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A Pollen Record Of Alluvium Unit And Vegetation Landscape From Bangka Island, Indonesia

Kumpulan Polen dan Bentang Vegetasi dari Satuan Aluvium dari Pulau Bangka, Indonesia

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Abstract-This study presents a pollen record of the purported Holocene Alluvium in Bangka Island, Indonesia. This alluvial unit's age and stratigraphic position have been disputed, and this pollen study is expected to provide crucial evidence on the matter. The pollen content is also likely to reveal the vegetation landscape and environment of the samples, further enhancing our understanding of the area. Three samples were taken from outcrops at three different points of the alluvial deposit, and the samples were rich in pollen and spores. We identified 54 pollen and 12 spore taxa. The pollen assemblages suggest that the samples were deposited in an open forest environment of the evolving disturbed heath forest ecosystem. Several cultivated plant pollens indicate that the samples were deposited in modern times.

Keywords: Holocene, alluvium, stratigraphy, pollen, Bangka, vegetation landscape

Abstrak*-Penelitian ini menyajikan rekaman polen yang tersimpan dalam endapan aluvium yang diduga berumur Holosen di Pulau Bangka, Indonesia. Terdapat perbedaan pendapat tentang posisi stratigrafi dan umur dari satuan aluvium ini. Penelitian polen ini diharapkan dapat memberikan bukti yang dapat menjawab persoalan tersebut. Kandungan polen diharapkan juga dapat mengungkap rekaman bentang vegetasi dan lingkungan pengendapan satuan tersebut. Tiga sampel dikumpulkan dari singkapan di tiga lokasi berbeda. Sampel-sampel ini mengandung polen dan spora dalam jumlah yang cukup melimpah. Terdapat 54 jenis polen dan 12 jenis spora yang teridentifikasi di semua sampel. Kumpulan polen dalam sampel-sampel tersebut menunjukkan sebuah lingkungan pengendapan hutan terbuka dari sebuah ekosistem hutan kerangas yang terganggu. Hadirnya beberapa polen tanaman budidaya menunjukkan bahwa sampel-sampel tersebut diendapkan pada masa modern.*

KataKunci: *Holosen, aluvium, stratigrafi, polen, Bangka, bentang vegetasi*

INTRODUCTION

Bangka Island is geologically composed of the Permo-Carboniferous Pemali Group, the Triassic Tempilang Group, the Paleocene Fan Formation, the Upper Miocene-Middle Pleistocene Ranggam Group, and capped by the Holocene Alluvium (Ko, 1986). Granitization and uplift occurred in two phases during the Upper Triassic-Lower Cretaceous (Ko, 1986; Ng et al., 2017), prior to the deposition of the Fan Formation in the Paleocene-Eocene, the Ranggam Group in the Miocene-Pleistocene, and the Alluvium in the Holocene.

The presence of the Holocene Alluvium unit was reported by Mangga & Djamal (1994) and Margono et al. (1995), but it is absent from the geological map of Ng et al. (2017). The age of the unit was inferred from its lithological characteristics and stratigraphic position (Mangga & Djamal, 1994; Margono et al., 1995). The presence of this unit provides an opportunity to reveal the history and dynamics of the heath forest. Heath forest is a natural forest in Bangka Island. Hilwan (1996, 2015) reported that the significant vegetation of undisturbed heath forest in Bangka-Belitung is composed of *Freycinetia sandens* Gaudich. (Pandanaceae), *Ploiraium alternifolium* Melchior (Bonnetiaceae), *Melaleuca leucadendron* (Myrtaceae), and *Syzygiium lepidocarpa* Kurz. (Myrtaceae). However, heath forest is a sensitive ecosystem vulnerable to both natural and anthropogenic disturbances. This ecosystem has hypothetically responded to Holocene environmental and climatic changes, as well as anthropogenic activities.

Despite many previous geological reports on Bangka Island, there is no report of a pollen study. This study attempts to determine whether the alluvium unit described in the geological map has preserved pollen and spore grains. It aims to reveal the unit's pollen content and verify its age and vegetation landscape based on pollen and spore evidence.

