https://doi.org/10.70882/ab0bda04

SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 26, (5 Special) (2026), 1393 - 1414

Science Forum (Journal of Pure and Applied Sciences)

Journal Homepage: https://atbuscienceforum.com.ng/index.php/jpas

Lithostratigraphy and palynology of the Cretaceous southern Bida Basin in central Nigeria

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Abstract

The Campanian–Maastrichtian succession of the southern Bida Basin traditionally comprises the Lokoja Formation, Patti Formation and Agbaja Ironstone. The distribution and status of the Patti Formation remain disputed, with recent interpretations restricting its diagnostic succession to *Ahoko and* proposing a new name. This study reassesses the framework using field observations of lateral and vertical lithological variation, facies relationships and contacts, supported by palynological analyses of *Jamata and Ahoko*. Shale, siltstone, claystone, sandstone, carbonaceous shale, coal and ironstone occur in the investigated succession; Patti-type lithologies are recognised at *Jamata*, *Ahoko*, Agbaja and along the Bassa axis. The *Jamata and Ahoko assemblages* are assigned to the *Foveotriletes margaritae* and *Milfordia sp.* Assemblage Zones, respectively, and interpreted as Campanian–Maastrichtian. Shared taxa include *Longapertites marginatus*, *Foveotriletes margaritae*, *Milfordia spp.*, *Retidiporites magdalenensis*, *Proteacidites spp.*, *Auriculiidites reticulatus* and *Periretisyncolpites spp.* Terrestrial pollen and spores associated with marine dinoflagellate cysts suggest a coastal, marginal- to shallow-marine system affected by marine incursions and relative sea-level fluctuations. The combined evidence supports retaining the Patti Formation between the Lokoja Formation and Agbaja Ironstone. *Ahoko is* proposed as a reference section, with *Jamata and* Agbaja as supplementary correlation sections. *Jamata and Ahoko are* interpreted as related local expressions and proposed members of the Patti Formation, providing a basis for regional correlation and reconstruction of basin evolution.

Keywords

Southern Bida Basin;
Lithostratigraphy;
Palynology;
Patti Formation;
Jamata;
Ahoko;
Coal;
Shale

EISSN: 3156-5190 (Online)
ISSN: 1119-4618 (Print)
JPAS
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1 Introduction

The Bida Basin, also known as the Middle Niger Basin, lies in central Nigeria (Figure 1). It extends approximately 350 km northwest–southeast from Kontagora to Lokoja, is 75–150 km wide, and spans Niger, Kwara, Nasarawa and Kogi states and the Federal Capital Territory. The basin lies within the Precambrian Basement Complex and has been investigated for its sedimentology, stratigraphy and mineral resources (Zaborski, 1998; Obaje et al., 2004, 2011). Its southern sector contains a Campanian–Maastrichtian succession whose nomenclature and stratigraphic relationships remain debated.

The regional framework was established from successive units distinguished by lithology and supported by sedimentological, palaeontological and geochemical evidence. Early studies described their distribution and relationships; subsequent work examined facies and depositional environments (Adeleye, 1973, 1974; Braide, 1990, 1992a, 1992b; Ojo and Akande, 2003, 2008, 2009; Obaje et al., 2011).

The Patti Formation is well exposed at *Ahoko but* is reportedly poorly developed or absent at Mount Patti and some Agbaja exposures. These differences have prompted questions about its regional definition.

Rahaman et al. (2019) proposed replacing the Patti Formation with the *Ahoko* Formation and revising its position relative to the Agbaja Ironstone. Their interpretation challenges earlier frameworks (Adeleye, 1972, 1974; Ojo and Akande, 2003; Obaje et al., 2011). The central issue is whether the observed differences identify formation boundaries or lateral changes in facies.

Lithostratigraphic units are defined by lithological characteristics and stratigraphic relationships. Individual lithologies may be absent or poorly developed within fluvial, deltaic and marginal-marine successions. Variations in thickness and facies therefore require regional evaluation before a unit is renamed.

This study examines the shale-, siltstone-, claystone- and coal-bearing interval to determine whether it is restricted to *Ahoko or* correlatable across the southern Bida Basin. It also assesses its relationships with the underlying Lokoja Formation and overlying Agbaja Ironstone, particularly at *Jamata and* Agbaja, where the observed succession differs from the proposed *Ahoko framework*.

Field evidence is evaluated alongside the interpretations of Rahaman et al. (2019), Adeleye (1973, 1974), Braide (1990, 1992a, 1992b), Ojo and Akande (2003, 2008, 2009) and Obaje et al. (2011). The study interprets the observed differences as variability within the Patti Formation and proposes *Jamata and Ahoko as* members or local expressions of that unit.

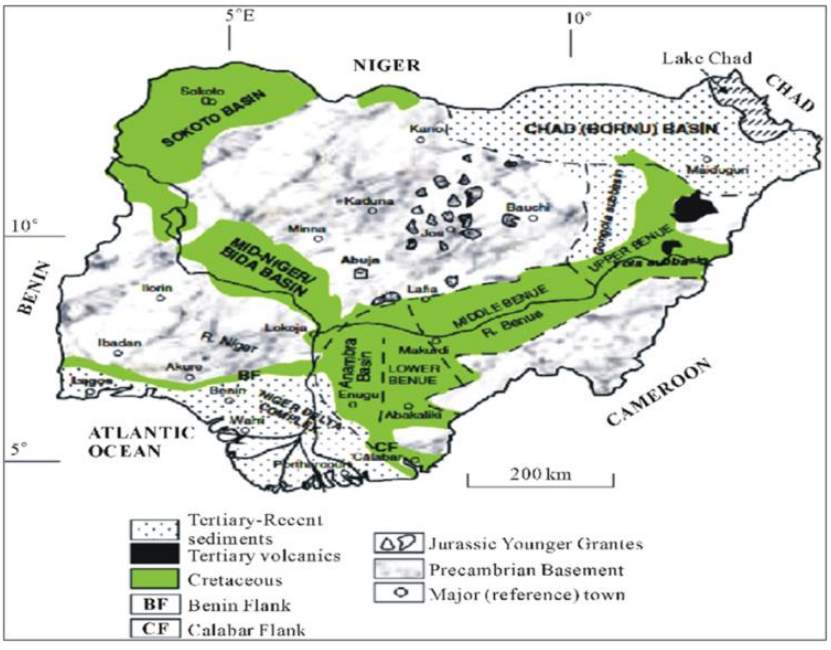


Figure 1. Geological map of Nigeria showing the study area (after Obaje et al., 2004).

2 Geological setting and stratigraphy

The southern Bida Basin forms part of Nigeria's intracratonic inland basin system. It occupies the southeastern sector of the northwest–southeast-trending Middle Niger Basin, which extends from Kontagora to Lokoja and is largely bounded by Precambrian basement. Basement highs and associated structures separate it from adjoining sedimentary basins. Its Upper Cretaceous succession contains sandstone, argillaceous sediments, coal and ironstone.

The conventional southern succession comprises the Lokoja Formation, Patti Formation and Agbaja Ironstone (Adeleye and Dessauvagie, 1972; Obaje et al., 2009; Figure 2).

The basin is reported to lack volcanic rocks, carbonates and Tertiary strata. Its three principal southern units have distinct lithological characteristics.

The framework draws on Adeleye (1973, 1974), Whiteman (1982), Braide (1990, 1992a, 1992b), Idowu and Enu (1992), Ladipo et al. (1994), Ojo and Akande (2003, 2008, 2009, 2020), Akande et al. (2005), Obaje et al. (2011, 2013) and Rahaman et al. (2019). These studies describe the units, their distribution, contacts and depositional history.

Figure 2 compares the southern and northern successions and their approximate ages. It includes the southern Agbaja Ironstone, Patti Formation and Lokoja Sandstone, the northern Batati Ironstone, Edozighi Member and Bida Sandstone, and the Precambrian crystalline basement.

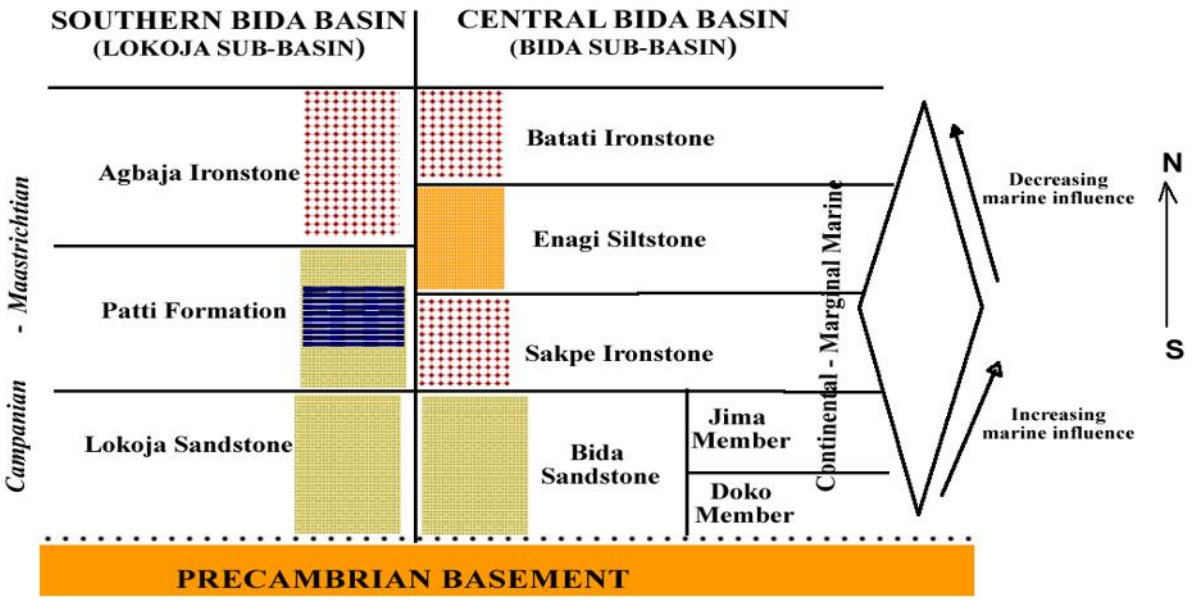


Figure 2. Lithostratigraphic subdivision of the Bida and Lokoja areas of the Bida Basin (after Obaje, 2009).

