palynomorphs is.

Keywords: Batuasih Formation; Grain Size; Palynomorph; Relationship; Walat Formation.

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Introduction

Palynomorph is dust-sized material that is resistant to acids (Dutta et al., 2013; Vernal, 2015). These materials include pollen, spores, dinocyst, foraminifera lining test, acritarch, and chitinozoa (Traverse, 2007). Basically, these materials can be deposited and preserved in rocks and turned into fossils (Suedy et al., 2011; Setijadi et al., 2011). Sedimentary rock is one of the rocks that stores fossil content both palynomorphs and other materials. However, these fossils are not preserved evenly in the rock (Mander & Punyasena, 2018). The number of preserved palynomorph fossils in the rock is influenced by various aspects, one of these factors is the texture of sedimentary rock (Havinga, 1967; Li et al., 2005; Delcourt & Delcourt, 1980).

Several previous studies stated that the texture of rock grain size does affect the preservation of fossil in the rock (Schoeninger et al., 1989; Dashtgard et al., 2008; Gardner et al., 2016; Evans et al., 2020). The finer the grain size of sedimentary rock, the better the rock will store fossil content (Evans et al., 2020). Previous research has been carried out on macrofossils and some have also discussed them from microfossil aspect (Schopf, 1975; Holland, 2016). However, the level of significance of influence or relationship between rock grain size and palynomorph preservation has not become the study of previous research. Therefore, this research is aimed to see how strong the effect of sedimentary rocks texture in form of grain size on the preservation of palynomorphs in the rock. This study took the Walat Formation and Batuasih Formation as a case study.