MATERIAL AND METHODS

Three organic clay samples were taken from the outcrop at three sites (Figure 1). The study employed Erdtman's standard technique of pollen preparation (Erdtman, 1943; Erdtman, 1960), which involves fluoride acid, chloride acid, potassium hydroxide, acetolysis method, and zinc chloride. Pollen and spore were mounted in glycerol jelly and identified under an optical microscope at 400- 1000x magnitude. Identification and counting of pollen and spore content on a glass slide was conducted for each sample. Pollen and spore identification follows Nakamura (1980), as well as Nasu and Seto (1986). It refers to the pollen and spore specimen collection at the Laboratory of Palynology, Center for Geological Survey, Geological Agency, Ministry of Energy and Mineral Resources of the Republic of Indonesia. Pollen and spore identification was carried out up to the level of genera or family unless the references allow identification up to the species level.

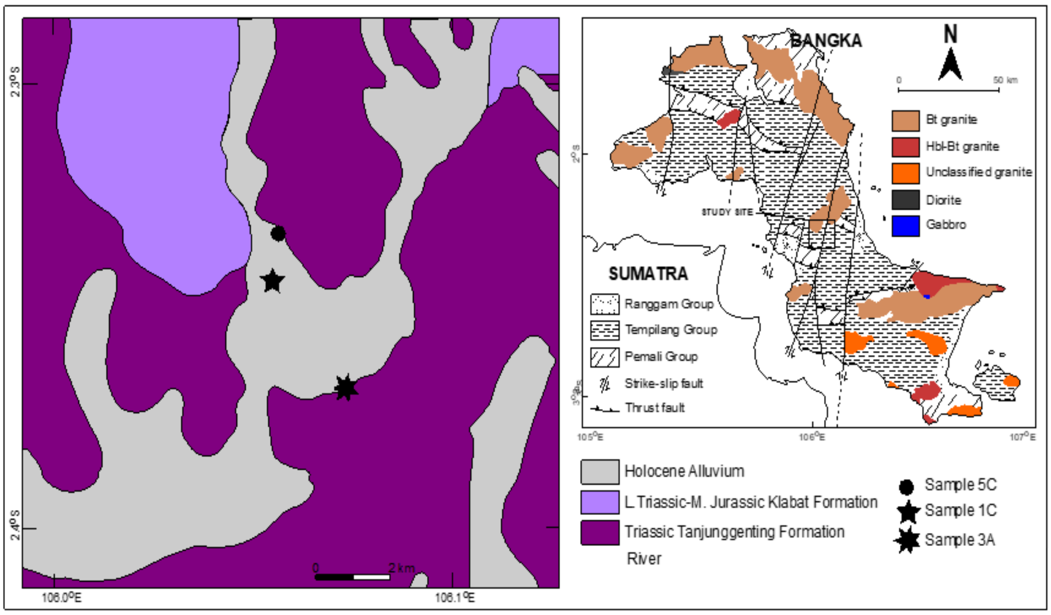

Figure 1. Map showing the geology of Bangka Island, the study site, and sampling points. The simplified geological map of Bangka (right), after Ng et al. (2017), indicates the study site (square). Three samples for this study were taken from the purported Holocene Alluvium in the modified geological map (left), after Mangga & Djamal (1994) and Margono et al. (1995).

Pollen and spore frequencies in each sample were calculated based on the total pollen sum. The composition of pollen and spore was calculated and presented in the Pollen-Spore Composition Diagram and Vegetation Types Diagram. Pollen taxa were grouped into lowland/peatland, montane, and grassland.

RESULT

Age

The relative age of the samples was inferred from the stratigraphic position of the outcrops from which the samples for this study were collected. According to the geological map of Ng *et al.* (2017), the study site consists merely of the Pre-Tertiary Biotite Granite and the Pre-Tertiary Tempilang Group with no alluvium (Figure 2). It is unlikely that the outcrops belong to the Pre-Tertiary Tempilang Group because all samples consisted of soft black organic clay, indicating relatively young sediment. However, the geological map of Mangga and Djamal (1994) indicates the presence of the Holocene Alluvium at the geographic position of the sampling points. The presence of young alluvium on top of the stratigraphic profile in Bangka Island was also reported by Ko (1986). Hence, based on the geological map and its stratigraphic position, the age of the samples is presumably Holocene. These findings significantly impact our understanding of the Holocene Alluvium unit and its stratigraphic position.

