Scientific Research Publishing

Journal of Geoscience and Environment Protection, 2024, 12, 113-151
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Palynostratigraphy and Paleoenvironment of Bukit Tigapuluh Area in the Jambi Subbasin from Oligocene to Miocene

Sapto Kis Daryono, Carolus Prasetyadi, Eko Teguh Paripurno, Sutanto, Aditya Zaenalfi Faozi

Geological Engineering Department, Faculty of Technology Mineral, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Kota Yogyakarta, Indonesia
Email: saptokisdaryono@upnyk.ac.id

How to cite this paper: Daryono, S. K., Prasetyadi, C., Paripurno, E. T., Sutanto, & Faozi, A. Z. (2024). Palynostratigraphy and Paleoenvironment of Bukit Tigapuluh Area in the Jambi Subbasin from Oligocene to Miocene. *Journal of Geoscience and Environment Protection, 12,* 113-151.
https://doi.org/10.4236/gep.2024.129007

Received: July 2, 2024
Accepted: September 24, 2024
Published: September 27, 2024

Abstract

The Oligocene-Miocene trajectory exposed at the Lubuk Lawas and Lubuk Bernai Stratigraphic Tracks in Bukit Tigapuluh, Jambi Subbasin, Indonesia, archives remnants of equatorial vegetation during extreme global warming and near the beginning of the East Java-Eurasia microcontinent collision, and was carried out using mapping surface analysis, petrological analysis, sedimentology, stratigraphy and palinology. The rock units were deposited during one sedimentation phase, that is the continental deposition phase, which consists of conglomerates, gravel sandstones and sandstones that fill the basin followed by transgressive deposits associated with the deepening of the basin environment. Three palynozones *Meyeripollis naharkotensis* (Oligocene), *Florschuetzia trilobata* (Early Miocene) and *Florschuetzia meridionalis* (Middle Miocene) were identified stratigraphically on the basis of these pollen. The rock layers are deposits from the Early Oligocene to Middle Miocene from bottom to top. The depositional environment changed over time, passing from a narrow, steep-sided tectonic basin, during the Early to Late Oligocene, followed by a lacustrine basin to a palustine with oceanic influence, as a result of distensive E-W movement between the Jambi Fault and the Sunda Fault in the Late Oligocene to the Middle Miocene. Occurrence of taxonomically highly diverse angiosperm pollen in all three palynozones attests to an extremely rich inland and nearshore tropical flora under a strong seasonal rainfall regime. The climate remained warm and became increasingly humid towards the end of the Miocene. The nature of the environment is related to the dynamics of the opening of the basin opening.

Keywords

Oligocene, Miocene, Palynostratigraphy, Paleoenvironment, Paleogeography,

Jambi Subbasin, Indonesia

1. Introduction

The Early Eocene was a critical period for the evolution of the flora of the South Sumatra Basin. Paleogeographically, what is now Jambi Province, is located at 0˚45' - 2˚45' South Latitude and 101˚10' - 104˚55' East Longitude in the central part of Sumatra Island as shown in **Figure 2** and **Figure 3**.

Barber et al., (2005) explained that in the Late Cretaceous-Paleocene (90 million years ago) on the edge of the Sunda Mainland (Sundaland) there were collisions (collisions) by several microcontinent blocks. On the west side, the Sundaland edge is collided by the Woyla Intra-oceanic arc block while on the southeast it is occupied by the East Java-West Sulawesi Block (**Figure 1**, Clements & Hall, 2011; Hall, 2009, 2014). These Late Cretaceous-Paleocene collisions resulted in the uplift of Sundaland characterized by regional inconsistency (Clements & Hall, 2011; Hall, 2014). This regional discrepancy is indicated by the absence of Late Cretaceous-Paleocene deposits in most parts of Sundaland (Southeast Asia) (Clements & Hall, 2011). The absence of sediment is thought to negate the presence of terrestrial biotics although biotic exchanges between some microcontinental blocks and Sundaland undoubtedly preceded the closure of the seas where the establishment of land links enhanced bioticexchanges. The formation of land (terrestrial) in the Paleocene was followed by erosion and weathering events that led to the formation and accumulation of thick paleosoil which indicates a semi-arid climate (Leisman & Retallack, 2001).

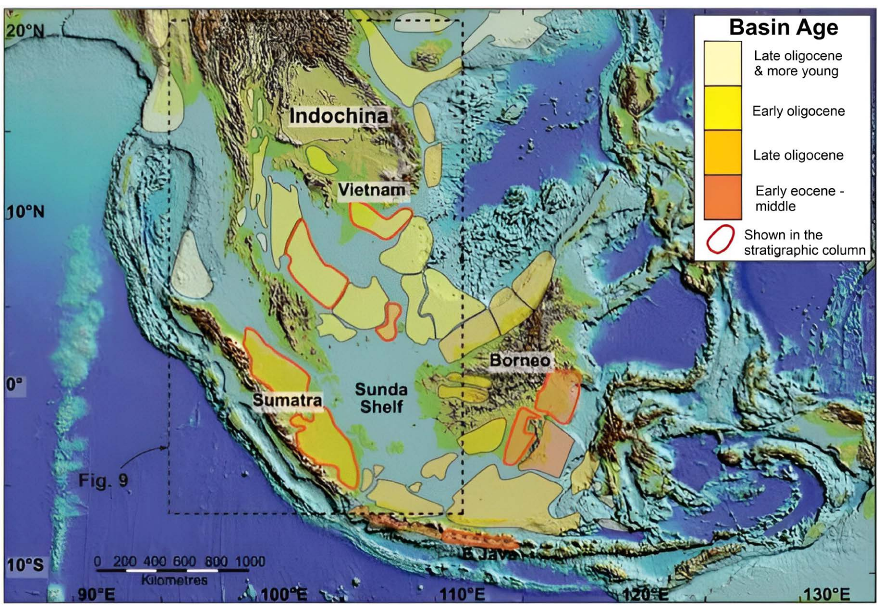


Figure 1. Sedimentary basins and their age in some areas in Southeast Asia affected by inconsistency (Clements & Hall, 2011).

Palinological studies preserved in fluvial deposits, show that the South Sumatra Basin experiences a climate characterized by strong seasonal rainfall, implying significant disruption to the always-wet rainfall regime that typically exists at equatorial latitudes at this time/day. Given these extraordinary circumstances, it is important to better understand the composition of Paleogene equatorial plant/vegetation in Bukit Tigapuluh, South Sumatra Basin which provides access to the abundance of pollen and spores in the Oligocene-Miocene. This is where research on microflora and palinofacies is carried out. Palinostratigraphic and palinofacial analyzes of the South Sumatra Basin were carried out with the objectives of 1) to establish spore/pollen zoning in the Oligocene-Miocene strata of the area, 2) to determine significant palinotax stratigraphic ranges, 3) to link the recorded palinoflora with regional stratigraphic succession and 4) to reconstruct the paleoenvironmental conditions that prevailed during sediment deposition.

This study provides basic information about the diversity of pollen and spore fossils in various habitats represented in stratigraphic succession.

No detailed and adequate research has been carried out to study palinology and try to analyze the palinostratigraphy of Oligocene-Miocene sediments in the Lubuk Lawas and Lubuk Bernai trajectories. This study is the first comprehensive work on palyno assemblages recovered from a sedimentary succession exposed in Bukit Tigapuluh, South Sumatra Basin.

2. Geology

The lack of Late Cretaceous to Paleocene sedimentary rocks suggests regional uplift on the Sunda mainland (Hall & Morley 2004; Hall et al., 2009) and has been interpreted by Clements & Hall (2011) in response to a dynamic topographic reversal and the entire area surfaced even without great elevation, eroded and transported to the continental margin.

Sedimentary records for the Late Cretaceous-Paleocene time interval have been lost, but the oldest Middle Eocene sediment deposited above the unconformity is an accumulation of widely recycled sediment and characterizes the Late Cretaceous-Paleocene regional elevation in Sundaland.

Tertiary basin development is largely controlled by step grabens. The accumulation of Tertiary sediments in this graben includes many layers of conglomerate, gravel sandstone, sandstone and siltstone occurring southeast of Bukit Tigapuluh as shown in **Figure 4**.

The bedrock consists of conglomerate units, volcanic gravel sandstone, and volcanic sandstone in the form of metamorphic and igneous rocks. The formation of tuffaceous balanau units comes from lapilli tuff due to volcanism activity, has been altered and may have originated from silica (andesite and granite) eruptions associated with the beginning of the East Java Block collision and the Woyla intraoceanic arc with Sundaland.

In this area, volcanic and tuffaceous units accumulate in the form of fluvial and alluvial deposits with the river system controlling them. The Tanjung Jabung

Barat area, which is the southeastern part of Bukit Tigapuluh, is in the Jambi Sub-basin.

This sediment sequence is represented on the measured stratigraphic trajectory of Lubuk Lawas and Lubuk Bernai, associated with conglomerate units, gravel sandstone units, sandstone units and siltstone units of Oligocene-Miocene age.

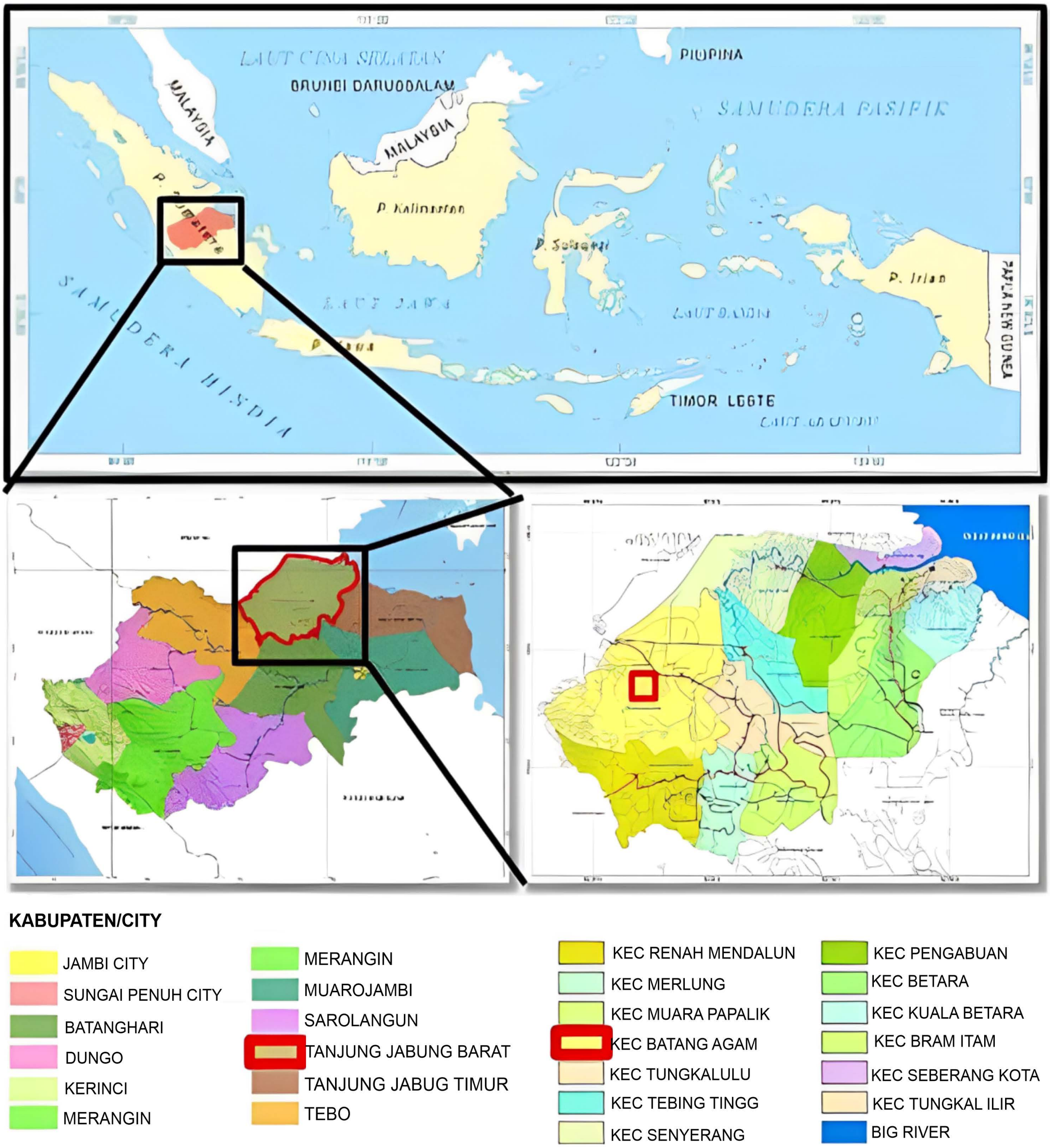


Figure 2. Map of the administration of Jambi Province (Bakosurtanal, 2008) and the research area of Kabupaten Tanjung Jabung Barat (Bakosurtanal, 2008).

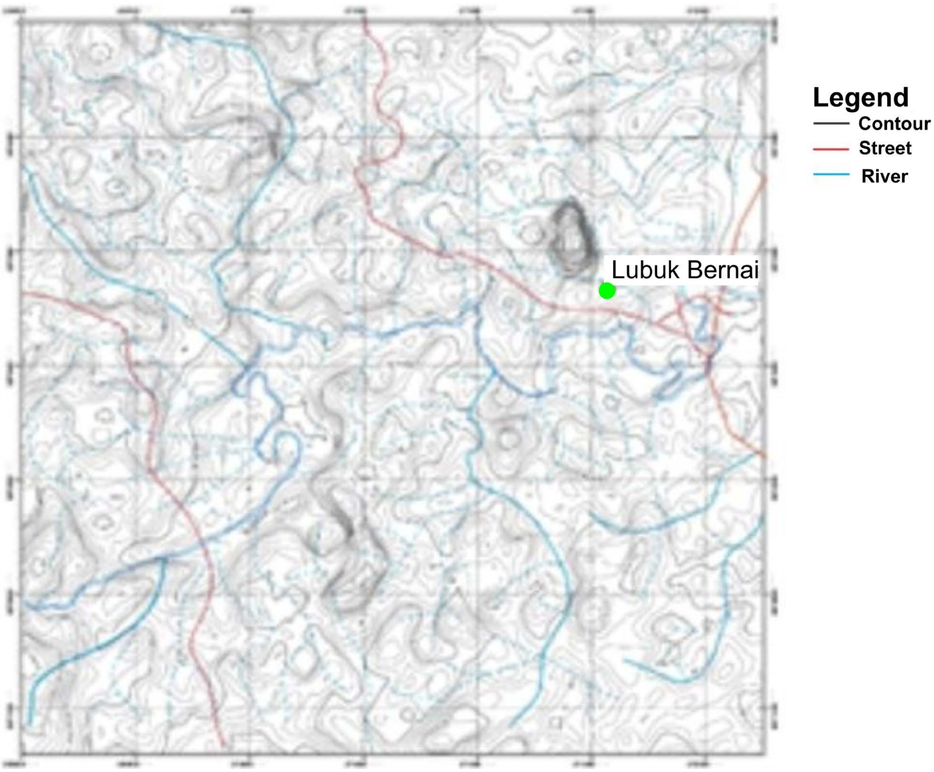


Figure 3. Topographic map of the research area (Source: SRTM 30 m).