2.1 Lokoja Formation

The Lokoja Formation rests unconformably on Precambrian basement (Figure 2). Conglomerate and sandstone dominate, with subordinate siltstone and claystone near the top. Conglomerates contain quartz pebbles and cobbles in sandy–muddy matrices and occur as both matrix-supported and clast-supported deposits (Figure 3; Plate I). Sandstones are feldspathic and range from pebbly to medium grained. Trough and planar cross-stratification, local herringbone-like structures, and bioturbation with *Ophiomorpha and Thalassinoides are* recorded. Upward fining from conglomerate and coarse sand to medium sand suggests channel deposition followed by abandonment or changing discharge, consistent with

alluvial and braided-fluvial interpretations (Braide, 1992a; Ojo and Akande, 2003; Akande et al., 2005).

2.2 Patti Formation

In the conventional succession, the Patti Formation overlies the Lokoja Formation and underlies the Agbaja Ironstone (Adeleye and Dessauvagie, 1972; Obaje et al., 2009; Figure 2; Obaje., 2011).

The Patti Formation comprises variable proportions of shale, carbonaceous shale, siltstone, claystone, sandstone and coal. Argillaceous beds are generally grey to dark grey and locally contain plant debris. Siltstones show parallel and wavy lamination; sandstone beds display cross-stratification and bioturbation, indicating variable current conditions.

Its facies represent floodplains, swamps, delta plains, fluvial channels and marginal-marine settings (Braide, 1992b; Ojo and Akande, 2009). Coal records low-energy conditions favourable to plant preservation, whereas ripples and bioturbation indicate changes in currents and substrate conditions. Marine incursions have been reported in the upper Lokoja–Patti succession. Maastrichtian age assignments have used palynological and foraminiferal evidence. Coal and shale have also been identified as potential hydrocarbon source rocks (Jan du Chêne et al., 1978; Mebradu et al., 1986; Akande et al., 2005).

Lithologies used to recognise the Patti Formation occur at several investigated localities, although they were not observed at the Mount Patti summit. The most extensive exposures are at *Jamata*, Agbaja and *Ahoko*, with a particularly thick argillaceous succession at *Ahoko*. Similar beds occur along the Bassa axis and at Abaji, supporting lateral correlation when considered with stratigraphic position (Figures 4, 5a, b, c& d).

2.3 Agbaja Ironstone

The Agbaja Ironstone caps the conventional southern succession above the Patti Formation. It comprises oolitic, pisolitic, concretionary and massive ironstone with subordinate sandstone and claystone.

Its formation has been related to Maastrichtian current activity (Adeleye, 1973, 1974; Ladipo et al., 1994). Its position above the finer-grained Patti succession makes it a useful regional marker (Figures 2 and 6).

3 Materials and methods

3.1 Field investigation and sampling

Reconnaissance examined exposed sections along road cuts, footpaths, riverbanks and other outcrops at Kwaita, Abaji, *Ahoko*, *Jamata*, Agbaja, Lokoja and Bassa. Fifteen sites were examined in detail, and selected traverses were repeated to assess zonation patterns.

Lithology, bed thickness, grain size, colour and sedimentary structures were recorded at each site. Particular attention was given to the vertical distribution and contacts of shale, siltstone, claystone, sandstone, coal and ironstone. Photographs, field sketches and stratigraphic columns documented facies relationships and supported comparisons between sections.

The investigation was primarily descriptive. Correlation combined lithology, stratigraphic position, unit relationships and published sedimentological, palaeontological and geochemical interpretations. No new type section is formally designated; *Ahoko is* proposed as a reference section for regional comparison.

3.2 Palynological preparation and analysis

Palynological samples came from the *Jamata shale*–coal succession (JMT) as JMT1,JMT2, JMT3,JMT4, JMT5, JMT6, JMT7,JMT8, JMT9, JMT10, JMT12 and JMT13 and *Ahoko shale* succession (AH) as AH1, AH2, AH3, AH6, AH7, AH8, AH9 and AH10.

The *Jamata outcrop* was measured and sampled along approximately 2.5 km from *Jamata junction* (Figure 4a c). *Jamata sample* codes progress from the base towards the top. The source records twelve analysed *Jamata samples* and twenty prepared samples overall. Preparation involved hydrofluoric acid (HF) digestion, sieving through a 5 µm mesh, heavy-liquid separation using zinc Bromide ($ZnBr_2$) with a specific gravity of about 2.0 - 2.1 g/cc and mounting residues on glass slides with DPX. Prepared slides were examined under a binocular microscope to identify and point-count pollen, spores, dinoflagellate cysts, microforaminiferal wall linings, algae and fungal spores; selected palynomorphs were

photographed. *Jamata contains* dark-grey, fissile shale and coal, with basal shale succeeded by coal, further shale, moderately hard sandstone and capping ironstone. *Ahoko samples* principally represent dark-grey shale (Figures 4a and 5a&b).

4 Results

Field observations identify the Lokoja Formation, Patti Formation and Agbaja Ironstone within the investigated Campanian–Maastrichtian succession.

4.1 Lokoja Formation

The lowermost unit comprises conglomerate and sandstone with subordinate fine-grained beds (Figure 3a, a–d). Conglomerates include granule- to cobble-sized quartz clasts in clast-supported and matrix-supported deposits. Their bases are erosional, and grain size generally decreases upwards.

Sandstones range from pebbly to medium grained and are locally poorly sorted. Trough cross-bedding is prominent; herringbone-like cross-stratification and bioturbation also occur (Figure 3a, b–d). These features indicate channel and bar facies, with finer, ferruginised sandstone towards the top.

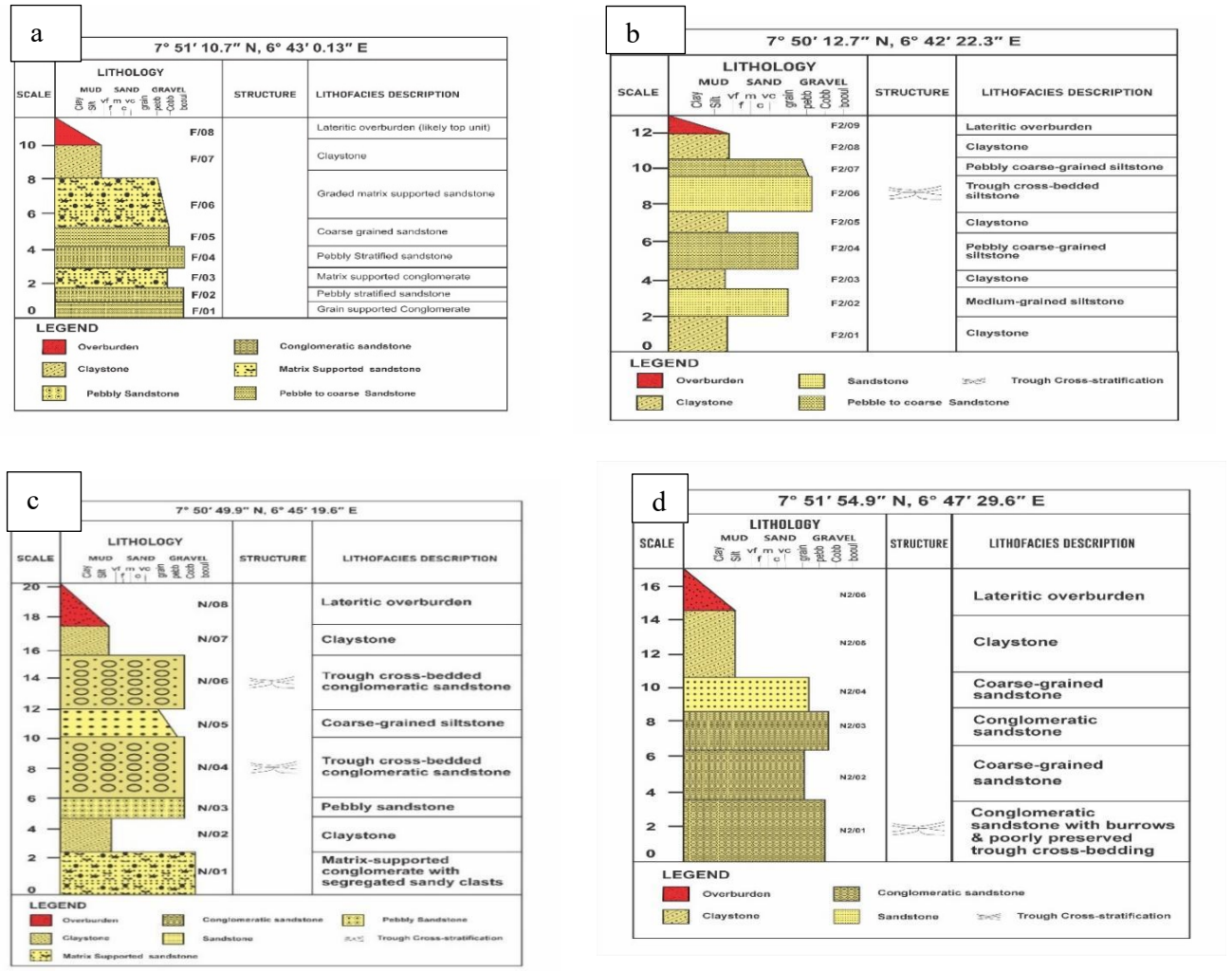


Figure 3a. Lithological sections of the Lokoja Formation exposed in the Lokoja area (a–d).

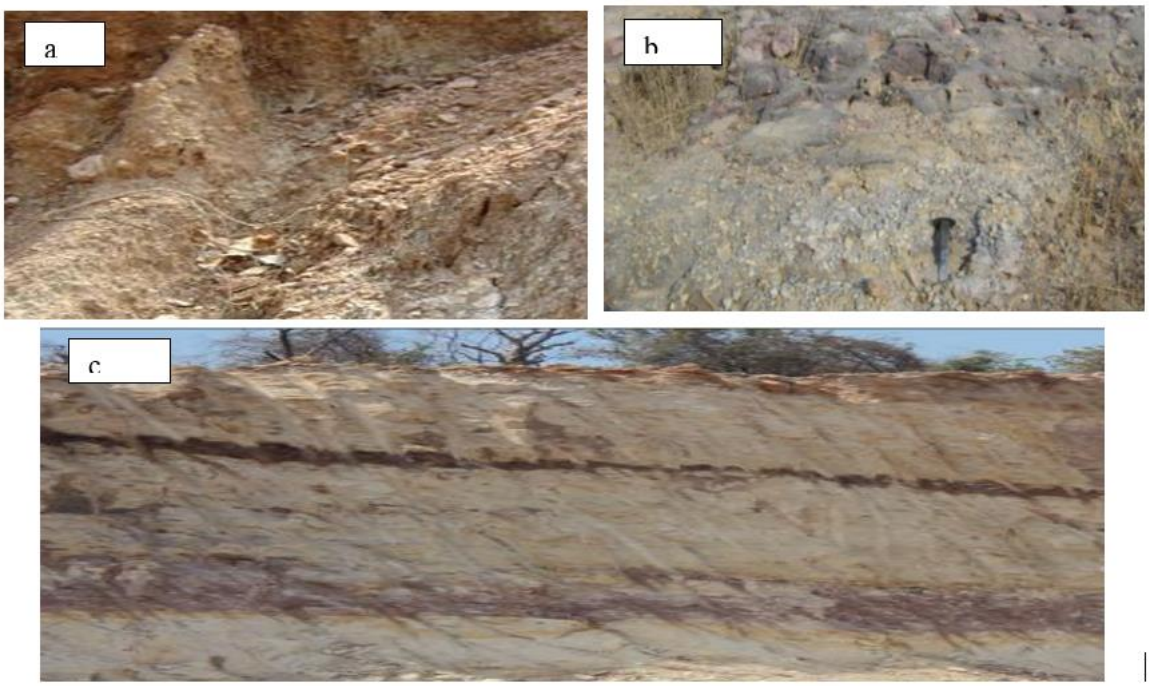


Figure 3b; Matrix supported paraconglomerate at Felele Lokoja (7°51'10.7"N, 6°43'01.3"E) (b); Grain supported quartzose orthoconglomerate facies characterized by rounded clasts at Felele Lokoja (7°51'10.7"N 6°43'01.3"E). (c): Road section of Lokoja Sandstone showing feldspathic poorly sorted cross bedded sandstone at km 1.8 along Lokoja -Abuja express way (7°51'54.9"N and 6°47'29.6"E).