Pollen and Spore Assemblages

The samples taken in this study show abundant pollen and spores, each carrying significant implications. A single glass slide of 1C, 3A, and 5C samples bears consecutively pollen and spores of 454, 306, and 617 grains. In total, 54 pollen and 12 Pteridophyte spore taxa were identified. Pollen was grouped into four vegetation groups, i.e., Mangrove, Lowland/ Peatland, Montane, and Grassland. Several taxa of vegetation groups are presented in Table 1. Pollen and spore taxa with 1% or higher frequency are presented in the pollen diagram (Figure 3). The number of taxa in each vegetation group is presented in Table 1. The frequency of vegetation groups in the pollen diagram is presented in Table 2. Photos of identified pollen and spore taxa are presented in Figure 4, each carrying significant implications for our understanding of the alluvium unit and the vegetation landscape.

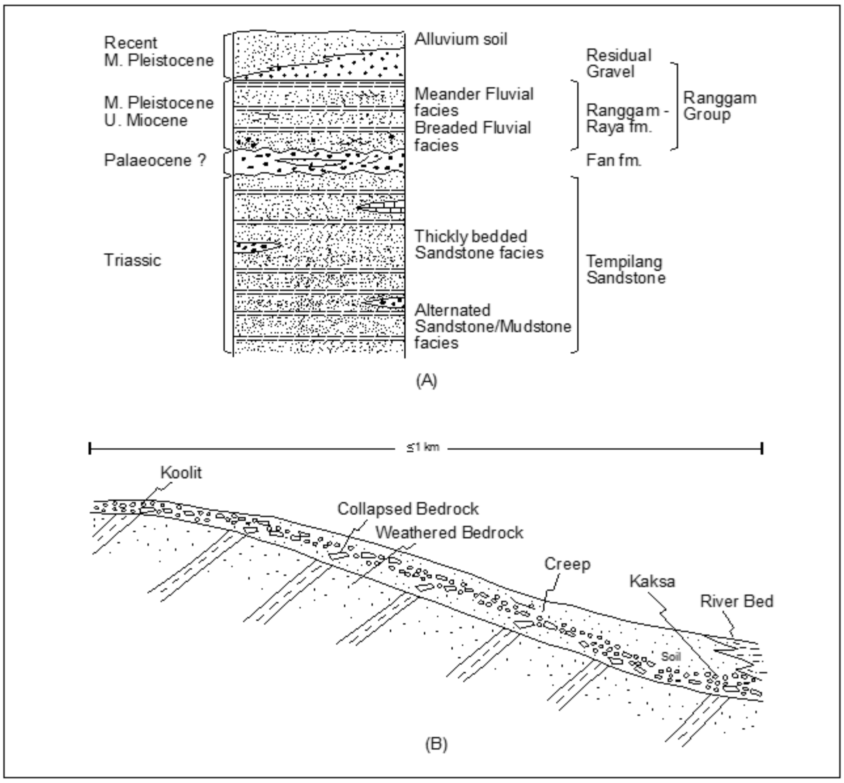

Figure 2. (A) The partial stratigraphic profile of Bangka Island was modified from Ko (1986), showing the position of the alluvium on top of the stratigraphic profile from which the samples for this study were collected. (B) A sketch of an idealized section of residual gravel (Kaksa/Koolit), after Ko (1986), indicating the interfingering stratigraphic position between the Mid-Upper Pleistocene Residual Gravel and the Riverbed deposit.

Table 1. Diversity of taxa in Vegetation Groups.

Vegetation Group		Number of Taxa		
		1C	3A	5C
Pollen	Pollen	20	41	52
	Trees	11	23	28
	Shrubs	4	5	9
	Herbs	5	13	15
	Mangrove associate	1	2	2
	Mangrove associate with prominent frequency (f>5%)	0	0	0
	Mangrove associate with moderate frequency (5%>f>2%)	1	2	0
	Mangrove associate with poor frequency (f<2%)	0	0	2
	Lowland/peatland	15	32	40
	Lowland/peatland with prominent frequency (f>5%)	0	0	3
	Lowland/peatland with moderate frequency (5%>f>2%)	0	4	3
	Lowland/Peatland with poor frequency	15	28	34
	Montane	2	2	2
	Montane with prominent frequency (f>5%)	0	0	0
	Montane with moderate frequency (5%>f>2%)	0	0	0
	Montane with poor frequency (f<2%)	2	2	2
	Grassland	3	5	7
	Grassland with prominent frequency (f>5%)	3	3	3
	Grassland with moderate frequency (5%>f>2%)	0	1	0
	Grassland with poor frequency (f<2%)	0	1	4
Spore	Spore	11	12	12
	Spore with prominent frequency (f>5%)	1	4	4
	Spore with moderate frequency (5%>f>2%)	3	3	3
	Spore with poor frequency (f<2%)	7	5	5