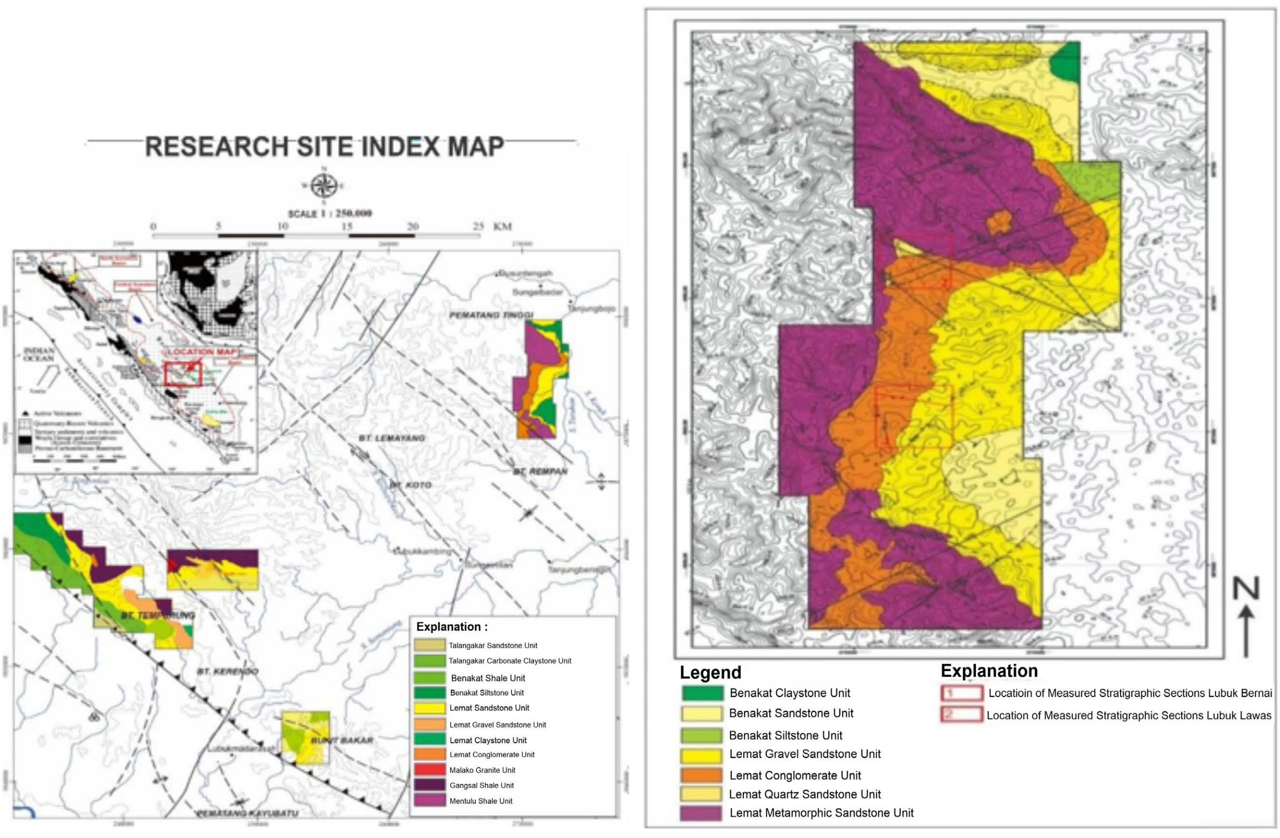


Figure 4. Distribution map of quartz sandstone, conglomerate and gravel sandstone units.

3. Materials and Methods

Surface geological mapping in Tanjung Jabung Barat, obtained twenty-five samples (13 samples in Lubuk Lawas and 13 samples in Lubuk Bernai) prepared for palinological analysis. Eight blank samples (barren) and eighteen samples were sufficient for palinofacies and palinostratigraphic analysis. Samples were prepared using standard techniques of the Palinology Laboratory of the National Development University "Veteran" Yogyakarta as follows: Twenty-five grams of stone was broken into 1 - 2 mm equidimensional pieces; followed by disintegration of the mineral matrix with HCl for carbonates and HF for silicates (24 hours). The sample was then cleaned with hot HCl and sieved using a 12 m mesh. The sample was oxidized with HNO_3 and the slide was mounted using Hydroxylethyl Cellulose (HEC) to homogenize the organic particles on the slide and Euparal to permanently attach the cover slip. At least one slide per stratigraphic level is scanned using an optical microscope. The best palynomorph specimens are photographed. They are placed on the slide using the England Finder (EF) system.

Petrological/petrographic (22 samples) and sedimentological analyzes (2 measured stratigraphic paths) on the identification of different sedimentary facies units were based on photomosaics and measured outcrop sections, as well as by surface mapping. The facies approach is divided and named based on differences in grain size, inter-grain relationships, and sedimentary structures specific to sedimentary rocks deposited in a fluvial environment. The fluvial depositional environment is obtained from paleogeographic map sketches, vertical profiles and block diagrams or a combination of the three.

4. Lithofacies

Lithofacies are described by taking into accounts lithology, texture, internal structure and contact surface properties. Each lithofacies was codified according to the nomenclature of Miall (1985) and Postma (1990). The three main facies and subfacies identified in the Jambi Subbasin are quartz sandstone, conglomerate, gravel sandstone facies.

5. Interpretation of Facies

Quartz sandstone facies is a fine-sized sedimentary material found as channel deposits. The presence of the FF facies characterizes the deposition of lagging rivers, as well as the presence of SB elements in the middle and top of this facies. In the conglomerate facies, architectural elements are found in the form of Sediment gravity flows (SG), Sandy bedform (SB), Gravel bedform (GB), Channel (CH), Scour Hollows (HO), and Floodplain Fines (FF). The depositional environment in this area can be described as a possibly braided channel system, which cuts and erodes itself. This is reflected in the dynamics of energy and high current velocities resulting in the deposition of material with grain size (sandstones and coarse-grained conglomerates) which is interpreted as a channel filling process. Then in the next phase, fine-sized sedimentary material appears, which is interpreted as floodplain fines deposits. The floodplain fines facies indicate a change in current from the previous strong current to a weaker current. At first, the coarse grains will settle to the bottom according to the existing rock mass and also the fine grains will settle at the very top because of the small density of the rock. The change in energy from high to low is probably caused by reduced sources of water supply and sedimentary material from the upstream channel. The dominance of sedimentary material which tends to be coarse and the many associations of GB, SG, and SB facies indicate a large number of river bars and are characteristic of braided rivers. The braided river has a bed load sediment transport mechanism (creeping on the riverbed). The geometry of the braided river is high slope, wide river geometry, and the highest river slope among all types of rivers. A braided river has a straight to curved river level. A braided river has more than one channel (multichannel). Two models obtained based on the results of the description according to Miall (1985) are alluvial fans system with gravity flow river or gravel bed braided river and shallow, gravel bed braided river as shown in **Figure 5** until **Figure 17**.

Based on facies analysis, the stratigraphic succession in the study area shows a fluvial depositional environment in braided river systems with gravel braided rivers with sedimentary gravity flows.

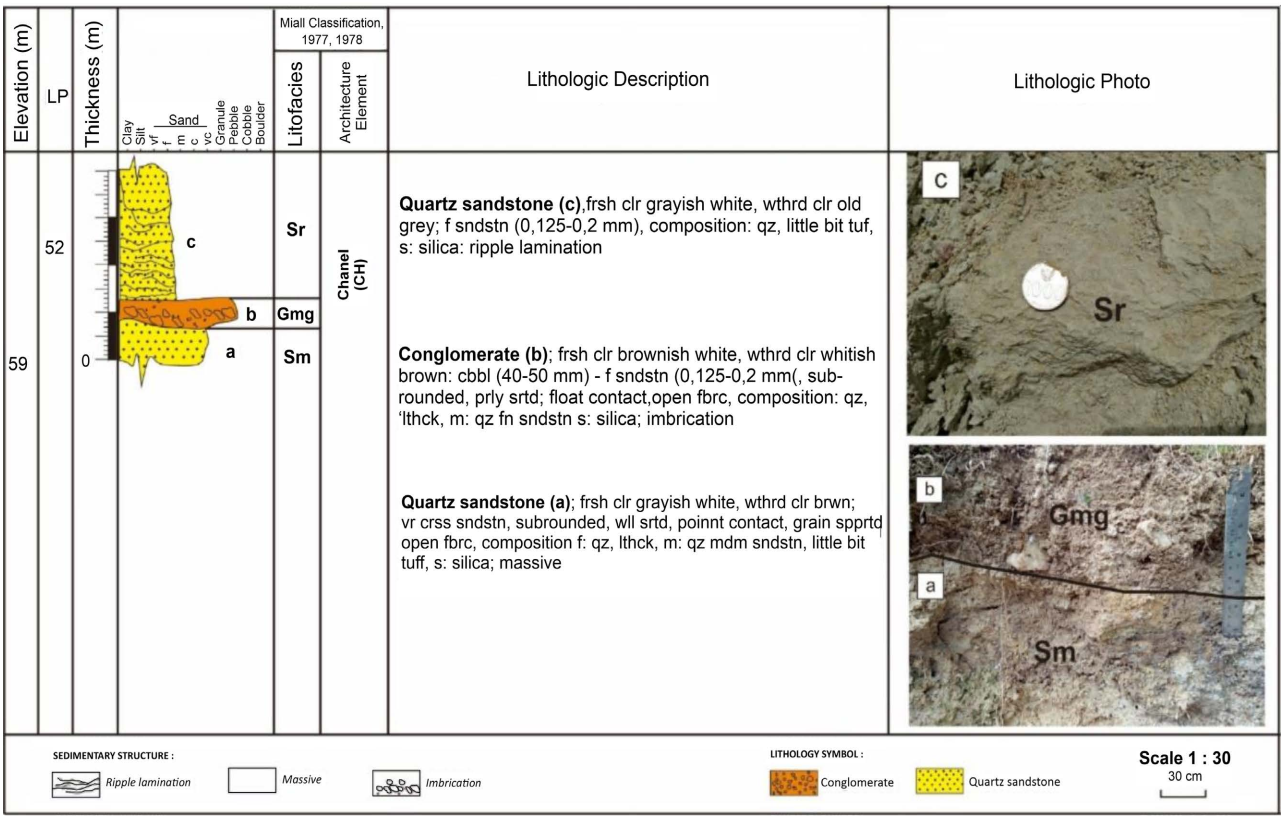


Figure 5. Analysis of facies and channel architectural elements (CH) in quartz sandstone units.

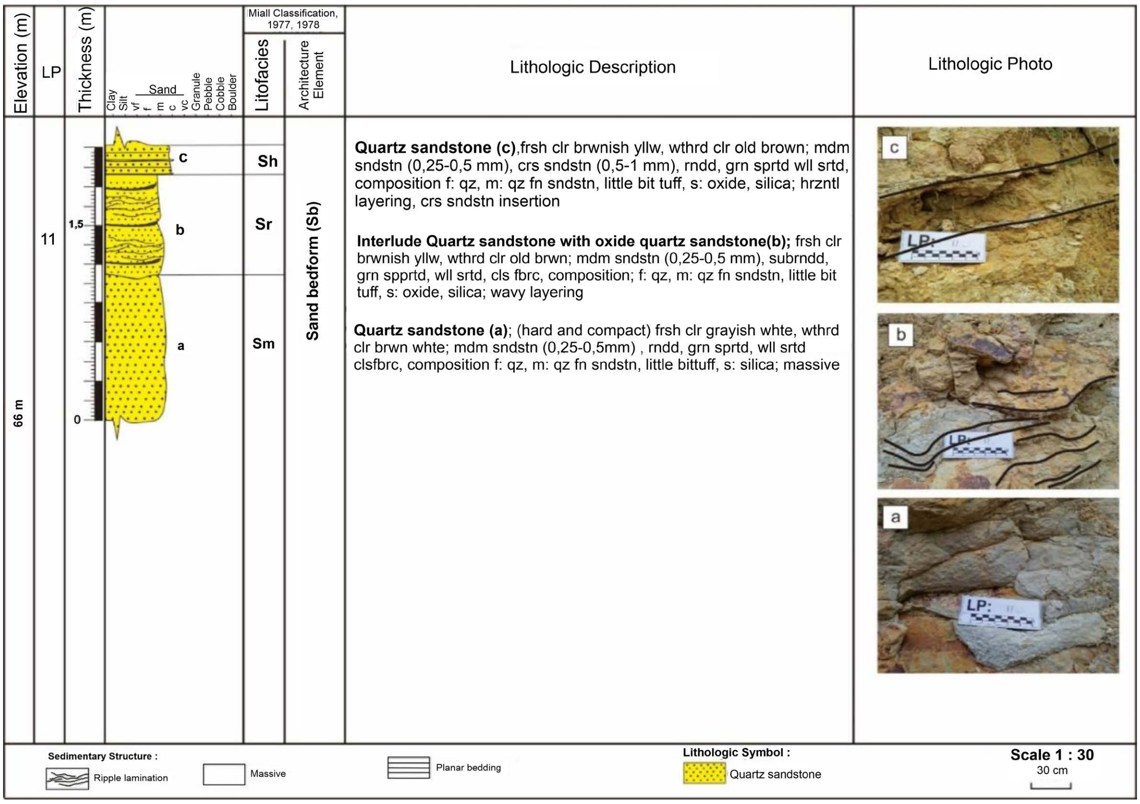


Figure 6. Analysis of facies and architectural elements of sand bedforms (SB) in quartz sandstone units.

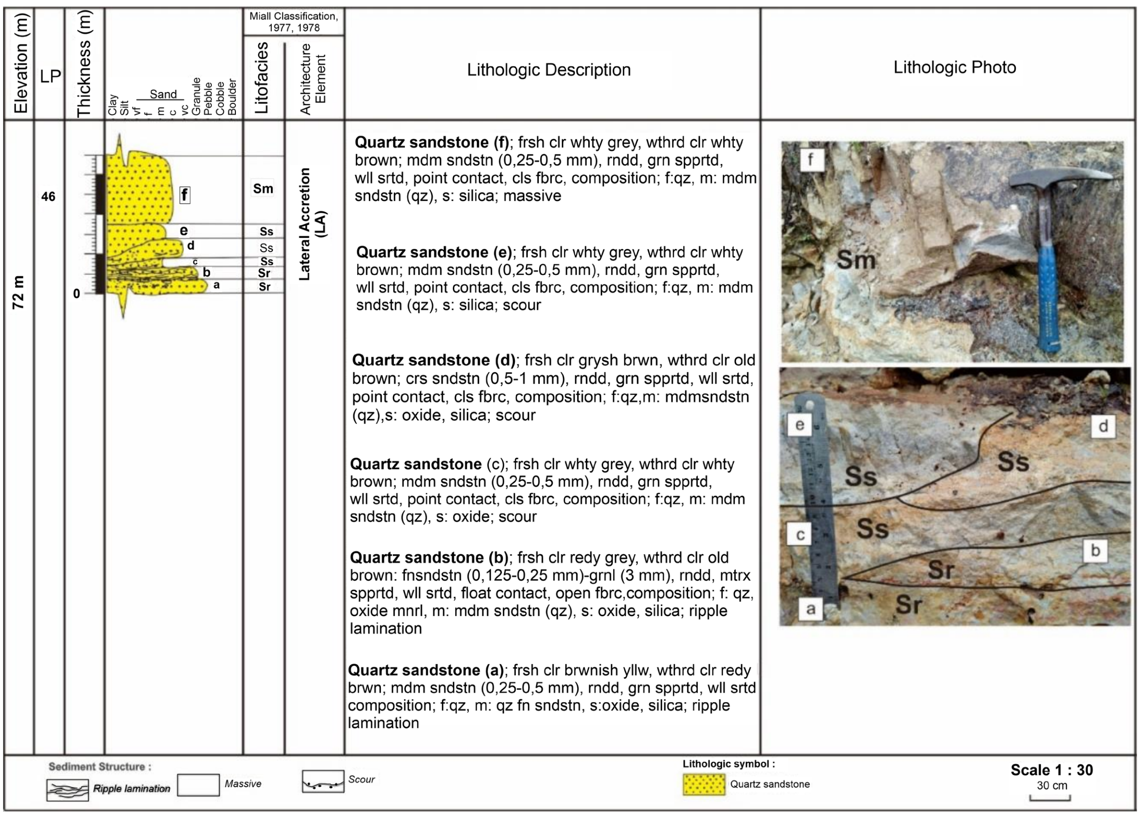


Figure 7. Facies analysis and lateral accretion (LA) architectural elements in quartz sandstone units.