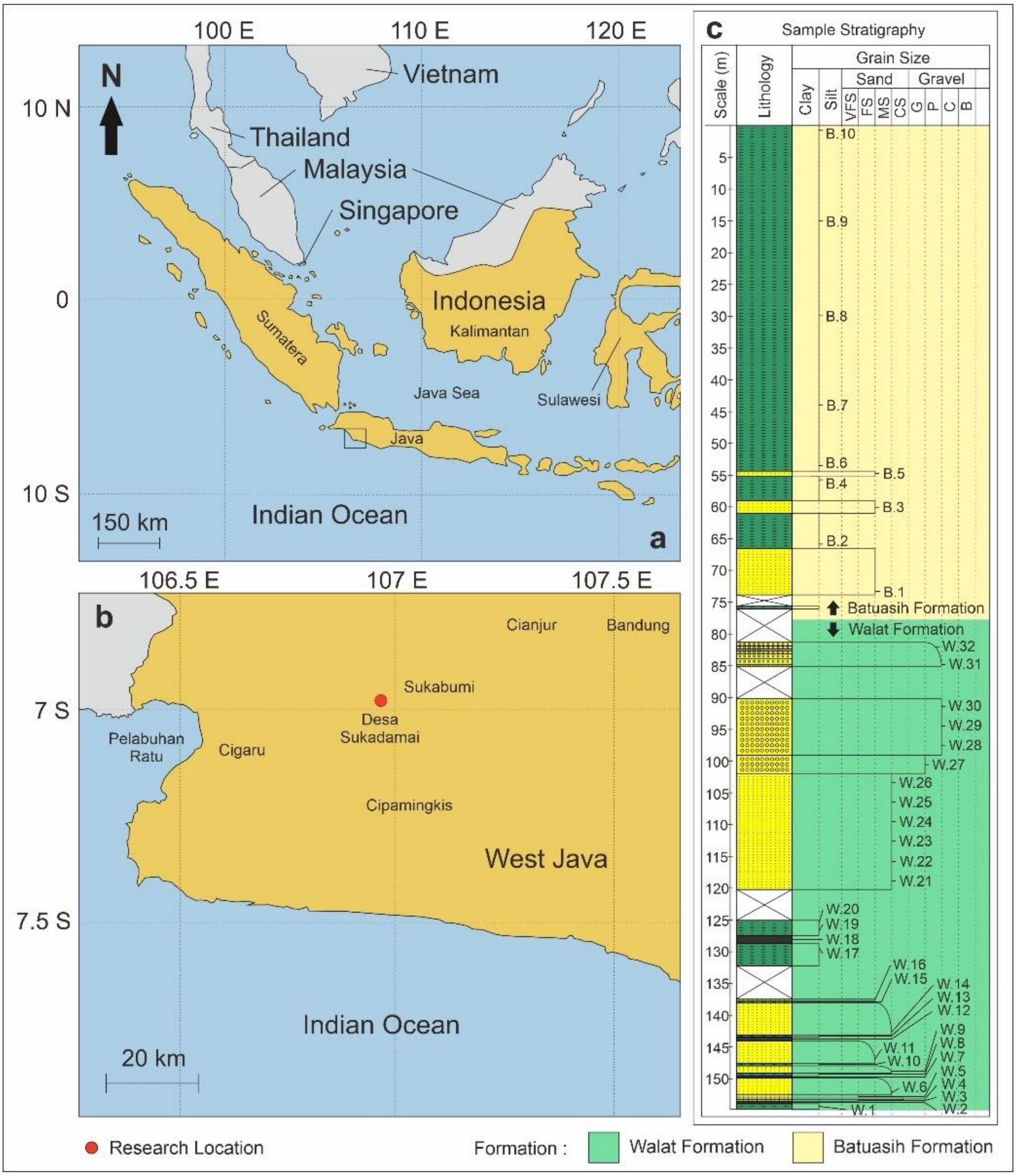

Figure 1. Location and Stratigraphy of the Study Area; a. Research Locations Relation to Indonesia; b. Research Location Relation to West Java; c. Stratigraphy of Study Area and Rock Sampling Points (Modification from Rachman et al., 2021).

The Walat and Batuasih Formations are rock formations exposed in Sukabumi area, West Java (Effendi et al., 1998; Martodjodjo, 2003). Rocks in the Walat and Batuasih Formations are very diverse, ranging from mudstone, sandstone, conglomerate, to coal as insert in several parts (Praptisih et al., 2009; Irawan, 2019). At least, Walat and Batuasih Formations have layer thickness up to 1400 m with Late Eocene - Late Oligocene age and terrestrial depositional environments to be precise in the fluvial to transition sections. (Schiller, 1991; Clements, 2007; Hendrizan et al., 2012; Wibowo & Kapid, 2014; Kurniawan et al., 2016). Seeing that these rock characteristics of Walat and Batuasih Formations are quite diverse. It is interesting to see how the relationship between different sedimentary rock types based on grain size and the preservation of palynomorph content in these formations (Martodjodjo, 2003).

Method

This research is divided into four basic steps, from field activities to laboratory analysis. The research sample was taken from the Walat and Batuasih Formation outcrops in Pasir Pogor mining area and Cibatu River in Sukadamai Village, Cicantayan, Sukabumi, West Java (Figure 1).

Sampling

Fieldwork was carried out to collect research samples along with general characteristics of the Walat and Batuasih Formations. Rock samples were taken using measured stratigraphic section method and taken for each lithology to obtain the diversity of rock lithology (Bellian et al., 2005; Yasin et al., 2017). There were 42 rock samples of various types from the Walat and Batuasih Formations. The sample was then prepared for rock and palynomorph preparation in the laboratory.

Palynomorph and Grain Size Preparation

Palynomorph preparation is carried out using basic method, which is the acid treatment method by reacting rock samples with various chemicals (HF, HCl, KOH, HNO3, and Alcohol) then filtered with a size of 5-200 microns (Dutta et al., 2013; Traverse, 2007). Residual results for each sample then identified its palynomorph content. The rock grain size preparation was carried out by homogeneous crushing method so that the sedimentary rock could decompose in each sediment grain. This is done to identify the grain size in the next step (Israwaty, 2013).

Palynomorph and Grain Size Identification

Palynomorph identification was carried out using binocular microscope CX-22 with 1000x magnification. The names and abundance of palynomorph fossils were identified in each rock formation sample (Winantris et al., 2012). The abundance of palynomorphs was obtained by dividing between the number of identified palynomorphs (P) and the number of residues in the palynomorph preparations (ml). Grain size identification was analyzed by Beckman Coulter LS 13320 Dry Powder System and Universal Liquid Module method to identify how the grain size distribution of rock samples from very fine (0.1 µ) to very coarse (1000 µ) grain size (Blott & Pye, 2006; Suckow, 2013; Schulte et al., 2018). The grain size was further classified according to the sedimentary rock grain size classification (Wentworth, 1922).