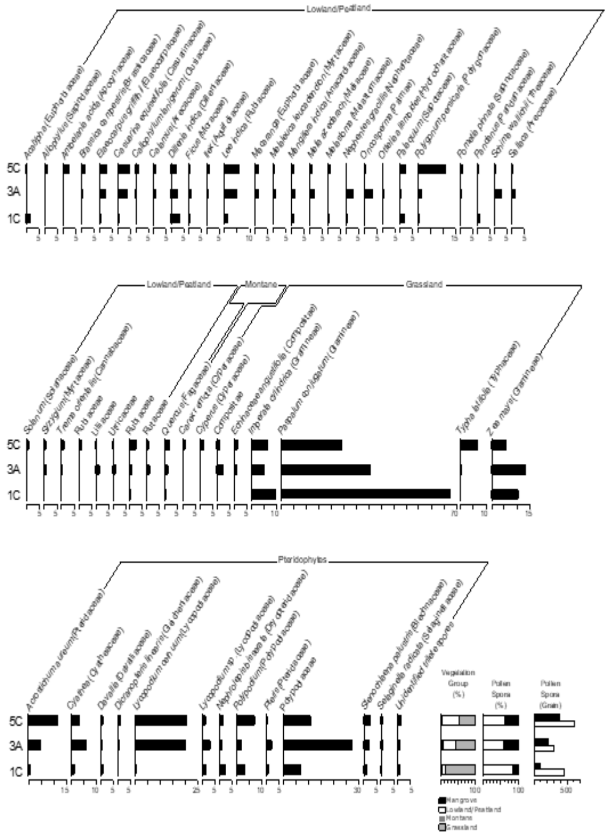

Figure 3. Pollen diagram of three samples (5C, 3A, 1C) of this study. Several pollen taxa excluded from the diagram due to very low representation (f<1%) are *Arenga pinnata, Celtis, Clerodendron paniculatum, Croton, Durio, Polygala, Palmae,* and *Podocarpus.*

Table 2. The frequency of Vegetation Groups presented in the pollen diagram is calculated based on the pollen sum and rounded to the nearest digit. The frequency of pollen and spore is calculated using the pollen-spore composition.

Vegetation Group	Frequency (%)		
	1C	3A	5C
Pollen	84	59	62
Spore	16	41	38
Mangrove associate	3	6	2
Lowland/peatland	9	36	56
Montane	0.2	0.3	0.2
Grassland	88	58	48

Figure 4. Identified pollen taxa in this study: (*1) Paspalum conjugatum; (2) Zea mays; (3) Palaquium; (4) Melaleuca leucadendron; (5) Acalypha; (6) Solanum; (7) Macaranga; (8) Ficus; (9) Elaeocarpus griffithii; (10) Polygala; (11) Mangifera indica; (12) Trema orientalis; (13) Carex remota; (14) Arenga pinnata; (15) Allophylus; (16) Callophylum lanigerum; (17) Croton; (18) Pandanus; (19) Rutaceae; (20) Ilex; (21) Rubiaceae; (22) Palmae; (23) Nephentes gracillis; (24) Oncosperma; (25) Dillenia indica; (26) Melia azedarach; (27) Acalypha; (28) Quercus; (29) Typha latifolia; (30) Podocarpus; (31) Casuarina equisetifolia; (32) Echinacea angustifolia; (33) Callophylum; (34) Brassica campestris; (35) Melastoma; (36) Lee indica; (37) Polygonum persicaria; (38) Ottelia alismoides; (39) Clerodendron paniculatum; (40) Ambelania acida; (41) Cyperus; (42) Palaquium; (43) Durio; (44) Calamus; (45) Celtis; (46) Schima wallichii; (47) Euphorbiaceae; (48) Imperata cylindrica; (49) Selaginella radicata; (50) Acrostichum aureum; (51) Stenochlaena palustris; (52) Davallia; (53) Nephrolepis bisserata; (54) Cyathea; (55) Polypodiaceae; (56) Lycopodiaceae; (57) Lycopodium cernuum.*

Spore proportions are lower than pollen in all samples, and herb frequencies overshadow tree and shrub frequencies. The frequency of pollen from Grassland is prominent in samples 1C, 3A, and 5C, but it decreases respectively. Meanwhile, the frequency of Lowland/Peatland pollen in these samples is also prominent but increases respectively. The Mangrove Associate is prominently present in sample 3A and moderately present in samples 1C and 5C. The frequency of spores is highest in sample 3A and lowest in sample 1C. Montane vegetation is poorly represented (f<2%) in all samples.