4.2 Patti Formation

At *Jamata*, the Patti interval contains interbedded shale, claystone, siltstone, sandstone and coal between the Lokoja Formation and capping ironstone (Figure 4c; Plate III). Fine- and medium-grained beds contain woody remains and organic debris. Coal is prominent, and shale is dark grey and carbonaceous.

Carbonaceous shale and coal, considered together with their stratigraphic position, provide useful correlation criteria within *Jamata and* between *Jamata and Ahoko*.

Ahoko provides the most extensive fine-grained exposure. Shale and siltstone alternate with concretionary and bioturbated ironstone (Figure 5a, b; Figure 5c, a–c). Claystone locally marks the top of the fine-grained facies. This section provides a basis for regional correlation.

Along the Bassa axis, shale, siltstone and claystone commonly display parallel lamination, with bioturbation and ferruginisation in some beds (Figure 5d). Thickness and lithology vary, but the facies resemble those at *Ahoko*.

At Agbaja, shale, siltstone, claystone, sandstone and coal occur beneath the Agbaja Ironstone (Figure 4 a,b). Medium- to coarse-grained sandstone displays herringbone cross-stratification, clay drapes and bioturbation (Figure 4b). Dark-grey, carbonaceous argillaceous beds resemble the equivalent interval at *Jamata*.

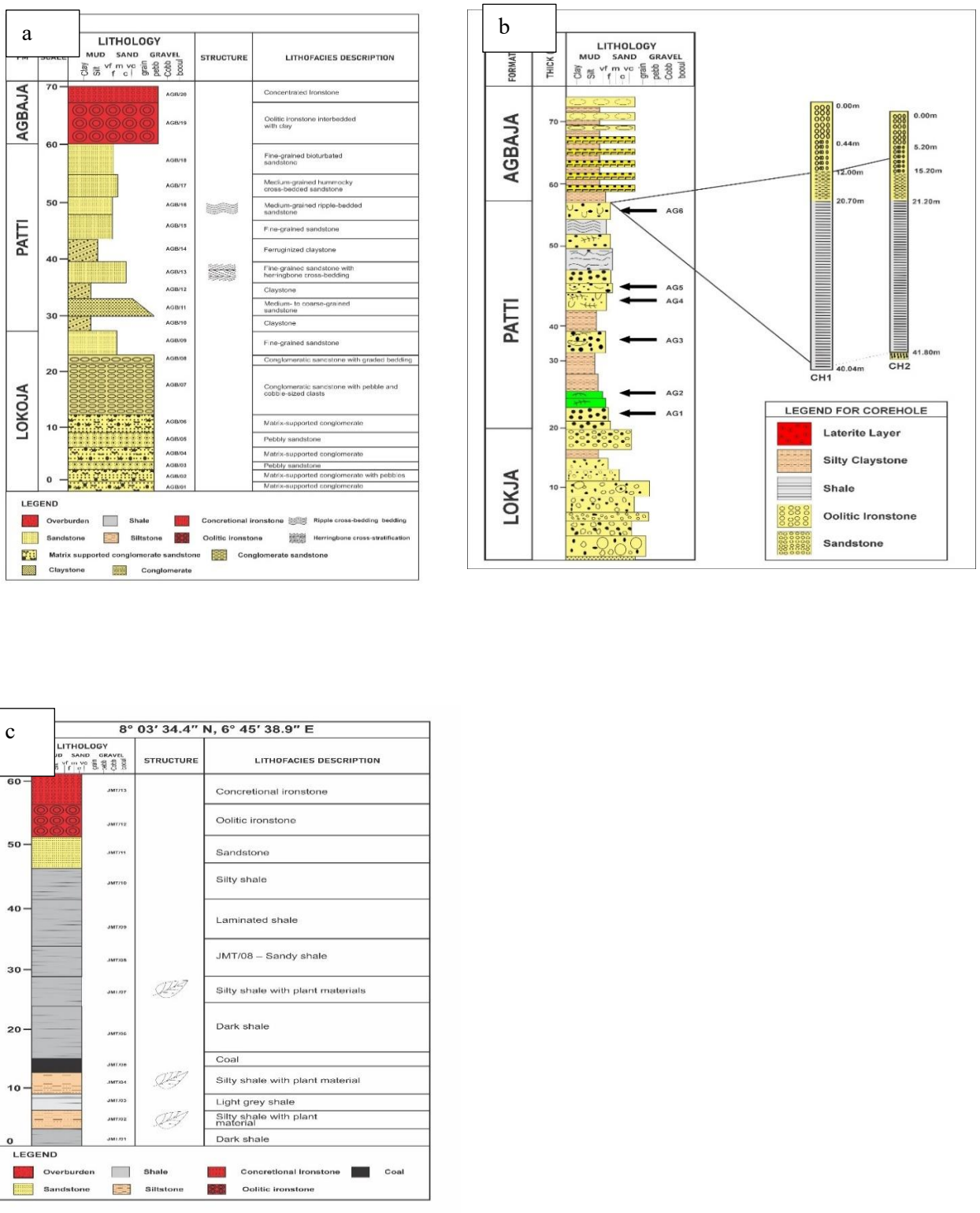


Figure 4a. Lithological sections of the Patti Formation at Agbaja and *Jamata* (a–c).

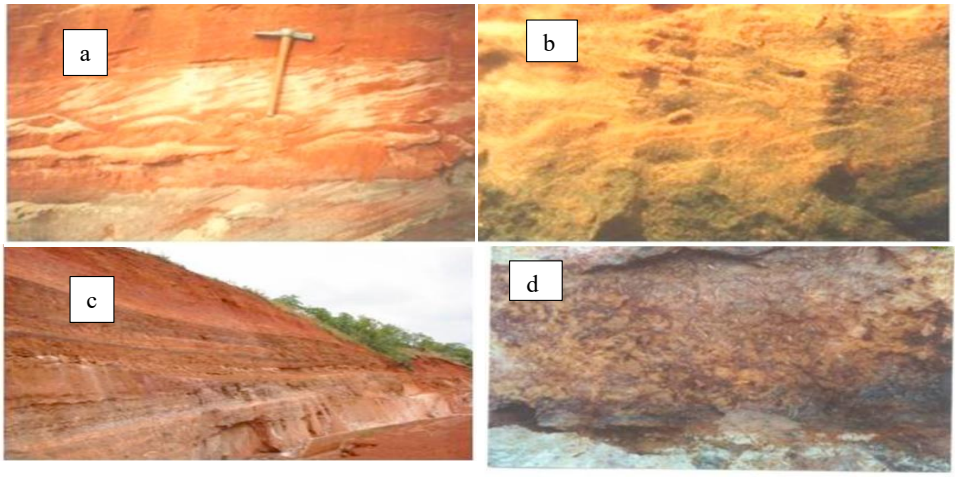


Figure 4b: (a) clay drape and convolute bedded sandstone facies of the Patti Formation at the Agbaja road cut section, (b) herringbone cross bedded sandstone facies, (c) bioturbated sandstone facies, and (d) Bands of oolitic ironstone facies of the Agbaja Formation at Agbaja Plateau (7°56'56.5"N and 6°39'41.0" E).