Palynomorph and Grain Size Statistical Analysis

Statistical analysis was carried out to see the relationship between palynomorph preservation in rock and grain size of sedimentary rocks from the Walat and Batuasih Formations. Statistical tests were carried out including several tests with their respective statistical test formulas and flows (Figure 2). Statistical analysis was performed using several tests: Normality Test using Shapiro Wilk and Liliefors; Homogeneity Test using Levene Test; Parametric Associative Test using Product Moment Correlation; and Non-Parametric Associative Test using Spearman Rank. Normality Test and Homogeneity Test were carried out to determine the Associative Test used in this research. From the results of this statistical test, research conclusions can be drawn to see the relationship between these two variables (Sugiyono, 2019).

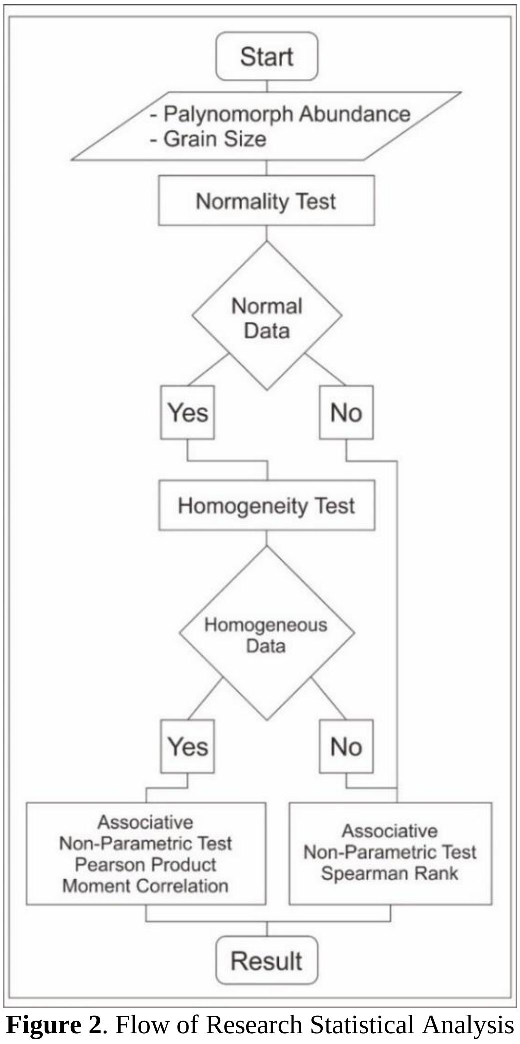

Figure 2. Flow of Research Statistical Analysis (Sugiyono, 2019).

Result and Discussion

Result

Results from measured stratigraphic sections show that in the Walat Formation, lithology is found in form of alternating among sandstones, mudstones and coal with several conglomerates found at the top section. While the Batuasih Formation lithology is dominated by mudstone and few sandstones. The Batuasih Formation is stratigraphically located above the Walat Formation (Figure 1c & 3).

Palynomorphs from study area were quite diverse, as found pollen from the Proxapertites group, Spores from Verrucatosporites, and in some samples other palynomorphs from dinocyst and foraminifera lining test were found (Figure 3). Palynomorph content in the study samples varied widely, many of study samples did not show the presence of palynomorphs. However, several samples contain very abundant palynomorphs. From this diversity results, the abundance of palynomorphs was calculated in each study sample. The abundance of palynomorphs in this study ranged from 0 P/ml in some samples to 70 P/ml in sample W.2 (Table 1).

Results from individual palynomorphs and grain size were subjected to statistical tests to see if there was relationship between these two aspects. First statistical test carried out with Normality Test using Shapiro Wilk and Liliefors. Result, all variables analysed, both abundance, clay, silt, and sand, has data types that were not normally distributed. This can be seen from the significance value of 0 (<0.05), it means that the analysed data has an abnormal distribution (Table 2). This causes associative statistical analysis to be carried out with the non-parametric associative analysis.