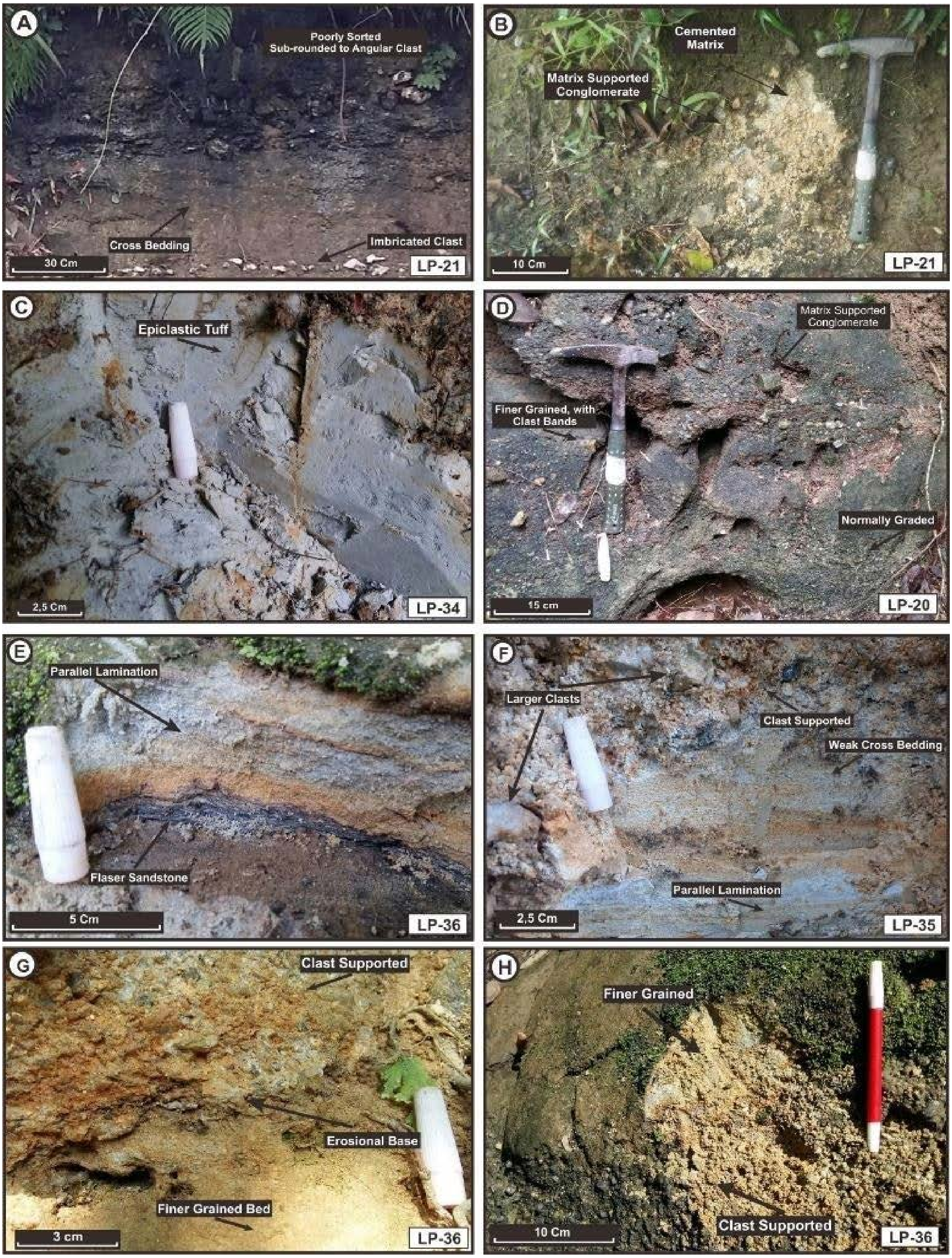
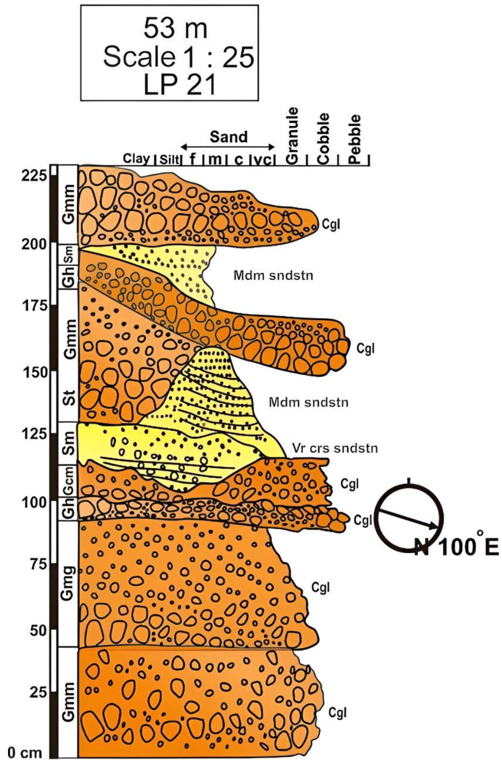


Figure 8. Texture and structure of sediment in conglomerate units.


53 m
Scale 1 : 25
LP 21
Sand
Clay
Silt
f
m
c
vc
Granule
Cobble
Pebble
225
200
175
150
125
100
75
50
25
0 cm
Gmm
Sm
Gh
Gmm
St
Sm
Gcm
Gh
Gmg
Gmm
Cgl
Mdm sndstn
Cgl
Mdm sndstn
Vr crs sndstn
Cgl
Cgl
Cgl
Cgl
N 100° E

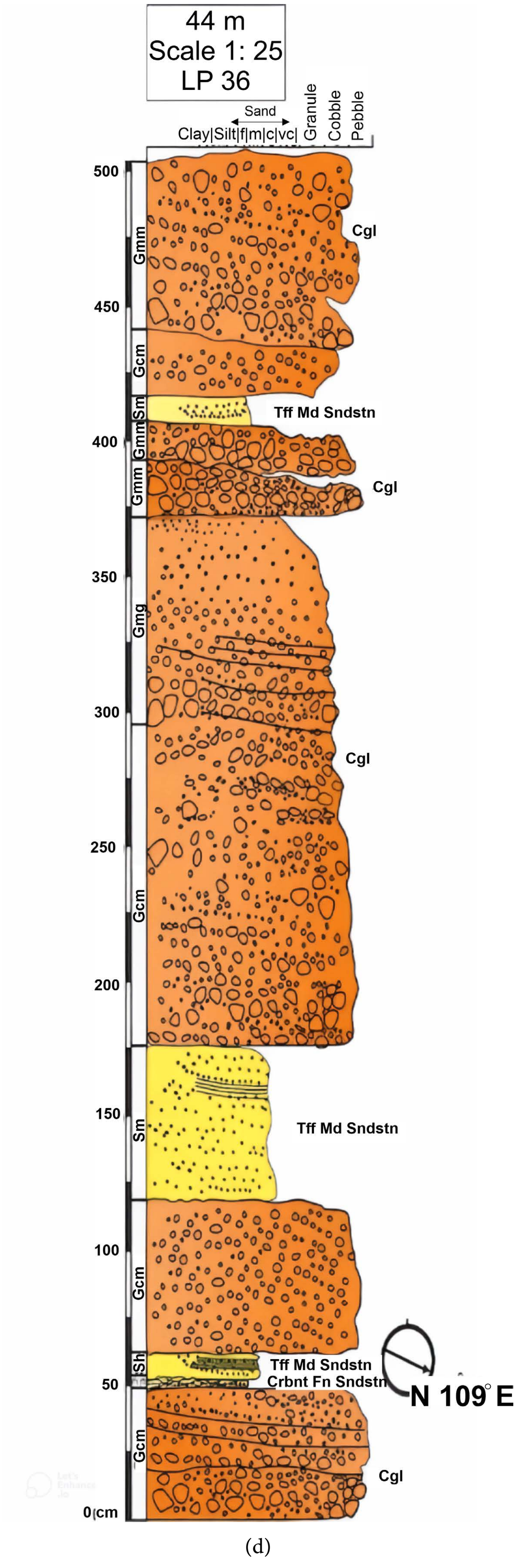
(a)


A
Poorly Sorted
Sub-rounded to Angular Clast
Gmm
Sp
Cross Bedding
Imbricated Clast
Gh
30 Cm
LP-21

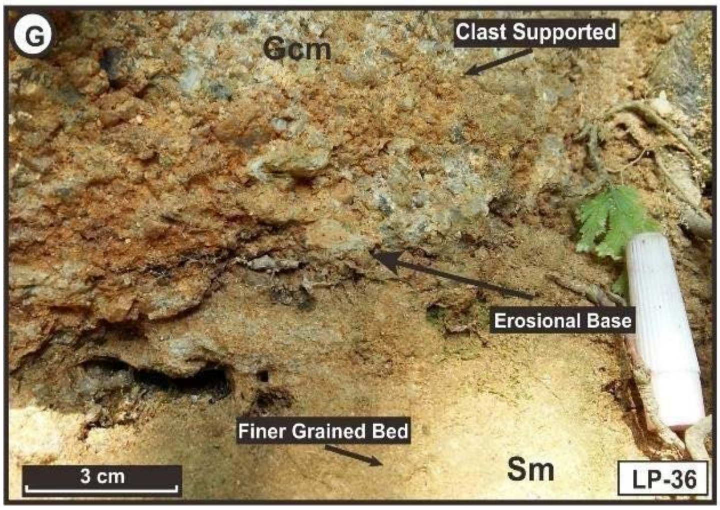
(b)


B
Cemented
Matrix
Matrix Supported
Conglomerate
Gmm
10 Cm
LP-21

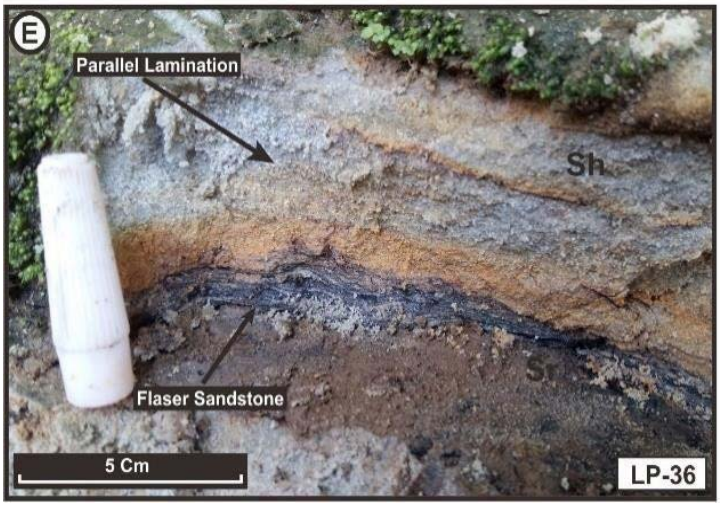
(c)


44 m
Scale 1: 25
LP 36
Sand
Clay|Silt|f|m|c|vc|
Granule
Cobble
Pebble
500
450
400
350
300
250
200
150
100
50
0 cm
Gmm
Gcm
Sm
Gmm
Gmm
Gmg
Gcm
Sm
Gcm
Sh
Gcm
Cgl
Tff Md Sndstn
Cgl
Cgl
Tff Md Sndstn
Tff Md Sndstn
Crbnt Fn Sndstn
N 109° E
Cgl

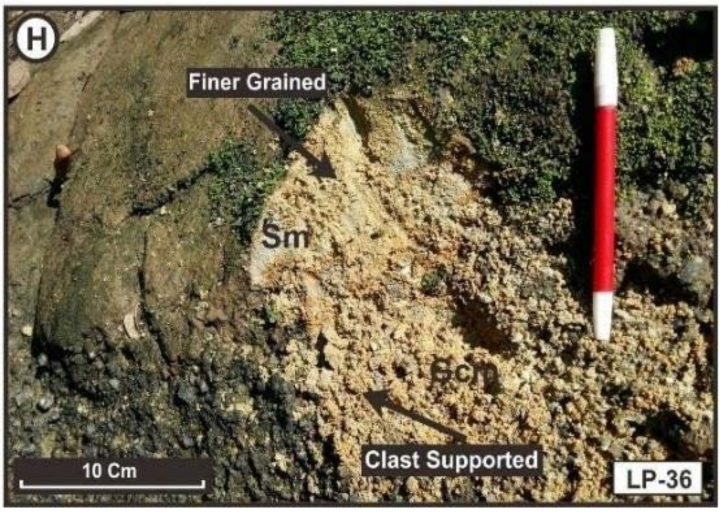
(d)



(e)



(f)



(g)

Figure 9. Litofacies in conglomerate units.

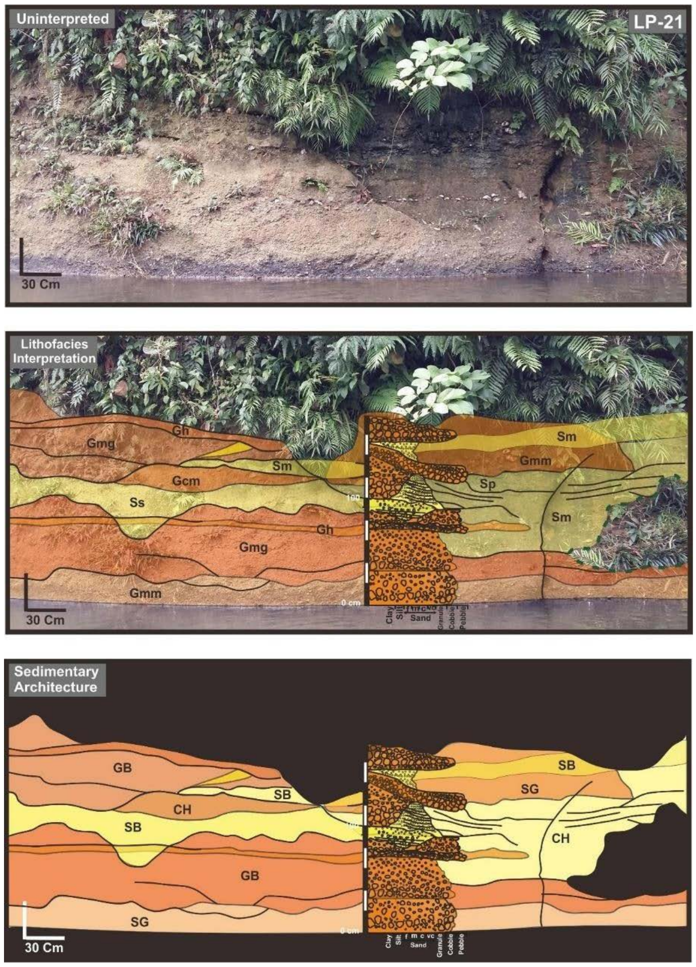
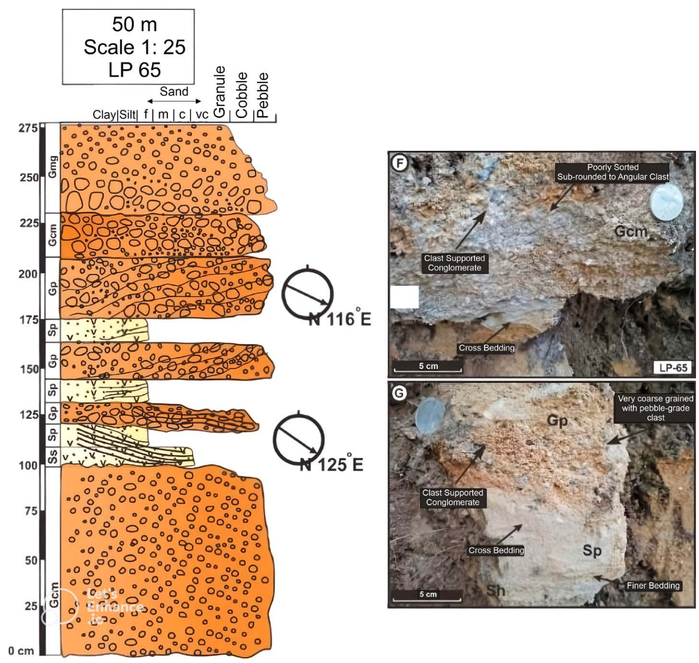
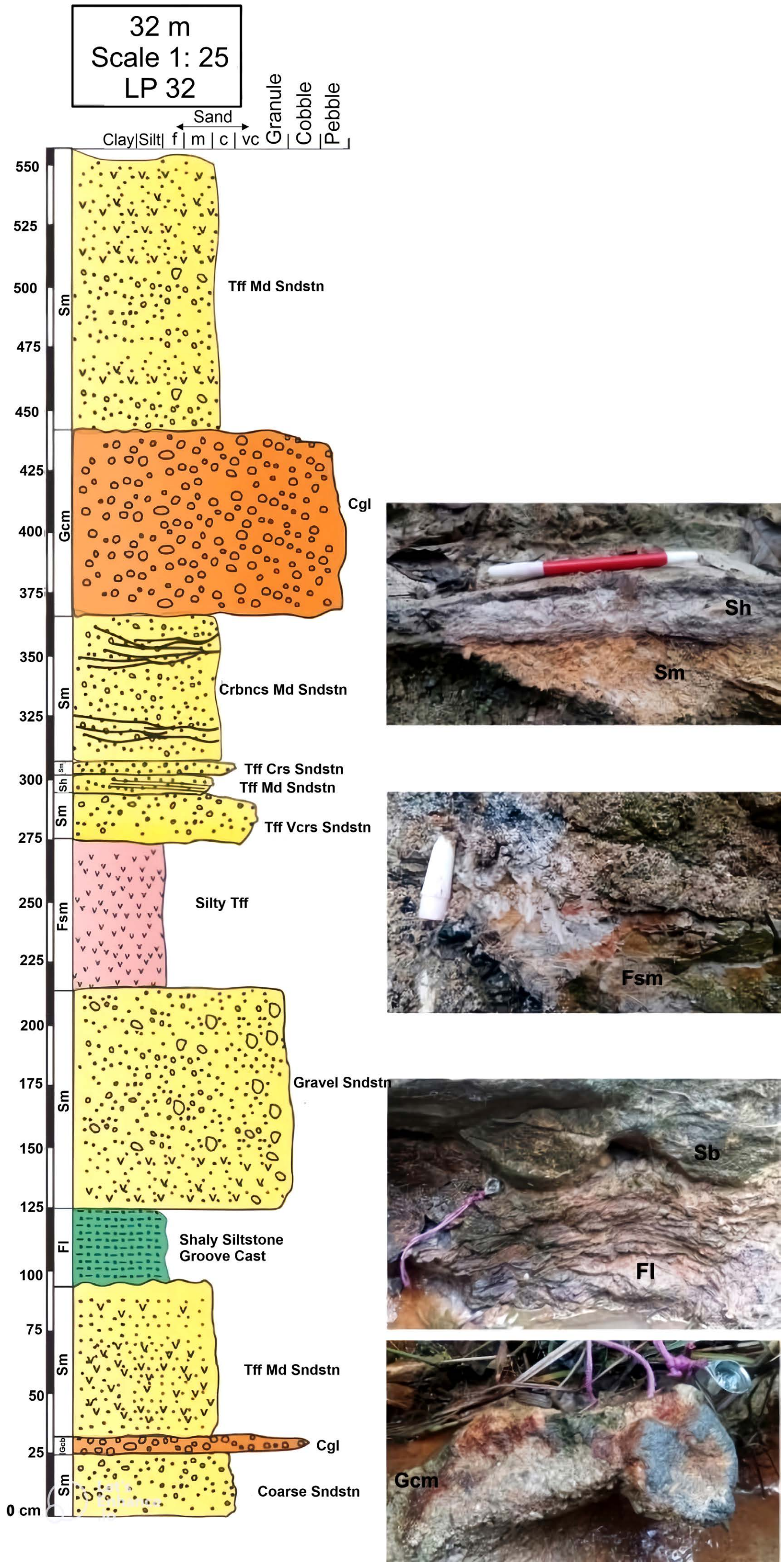