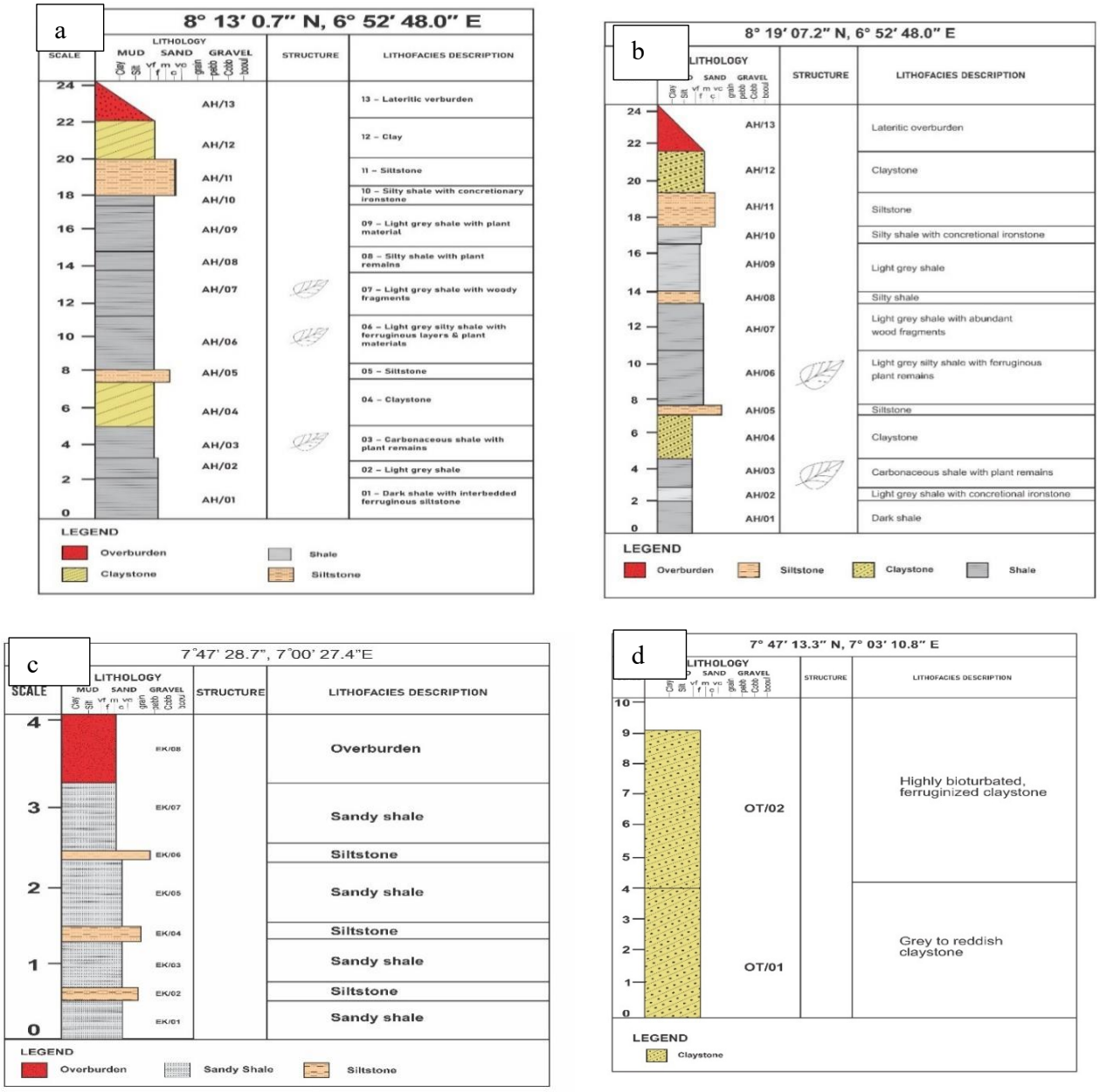


Figure 5a. Lithological sections of the Patti Formation at *Ahoko and* Bassa (a–d).

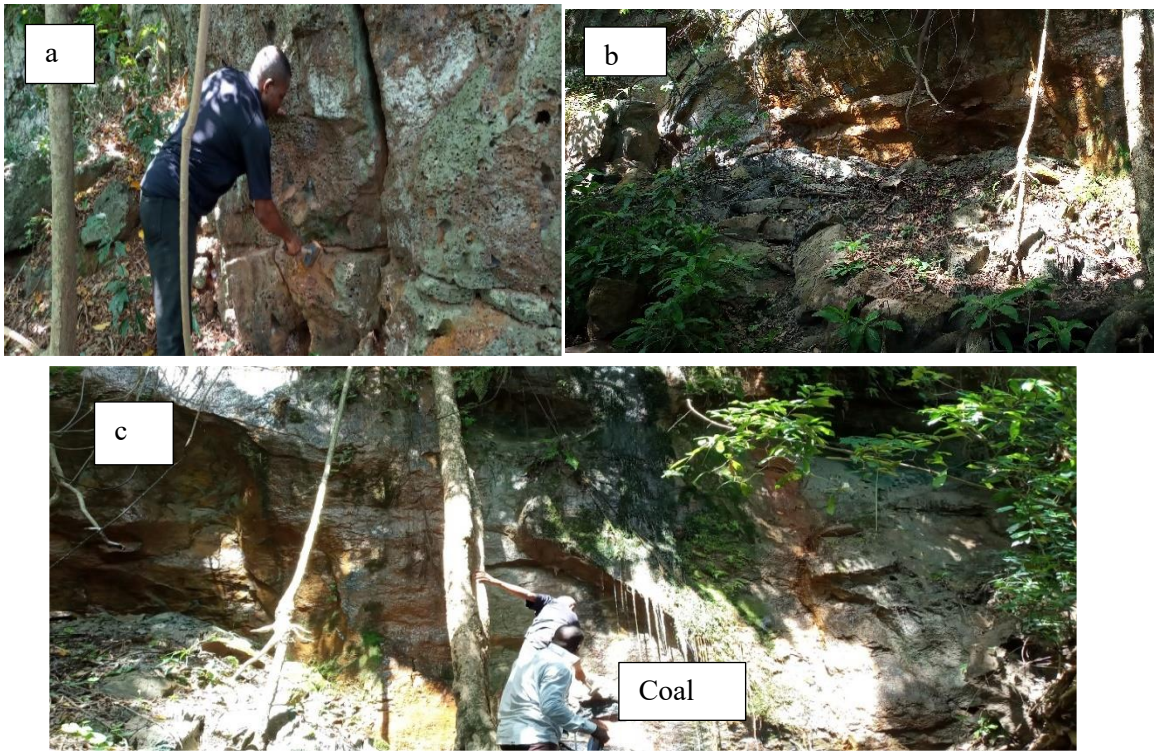


Figure 5b: Exposed section of the Patti Formation (showing a; Ironstone capping the entire succession, b; shale, c; coal, and sandstone facies at *Jamata* (8° 03' 34.4"N and 6°45'38.9"E).

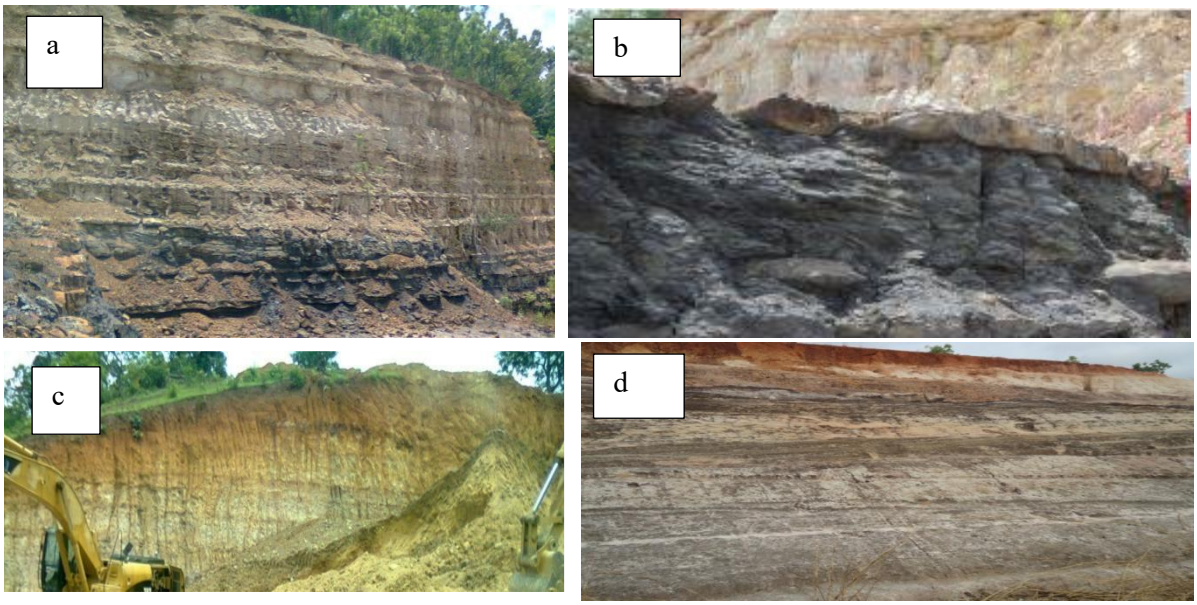


Figure 5c: Lithologic log of Patti Formation at *Ahoko* (08°19'07.2"N and 006°52'48"E) showing shale and siltstone rhythmically interbedded with concretional to massive, bioturbated ironstones. b: Lithologic sections of Patti Formation at *Ahoko* (08°19'07.2"N and 006°52'48"E) showing shale and siltstone rhythmically interbedded with concretional, bioturbated ironstones. c: Claystone and siltstone deposits of the Patti Formation exposed at *Ahoko clay* quarry along Lokoja –Abuja -express way (8°23'12.2"N and 6°55'56.0"E). d: Lokoja Sandstone and Patti Formation exposed at Abaji characterized by sandy claystone at the top (8°27'52.8"N and 6°56'24.3"E).

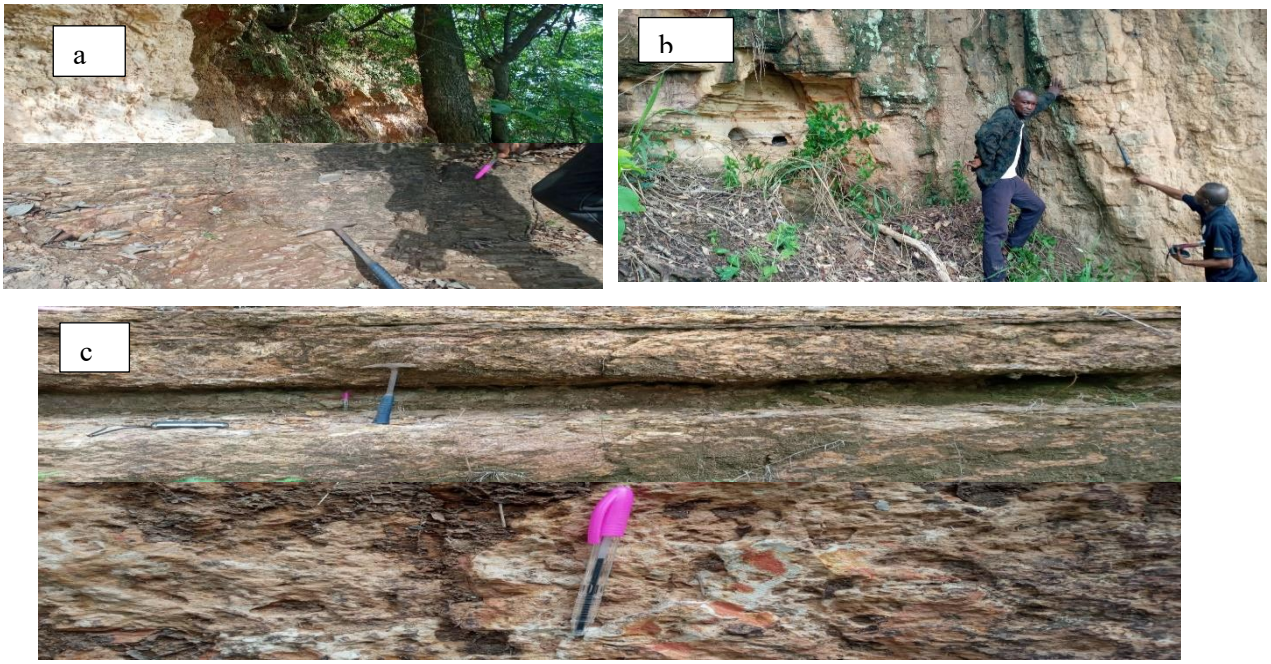


Figure 5d: a Patti Formation showing shale, silt and claystone along Bassa road (7° 43' 51.1"N and 7°03'04.4"E) b: Section of Patti Formation showing parallel laminated light grey siltstone along Bassa road (7° 43' 59.1"N and 7° 03'13.9"E) c: Section of Patti Formation showing a bioturbated siltstone (7° 47' 36.9"N and 6° 59 '53.3"E)

4.3 Agbaja Ironstone

Oolitic, pisolitic, concretionary and massive ironstone generally overlies the finer-grained Patti deposits, with subordinate sandstone and claystone. The capping ironstone provides a correlation marker despite lateral and vertical facies variability. Interbedded ironstone also occurs within the fine-grained succession and must be distinguished from the regional cap (Figures 4a, 4ba and 6).