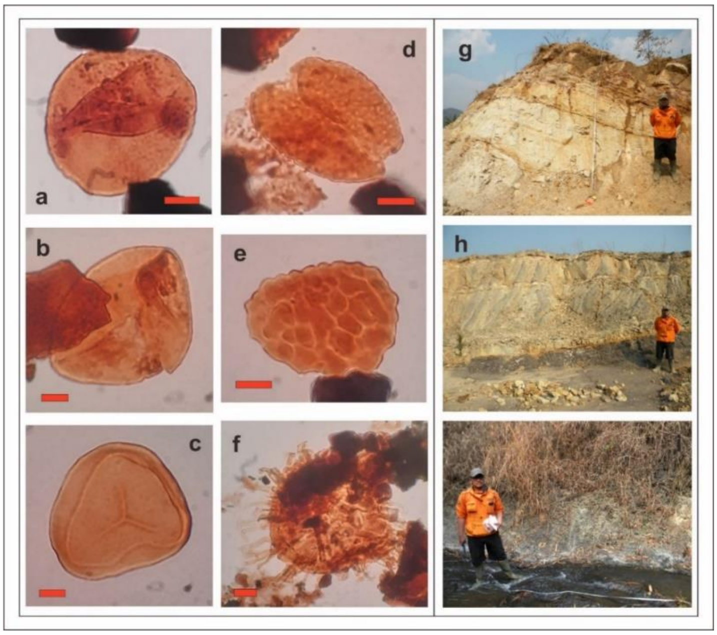

Figure 3. Left; Palynomorph of Research Sample; a. *Proxapertites operculatus*; b. *Eucalyptus type*; c. *Lycopodium cernuum type*; d. *Dicolpopollis sp*; e. *Verrucatosporites usmensis*; f. Dynocyst, Right; Rock Outcrop of Research Area; g. Conglomerate from Walat Formation; h. Alternating among sandstones, mudstones and coal from Walat Formation; i. Mudstone from Batuasih Formation.

Table 1. Grain size and abundance of palynomorphs.

Sample Code	Number of Palynomorphs	Residue Amount	Abundance (P/ml)	Clay (%)	Silt (%)	Sand (%)
W.1	31	15	2.07	100	0.00	0.00
W.2	210	3	70.00	100	0.00	0.00
W.3	50	9	5.56	100	0.00	0.00
W.4	1	9	0.11	4.68	18.23	77.09
W.5	8	9	0.89	100	0.00	0.00
W.6	0	9	0.00	3.06	10.37	86.57
W.7	205	6	34.17	100	0.00	0.00
W.8	3	9	0.33	53.01	46.99	0.00
W.9	0	9	0.00	2.73	11.24	86.03
W.10	0	9	0.00	100	0.00	0.00
W.11	0	9	0.00	3.60	15.84	80.56
W.12	55	9	6.11	100	0.00	0.00
W.13	0	9	0.00	49.77	50.23	0.00
W.14	0	9	0.00	2.61	10.15	87.24
W.15	0	9	0.00	100	0.00	0.00
W.16	0	9	0.00	3.67	12.96	83.37
W.17	0	9	0.00	100	0.00	0.00
W.18	203	6	33.83	6.45	26.96	66.59
W.19	222	6	37.00	47.63	52.37	0.00
W.20	41	15	2.73	100	0.00	0.00
W.21	20	9	2.22	100	0.00	0.00
W.22	0	9	0.00	4.99	11.75	83.26
W.23	0	9	0.00	4.56	15.65	79.79
W.24	0	9	0.00	0.93	7.82	91.25
W.25	0	9	0.00	3.84	8.26	87.90
W.26	0	9	0.00	3.8	10.78	85.44
W.27	0	9	0.00	3.53	9.72	86.75
W.28	0	9	0.00	4.07	24.47	71.45
W.29	0	9	0.00	2.59	8.04	89.37
W.30	0	9	0.00	2.86	9.42	87.72
W.31	0	9	0.00	5.55	13.64	80.81
W.32	0	9	0.00	1.95	10.97	87.08