Figure 10. Architectural elements of conglomerate unit deposition.



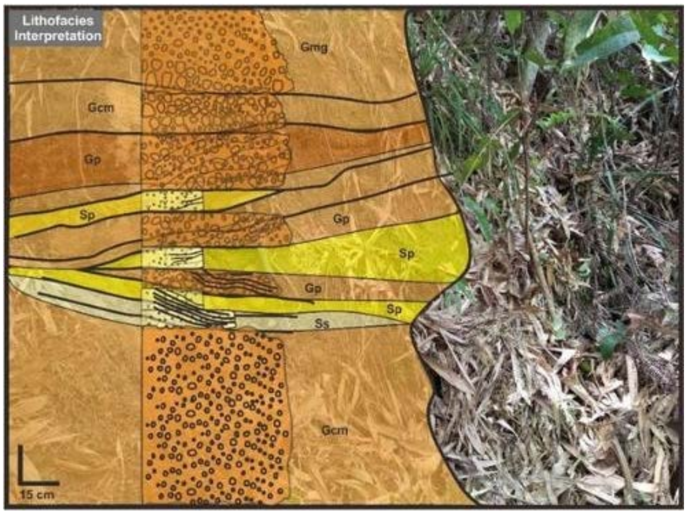
(a)



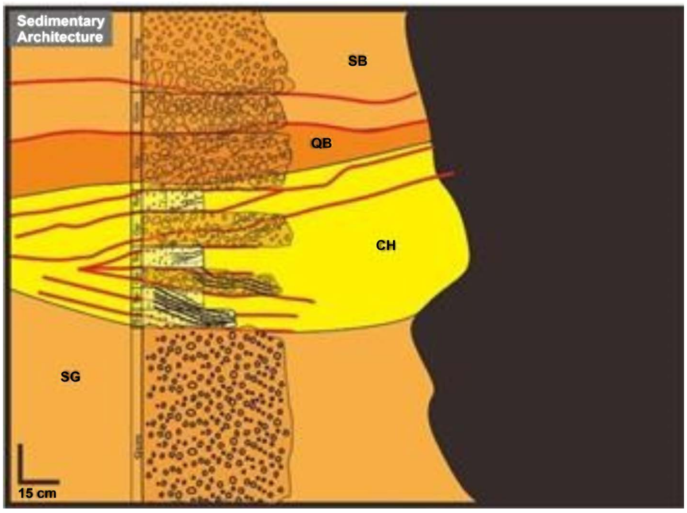
(b)

Figure 11. Architectural elements of conglomerate unit deposition.

(a)



(b)



(c)

Figure 12. Architectural elements of gravel sandstone deposition.

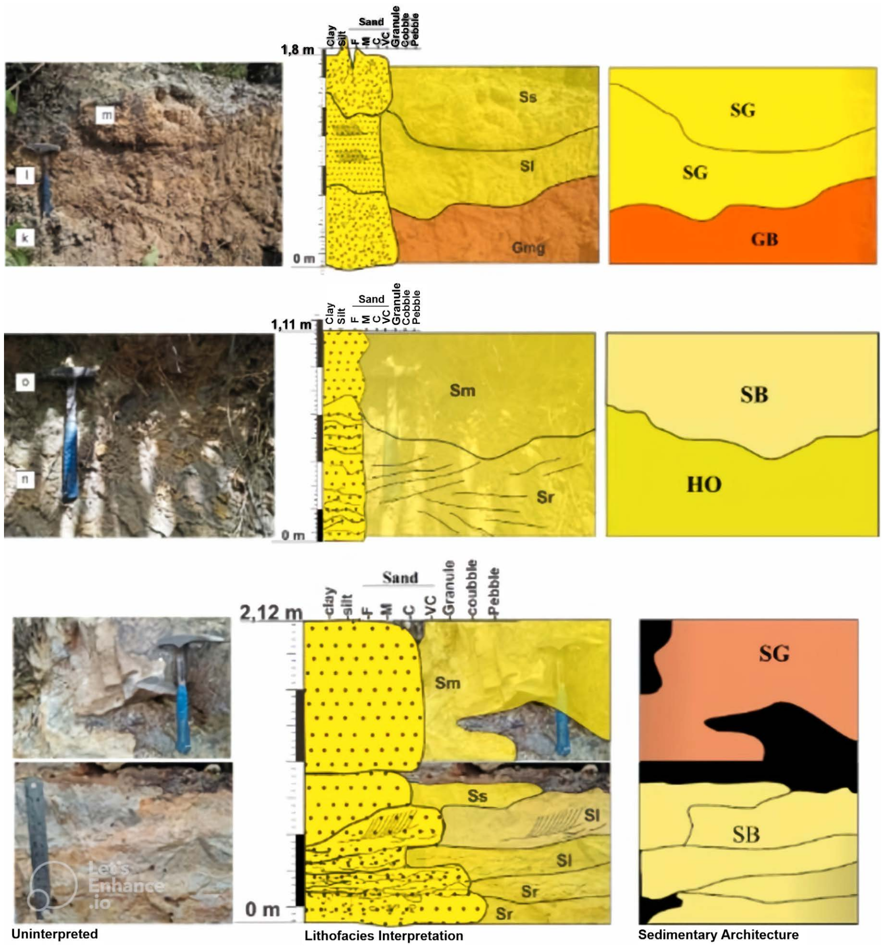


Figure 13. Litofacies of Lubuk Lawas trajectory gravel sandstone.

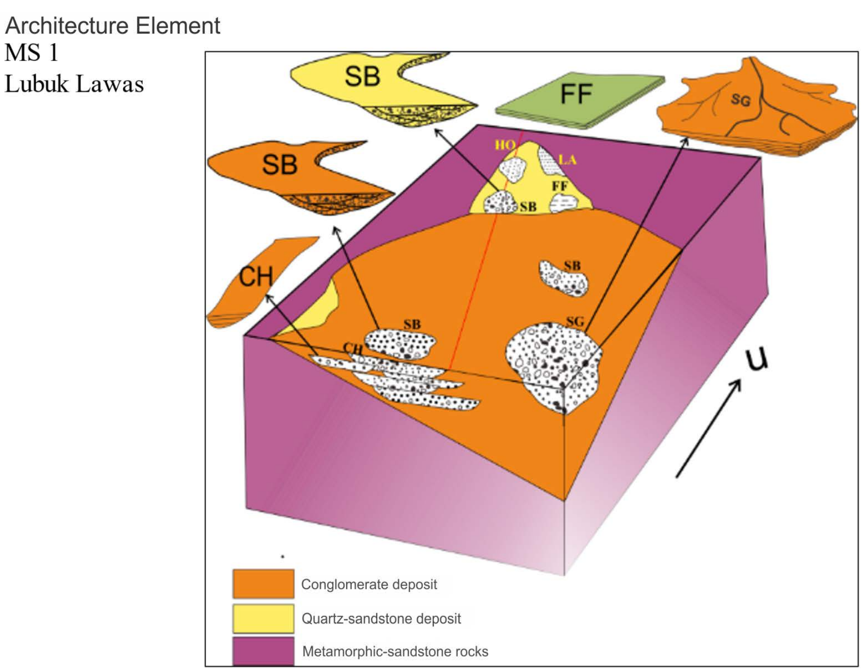


Figure 14. Architectural elements of gravel sandstone deposition (Lubuk Lawas).

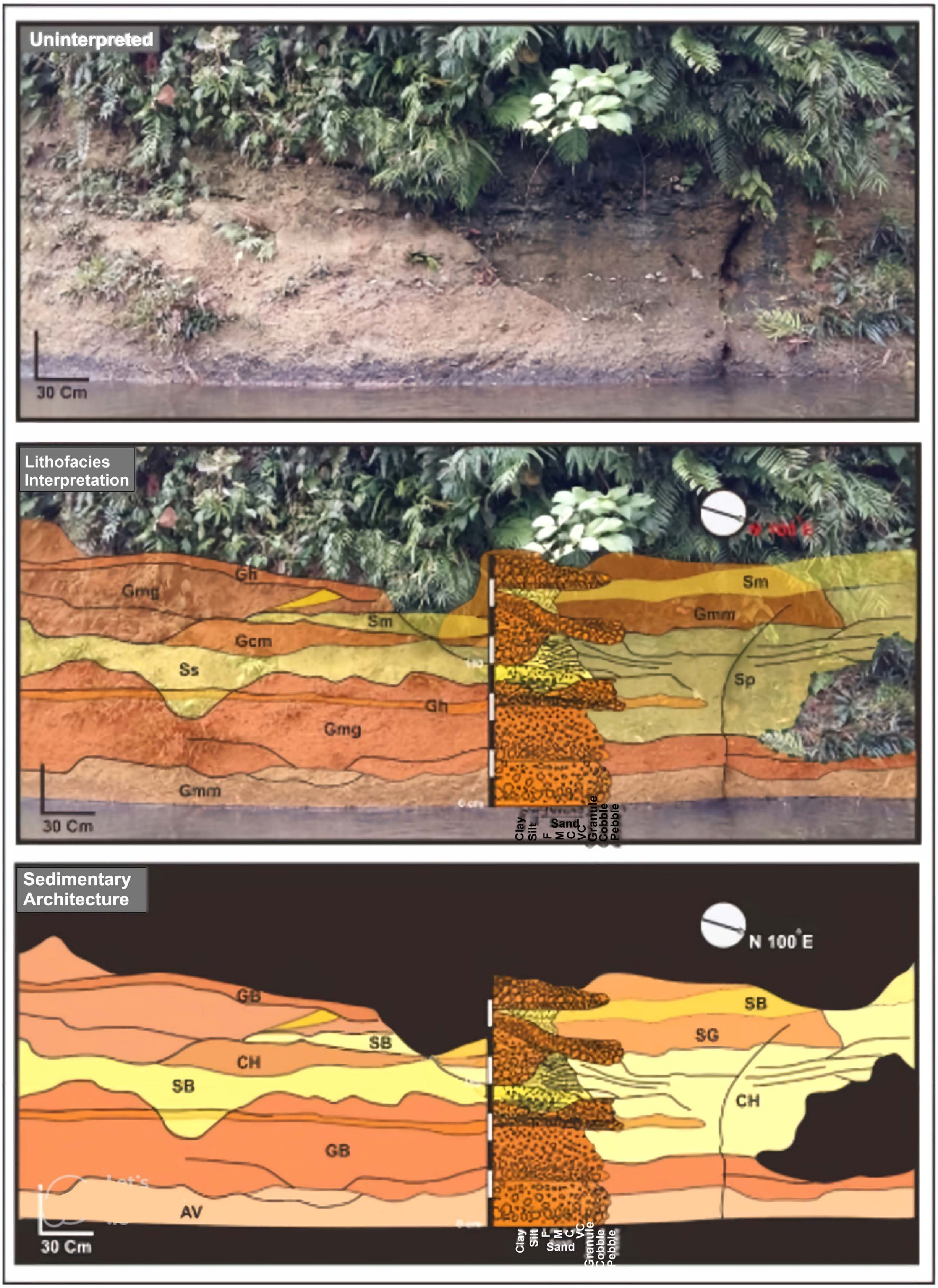


Figure 15. Litofacies of Bernai.

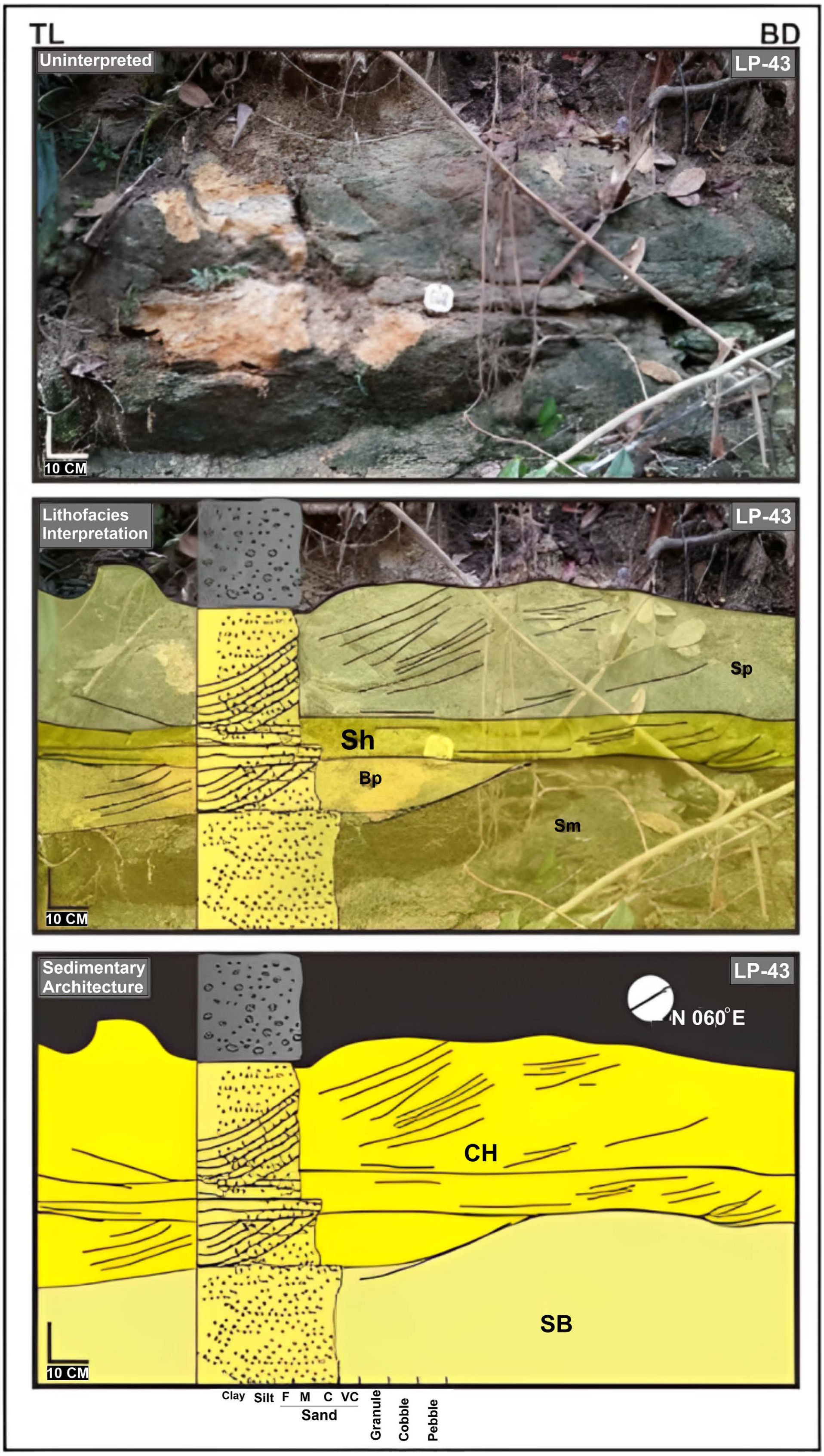


Figure 16. Litofacies Lubuk Bernai 2.