Age	Northern Bida Basin Obaje et al. (2009/2011)		Southern Bida Basin Obaje et al. (2009)	Southern Bida Basin Rahaman et al. (2019)	Southern Bida Basin Ojo et al. (2020)	Southern Bida Basin (Present Work)	
Mastridtian	Batati Ironstone Enagi Siltstone Sakpe Ironstone		Agbaja Ironstone Patti Formation	Ahoko Formation Agbaja Ironstone	Agbaja Formation Patti Formation	Agbaja Formation Patti Formation	Jamata Member Ahoko Member
Campanian	Bida Sandstone	(Jima Member) (Doko Member)	Lokoja Sandstone	Lokoja Sandstone	Lokoja Formation	Lokoja Formation	
Precambrian to Paleozoic	Precambrian Basement						

Figure 6. Stratigraphic succession in the southern Bida Basin.

4.4 Palynological assemblages

The *Jamata* (JMT) JMT1, JMT2, JMT3, JMT4, JMT5, JMT6, JMT7, JMT8, JMT9, JMT10, JMT12 and JMT13 and *Ahoko* (AH) AH1, AH2, AH3, AH6, AH7, AH8, AH9 and AH10 samples predominantly represent shale, with subordinate claystone and coal. Interpretation used taxonomic composition, relative abundance, diversity, stratigraphic distribution and association with diagnostic forms.

Pollen and spores dominate, with organic-walled microplankton in some intervals. The assemblages were compared with published zonations and diagnostic records from Nigeria and West Africa (Germeraad et al., 1968; Evamy et al., 1978; Lawal, 1982; Edet and Nyong, 1994; Ogala et al., 2009; Ola-Buraimo, 2012, 2013, 2020; Ola-Buraimo and Akaegbobi, 2013).

Comparisons also used tropical and subtropical records from Africa and South America (Van Hoeken-Klinkenberg, 1964; Jardine and Magloire, 1965; Jan du Chêne et al., 1978; Salami, 1983; Lawal and Moullade, 1986; Salard-Cheboldaeff, 1990). These records provide context for evaluating the recovered taxa and their affinity with Campanian–Maastrichtian assemblages.

Figures 7 and 8 present palynomorph distributions, lithostratigraphic assignment, interpreted age and palaeoenvironment for *Jamata and Ahoko*. *Jamata samples* are presented for JMT1, JMT2, JMT3, JMT4, JMT5, JMT6, JMT7, JMT8, JMT9, JMT10, JMT12 and JMT13 and *Ahoko samples* are discussed by code, AH1, AH2, AH3, AH6, AH7, AH8, AH9 and AH10.

The assemblages resemble Campanian–Maastrichtian records from the Anambra, Bornu, Bida, Sokoto and Dahomey basins and the Middle Benue Trough. Diagnostic pollen and spores support the proposed Late Cretaceous correlation, subject to verification of individual identifications and stratigraphic ranges.

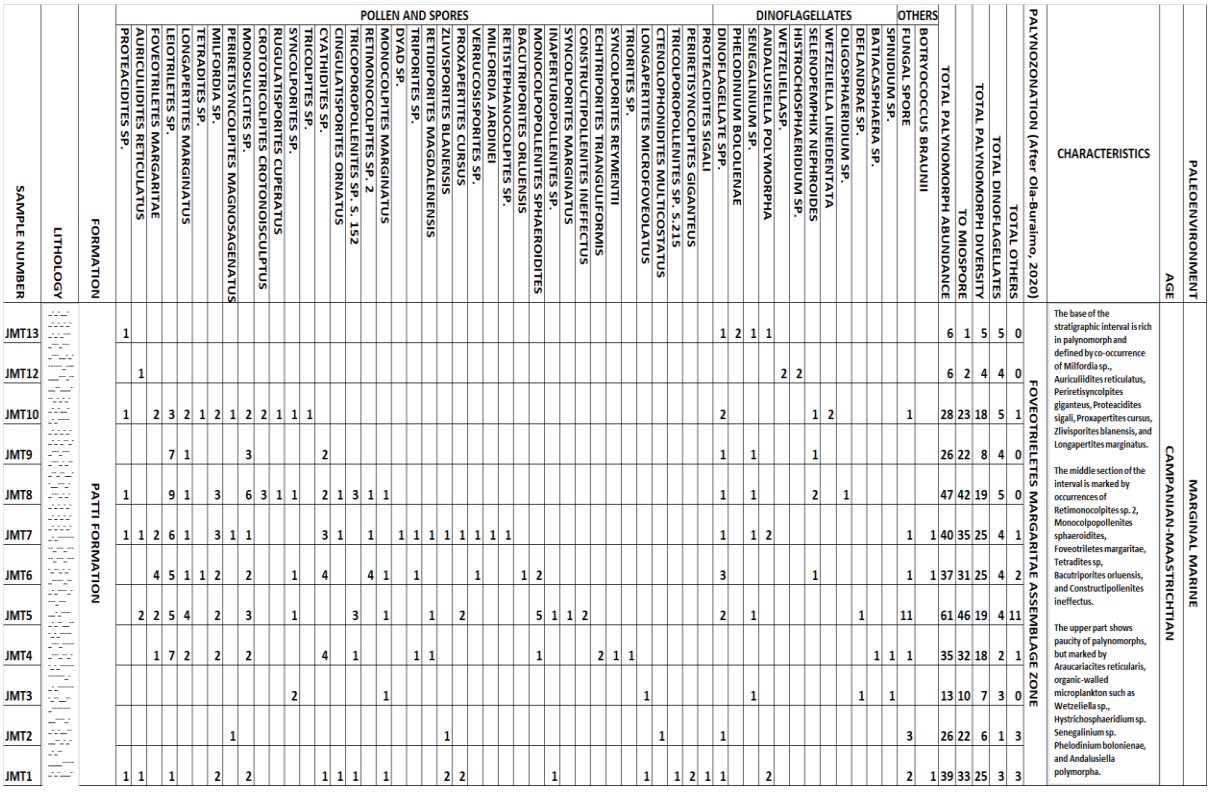


Figure 7. Palynomorph distribution, lithostratigraphic unit, interpreted age and palaeoenvironment of the *Jamata* (JM) section.

| SAMPLE NUMBER | LITHOLOGY | FORMATION | POLLEN AND SPORES | | |

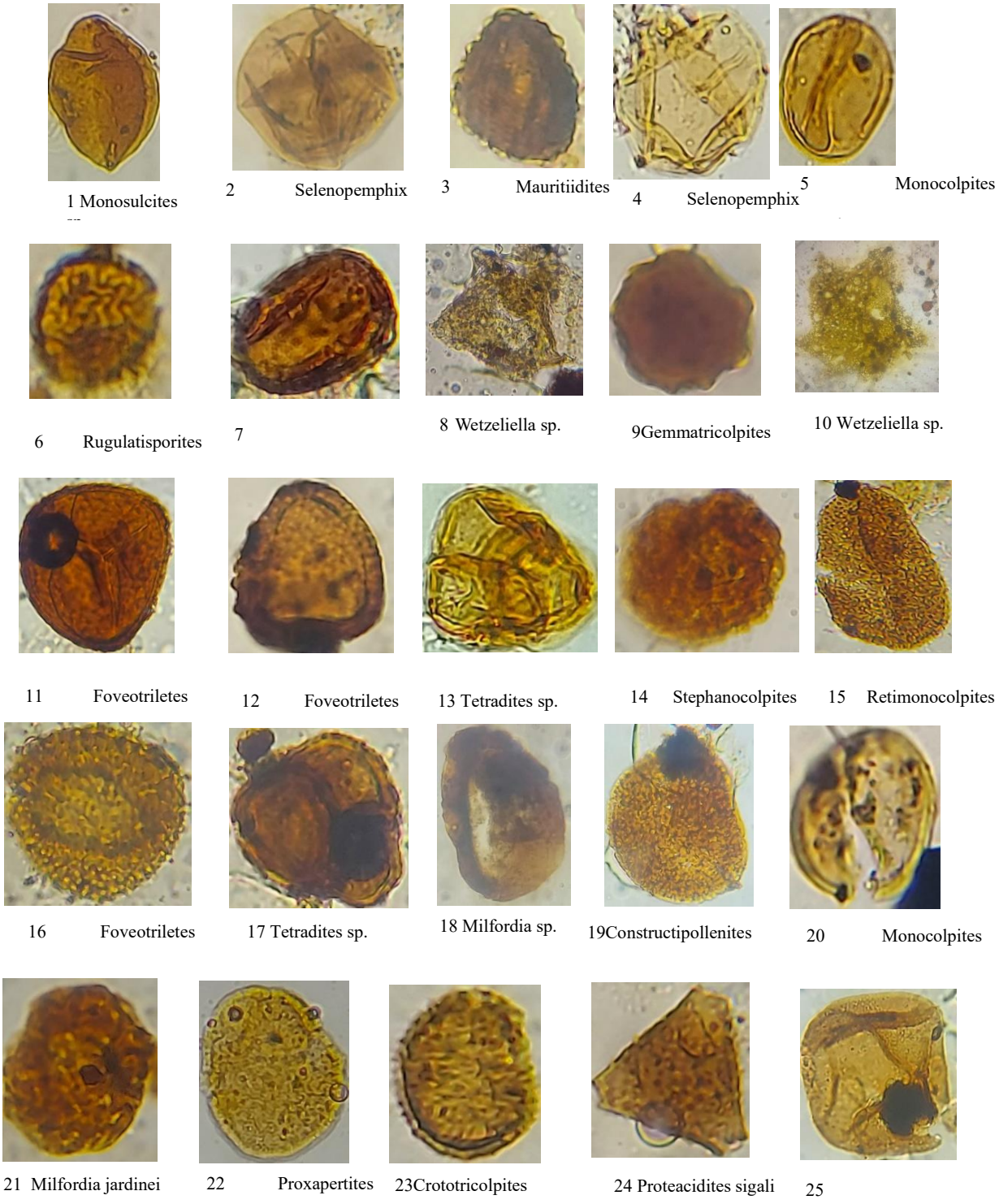
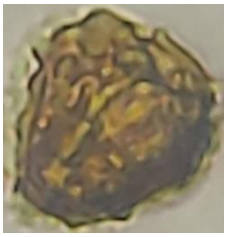
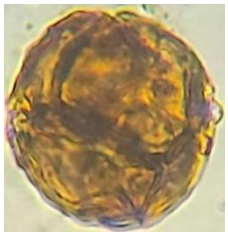