In the pollen assemblage of all samples, angiosperms are represented by 53 taxa, composed of two Mangrove Associate taxa (*Oncosperma*, *Dillenia indica*), 40 Lowland/Peatland taxa, three Montane/Sub-montane taxa (*Podocarpus*, *Pinus*, *Quercus*), and eight Grassland taxa. Two gymnosperms are identified in the pollen assemblage with very low representation, i.e., *Podocarpus* and *Pinus*. *Pinus* is primarily found in temperate and subtropical regions of the Northern Hemisphere (Farjon, 1990; Farjon, 2005), while *Podocarpus* is typical gymnosperms of the Southern Hemisphere (Hill & Brodribb, 1999).

Gramineae, i.e., *Imperata cylindrica*, *Paspalum conjugatum*, *Typha latifolia*, and *Zea mays*, are significant components with frequencies over 5% (f>5%) in all samples. Only six pollen taxa and five spore taxa are present in significant frequencies (f>5% in at least one sample), i.e., *Lee indica*, *Polygonum persicaria*, *Typha latifolia*, *Imperata cylindrica*, *Paspalum vaginatum*, *Zea mays*, *Acrostichum aureum*, *Cyathea*, *Lycopodium cernuum*, *Polypodium,* and Polypodiaceae. *Ambelania acida*, *Elaeocarpus griffithii*, *Casuarina equisetifolia*, *Dillenia indica*, *Melia azedarach*, *Nephentes gracillis*, *Oncosperma*, *Palaquium*, *Quercus*, *Schima wallichii*, Rubiaceae, Compositae, *Lycopodium* sp., *Nephrolepis bisserata*, *Pteris,* and *Stenochlaena palustris*, are present in moderate components (2%<f<5%). Other taxa shown in the pollen diagram are minor components (1%<f<2%).

INTERPRETATION AND DISCUSSION

Vegetation Landscape

Despite the presence of 66 pollen and spore taxa in the pollen assemblage, the vegetation landscape is primarily indicated merely by the total frequency of Grassland vegetation, mainly three pollen taxa of Gramineae, i.e., *Imperata cylindrica*, *Paspalum conjugatum*, and *Zea mays,* which are prominently present in all samples. *Imperata cylindrica* suggests that the samples were probably deposited in abandoned tin-mine soils. A study of the vegetation composition of an abandoned tin-mine in South Bangka shows that *Imperata cylindrica* was absent in the secondary heath forest. However, it was present in the abandoned tin-mine (Sari et al., 2017).

Assuming *Zea mays* pollen was derived from cultivated plants, the pollen would not represent a natural vegetation landscape. The representation of an open vegetation landscape may be more reliably interpreted based on the frequencies of *Imperata cylindrica* and *Paspalum conjugatum*. *Imperata cylindrica* is a native plant in Bangka (Veldkamp et al., 2019). *Paspalum conjugatum* is of American origin and was introduced into the Malesian region in the nineteenth century (Veldkamp et al., 2019). Excluding *Zea mays*, the frequencies of Grassland in samples 1C, 3A, and 5C are 86%, 52%, and 38%, respectively. The frequencies of *Imperata cylindrica* are 11%, 6%, and 7%, respectively, and the frequencies of *Paspalum conjugatum* are 75%, 42%, and 26%, respectively.

The high representation of Grassland in samples 1C, 3A, and 5C indicates the presence of open forest landscapes. These open vegetation landscapes probably flourished following the disturbance of the original heath forests. However, the difference in their frequencies suggests different stages of vegetation succession. The lowest frequency of Grassland in sample 5C, an intermediate frequency in sample 3A, and highest frequency in sample 1C presumably represent vegetation succession toward more evolved stages.