MS 2 LUBUK BERNAI

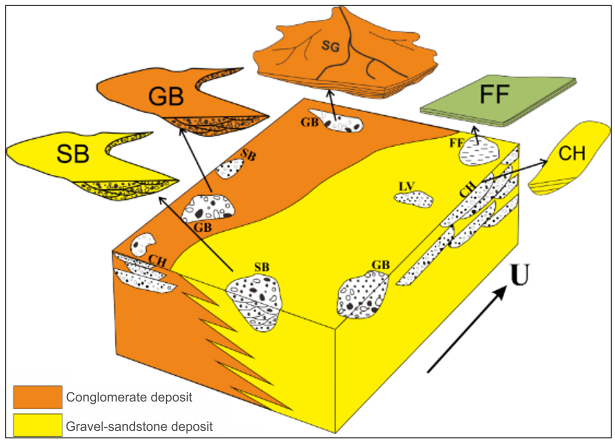


Figure 17. Geological block of Lubuk Bernai 2.

6. Palynology

Thin palynomorph slides (18) were obtained in Lubuk Lawas and Lubuk Bernai shown in **Figure 18** and **Figure 19**. From these slides, 57 different palynomorph species were found. In the context of this work, 52 species, including 5 marine and 47 continental, were used for paleoenvironment (47) and dating (5) the sediments studied shown in **Figure 20** until **Figure 27**. These are:

A. Index Fossil/Ages Marker

Florschuetzia levipoli, Florschuetzia meridionalis, Florschuetzia trilobata, Meyeripollis naharkotensis, Cicatricosisporites dorogensis.

B. Palynomorph Marine

Foraminifera Lining Test, Indeterminated Dinoflagellate, Operculodinium spp., Operculodinium centrocarpum, Spiniferites ramosus.

C. Palynomorph Continental.

Mangrove-Backmangrove: Acrosthicum aureum, Zonocostites ramonae, Spinizonocolpites echinatus, Discoidites borneensis, Discoidites novaguensis, Oncosperma type, Acanthus type, Aegialitis spp., Lumnitzera spp., Avicennia type.

Peat Swamp: *Sapotaceoidaepollenites sp., Retistephanocolpites williamsi, Elaeocarpus spp., Cephalomappa, Lugopollis, Striaticolpites catatumbus, Austrobuxus nitidus.*

Freshwater Swamp: *Margocolporites vanwijhei, Melanorrhoea type, Casuarina spp. (Haloragacidites harisii), Malvacipollis diversus, Myristica type, Monoporites annulatus, Palmaepollenites kutchensis, Dicolpopollis malesianus, Palmaepollenites spp., Dicolpopollis kawalaensis, Pandanus sp., Dicolpopollis (fine ret.), Paravuripollis mulleri, Eugessona insignis, Quilonipollenites spp., Gemmaticolpites pilatus, Shorea type, Lanagiopollenites emergiantus, Schoutenia sp., Lanagiopollenites spp., Lakiapollis ovatus, Lithocarpus spp.*

Freshwater Algae: *Concentricystes circula.*

Riparian: *Marginipollis concinnus, Canthiumidites, Myrtaceidites.* Montane: *Podocarpidites spp., Pinuspollenites spp.*

Spore: *Magnastriatites howardii.*

The known periods of occurrence for the palynomorphs found in the sampled outcrops were compared with the age of the lithofacies established by reference collections, to make dating of exposed palynoplanctonic zones more reliable.

7. Palynofacies Lubuk Lawas

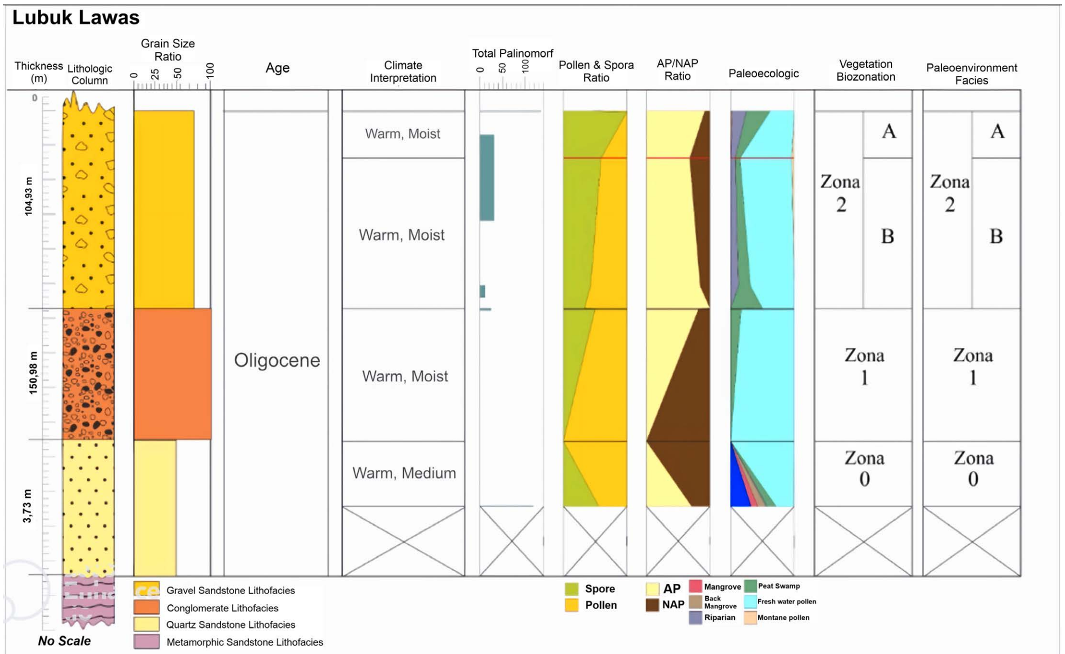


Figure 18. Palynofacies Lubuk Lawas.

8. Palynofacies Lubuk Bernai

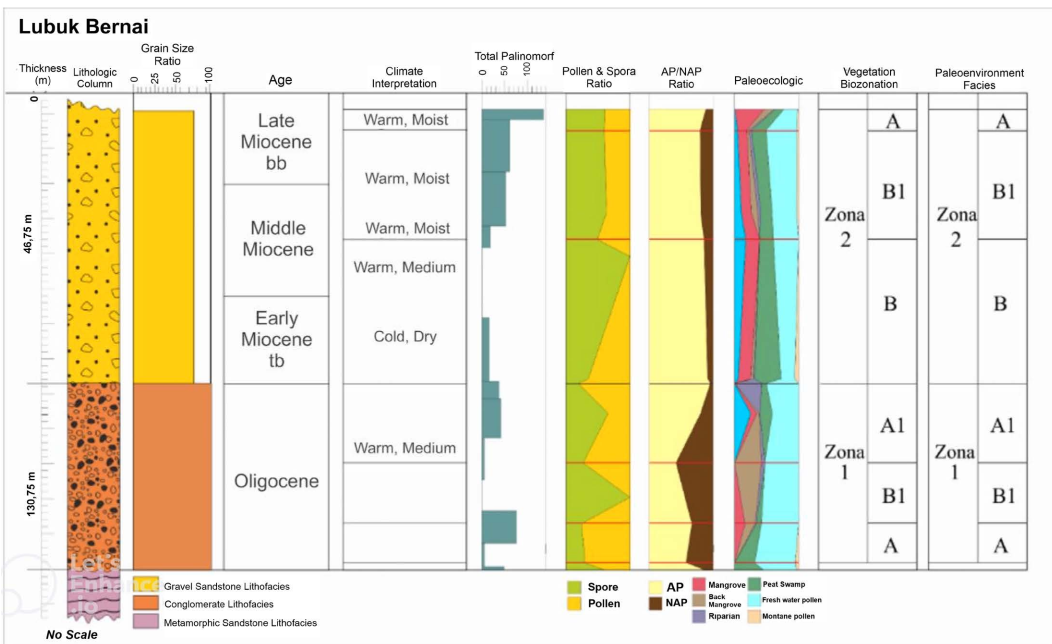


Figure 19. Palynofacies Lubuk Bernai.

9. Palynostratigraphic Zones

- Zone A

This zone corresponds to the quartz sandstone unit where the tuffaceous sandstone is in direct contact with the bedrock of this basin. The black claystone above the tuffaceous sandstone was analyzed for pollen fossils with the presence of *Meyeripollis naharkotensis* in the absence of *Proxaperpites operculatus*. This age range is called the Zona *Meyeripollis naharkotensis* and is interpreted to be Oligocene.

More recently above, the conglomerate terrestrial facies deposited with a supported matrix, the composition of fragments of quartz, tuff and lithic with plagioclase and quartz matrices. The bottom is occupied by fine tuffaceous sandstones, carbonaceous sandstones, black claystones and very fine tuffaceous sandstones that often contain plant debris or carbon. Gradually this unit is dominated by alternating conglomerate, volcanic sandstone and gravel sandstone with fragments in the form of quartz with insertions of epiclastic tuff, carbonaceous sandstone and local claystone. The top of the unit ends with a thin layer of black claystone containing a small amount of fossil pollen. Some authors attribute land deposits based on their stratigraphic position to an Oligocene age. Based on palinological analysis, the unit from the bottom to the top is Oligocene.

In the last sequence of the Lubuk Lawas and Lubuk Bernai trajectories, the zoning consists of a gravel sandy land facies with alternating volcanic sandstones and conglomerates with insertions of epiclastic tuff, claystone, carbonaceous sandstone, tuffaceous siltstone, and coal.

Based on palinological analysis, the unit from the bottom to the top is Oligocene. Thus, the zoning occupied by quartz sandstone, conglomerate and gravel sandstone units is proposed to be Oligocene in age.

- Zone B

This zone consists of a gravel-sand land facies with alternating volcanic sandstones and conglomerates with insertions of epiclastic tuff, claystone, carbonaceous sandstone, tuffaceous siltstone, and coal.

At the top of the gravel sandstone unit represented by black claystone and carbonaceous silt sandstone and volcanic sandstone there is a carbonaceous spout with a brownish gray color, sometimes there are coal lenses.

Zone B is further divided as follows:

Zone B1: In the lower black claystone lithology of this unit, based on palinological analysis, it is characterized by the extinction of Meyeripollis naharkotensis and the early appearance of Florschuetzia trilobata proposed as Zona Florschuetzia trilobata and Early Miocene age.

Zone B2: The upper part of the gravel sandstone unit with black claystone and carbonaceous siltstone lithology has a Middle Miocene age characterized by the presence of Florschuetzia levipoli together with Florschuetzia trilobata without the presence of Florschuetzia meridionalis. This zone is called the Zona Florschuetzia levipoli.

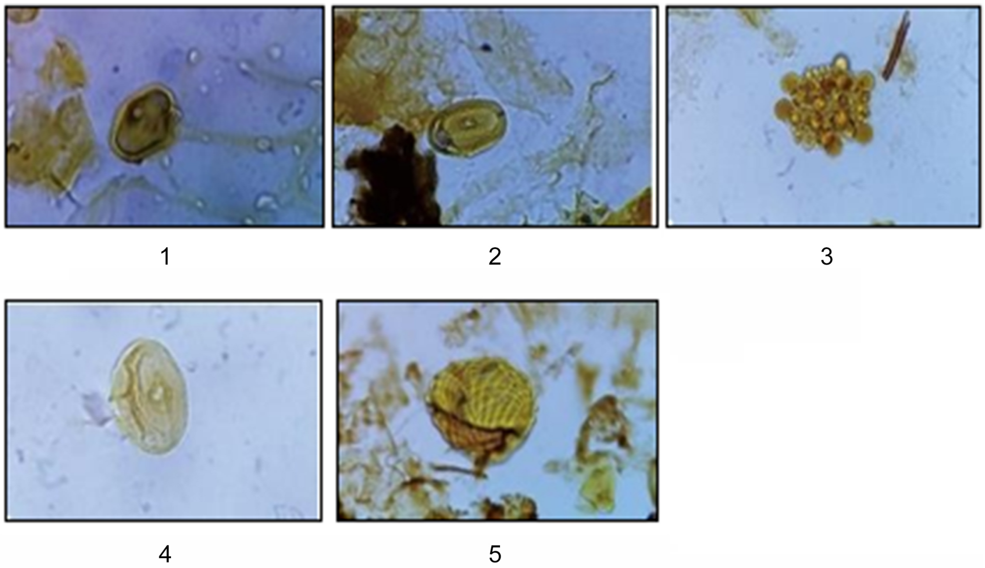


Figure 20. Fossil Age Index/Marker: 1. *Florschuetzia levipoli* (1000×), 2. *Florschuetzia trilobata* (1000×), 3. *Florschuetzia meridionalis* (1000×), 4. *Meyeripollis naharkotensis* (1000×), 5. *Cicatricosisporites orogensis* 1000×).

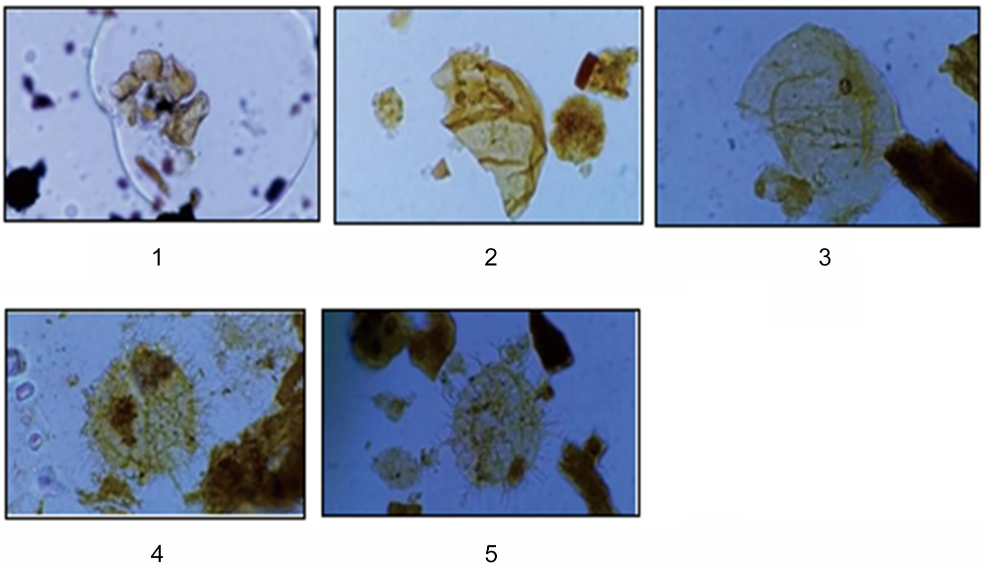
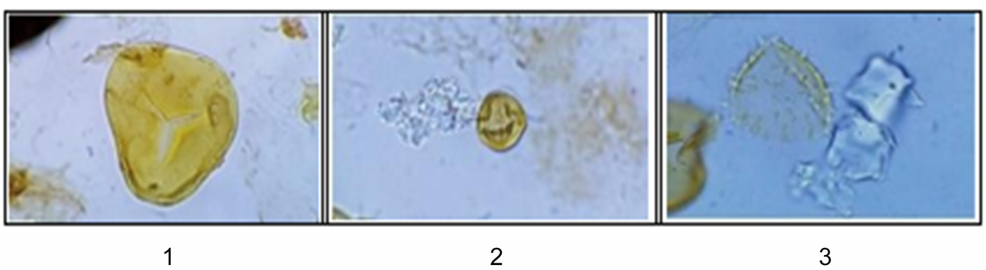


Figure 21. Marin Palinomorph Fossil: 1. *Foraminifera Lining Test* (1000×), 2. *Indeterminated Dinoflagellate* (1000×), 3. *Operculodinium spp.* (1000×), 4. *Operculodinium centrocarpum* (1000×), 5. *Spiniferites ramosus* (1000×).