Figure 9b:Palynomorph photomicrographs at ×400 magnification.
1 *Monosulcites sp.* 2,4 *Selenopemphix nephroides* 3 *Mauritiidites crassibaculatus* 5 *Monocolpites marginatus* 6 *Rugulatisporites cuperatus* 7 *Tricolporopollenites sp.* 8, 10 *Wetzeliella sp.* 9 *Gemmatricolpites* Pilatus 11,12,16 *Foveotriletes margaritae* 13 *Tetradites sp.* 14 *Stephanocolpites sp.* 15 *Retimonocolpites sp.* 17 *Tetradites sp.* 18 *Milfordia sp.* 19 *Constructipollenites ineffectus* 20 *Monocolpites marginatus* 21 *Milfordia jardinei* 22 *Proxapertites cursus* 23 *Crototricolpites crotonoisculptus* 24 *Proteacidites sigali* 25 *Inaperturopollenites sp.*



1 Gemmatricolpites



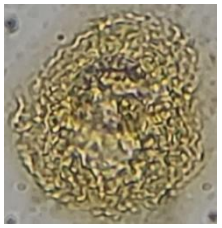
2 Ulmoideipites



3 Crototricolpites



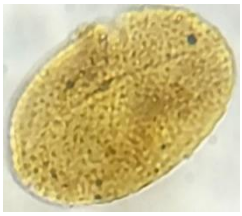
4 Dyad pollen



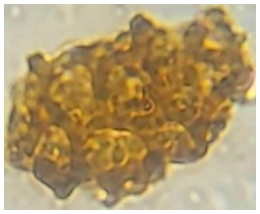
5 Milfordia jardinei



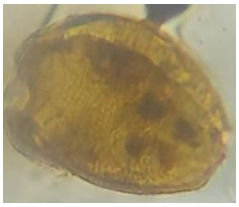
6 Retimonocolpites sp.



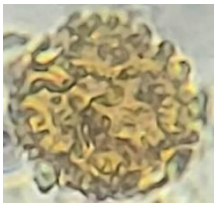
7 Retimonocolpites sp.



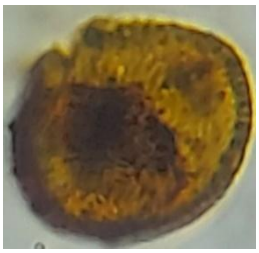
8 Periretisyncolpites sp.



9 Longapertites Sp.



10Proxapertites faceius



11 Proxapertites cursus

Figure 9c:Palynomorph photomicrographs at ×400 magnification.
1 *Gemmatricolpites sp.* 2 *Ulmoideipites krempii* 3 *Crototricolpites crotonoisculptus* 4 Dyad pollen 5 *Milfordia jardinei* 6,7 *Retimonocolpites sp.* 8 *Periretisyncolpites sp.* 9 *Longapertites sp.* 10 *Proxapertites faceius* 11 *Proxapertites cursus*

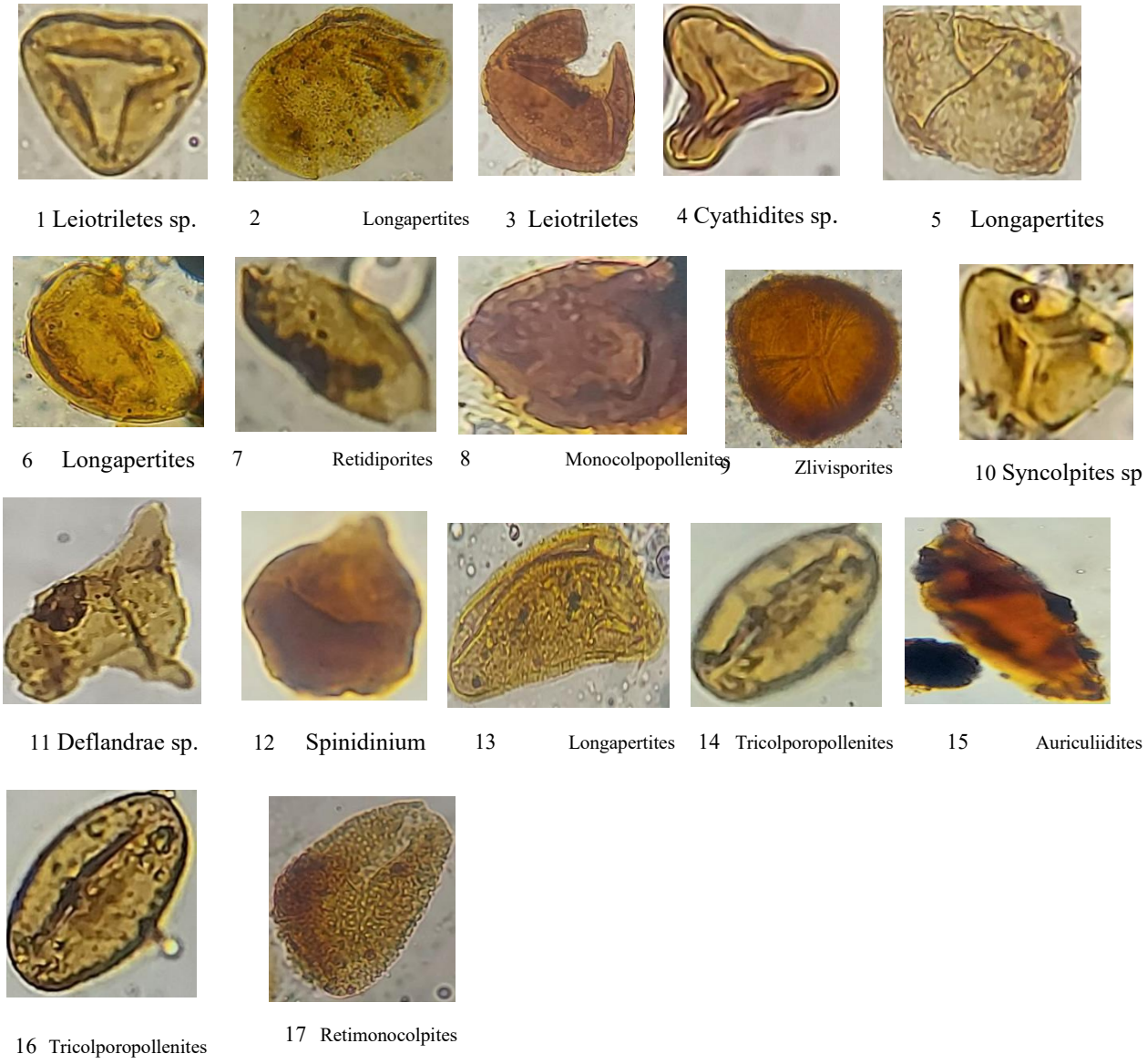


Figure 9d:Palynomorph photomicrographs at ×400 magnification.
1,3 *Leiotriletes sp.* 2 *Longapertites microfoveolatus* 4 *Cyathidites sp.* 5,6 *Longapertites sp.* 7 *Retidiporites magdalenensis* 8 *Monocolpopollenites sphaeroidites* 9 *Zlivisporites blanensis* 10 *Syncolpites sp* 11 *Deflandrea sp.* 12 *Spinidinium sp.* 13 *Longapertites marginatus* 14, 16 *Tricolporopollenites sp.* 15 *Auriculiidites reticulatus* 17 *Retimonocolpites sp.* 2

5 Discussion

The field investigation shows the Patti Formation is clearly exposed at Jamata village (Figure 4a, c)

(8° 03' 34.4"N and 6°45'38.9"E) and from the correlations of the lithologies penetrated by the core holes with composite section of the exposed sediments at Agbaja (Figure 4a, b) as reported by (Ojo and Akande, 2019) which indicate the presence of the rock sequence that defined Patti Formation, it clearly shows that Agbaja Ironstone lies on top of the Patti Formation at Jamata making it younger than Patti Formation as against the information reported by Rahaman et al., 2019 that the rock sequence that define the Patti Formation are not present at the location of mount Patti and in Lokoja and Agbaa area hence it should be renamed Ahoko Formation

The observed distribution of shale, carbonaceous shale, siltstone, claystone, sandstone and coal does not support restricting the Patti Formation to *Ahoko*. Comparable intervals that occur at *Jamata and* Agbaja, and finer-grained deposits along the Bassa road suggest a wider lateral extent. These correlations depend on lithology and position within the succession, rather than on lithological similarity alone.

The absence of diagnostic fine-grained beds at Mount Patti may reflect lateral facies variability. Fluvial and coastal systems can pass laterally from coarse channel deposits to floodplain, swamp and marginal-marine facies over several kilometres. Their local absence therefore does not, by itself, establish that the regional unit is invalid.

Rahaman et al. (2019) notes that the Ahoko section is well exposed at Ahoko, which they use as justification for proposing a new nomenclature.

The present study is in agreement with these findings, as Ahoko provides information about the section that defines Patti Formation. However, different considerations apply to the proposed formations. The principle of priority applies to the formation classification, and there is no requirement for an alternative to the Patti Formation given the availability of supporting outcrops.

Ahoko is well exposed, as recognised by Rahaman et al. (2019), and offers a suitable reference for comparison. The present observations support retaining the established Patti name because comparable successions occur elsewhere. Historical priority supports nomenclatural continuity, but the proposal ultimately depends on demonstrable lithological character, contacts and regional correlation.

Ahoko is therefore proposed as the reference section, with *Jamata and* Agbaja as supplementary correlation sections. *Jamata and Ahoko may* be described as related local expressions and proposed members; formal member designation would require documented boundaries and defining sections.

Vertical variation is also substantial: shale and siltstone dominate some sections, coal and carbonaceous beds others, while sandstone and ironstone occur locally. These differences are consistent with changes in facies, accommodation and sediment supply within a fluvial to marginal-marine depositional system.