B.1	1	9	0.11	100	0.00	0.00
B.2	3	9	0.33	4.59	21.08	74.33
B.3	0	9	0.00	100	0.00	0.00
B.4	30	9	3.33	100	0.00	0.00
B.5	0	9	0.00	7.63	29.91	62.46
B.6	43	9	4.78	100	0.00	0.00
B.7	50	9	5.56	27.23	72.77	0.00
B.8	10	9	1.11	100	0.00	0.00
B.9	34	9	3.78	100	0.00	0.00
B.10	2	9	0.22	100	0.00	0.00

Table 2. Normality test results with Shapiro Wilk and Liliefors.

Variable	Significance	Conclusion
Abundance (A)	0	Distribution data is Not Normal
Clay (C)	0	Distribution data is Not Normal
Silt (Si)	0	Distribution data is Not Normal
Sand (Sa)	0	Distribution data is Not Normal

Next, statistical analysis was the homogeneity test using the Levene Test. Results were mixed, non-homogeneous data were obtained in comparison of Abundance and Clay; Abundance and Sand; Clay and Silt; Silt and Sand. Meanwhile, homogeneous data were obtained in the comparison of Abundance and Silt; Clay and Sand. This can be seen from the significance value of 0.15 and 0.19 (>0.05), which means that the data is homogeneous data (Table 3). Although some data show homogeneous data, the normality test conducted previously showed that all data were not normally distributed. This causes associative statistical analysis to be carried out with the non-parametric associative analysis and is not affected by the homogeneity of data.

Table 3. Homogeneity test results with the Levene Test

Variable	Significance	Conclusion
Abundance and Clay	0	Non-Homogeneous data
Abundance and Silt	0.15	Homogeneous data
Abundance and Sand	0	Non-Homogeneous data
Clay and Silt	0	Non-Homogeneous data
Clay and Sand	0.19	Homogeneous data
Silt and Sand	0	Non-Homogeneous data

Last, statistical analysis is the Associative Test using Spearman Rank. Result, palynomorph preservation (abundance) has a significant relationship or correlation with clay and sand. This can be seen from the significance value of 0 (<0.05), which means the two variables have relationship with certain level of correlation (Table 4). Abundance and clay obtained positive correlation of 0.613 which is classified as strong correlation based on Sugiyono (2019). This means that palynomorph preservation in rock will be more effective when there is more clay grain size content in the rock. Abundance and sand obtained negative correlation of -0.653 which is classified as a strong correlation based on Sugiyono (2019). This means that palynomorph preservation in rock will be less effective when there is more sand grain size content in the rock. Whereas Abundance and Silt did not have significant correlation. This means that the amount of silt grain size in the rock does not affect abundance of palynomorph preservation in the rock.

Table 4. Associative test results with Spearman Rank

Variable	Significance	R	Conclusion
Abundance and Clay	0	0.613	Correlated
Abundance and Silt	0.097	0.26	Uncorrelated
Abundance and Sand	0	-0.653	Correlated

Discussion

Results from associative test show the effect of grain size on preservation of palynomorphs in the rock (Table 4). Palynomorphs are more dominant in fine-grained sedimentary rocks, both in clay and coal. However, some rock samples with sand grain size can still contain palynomorph. Palynomorphs that are present in mudstone and coal come from all species with various distributions that have size range of 10 – 99 µ. Whereas in the sandstones, palynomorphs that are present only come from certain species which have size range of 10 – 89 µ.

In the Table 5, the lithology of coal, mudstone and sandstones contains palynomorphs that range from small to large species sizes. But in sandstones, palynomorphs come from species *Crassoretitriletes vanraadshoveni, Dipterocarpus intricatus, Laevigatosporites, Lycopodiumsporites semimuris, Malvacipollis diversus, Palmaepollenites kutchensis, Proxapertites cursus*, and *Proxapertites operculatus*. These palynomorphs have large species size which is higher when compared to other species. Thus, in sandstones, palynomorphs can be preserved in small amounts. But, this palynomorph must have sufficiently large species size. Batten (1974) suggests that small and medium sized palynomorphs increase in silt-clay grain size and decrease closer to the sand grain size. Meanwhile, large palynomorphs increased closer to the silt-sand grain size and then decreased to grain size, which is larger than sand. The result is consistent with this study, large palynomorphs tend to be preserved in sandstone lithology in several species.