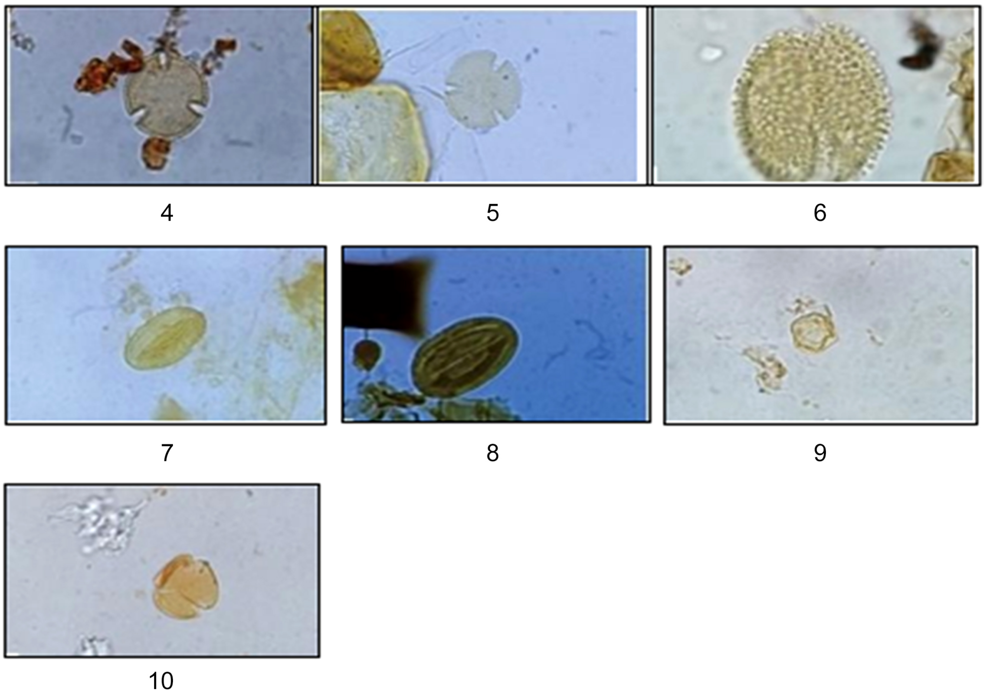


Figure 22. Mangrove-Backmangrove Palinomorph Fossil: 1. *Acrosthicum aureum* (1000×), 2. *Zonocostites ramonae* (1000×), 3. *Spinizonocolpites echinatus* (1000×), 4. *Discoidites borneensis* (1000×), 5. *Discoidites novaguensis* (1000×), 6. *Oncosperma type* (1000×), 7. *Acanthus* type (1000×), 8. *Aegialitis spp.* (1000×), 9. *Lumnitzera spp.* (1000×), 10. *Avicennia type* (1000×).

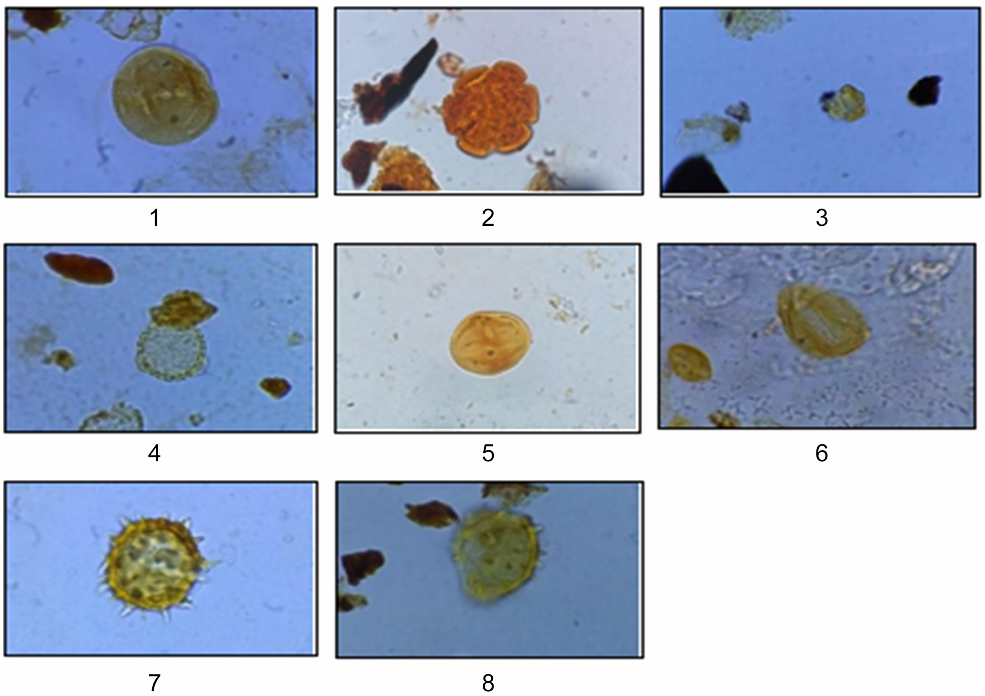


Figure 23. Peat Swamp. Palinomorph Fossil: 1. *Sapotaceoidaepollenites sp.* (1000×), 2. *Retistephanocolpites williamsi* (1000×), 3. *Elaeocarpus spp.* (1000×), 4. *Cephalomapp*a (1000×), 5. *Lugopollis* (1000×), 6. *Striaticolpites catatumbus* (1000×), 7. *Austrobuxus nitidus* (1000×), 8. *Camptostemon* (400×).

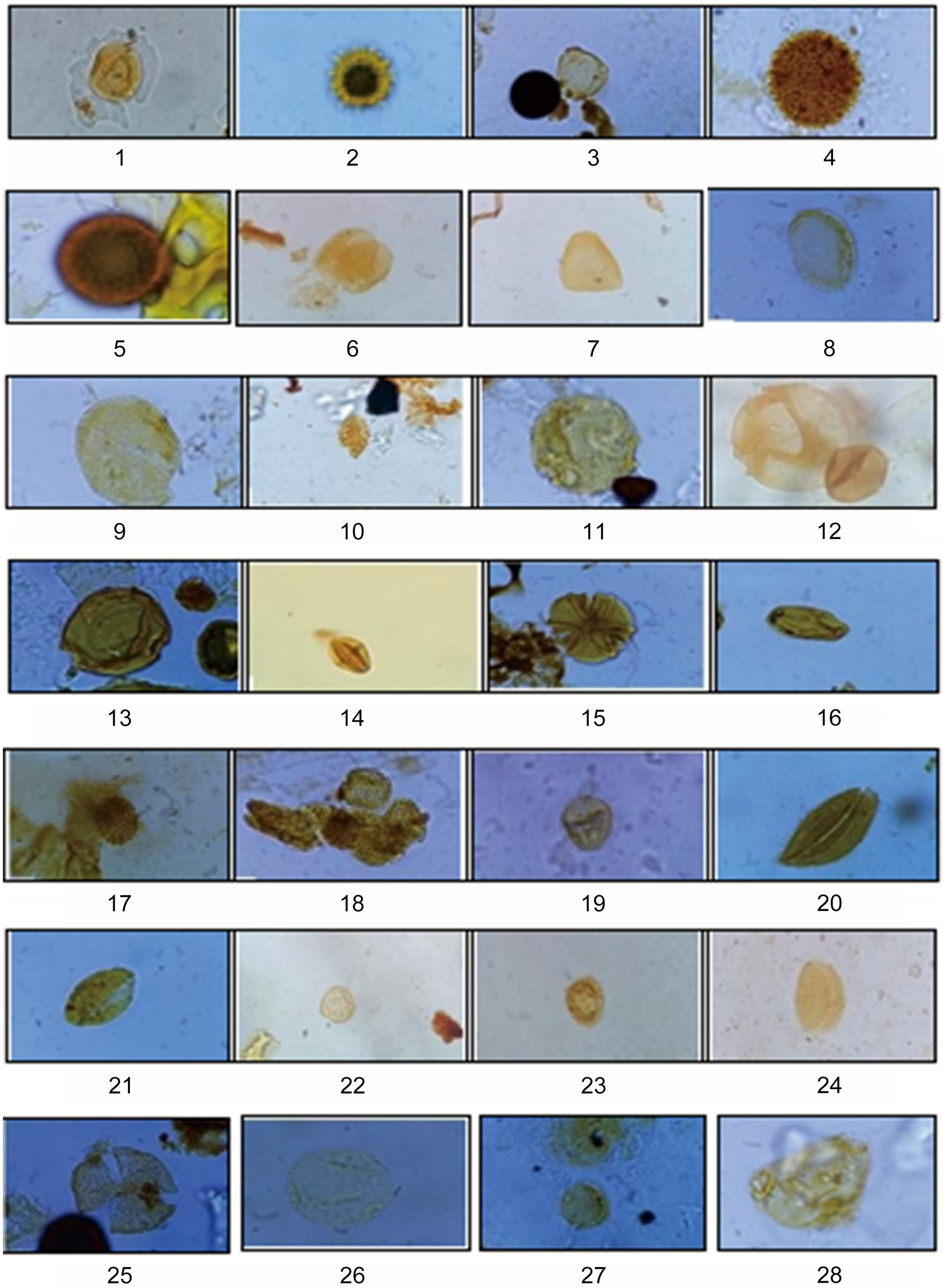


Figure 24. Freshwater Swamp. Palinomorph Fossil. 1. *Retritricolporites equatoralis* (1000×); 2. *Compositae* (400×); 3. *Casuarina spp. (Haloragacidites harisii)* (1000×); 4. *Croton (Euphorbiaceae)* (1000×); 5. *Chenopodiaceae* (1000×); 6. *Dicolpopollis malesianus* (1000×); 7. *Dicolpopollis kawalaensis* (1000×); 8. *Dicolpopollis* (fine ret.) (1000×); 9. *Eugessona insignis* (1000×); 10. *Gemmaticolpites pilatus* (1000×); 11. *Lanagiopollenites emergiantus* (1000×); 12. *Lanagiopollenites spp.* (1000×); 13. *Lakiapollis ovatus* (1000×); 14. *Lithocarpus spp* (1000X); 15. *Margocolporites vanwijhei* (1000×); 16. *Melanorrhoea type* (1000×); 17. *Malvacipollis diversus* (1000X); 18. *Myristica type* (1000×); 19. *Monoporites annulatus* (1000×); 20. *Palmaepollenites kutchensis* (1000×); 21. *Palmaepollenites spp.* (1000×); 22. *Pandanus sp.* (1000×); 23. *Paravuripollis mulleri* (1000×); 24. *Quilonipollenites spp.* (1000×); 25. *Shorea type* (1000×); 26. *Schoutenia sp.* (1000×); 27. *Stemonurus* (1000×); 28. *Pometia spp.* (1000×).

Figure 25. Freshwater Algae Fossil: 1. Bosedinia type (1000×), 2. *Concentricystes circula* (1000×), 3. Pediastrum (1000×).

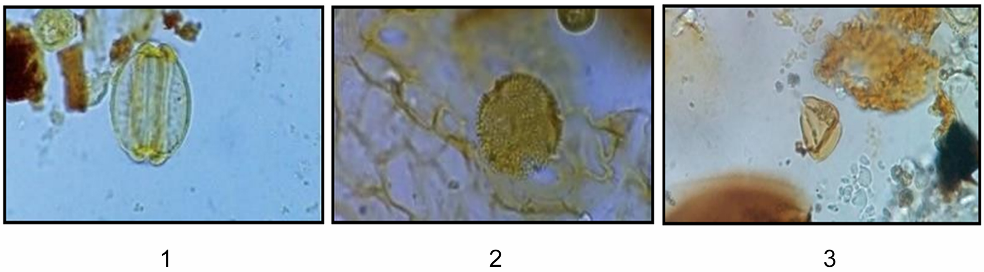


Figure 26. Riparian Palinomorph Fossil: 1. *Marginipollis concinnus* (1000×), 2. Canthiumidites (1000×), 3. Myrtaceidites (1000×).

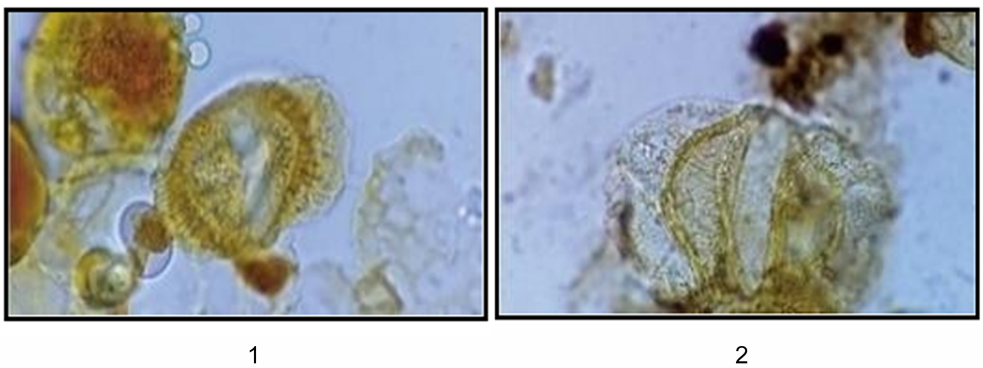


Figure 27. Mountain/Montana Palinomorph Fossil: 1. *Podocarpidites spp* (1000×), 2. *Pinuspollenites spp* (1000×).

10. Discussion

Analysis of rock petrology/petrography, sedimentology and palinology of rocks in the Lubuk Lawas and Lubuk Bernai stratigraphic paths shown in Table 1 shows that rock units that develop from old to young are quartz sandstone units, conglomerate units and gravel sandstone units. Based on the explanation of silicified coal regarding the characteristics and genesis associated with the roof sedimentary rock, it is important to conduct research on the role of the roof sedimentary rock composition on the genesis of silicified coal. The roof sedimentary rock layer with carbonaceous claystone lithology must be carried out with an X-ray diffraction (XRD) clay oriented analysis to identify the clay mineral composition which influences the formation of silicified coal.

Table 1. Palinofacies and lithofacies of Lubuk Lawas track (X = 270,600, Y = 9,876,060 − X = 270,950, Y = 9,875,460) and Lubuk Bernai (X = 270,500, Y = 9,873,125 − X = 270,700, Y = 9,872,325).

No	Palynostratigraphy	Palynofacies	Litofacies	Units
5	Middle Miocene	LDP d-DF	*Channel, gravel sand braided river*	Gravel sandstone
4	Early Miocene			
3	Oligocene	AP	*Alluvial fans system*	Gravel sandstone
2	Oligocene	AP-UDP-LDPp-DF	*Alluvial fans system with gravity flow river, gravel sand braided river*	Conglomerate
1	Oligocene	LDPp-DF	*Ephemeral sand bed braided river*	Quartz sandstone

11. Palynostratigraphy

The quartz sandstone unit is dominated by quartz sandstone with thin inserts of conglomerate, claystone, black claystone and at the top there is an insert of grayish white siltstone. The presence of silica cement which glues the rock constituent grains indicates that the rock was deposited in a non-marine environment. In the quartz sandstone unit based on the presence of pollen index fossil species analyzed in the black claystone samples, namely *Meyeripollis naharkotensis* and *Florschuetzia trilobata*, *palinostratigraphically*, the sedimentary age is Oligocene.

In the younger sequences, conglomerate dominance was deposited with the insertion of claystone, volcanic sandstone and breccia. Gradually this unit is dominated by alternating conglomerate, volcanic sandstone and gravel sandstone with fragments in the form of quartz with insertions of epiclastic tuff, carbonated sandstone and local claystone. Palinostratigraphically, the age of the conglomerate unit can be determined based on the presence of the species *Meyeripollis naharkotensis* and *Florschuetzia trilobata* which indicates the age of the sediment is Oligocene.

In the gravel sandstone unit, there are 3 palinostratigraphic zones based on the presence of marker species, namely:

1) *Meyeripollis naharkotensis* and *Florschuetzia trilobata* zones showing Oligocene age in quartz sandstone, conglomerate and gravel sandstone units.

2) *Florschuetzia trilobata* zone showing the lower Early Miocene age on the lower gravel sandstone.