The difference in stages of vegetation succession in those samples is also indicated by the number and diversity of taxa (see Table 1 and Table 2). The higher and more diverse the taxa, the more evolved the stage of vegetation succession. Tjhiaw & Djohan (2009), Nurtjahya et al. (2009, 2016), and Nurtjahya & Santi (2018) observed a similar relationship pattern between the number and diversity of species with stages of modern vegetation succession in an abandoned tin-mine on Bangka Island. Nurtjahya et al. (2009) reported that species composition (measured by Importance Value Index, IVI) for all stages of plant development differs between all study sites. *Gaertnera vaginata* (Rubiaceae), *Calophyllum pulcherri* (Clusiaceae), *Calophyllum lanigerum*, *Syzygium lineatum* (Myrtaceae), *Garcinia parvifolia* (Clusiaceae), *Pternandra galeata* (Melastomataceae), *Tristaniopsis whiteana* (Myrtaceae), and *Rhodamnia cinerea* (Myrtaceae) are the major components in secondary riparian forest. *Scleria levis* (Cyperaceae), *Trema orientalis* (Ulmaceae), *Dicranop teris linearis* (Gleicheniaceae), *Melastoma malabathricum* (Melastomataceae), *Paspalum conjugatum* (Gramineae), *Pternandra galeata* (Melastomataceae), *Gynotroches axillaris* (Rhizophoraceae), *Adinandra dumosa* (Theaceae), and *Schima wallichii* on abandoned farmland. *Rhodomyrtus tomentosa* (Myrtaceae), *Eriachne pallescens* (Gramineae), *Ischaemum* sp. (Gramineae), *Crotalaria* sp. (Fabaceae), and *Melastoma malabathricum* (Melastomataceae) on 38-year-old tin-mined land. *Blumea balsamifera* (Compositae), *Paspalum conjugatum*, *Imperata cylindrica* (Gramineae), *Fimbristylis pauciflora* (Cyperaceae), *Melastoma malabathricum* (Melastomataceae), and *Commersonia bartramia* (Sterculiaceae) on 11-year-old tin-mined land. *Fimbristylis pauciflora*, *Imperata cylindrica* (Gramineae), *Melastoma malabathricum, Eupatorium inulaefolium* (Compositae), and

Paspalum orbiculare on 7-year-old tin-mined land. Accordingly, pollen assemblages in samples 1C, 3A, and 5C represent the higher stage of vegetation succession.

The presence of several wetland and riparian taxa, such as *Typha latifolia*, *Ottelia*, *Cyperus*, *Carex*, *Melaleuca*, and *Pandanus*, particularly in samples 3A and 5C, suggests the occurrence of wetland environments close to these sampling points. In contrast, the prominent frequency of *Typha latifolia* in sample 5C reveals the presence of ponds or slow-flowing rivers at or close to this sampling point, because their habitat ranges from temporary floodplains, ditches, ponds, lakes, and slow-flowing rivers (Stace, 1977). The prominent pollen of *Typha latifolia* in sample 5C also suggests a more eutrophic environment (Stace, 1977) and more fertile soil. It supports the conclusion that sample 5C was deposited in a more evolved stage of vegetation succession environment compared to samples 1C and 3A.

The minor frequency of Lowland/Peatland components in sample 1C can be triggered by their low presence in the vegetation landscape or their distant pollen sources. However, their increased frequencies in samples 3A and 5C suggest that many of the Lowland/Peatland were local components. Consequently, their patchy presence in the vegetation landscape triggered their minor frequencies of Lowland/Peatland components in sample 1C.

Indicator of Anthropogenic Activity and Age of Sample

The prominent representations of *Paspalum conjugata*, *Zea mays*, and *Imperata cylindrica* in the pollen assemblage indicate local pollen sources. Hence, high frequencies of *Zea mays* indicate intensive agricultural activity along with the deposition of the samples. The presence of other purportedly cultivated plants' pollen, such as *Brassica campestris* and *Solanum*, supports this interpretation.

Index fossils of pollen are absent in the pollen assemblages. Alternatively, the presence of pollen from introduced plants (e.g., *Paspalum conjugatum*) and cultivated plants (e.g., *Zea mays* and *Paspalum conjugatum*) implies the modern age of the samples. The presence of pollen from those species resolves the dispute over the age of the alluvium unit. It suggests that at least part of the alluvium unit was deposited in modern times.

CONCLUSIONS

A pollen record of three samples taken from outcrops of an alluvium unit in Bangka suggests that the unit was deposited in modern times, as indicated by the presence of pollen from introduced and cultivated plants. The samples were deposited in open forest environments of evolving disturbed heath forest ecosystems at different stages of vegetation succession. The pollen assemblages and composition may be analogous to pollen records of disturbed heath forests.

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Author Contributor

In this study, K and S collected the samples, WSS conducted the pollen preparation and identification, and EY prepared the pollen diagram, figures, and tables, as well as performed the analysis and paper draft writing. The authors contributed equally to this study.

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