5.1 Lithostratigraphic framework and palynostratigraphic interpretation

The proposed framework retains the basal, fluvial-dominated Lokoja Formation, the heterogeneous Patti Formation and the overlying Agbaja Ironstone marker interval (Figure 6). Fine-grained successions at *Ahoko and Jamata* are assigned to the Patti Formation where their contacts and stratigraphic positions support that correlation. *Ahoko provides* the reference exposure, supplemented by *Jamata*. This accommodates facies variation without treating every lithological change as a separate formation.

Jamata and Ahoko differ in lithology and assemblage dominance but share numerous pollens, spore and microplankton taxa (Table 1 and 2). This overlap supports a biostratigraphic and depositional relationship within the interpreted Campanian–Maastrichtian succession, although assemblage similarity alone does not establish exact bed-by-bed equivalence.

Jamata is dominated by shale, carbonaceous shale and coal, with subordinate sandstone and ironstone, and records a strong terrestrial organic signal.

Ahoko comprises mainly shale and siltstone with concretionary, massive and bioturbated ironstone, and shows more conspicuous variation between terrestrial palynomorphs and marine microplankton.

Shared terrestrial assemblages include *Foveotriletes*, *Milfordia*, *Longapertites*, *Retidiporites*, *Proteacidites*, *Auriculiidites*, *Periretisyncolpites*, *Tetradites*, *Triporites and Retimonocolpites*. Marine forms include *Andalusiella*, *Senegalinium*, *Deflandrea*, *Selenopemphix*, *Wetzeliella*, *Subtilisphaeridium and Phelodinium*. Their association suggests a marginal- to shallow-marine system receiving substantial terrestrial floral input.

At *Jamata*, basal JMT1 contains *Milfordia sp.*, *Zlivisporites blanensis*, *Longapertites marginatus*, *Proxapertites cursus*, *Proteacidites sigali*, *Auriculiidites reticulatus* and *Periretisyncolpites giganteus*, together with *Andalusiella polymorpha* and peridinioid dinoflagellates. The diverse assemblage indicates marine influence at the base.

Recovery is poorer in JMT2–JMT3. *Ctenolophonidites costatius*, *Zlivisporites blanensis*, *Periretisyncolpites sp.*, *Longapertites microfoveolatus* and marine dinoflagellates persist, retaining the interpreted Campanian–Maastrichtian signal. Lower abundance may reflect reduced accommodation, greater sediment influx or poorer production and preservation.

Abundance and diversity generally increase across JMT4–JMT10. Persistent *Foveotriletes margaritae* occurs with *Longapertites marginatus*, *Auriculiidites reticulatus*, *Proxapertites cursus*, *Monocolpopollenites sphaeroidites*, *Retidiporites magdalenensis*, *Monocolpites marginatus*, *Retimonocolpites sp. 2*, *Bacutriporites orluensis*, *Tetradites sp.* and *Triporites sp.*

JMT7–JMT8 records peak abundance and diversity, including *Foveotriletes margaritae*, *Milfordia spp.*, *M. jardinei*, *Retidiporites magdalenensis*, *Longapertites marginatus*, *Proxapertites cursus*, *Auriculiidites reticulatus* and *Crototricolpites crotonoisculptus*. Enhanced accommodation, marine influence and preservation are possible explanations. This interval is interpreted as a candidate maximum-flooding interval.

Sandstone-associated JMT9 records lower abundance and is interpreted as a possible regressive or highstand interval. Productivity recovers at JMT10, with *Foveotriletes margaritae*, *Longapertites marginatus*, *Milfordia sp.*, *Periretisyncolpites sp.*, *Proteacidites sp.* and *Crototricolpites crotonoisculptus*.

Uppermost JMT12–JMT13 shows relatively fewer terrestrial pollen and spores and more marine microplankton, including *Phelodinium bolonienae*, *Histrichosphaeridium sp.*, *Senegalinium sp.* and *Andalusiella polymorpha*. This suggests renewed or stronger marine influence.

The *Jamata assemblage* is assigned to the *Foveotriletes margaritae* Assemblage *Zone and* interpreted as Campanian–Maastrichtian.

Table 1: (Palynomorph abundance and diversity and quantitative counts of terrestrial to marine ratio

S/N	Sample	Abundances	Diversity	Land Sourced	Marine Sourced	Marine/terrestrial ratio (M/T)	Lithofacies
1	JMT13	6	5	1	5	5.00	Shale
2	JMT12	6	4	2	4	2.00	Shale
3	JMT10	28	18	23	6	0.26	Shale
4	JMT9	26	8	22	4	0.18	Shale
5	JMT8	47	19	42	5	0.12	Shale
6	JMT7	40	25	35	4	0.11	Shale

7	JMT6	37	20	31	6	0.19	Shale
8	JMT5	61	19	46	15	0.33	Coal
9	JMT4	35	18	32	3	0.09	Shale
10	JMT3	13	7	10	3	0.30	Shale
11	JMT2	26	6	22	4	0.18	Shale
12	JMT1	39	25	33	6	0.18	Shale
13	AH10	165	39	143	22	0.15	Shale
14	AH9	41	20	37	5	0.14	Shale
15	AH8	74	23	65	9	0.14	Shale
16	AH7	31	20	25	6	0.24	Shale
17	AH6	9	9	6	3	0.50	Shale
18	AH3	52	24	44	8	0.18	Shale
19	AH2	8	8	6	2	0.33	Shale
20	AH1	30	17	27	7	0.26	Shale

At *Ahoko*, principal terrestrial taxa include *Milfordia sp.*, *M. jardinei*, *Retidiporites magdalenensis*, *Longapertites marginatus*, *Tetradites sp.*, *Triporites sp.*, *Monocolpites marginatus*, *Retimonocolpites sp.* 2, *Proteacidites sp.* and *Foveotriletes margaritae*. Marine forms include *Senegalinium sp.*, *Selenopemphix nephroides*, *Andalusiella polymorpha*, *Subtilisphaeridium deformans* and *Wetzeliella spp.*

AH1 is relatively rich and diverse, containing *Milfordia jardinei*, *Milfordia sp.*, *Proteacidites sigali*, *Retimonocolpites sp.* 2, *Monocolpopollenites sphaeroidites*, *Constructipollenites ineffectus* and *Longapertites marginatus*. *Senegalinium and Selenopemphix nephroides* indicate marine influence. The interval is interpreted as Late Campanian–Early Maastrichtian.

AH2 yields fewer palynomorphs but retains diagnostic taxa and *Andalusiella polymorpha*, suggesting continued marginal-marine conditions. AH3 shows increased abundance and diversity, with *Milfordia*, *M. jardinei*, *Auriculiidites reticulatus*, *Retidiporites magdalenensis*, *Zlivisporites blanensis*, *Tetradites*, *Retimonocolpites*, *Proteacidites and* marine dinoflagellates.

AH6 is comparatively poor, but *Tetradites*, *Retimonocolpites*, *Triporites*, *Longapertites marginatus* and *Subtilisphaeridium deformans* sustain the proposed age and marginal-marine interpretation.

Abundance and marine influence increase across AH7–AH10 in sample-code order. AH7 contains *Milfordia sp.*, *Periretisyncolpites magnosagenatus*, *Longapertites marginatus*, *Retidiporites magdalenensis*, *Echitriporites trianguliformis*, *Wetzeliella giganteus*, *Deflandrea sp.*, *Senegalinium sp.* and *Selenopemphix nephroides*.

AH8 contains *Foveotriletes margaritae*, *Rugulatisporites*, *Gemmatricolpites*, *Bacutriporites orluensis* and *Lycopodium sp.*, with increased *Longapertites marginatus*, *Leiotriletes and Retidiporites magdalenensis*. The greater marine component is interpreted as a possible transgressive signal; its vertical direction depends on confirmation of sample order.

AH9 retains forms assigned to the Campanian–Maastrichtian. *Mauritiidites crassibaculatus* may indicate a younger Maastrichtian component, while *Milfordia spp.* supports the broader age interpretation.

AH10 is the most productive *Ahoko sample*, with abundant and diverse terrestrial palynomorphs and marine microplankton. *Leiotriletes sp.* and *Longapertites marginatus* are particularly abundant. Forms interpreted as relatively younger include *Ulmoideipites krempii*, *Proxapertites cursus*, *Proteacidites deehani*, *Leiotriletes adriennis* and *Momipites africanus*. Abundant *Deflandrea and* Cometodinium, with rare microforaminiferal wall linings, suggest stronger marine influence. AH10 is interpreted as a candidate maximum-flooding interval.

The *Ahoko assemblage* is assigned to the *Milfordia sp.* Assemblage *Zone and* broadly interpreted as Campanian–Maastrichtian. The age significance of potentially younger forms requires taxonomic and range verification.

Table 2. Comparative palynomorph assemblages of the *Jamata and Ahoko sections*

Palynomorph group	**Jamata Member**	**Ahoko Member**
Foveotriletes margaritae	Common/prominent	Present, especially upper interval
Milfordia sp.	Present	Common/prominent
Milfordia jardinei	Present	Common
Longapertites marginatus	Common	Common to abundant
Retidiporites magdalenensis	Present/common	Common
Proxapertites cursus	Present	Present
Proteacidites sigali	Present	Present
Proteacidites sp.	Present	Present
Auriculiidites reticulatus	Present/common	Present
Periretisyncolpites spp.	Present	Present
Zlivisporites blanensis	Present	Present
Retimonocolpites sp. 2	Present	Present
Tetradites sp.	Present	Present
Triporites sp.	Present	Present
Monocolpites marginatus	Present	Present
Monocolpopollenites sphaeroidites	Present	Present
Bacutriporites orluensis	Present	Present
Andalusiella polymorpha	Present	Present
Senegalinium spp.	Present	Present
Deflandrea sp.	Present	Present
Selenopemphix nephroides	Present	Present

Palynomorph group	Jamata Member	Ahoko Member
Wetzeliella spp.	limited	Present
Subtilisphaeridium deformans	limited	Present
Phelodinium bolonienae	Present	—
Cometodinium	limited	Present

Longapertites marginatus occurs repeatedly in both sections and is particularly useful for correlation. *Foveotriletes margaritae* is more prominent at *Jamata but* also occurs at *Ahoko; Milfordia spp.* dominates at *Ahoko but* are present at *Jamata*. Their overlap supports correlation within a common regional succession.

6 Conclusions

Patti-type shale, carbonaceous shale, siltstone, claystone, sandstone and coal occur at *Jamata and* Agbaja as well as *Ahoko*. Similar fine-grained facies along the Bassa axis suggest a possible lateral extension. These observations support retaining the Patti Formation rather than restricting it to *Ahoko*.

The absence of diagnostic beds at Mount Patti may reflect lateral facies variability within a fluvial to marginal-marine system. This explanation is consistent with the observed regional heterogeneity but requires further contact mapping.