3) *The Florschutzia meridionalis* zone which shows the age of the sediment is Middle Miocene. The presence of the marker species Cicatricosisporites dorogensis found was considered a rework of older sediments that were transported and then re-deposited.

Thus, the Palinostratigraphy of Bukit Tigapuluh, Jambi Subbasin, from old to young, are Oligocene, Early Miocene and Middle Miocene, respectively.

12. Paleoenvironment

In the quartz sandstone unit, the sedimentary structures that develop are ripple marks, parallel bedding, scour, massive and imbrication. In the unit, there are 7 types of facies Gmg, Sr, Sl, Sm, Ss, Sh and Fsm and 3 architectural elements in the form of channel (CH), lateral accretion (LA), sand bedform (SB) and floodplain (FF). In this unit, *Foraminifera test lining*, Indeterminated *Dinoflagellate cysts, Spiniferites ramosus, Operculodinium centrocarpum* and *Operculodinium spp*. were present, although in small to abundant quantities. Other environmental markers of mangrove/backmangrove pollen were also present. The influence of sediment input from land can be seen in the presence of pollen from the riparian group of taxa, peat swamp taxa and freshwater swamp pollen groups. The bisaccate pollen group which is characteristic of the mountains, which were also present, were *Pinuspollenites spp*. and freshwater spores of *Magnastriatites howardii*. Analysis of the lithology with the presence of silica cement, biofacies that control the diversity of biota and the presence of various lithofacies indicates that the quartz sandstone unit was deposited in a distal Lower Deltaic Plain environment that develops in a continuous Delta Front direction. The abundance of % Arboreal Pollen value is 74.07% and Non Arboreal Pollen percentage is 29.63% which gives an overview of the depositional environment which tends to be basinward and architectural elements in the form of channel (CH), lateral accretion (LA), sand bedform (SB). and floodplain (FF), indicating that the rock units were deposited in an ephemeral sand bed meandering river environment.

The conglomerate unit has a massive sedimentary structure, scouring, graded bedding and lithofacies Gmm, Gmg, and Gcm. Monomic breccia has a supported matrix, quartzite fragments are found, with a plagioclase matrix, quartz, massive sedimentary structures and scouring and Gmg lithofacies are present with architectural elements of SG (sedimentary gravity flow). While volcanic sandstones with massive structures, cross bedding, and scouring, sometimes there are traces of hematization, present as Sm, Ss, and Sh lithofacies.

Gradually upwards, the unit is dominated by alternating conglomerates, volcanic sandstones and gravel sandstones with fragments of quartz with insertions of epiclastic tuff, carbonaceous sandstone and local claystone.

Gravel sandstone with matrix supported, found quartz fragments, plagioclase matrix, lithic, silica cement, massive sedimentary structure, scouring, cross bedding, imbrication, architectural elements SB and GB. Tuff is present as an insert with a massive parallel lamination structure, and architectural elements of Fl. Carbonated volcanic sandstone with flaser structure.

In this unit there are freshwater swamp taxa such as *Melanorrhoea type* and *Dicolpopollis sp.* (fine ret.). The small amount of pollen found in the sediments is most likely related to the high energy of deposition (distributary channel) so that only a small amount of pollen was deposited and fossilized. Also present were pollen from other peat swamp taxa groups such as *Elaeocarpus spp., Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp*. and *Lugopollis*. The influence of sedimentation from land is also seen by the presence of freshwater swamp taxa such as *Calophyllum type, Dicolpopollis maleianus, Dicolpopollis* *sp*. (fine ret.), *Eugeissona insignis, Margocolporites vanwijhei, Palmaepollenites kutchensis, Palmaepollenites spp*. and the presence of freshwater algae *Concentricystes circula* which gives an idea of the existence of stagnant waters.

The presence of freshwater algae *Concentricystes circula* which gives an idea of the existence of stagnant waters. The presence of very abundant taxa from *Myrtaceidites* which is a group of plant taxa that usually live on the banks of rivers (riparian), the presence of pollen whose environment is more inland such as the peat swamp taxa group.

The interpretation of the environmental analysis of the conglomerate unit deposition is Alluvial Plain. At higher elevations, conglomerate units were deposited in the Upper Deltaic Plain based on the presence of assemblages of pollen that characterizes the backmangrove environment such as Acanthus type and riparian species such as *Marginipollis concinnus*, the absence of assemblages of pollen that characterizes the mangrove/backmangrove environment, the presence of pollen from peat swamp and pollen fossils. of freshwater swamp taxa. At a deeper level, the environment shifted toward a proximal Upper Deltaic Plain-Lower Deltaic transition based on the abundance of *Zonocostites ramonae* and pollen and spore assemblages that characterize other mangrove environments. Pollen from riparian taxa such as *Marginipollis concinnus* and *Myrtaceidites*, freshwater swamp taxa and abundant peat swamp taxa also began to develop.

There was a continuous deepening of the environment, namely the Lower Deltaic Plain distal-Delta Front based on the presence of Foraminifera test lining, Indeterminated *Dinoflagellate cysts*, *Operculodinium centrocarpum* and *Operculodinium spp*. although in very small to moderate amounts as well as other environmental markers of mangrove/backmangrove pollen.

The influence of sediment input from the mainland can be seen in the presence of pollen from the riparian group of taxa, the peat swamp group of taxa. Presence of pollen characteristic of freshwater swamp.

At the top of the unit it ends with the occurrence of siltation of the environment as Alluvial Plain based on the very abundance of *Myrtaceidites* from the riparian taxa group and the very abundance of *Calophyllum type* and *Malvacipollis diversus* which are freshwater swamp taxa and the presence of pollen whose environment is more inland. peat and freshwater swamp taxa groups.

The interpretation of palinofacies, cement binding between the grains of rock constituents and supported by the abundance of % Arboreal Pollen values of 57.89% - 80.65% and % Non Arboreal Pollen of 11.96% - 42.11% which gives an overview of a large forest area so that The Alluvial Plain environment is found to develop towards a greater depth, namely the Lower Deltaic Plain distal to the Delta Front.

Variations in changes in depositional environment in rock units based on lithofacies and architectural elements interpreted that this unit was deposited in an alluvial fan system environment with gravity flow rivers and woven rivers with gravel sandstone grains.

Alternating sequences of gravel sandstone, volcanic sandstone and conglomerate with insertions of epiclastic tuff, claystone, carbonaceous sandstone, tuffaceous siltstone, and coal. Gravel sandstone, poorly sorted, clast supported, quartz fragment composition, lithic and tuff matrix, silica cement. Conglomerate, poorly sorted, packed closed, clast supported, has a composition of quartz and lithic fragments with silica cement, sedimentary structure in the form of massive, scouring and gradded bedding, present as lithofacies Gmm, Gmg, and Gcm.

The conglomerate in this rock unit differs from the conglomerate unit in that the grains are predominantly clast supported. In volcanic sandstone inserts, the structures commonly found are massive, cross bedding, parallel stratification and scouring, sometimes there are traces of hematization, present as Sm, Ss, and Sh lithofacies, smoothing upwards. The presence of carbonaceous volcanic sandstone is brownish gray with coal lenses in it, the structure that develops is a flaser.

Based on the collection of architectural elements found in the gravel sandstone unit, it is interpreted that this unit was deposited in a channel environment in a woven river system with gravel sandstone deposits.

The analysis of palinofacies on the sandstone and gravel units continues in the same depositional environment as the conglomerate unit, namely the Alluvial Plain based on the presence of pollen whose environment is more inland such as *Marginipollis concinnus, Myrtaceidites* (riparian). This can also be seen from the peat swamp taxa group and the freshwater swamp taxa group. The presence of freshwater algae *Concentricystes circula* provides an overview of the depositional environment that is inundated by fresh water.

Increasingly towards younger, the depositional environment transitions to the Alluvial Plain-Upper Deltaic Plain based on the presence of pollen that characterizes the backmangrove environment *Discoidites borneensis* whose depositional environment is more landward than the delta.

The influence of sediment input from land is very large, seen in the presence of pollen from riparian group taxa such as *Marginipollis concinnus* and *Myrtaceidites sp.* very abundant. Peat swamp taxa group. Freshwater swamp marker pollen is also present as are freshwater spores of *Magnastriatites howardii*.

At the top of the environmental sandstone unit, the Lower Deltaic Plain distal-Delta Front develops based on the abundance of pollen that characterizes the mangrove/backmangrove environment. The influence of the marine environment was recorded by the presence of Foraminifera test lining and Indeterminated Dinoflagellate cysts.

The depositional environment further developed in a basinward direction, as seen in the presence of pollen from the riparian group of taxa and the peat swamp group of taxa. Freshwater swamp pollen is also present. The bisaccate pollen group which is a feature of the mountains present includes *Pinuspollenites spp*. and *Podocarpidites spp*. and freshwater spores of *Magnastriatites howardii*.

13. Paleoclimate and Paleoecology

Quartz sandstone unit initiates the depositional sequence with a value of % Arboreal Pollen of 74.07% and a percentage of Non Arboreal Pollen of 29.63% which provides an overview of the depositional environment which tends to be basinward but large forest area is formed with a hot and wet climate. The dominance of the AP component from the mangrove/backmangrove group *Zonocostites ramonae*, *Lumnitzera* and trees that live in peat swamp and freshwater environments such as *Elaeocarpus spp*. and *Calophyllum type*.

The next sequence at the bottom of the conglomerate unit, the ratio of the AP/NAP percentage is very large with Arboreal Pollen reaching 57.89% - 93.33% and the NAP percentage of 11.96% - 42.11% giving an overview of the environment in the form of land and forest area. large with water swamp forest with the largest component of *Calophyllum type*. Hot and wet climate that supports the expansion of forest areas with an abundance of forest-forming pollen.

In the middle part of the conglomerate rock unit, there was a decrease in the percentage of AP by 42.11% and NAP by 57.8%, where there was a decrease in forest-forming pollen and the development of herbaceous plants as an indicator of forest loss. This condition may be caused by climate change which is becoming warmer/hotter (wet climate). The largest constituent components of AP were from the pollen of peat swamp taxa *Cephalomappa type* and *Ctenolophon parvifolius* as well as from the mangrove pollen group *Zonocostites ramonae (Rhizoporaceae)* and *Acanthus type*. The conglomerate unit ends with a description of the depositional environment that tends to be basinward with large forest area, hot and wet climate and is dominated by the AP component of the mangrove, backmangrove *Zonocostites ramonae* group and trees that live in the peat swamp environment of *Elaeocarpus spp*. and the dominance by *Myrtaceidites (riparian)*, *Calophyllum type* and *Malvacipollis diversus* (fresh water swamp). The percentage value is Arboreal Pollen 76.35% - 80.65% and Non Arboreal Pollen percentage is 19.35% - 23.65%.

In the period of deposition of gravel sandstone units, the % Arboreal Pollen value is 50.00% - 91.49% and the Non Arboreal Pollen percentage is 7.14% - 23.33% giving an environmental picture that is inland (basinward) with forest expansion. large, hot and wet climate represented by *Austrobuxus nitidus*, *Calophyllum type* and *Malvacipollis diversus* (freshwater swamp), riparian taxa *Marginipollis concinnus* and *Myrtaceidites sp*., trees that live in peat swamp environment (*Elaeocarpus spp*.), and mangrove groups /backmangrove *Zonocostites ramonae, Florschutzia levipoli, Florschutzia meridionalis*.

14. Novelty

This study found a novelty that had never been done before and found by previous researchers, that is, determining the age of land deposits from rock units of the Lemat Formation based on palinological data and validation of U-Pb zircon detritals. The determination of the palinostratigraphy and depositional environment has also been determined based on the palinological data.

15. Conclusion

Quartz sandstone unit, Oligocene age. The results of the interpretation of the palinological analysis show that the unit was deposited in a distal Lower Deltaic Plain environment that develops continuously towards the Delta Front, while the sedimentological and stratigraphic analysis supports this interpretation, namely the ephemeral sand bed meandering river environment. Paleoclimate and ancient ecology provide an environmental interpretation that tends to be basinward with large forest areas formed in hot and wet climates.

The conglomerate unit showing the age of the sediment is Oligocene. The interpretation of the palinofacies analysis of units deposited in the Alluvial Plain environment. In the middle, the unit develops towards the Upper Deltaic Plain environment which then changes to a transitional direction, namely the Upper Deltaic Plain-Lower Deltaic proximal. Continuous environmental deepening continues in the Lower Deltaic Plain distal-Delta Front. At the top of the unit, it ends with the occurrence of environmental siltation as Alluvial Plain. Based on the lithofacies and architectural elements, the unit was deposited in an alluvial fan system environment with gravity flow rivers and woven rivers with gravel sandstone grains.

At the beginning of deposition, ecology provides an environmental description in the form of land and large forest area with water swamp forest and a hot and wet climate that supports the expansion of forest areas with an abundance of forest-forming pollen. The next phase, there is a decrease in the percentage of AP/NAP where there is a decrease in forest-forming pollen and the development of herbaceous plants as a sign of forest loss as a result of climate change which is becoming warmer/warmer (wet climate). At the end of unit deposition, the environment tends to be basin ward with large forest areas, hot and wet climate.

The period of gravel sandstone units was deposited during the Oligocene to Middle Miocene. The results of sedimentological and stratigraphic analysis, the unit was deposited in a channel environment in a woven river system with gravel sandstone deposits based on the Miall classification (1985). Palinofacies interpretation provides an overview of the Alluvial Plain depositional environment at the bottom of the unit, while getting younger, the depositional environment transitions to Alluvial Plain-Upper Deltaic Plain. At the top, the gravel sandstone unit was deposited in the Lower Deltaic Plain distal-Delta Front environment. Climate and ecology that control unit deposition show a basin ward environment with large forest expansion, hot and wet climate.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Bakosurtanal (2008). *Peta Provinsi Jambi, Direktorat Pekerjaan Umum, Republik Indonesia.*

Barber, A. J., Crow, M. J., & dan Milsom, J. S. (2005). *Sumatra: Geology, Resources and Tectonic Evolution.* The Geological Society.

Clements, B., & dan Hall, R. (2011). Subsidence and Uplift by Slab-Related Mantle Dynamics: A Driving Mechanism for the Late Cretaceous and Cenozoic Evolution of Continental SE Asia? (Vol. 355, pp. 37-51). Geological Society, London, Special Publications. https://doi.org/10.1144/SP355.3

Hall, R. (2009). Hydrocarbon Basins in SE Asia: Understanding Why They Are There. *Petroleum Geoscience, 15,* 131-146. https://doi.org/10.1144/1354-079309-830

Hall, R. (2014). The Origin of Sundaland. In *Proceedings of Sundaland Resources Annual Convention*.

Hall, R., & Morley, C. K. (2004). Sundaland Basins (pp. 55-85). In P. Clift, P. Wang, W. Kuhnt, & D. E. Hayes (Eds.), *Continent-Ocean Interactions within the East Asian Marginal Seas*. Geophysical Monograph, 149. American Geophysical Union. https://doi.org/10.1029/149GM04

Leisman, G., & Retallack, G. (2001). Paleobotany. In *Encyclopedia of Life Sciences*.

Miall, A. D. (1985). Architectural-Element Analysis: A New Method of Facies Analysis Applied to Fluvial Deposits. *Earth-Science Reviews, 22,* 261-308. https://doi.org/10.1016/0012-8252(85)90001-7

Postma, G. (1990). Depositional Architecture and Facies of River and Fan Deltas: A Synthesis (Vol. 10, pp. 13-28.). In A. Colella, & D. B. Prior (Eds.), *Coarse-Grained Deltas*, Blackwell Publishing Ltd. https://doi.org/10.1002/9781444303858.ch2

Appendix

Quarzt Sandstone Facies Description

The sandstone-quartz facies are minor deposits found in contact with bedrock. Sandstones are of medium to fine size with clay cement in layers of centimeters to meters.

Based on the facies association, five types of architectural elements were found in the sandstone-quartz deposits, namely: HO (Scour Hollows) elements resembling a small channel, with a thickness of 6 meters in profile and this element is a channel with a spade shape. The elements are composed of Ss, SI, Gmg, and Gt lithofacies with sedimentary structures in the form of through cross bedding, planar cross bedding, scour, massive, and graded bedding. In the Channel (CH) element, Gmg, Sr, Sl, and Ss facies are found. In the sandstone-quartz deposit, channel elements are found (**Figure 5**), namely at the bottom and the top of the deposit. The channel element is a combination of several architectural elements, showing a smooth upward pattern and the bottom part in the form of scouring or grinding. Sand bedform (SB) is present in the middle and top of this facies, namely in the form of Sm, Sr, and Sh facies. In the Floodplain (FF) element, the Fsm facies is found, in the form of massive siltstone in quartz sandstone deposits. This element characterizes deposition in lagging rivers or back marshes. Lateral accretion (LA) is present with Sr, Sm, Ss facies in the form of massive sandstone-quartz, quartz sandstone with wavy layered structure in sandstone-quartz deposits.