Table 5. Palynomorph relations and grain size.

Fossil Name	Quantity	Size (µ)	Lithology
Acritarchs	4	20 – 49	L, MS
Acrostichum type	84	20 – 69	L, MS
Apocynaceae type	1	30 – 49	L
Cicatricosisporites dorogensis	2	40 – 89	L, MS
Chepalomappa malloticarpa	7	30 – 59	MS
Clavifera triplex	1	20 – 29	MS
Crassoretitriletes vanraadshoveni	2	40 – 69	MS, SS
Dicolpopollis sp	16	10 – 89	L, MS
Dipterocarpus intricatus	3	40 – 69	SS
Distaeverrusporites simplex	1	30 – 39	MS
Eucalyptus type	1	40 – 49	L
Foraminifera Test Lining	2	30 – 69	MS
Indeterminate	4	10 – 39	MS
Laevigatosporites	29	30 – 69	L, MS, SS
Ligaria cuneifolia	1	10 – 29	L
Lycopodium cernuum type	2	20 – 39	L, MS
Lycopodiumsporites semimuris	47	20 – 69	L, MS, SS
Malvacipollis diversus	12	20 – 89	L, SS
Palmaepollenites kutchensis	8	10 – 89	L, MS, SS
Podocarpidites marwickii	2	30 – 99	MS
Podocarpidites otagoensis	1	30 – 49	L
Polyadopollenites microreticulatus	1	30 – 39	L
Proxapertites cursus	116	20 – 89	L, MS, SS
Proxapertites operculatus	780	20 – 89	L, MS, SS
Proxapertites psilatus	61	20 – 89	L, MS
Spiniferites pseudofurcatus	1	70 – 89	MS
Spiniferites ramosus	1	20 – 39	MS
Trichotomosulcites subgranulatus	1	20 – 39	MS
Tricolpites confessus	2	30 – 49	MS
Tricolpites reticulatus	4	30 – 59	L, MS
Verrucatosporites usmensis	24	20 – 69	L, MS

Figure 4, shows that the whole rock sample (coal, mudstone, and sandstone) dominated by individual palynomorphs of 30 - 59 µ size. Palynomorphs with 10 - 59 µ size have higher content in coal and claystone than sandstones. However, larger individuals (60 - 89 µ) palynomorphs are higher preserved in sandstones than in coal and mudstones. From Figure 4, it can also be seen that lithology of coal and claystone has plot points that are always higher than sandstones for small individual sizes (10 - 59 µ). Whereas at the transition size 59 - 60 µ, the crossover occurs so that sandstone lithology has a higher plot point than coal and claystone for large individual sizes (60 - 89 µ). From this description, palynomorph fossils can be preserved in sandstones but with lower abundance compared to coal and claystone. As for sandstones, larger individual palynomorph sizes are easier to preserve than for coal and claystones. So that large palynomorphs such as *Proxapertites* group can be well preserved in sand grain size (Hesse & Zetter, 2007). Due to its abundance and large species size, *Proxapertites* became the most dominant palynomorph from this study.

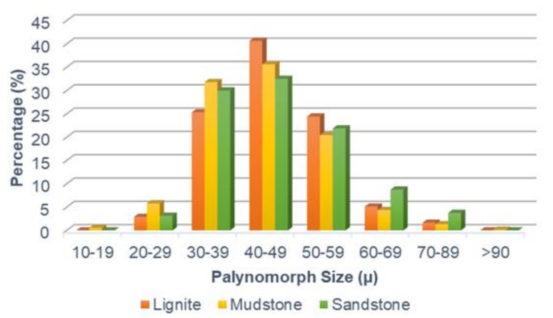

Figure 4. Bar diagram showing percentage of each palynomorph size from rock sample

Results showed that palynomorphs were more abundant in rocks with fine grain size (clay) and less in rocks with coarse grain size (sand). It happens because the sand grain size tends to have pores that have potential to flow air into the rock. So that the rocks are not in anoxic conditions (no oxygen) which is one of conditions for fossils to be formed. When air enters the rock, palynomorphs are immediately destroyed. Whereas in clay grain size, air tends not to enter the pores of rock and can better preserve fossils. Consistent with the literature, this research found that the preservation of fossils in rocks is greatly influenced by the texture of the rock itself so that fossils can avoid destructive factors such as oxygen.