Ahoko is proposed as the reference section, with *Jamata and* Agbaja as supplementary correlation sections. *Jamata and Ahoko are* interpreted as related local expressions and proposed members of the Patti Formation. This framework recognises facies variation while maintaining regional stratigraphic continuity.

Jamata and Ahoko are assigned to the *Foveotriletes margaritae* and *Milfordia sp.* Assemblage Zones, respectively, and interpreted as Campanian–Maastrichtian. Shared *Longapertites marginatus*, *Foveotriletes margaritae*, *Milfordia spp.*, *Retidiporites magdalenensis*, *Proteacidites spp.*, *Auriculiidites reticulatus* and *Periretisyncolpites spp.* support a common Upper Cretaceous framework.

Terrestrial pollen and spores associated with marine dinoflagellate cysts suggest coastal, marginal- to shallow-marine deposition affected by marine incursions and relative sea-level change. Differences in lithology, abundance and assemblage dominance are interpreted as facies and ecological variations. Verification of sample totals, *Ahoko sample* order and potentially younger taxa is necessary to strengthen the detailed age and sequence-stratigraphic interpretations.

References

Adeleye, D.R. and Dessauvagie,T.F.J (1972) Stratigraphy of Niger embayment near Bida Nigeria. In : Dessauvagie,T.F.J. and Whiteman,A.J.(Eds), proceedings of the Conference on African Geology *Ibadan university press,Ibadan, Nigeria*. pp 181- 186.

Adeleye, D.R (1973): Origin of Ironstone, an example from the Middle Niger Basin, Nigeria. Journal Sedimentary Petrology. Vol. 43 pp 709-727

Adeleye, D.R. (1974). Sedimentology of the fluvial Bida Sandstone (Cretaceous) Nigeria. Sedimentary Geology (12) pp 1-24

Akande, S.O. Ojo, S.B. Erdtmann,B.D. Hetenyi, M. (2005). Palaeoenvironments, organic petrology and Rock-Eval studies on source rock facies of the Lower Maastrichtian Patti Formation southern Bida Basin Nigeria. Journal African Earth sciences. (41) pp394- 406

Braide, S. P. (1990). Sedimentation and Tectonic in the southern Bida Basin, Nigeria. Depositional Responses to various Tectonic context. American Association of Petroleum Geologists Bulletin. Vol. 74, 618 p

Braide, S. P. (1992a). Geological development, origin and energy mineral resources potential of the Lokoja Formation in the southern Bida Basin. Journal of Mining and Geology, (28) pp 33-44.

Braide, S.P. (1992b). Syntectonic fluvial sedimentation in the central Bida Basin. Journal Mining and Geology. (28): pp 55–64

Edet, J.J. & Nyong E.E., (1994) Palynostratigraphy of Nkporo Shale exposures (Late Campanian-Maastrichtian) on the Calabar Flank, SE Nigeria. Review of Paleobotany and Palynology, 80: 131-147.

Evamy, D.D., Heremboue, J., Kemeling, P., Knaap, W.A., Morlly, F.A. and Rowland, P.H. (1978). Hydrocarbon habit of Tertiary Niger Delta. American Association of Petroleum Geologists Bulletin, 62: 1-39.

Germeraad, J.H., Hopping, C.A. & Muller, J. (1968) Palynology of Tertiary sediments from tropical areas. Rev. Paleobot. Palynol., 6: 189-348.

Idowu, J.O., Enu, E.I., 1992. Petroleum Geochemistry of some Late Cretaceous Shales from the Lokoja Sandstone of the Middle Niger Basin, Nigeria. Journal of African Earth Sciences, 14, pp. 433-455.

Jardine, S. & Magloire, I. (1965) Palynologie et stratigraphic du Cretace des Basins du Senegal et de Cote d' Ivoire ler Coll. Memoire du. Bureau Recherches Geologiques et Minieres, 32: 187-245.

Jan Du Chene, R.E.de Klasz, I. Archibong, E.E. (1978). Biostratigraphic study of the borehole SW Nigeria, with special emphasis on the Cretaceous microflora. Revue de Micropalaeontologie, (21) pp123- 139.

Ladipo, K.O. Akande, S.O. and Mucke, A. (1994). Genesis of ironstones from the Mid-Niger sedimentary basin: evidence from sedimentological, ore microscopic and geochemical studies. Journal of Mining and Geology (30) pp 161-168

Lawal, O., 1982: Biostratigraphie palynologique es paleoenvirunmens des formations Cretacee de la Haute- Benoue, Nigeria mord - oriental. These-3-cycle, Univ. Nice, 218p.

Lawal, O. and Moullade, M. (1986). Palynological biostratigraphy of the Cretaceous sediments in the upper Benue Basin, N.E. Nigeria. Revue micropaleontologie, 29(1): 61-83.

Mebradu, S., Imhanobe, J., & Kpandei, L. Z. (1986). Palynostratigraphy of the Ahoko sediments from the Nupe Basin, N.W. Nigeria. *Review of Palaeobotany and Palynology, 48*(1–3), 303–310. https://doi.org/10.1016/0034-6667(86)90064-3

Mebradu, S., Imhanobe, J. and Kpandei, L.Z. (1986). Palynostratigraphy of *Ahoko sediments* from the Nupe Basin, NW Nigeria. Review of Palaeobotany and Palynology, 48, 303–310.

Obaje, N. G., Wehner, H., Scheeder, G., et al. (2004). Hydrocarbon prospectivity of Nigeria's inland basins from the viewpoint of organic geochemistry and organic petrology. American Association of Petroleum Geologists Bulletin, 88, pp 325-353.

Obaje, N. G., (2009), Geology and Mineral Resources of Nigeria. Sringer, Heidelberg, 221 p

Obaje, N. G. Musa, M. K Odoma, A. N. and Hamza, H. (2011). The Bida Basin In north- central Nigeria: sedimentology and petroleum geology. Journal of Petroleum and Gas Exploration Research (1) pp. 001-013.

Obaje, N.G., Balogun, D.O., Idris-Nda, A., Goro, I.A., Ibrahim, S.I., Musa, M.K., Dantata, S.H, Yusuf, I, Mamud-Dadi, N., Kolo, I.A., 2013. Preliminary Integrated Hydrocarbon Prospectivity Evaluation of the Bida Basin in North Central Nigeria. Petroleum Technology Development Journal: An International Journal; July 2013 v.3 No.2, p. 36 – 65.

Ogala, J. E., Ola - Buraimo A. O., and Akaegbobi, I. M., 2009: Palynological Investigation of the Middle- Upper Maastrichtian Mamu Coal facies in Anambra Basin, Nigeria. World Applied Sciences Journal, vol. 7, n. 12, p. 1566-1575.

Ojo, O. J. & Akande, S. O. (2003). Facies Relationships and Depositional Environments of the Upper Cretaceous Lokoja Formation in the Bida Basin, Nigeria. Journal of Mining and Geology, (39) pp 39-48.

Ojo, O.J., Akande, S.O., 2008. Microfloral assemblage, age and paleoenvironment of the Upper Cretaceous Patti Formation, southeastern Bida Basin, Nigeria: Journal of Mining and Geology, 44: 71-78.

Ojo, O.J., Akande, S.O., 2009. Sedimentology and depositional environments of the Maastrichtian Patti Formation, southeastern Bida Basin, Nigeria. Cretaceous Research, 30: 1415 – 1425.

Ojo, O.J., Akande, S.O., 2020. A revised stratigraphy of the Bida Basin, Nigeria by Rahaman et al. J. Afr. Earth Sci. 172, 103983. https://doi.org/10.1016/j. jafrearsci.2020.103983 (2019) [J. Afr. Earth Sci., 151, 67–81]: A rebuttal.

Ola-Buraimo, A.O. (2012). Lithostratigraphy and palynostratigraphy of Tuma -1 well, Bornu Basin, Northeastern Nigeria. Journal of Biological and Chemical Research, 29(2): 206-223.

Ola-Buraimo, A.O. 2013. "Biostratigraphy of Section of Murshe-1 well, Bornu Basin, Northeastern Nigeria". Unpublished.

Ola-Buraimo A.O. & Akaegbobi I. M. (2013a) Palynological and paleoenvironmental investigation of the Campanian Asata/Nkporo Shale in the Anambra Basin, Southeastern Nigeria. British Journal of Applied Science and Technology, vol. 3(4): 898-915

Ola-Buraimo,A.O, Adebayo, O.F. and Umaru, S. (2015). Palynological characterization of the organic richness, kerogen type and thermal maturity of Kemar-1 well, northeastern Nigeria. Journal of Biological and Chemical Research, 32(2): 720-732.

Ola-Buraimo, A.O. (2020). Palynozonation Chronostratigraphy of deposition of the Albian to Pliocene Sediments of the Nzam-1, Umuna-1, and Akukwa-2 wells Anambra Basin, Southwestern Nigeria. University of Ibadan PhD thesis, 182p.

Ola-Buraimo A.O., Oladimeji R.G. and Faruk A.K. (2022). Palynology, paleoenvironment and stratigraphy relationship of tungan buzu hill with adjacent valley gwandu formation, sokoto basin, northwestern Nigeria African Journal of Environment and Natural Science Research Volume 5, Issue 2, 2022 (pp. 15-26)

Rahaman, M.A.O., Fadiya, S.L., Adekolaa, S.A., Coker, S.J., Bale, R.B., Olawoki, O.A., Omada, I.J., Obaje, N.G., Akinsanpe, O.T., Ojo, G.A., Akande, W.G., (2019). A revised stratigraphy of the Bida Basin, Nigeria. J. Afr. Earth Sci. (151), pp 67–81.

Salami, M. B. (1983) Some late Cretaceous and early Tertiary Pteridophytic spores from the southern Nigeria sedimentary basins. Rev EspMicropale. 15(2): 257-272.

Salard-Cheboldaeff, M. (1990). Intertropical African palynostratigraphy from Cretaceous to Late Quaternary times. Journal of African Earth Sciences, 11(1–2), 1–24.

Van Hoeken-Klinkenberg, P. M. J. (1964) A palynological investigation of some Upper Cretaceous sediments in Nigeria. Pollen et Spores, 6(1): 209-231.

Whiteman, A., 1982. Nigeria: Its Petroleum Geology, Resources and Potential. Vol. 1 and 2, Graham and Trotman, London, 349.

Whiteman, A.J. (1982). Nigeria: its petroleum geology resources and potentials Graham and Trotman, London, UK. (176) pp 2,238

Zaborski, P.M. (1998). A review of Cretaceous system in Nigeria.African Geosciences Review (5) pp 385 485.