Conglomeratic Facies Description

Based on the results of the analysis on the conglomerate facies, the Gp, Gcm, Gmg, Gh, Sm, Ss, and St. facies were found. Elements of Sediment Gravity Flows (SG) are narrow, forming elongated lobes. This type can be associated with GB and SB elements. Grading and Inverse grading occur frequently, gravel criss-cross with a low angle can indicate the process of moving from the debris flow to the transport mechanism of the traction system. In the Channel (CH) element, Gmg, Sp, Sl, and Ss facies are found. The channel element is a combination of several architectural elements, showing a smooth upward pattern and the bottom part in the form of scouring or grinding. Spade-shaped channels are found in Scour Hollows (HO) elements with Gt, Gmg, Sl, Ss facies in conglomerate deposits. The HO element resembles a small channel, Campbell (1976), with a depth of 20 m and a width of about 250 m, with a curved bottom boundary, concave upwards. In the Sandy bedform (SB) elements, Gcm, Sr, and Sm facies are found. Architectural elements of Sandy Bedforms are usually sandstone layers with a lens geometry, layered, wedged. The structures found in the facies are massive and scour. The presence of this Gcm Facies is interpreted as being deposited on a high energy debris flow rich in clastics. The association of gravel bedform (GB) facies is dominated by Gcm facies. In addition, the GB facies association also consists of Gp, Gh, Sm and Sh facies. The Gcm facies, which dominates this interval, are interpreted as sediments with low energy debris flows. Seeing the association of GB facies which is composed of sand-gravel grain size material, this facies was deposited through a bedload mechanism and interpreted as dune elements in river flows. In the river flow, there is also a cross structure that indicates dune migration.

Gravel Sandstone Facies Description

In this Channel (CH) element, Gmg, Sp, Sl, and Ss facies are found. The channel element is a combination of several architectural elements, showing a smooth upward pattern and the bottom part in the form of scouring or grinding. The shallower the depth of the channel, the wider the channel and vice versa. Sandy bedform (SB), this element is found in St, Sm, Sr, and Sh facies. Architectural elements of sandy bedforms are usually sandstone layers with a lens geometry, layered, wedged. The structures found in the facies are massive, ripple marks, and wavy bedding. The association of gravel bedform (GB) facies is dominated by Gcm facies. In addition, the GB facies association also consists of Gp and Sh facies. The thickness of the SB facies association reaches 20 m. The Gcm facies that dominates this interval are interpreted to be deposited with a low energy debris flow. The GB facies association, composed of sand-gravel grain size material, was deposited through a bedload mechanism. Therefore, this interval is interpreted as a dune element in the river flow. What strengthens the notion that this material is a dune element in the river flow is the existence of an ambiguous cross structure that indicates dune migration. Architectural elements of floodplain fines (FF) also developed and are part of the overbank deposit of the river body. Consists of Fsm and C with fine sizes which are interpreted as floodplain areas. This indication is further strengthened by the discovery of carbon spouts in the lithology of very fine sand and clay

Palynofacies of Lubuk Lawas

Quarzt Sandstone Facies Description

Palinofacies in rock units is determined based on the pollen and spore fossils contained in the rock. The presence of *Foraminifera test lining*, Indeterminated *Dinoflagellate cysts, Spiniferites ramosus, Operculodinium centrocarpum* and *Operculodinium spp.*, although in small to abundant quantities indicates a Lower Deltaic Plain distal-Delta Front environment. Other environmental markers of mangrove/backmangrove pollen include *Zonocostites ramonae*, *Avicennia type, Oncosperma, Acrosthicum aureum, Acanthus type, Aegialitis type, Discoidites borneensis, Lumnitzera* and *Spinizonocolpites echinatus*. The influence of sediment input from land is seen in the presence of pollen from riparian group taxa such as *Canthiumidites, Myrtaceidites sp.* a collection of taxa from the peat swamp group, such as *Elaeocarpus spp., Cephalomappa type, Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp., Striatricolpites catatumbus* and *Lugopollis.* The present markers of freshwater swamp pollen include *Casuarina sp., Calophyllum type, Gemmatricolpites pilatus, Monoporites* *annulatus, Dicolpopollis malesianus, Dicolpopollis sp. (fine ret.), Eugeissona insignis, Florschuetzia trilobata, Lakiapollis ovatus, Lanagiopollis emarginatus, Lanagiopollis sp., Malvacipollis diversus, Magnatricolpites sp., Margocolporites vanwijhei, Meyeripollis naharkotensis mulleri* and *Schoutelleri type*. The bisaccate pollen group which is a feature of the mountains present includes *Pinuspollenites spp*. and freshwater spores of *Magnastriatites howardii*.

From the results of the analysis, the value of % Arboreal Pollen is 74.07% and the percentage of Non Arboreal Pollen is 29.63%. This illustrates that although the environment tends to be basinward, the forest area that is formed is large with a hot and wet climate dominated by the AP component of the mangrove group. Backmangrove *Zonocostites ramonae, Lumnitzera* and trees that live in peat swamp and freshwater environments such as *Elaeocarpus spp*. and *Calophyllum type*.

Conglomeratic Facies Description

The pollen and spore fossils found in this unit are freshwater swamp taxa such as *Melanorrhoea type* and *Dicolpopollis sp. (fine ret.).* The small amount of pollen found in the sediments is most likely related to the high energy of deposition (distributary channel) so that only a small amount of pollen was deposited and fossilized. Also present were pollen from other peat swamp taxa groups such as *Elaeocarpus spp., Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp*. and *Lugopollis*. The influence of sedimentation from land is also seen by the presence of freshwater swamp taxa such as *Calophyllum type, Dicolpopollis maleianus, Dicolpopollis sp. (fine ret.), Eugeissona insignis, Margocolporites vanwijhei, Palmaepollenites kutchensis, Palmaepollenites spp*. and the presence of freshwater algae *Concentricystes circula* which gives an idea of the existence of stagnant waters. Environmental analysis indicates Alluvial Plain condition.

The comparison of the percentage of AP/NAP is very large with Arboreal Pollen reaching 93.33% and the percentage of NAP of 20% providing an overview of the environment in the form of land and water swamp forest with the largest component of *Calophyllum type*.

Gravel Sandstone Facies Description

The presence of pollen whose environment is more inland such as *Myrtaceidites (riparian)* is also seen in groups of peat swamp taxa such as *Elaeocarpus spp., Lugopollis* and groups of freshwater swamp taxa such as *Casuarina sp., Calophyllum type Dicolpopollis sp. (fine ret.), Florschuetzia trilobata, Lanagiopollis sp., Meyeripollis naharkotensis, Myristica* and *Quillopollenites.* Environmental analysis on the basis of developing palinofacies shows the environmental conditions of the Alluvial Plain. From the results of the analysis, the % Arboreal Pollen value of 68.75% and the Non Arboreal Pollen percentage of 12.5% provide an overview of a large forest area with a hot and wet climate represented by *Calophyllum type* and *Malvacipollis diversus* (fresh water swamp).

Increasingly younger in the same environment, the presence of pollen whose environment is more inland, such as the riparian group *Marginipollis concinnus*, peat swamp taxa groups such as *Elaeocarpus spp., Sapotaceoidaepollenites sp*. and freshwater swamp taxa groups such as *Dicolpopollis sp*. (fine ret.), *Florschuetzia trilobata, Lanagiopollis emarginatus, Lanagiopollis sp., Magnatricolpites sp., Meyeripollis naharkotensis, Palmaepollenites kutchensis* and *Palmaepollenites spp*. The presence of freshwater algae *Concentricystes circula* provides an overview of the depositional environment that is inundated by fresh water. The value of % Arboreal Pollen of 50.00% and % of Non Arboreal Pollen of 23.33% gives an overview of large forest area with hot and wet climate that supports the expansion of forest area.

The development of the depositional environment is more inward, namely the Alluvial Plain-Upper Deltaic Plain based on the presence of pollen that characterizes the back mangrove environment Discoidites borneensis where the depositional environment is more landward than the delta. The influence of sediment input from land is very large seen in the presence of pollen from riparian group taxa such as *Marginipollis concinnus* and *Myrtaceidites sp*. very abundant. A collection of peat swamp taxa such as *Austrobuxus nitidus Elaeocarpus spp., Cephalomappa type, Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp.* and *Striatricolpites catatumbus*.

Pollen that characterizes freshwater swamps that are present include *Casuarina sp., Calophyllum type, Dicolpopollis sp. (fine ret.), Eugeissona insignis, Gemmatricolpites pilatus, Lanagiopollis emarginatus, Lanagiopollis sp., Margocolporites vanwijhei, Meyeripollis naharkotensis, Monoporites annulatus, Palmaepollenites kutchensis, Palmaepollenites spp., Schoutenia type* and fresh water spora *Magnastriatites howardii*.

The results of the analysis of the value of % Arboreal Pollen of 81.63% and % of Non Arboreal Pollen of 7.14% provide an overview of the environment towards the mainland with large forest expansion reflecting a hot and wet climate dominated by the riparian taxa *Marginipollis concinnus* and *Myrtaceidites sp*., a tree that lives in peat swamp *(Elaeocarpus spp.)* and freshwater swamps such as *Calophyllum type*.

Palynofacies of Lubuk Bernai

Conglomeratic Facies Description

The most abundant taxa are Myrtaceidites which is a group of plant taxa that usually live on the banks of rivers (riparian), the presence of pollen whose environment is more inland such as peat swamp taxa groups such as *Elaeocarpus spp., Sapotaceoidaepollenites sp., Lugopollis* and groups of swamp taxa. fresh water such as *Casuarina sp., Calophyllum type, Dicolpopollis sp. (fine ret.), Florschuetzia trilobata, Malvacipollis diversus, Lithocarpus type, Meyeripollis naharkotensis Palmaepollenites kutchensis* and *Palmaepollenites spp*. Analysis of environmental conditions based on the palinofacies is Alluvial Plain. Analysis of the value of %

Arboreal Pollen of 77.17% and % Non Arboreal Pollen of 11.96% provides an overview of large forest areas with hot and wet climates that support the expansion of forest areas.

In younger sequences, the unit was deposited in the Upper Deltaic Plain environment based on the absence of a collection of pollen that characterizes the mangrove/backmangrove environment. The presence of pollen from peat swamps such as *Cephalomappa type* and *Ctenolophon parvifolius*. Presence of pollen fossils from taxa freshwater swamp such as *Calophyllum type*, *Dicolpopollis malesianus, Monoprites annulatus, Shorea type*, *Pandanus* and *Palmaepollenites spp*.

From the results of the analysis, the value of % Arboreal Pollen is 57.89% and % Non Arboreal Pollen is 42.11%, which means that there is an abundance of forest-forming pollen (increased forest area) which may be caused by climate change that becomes warmer/hotter (wet climate). The largest constituent components of AP are pollen from the peat swamp taxa *Cephalomappa type* and *Ctenolophon parvifolius*.

The change towards the Upper Deltaic Plain-Lower Deltaic proximal is characterized by the abundance of *Zonocostites ramonae* and a collection of pollen and spores that characterize other mangrove environments such as *Oncosperma, Acrosthicum aureum*, *Acanthus type, Aegialitis type, Discoidites borneensis*. Pollen from riparian taxa such as *Marginipollis concinnus* and *Myrtaceidites* and abundant peat swamp taxa include *Cephalomappa typ*e, *Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceidaepollenites and Striatricolpites catatumbus. Freshwater swamp taxa such as Casuarina sp., Calophyllum type, Croton, Dicolpopollis maleianus, Dicolpopollis sp. (fine ret.), Eugeissona insignis, Gemmatricolpites Pilatus, Lakiapollis ovatus, Lanagiopollis emarginatus, Lanagiopollis sp., Magnatricolpites spp., Margocolporites vanwijhei, Monoporites annulatus, Pandanus, Palmaepollenites kutchensis, Sholleris type.*

From the results of the analysis, the value of % Arboreal Pollen is 61.51% and % Non Arboreal Pollen is 30.58%, which means that there is an abundance of forest-forming pollen (increased forest area) which may be caused by climate change that becomes warmer/hotter (wet climate). The largest component of AP is from the mangrove pollen group *Zonocostites ramonae (Rhizoporaceae)*.

This unit terminated in the Lower Deltaic Plain distal-Delta Front depositional environment based on the presence of Foraminifera test lining, Indeterminated *Dinoflagellate cysts, Operculodinium centrocarpum* and *Operculodinium spp*. although in very small to moderate amounts. Polen that characterizes the environment of mangroves/other mangroves, such as *Zonocostites ramonae, Avicennia type* and *Aegialitis type*.

The influence of sediment input from the mainland can be seen in the presence of pollen from the riparian group of taxa *Myrtaceidites sp*., a collection of taxa from the peat swamp group such *as Elaeocarpus spp., Cephalomappa type,* *Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp.* and *Lugopollis*. Pollen that characterize freshwater swamps that are present include *Gemmatricolpites pilatus, Melanorrhoea type, Dicolpopollis malesianus, Dicolpopollis sp. (fine ret.), Eugeissona insignis, Florschuetzia trilobata, Lakiapollis ovatus, Lanagiopollis sp., Malvacipollis diversus, Magnatricolpites sp., Margocolporites vanwijhei, Meyeripollis naharkotensis, Paravuripollis mulleri, Palmaepollenites kutchensis, Shorea type* and *Schoutenia type*. The results of the analysis show that the % Arboreal Pollen value is 80.65% and the Non Arboreal Pollen percentage is 19.35%. Backmangrove *Zonocostites ramonae* and trees living in peat swamp environment *Elaeocarpus spp*.

Gravel Sandstone Facies Description

The depositional environment of this unit is interpreted as a Delta Front based on the presence of markers of marine Foraminifera test lining, Indeterminated *Dinoflagellate cysts* and pollen that characterizes other mangrove/backmangrove environments such as *Zonocostites ramonae, Acrostichum aureum* and *Lumnitzera type* in minor amounts.

The influence of sediment input from the mainland even though the depositional environment is further in the basinward direction can be seen in the presence of pollen from riparian taxa groups such as *Myrtaceidites sp*., peat swamp taxa groups such as *Elaeocarpus spp., Cephalomappa type, Sapotaceoidaepollenites sp., Lugopollis*. Pollen that characterize freshwater swamps that are present include *Calophyllum type, Dicolpopollis sp. (fine ret.), Lanagiopollis sp*. and *Melanoorrhoea type*. The bisaccate pollen group which is a characteristic of the mountains present, among others *Pinuspollenites spp. and Podocarpidites spp*.

The results of the analysis show that the % Arboreal Pollen value is 91.49 % and the % Non Arboreal Pollen is 8.51%. This illustrates that although the depositional environment tends to be basinward, the forest area formed is large with a hot and wet climate dominated by the AP component of the group. mangroves/backmangroves *Zonocostites ramonae* and trees that live in peat swamp *(Elaeocarpus spp*.) and fresh water *(Calophyllum type*) environments.

In the younger sequences, the unit developed in the Lower Deltaic Plain distal-Delta Front environment based on the abundance of pollen that characterizes the mangrove/backmangrove environment such as *Zonocostites ramonae, Avicennia type* and *Oncosperma*. The influence of the marine environment is recorded by the presence of Indeterminated *Dinoflagellate cysts*.

The influence of sediment input from the mainland can be seen in the presence of pollen from the peat swamp group of taxa such as *Elaeocarpus spp., Ctenolophon parvifolius/Retistephanocolpites williamsi, Sapotaceoidaepollenites sp*. Pollen that characterize freshwater swamps that are present include *Casuarina sp., Calophyllum type, Dicolpopollis sp. (fine ret.), Lakiapollis ovatus, Florschuetzia trilobata, Monoporites annulatus, Palmaepollenites kutchensis* and *Palmaepollenites spp*., *Paravuripollis mulleri, Melanorrhoea type* and *Magnatricolpites sp*.

The results of the analysis show the value of % Arboreal Pollen is 88.10% and % Non Arboreal Pollen is 14.29%. peat (*Elaeocarpus spp*.) and fresh water such as *Calophyllum type*.