Several studies of palynomorphs suggest that the condition of rock grain size affects the level of palynomorph preservation in these rocks. Delcourt & Delcourt (1980) states that palynomorphs tend not to be preserved at coarse grain size for two reasons. First, it is caused by oxidation of palynomorphs due to rock pores that are large enough for oxygen to enter, second is the possibility that palynomorphs in the coarse grain size area have high enough energy level so that the palynomorphs are not deposited in that area and are carried away to areas with lower energy. This is what causes the rock grain size in this study to affect palynomorphs. Rock samples that have coarse grain size tend to be very little and do not even show palynomorph in them. Li et al. (2005) states that depth, age, and depositional environment affect preservation of palynomorphs in the rock. In this research, age and environment are interpreted in same condition because these samples are taken in the same formation and are similar both in terms of age and depositional environment. So that the effect of grain size on palynomorph preservation here is not influenced by changes in age and depositional environment.

Results of this study are also in line with Schoeninger et al. (1989) dan Evans et al. (2020) who found that fossils in rocks are greatly affected by the rock grain size. Fossils are more effective for preservation in rocks with finer grain sizes. It happens because the grain size of rock can protect the fossil from environmental influences that can destroy the fossil. While Batten (1974) states that palynomorphs are very sensitive to changes in rock grain size, many palynomorphs are preserved in rocks with fine grain sizes, so that fossils can be preserved in anoxic conditions.

Several studies have found that the preservation of palynomorphs is also influenced by the composition and characteristics of palynomorphs themselves. Campbell (1999) found that the preservation of palynomorphs in rocks is influenced by the exine composition of each palynomorph. Basically, the exine of each palynomorph has different thickness and sporopollenin content. In this study, the effect of sporopollenin was not significant because the same palynomorphs were present and randomly distributed in the rock samples. There is no grouping as particular genus is present only in fine grain size and another genus is present at coarse grain size indicating that sporopollenin composition does not affect palynomorph preservation in this study. Therefore, palynomorph preservation in this study is strongly influenced by grain size distribution compared to other influences. However, the effects described in previous studies still influence the preservation of palynomorphs with their respective aspects.

From the description above, rock grain size is one of the significant influences in palynomorph preservation of rock from certain formation. Palynomorphs are more effectively preserved in finer grain sizes than coarse grain sizes. As for coarse grain size, palynomorphs with large sizes tend to be better preserved than those with fine grain sizes. Therefore, in palynomorph analysis, the research sample used as best as possible has fine grain size so that interpretation can be carried out properly because of enough palynomorphs.

Conclusion

The Walat and Batuasih Formations have various lithologies in form of conglomerates, sandstones, mudstone, and coal. Palynomorph of research sample was quite diverse with the discovery of pollen in form of *Proxapertites* groups, Spores from *Verrucatosporites*, as well as dinocysts and foraminifera lining tests. The abundance of palynomorphs in this study ranged from 0 P / ml in some samples to 70 P / ml in sample W.2.

The statistical results show that all variables have data that are not normally distributed with a tendency not to be homogeneous. In addition, it was found that the rock grain size had significant effect on palynomorph preservation. The clay grain size has positive correlation of 0.613 and the sand grain size has negative correlation of -0.653. This indicates that the finer the grain size, the more effective palynomorph preservation will be. In addition, lithology with coarse grain size (sandstone) contains palynomorphs with large individual sizes higher than fine grain sizes (coal and claystone).

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Author Contribution

The author is a researcher who carries out activities from sampling to completing paper writing with guidance from the author's lecturer.

Conflict of Interest

No potential conflict of interest was reported by the authors. This research was carried out entirely by the author under the guidance of author’s lecturer. The research fee was provided by author’s lecturer through research fees from the university.

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