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Pollen and Spores Recovery in Tunga Buzu Carbonaceous Shale Type Section Member: Significance in Sequence Stratigraphy, Age Dating and Paleoenvironment Deduction of the Early Miocene Gwandu Formation, Sokoto Basin, Northwestern Nigeria

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ABSTRACT: *Feld samples were collected from an outcrop at Tunga Buzu with the intention of comparing field relationship between the claystone member and the underlying carbonaceous shale Type Section for palynological study. The study was carried out in order to determine the geologic age relationship of the facies sequence, sequence stratigraphy and paleoenvironment of deposition of the sediments. Lithological description of the beds follows notation of colour, facies composition, texture, fossil content, structure and post depositional diagenetic effects. Laboratory preparation of palynological slides involved decarbonisation, sample digestion using hydrofluoric acid, sieving with 10µm mesh, bleaching of organic debris with nitric acid, maceral separation with zinc bromide, rinsing of separated maceral with ethanol and final mounting of the organomaceral on the slides for microscopic analysis.The carbonaceous shale is light grey in colour, fissile, carbonaceous, slightly bioturbated and ferruginized. Pollen, spores, dinoflagellates and algae were recovered from samples N1-N4. The samples N1-N3 are claystone samples characterised by relatively low assemblage assemblage of miospores with downhole increase in dinoflagellate cysts. The carbonaceous shale (sample N4) is relatively rich in palynomorphs with corresponding high palynomorph population and diversity compared with the claystone facies. Both the claystone and carbonaceous shale contain marker fossils such as Striamonocolpites sp., Retibrevitricolporites obodoensis, Verrutricolporites sp., Praedapollis sp., Belskipollis elegans and Peregnipollis nigericus; indicative of Early Miocene age. The litho-sequence of claystone and carbonaceous shale indicated alternation of continental and marginal marine deposits characterised by paucity and preponderance of peridinacean dinocysts. This suggests eustatic change in sea level of continental Lowstand Systems Tract (LST) and marginal marine Transgressive Systems Tract (TST) deposits respectively. The Tunga Buzu Carbonaceous Shale Type Section constitutes a member of the Early Miocene Gwandu Formation of the Sokoto Basin, Nigeria*.

KEY WORDS: Miospore, Dinoflagellate, Carbonaceous shale, Marginal marine, Type Section, Eustatic change in sea level

INTRODUCTION

Sediments of the Sokoto Basin were described to have formed in four phases; the Pre-Cambrian Crystalline Basement rock at the bottom, overlain by Illo and Gundumi Formations of Cretaceous age. The Maastrichtian sediments of Rima Group is characterized by mudstone and

unconsolidated sandstone of Taloka and Wurno Formations, separated by fossiliferous shally Dukamaje Formation. The Sokoto Group (Paleocene age) constitutes the Dange and Gamba Formations, distinguished by the calcareous Kalabaina Formation. The geology of Sokoto Basin was widely investigated by Kogbe (1972, 1974, 1976 and 1989), Adeleye (1975), Okosun (1989), Obaje *et al*., (2013) Ola-Buraimo *et al*. (2018), Ologe *at al*. (2018), Ola-Buraimo and Ologe (2020), Ologe and Ola-Buraimo (2022) and Ola-Buraimo and Adamu (2022, in press).

Geological studies of the stratigraphic successions and their characteristics in the Gwandu Formation of the Sokoto Basin Nigeria is inconclusive. A further probe into new frontiers of the outcrop exposures continue to attract interests which unveil new geological features and facies members. The study area is situated at Tunga Buze, outskirt of Birnin Kebbi; lying between Longitude $13^{o}\ 42^{I}\ 0^{II}$ to $13^{o}\ 45^{I}\ 0^{II}$ and Latitude $5^{o}\ 38^{I}\ 0^{II}$ to $5^{o}\ 42^{I}\ 0^{II}$ (Fig. 1). The study part of Tunga Buzu is situated in the valley side of the mountainous area, where a section of the channel exposed a carbonaceous shale facies. The carbonaceous shale is here first described as shale member of the Gwandu Formation. The carbonaceous shale and the overlying claystone beds synonymous with Gwandu Formation were studied in order to compare the palynomorph assemblages of the latter with the underlying carbonaceous shale.
The Gwandu Formation is ambiguous in nature in terms of lithological variation from place to place. This observation is in tandem with the report of Ola-Buraimo *et al*. (2022 in press). The lithological succession and their relationship was extensively described in the work of Ola-Buraimo *et al*. (2018). The stratigraphic stacking pattern exhibited vary from top with conglomeratic bed through sandstone and siltstone to carbonaceous shale at the bottom. The paleoenvironment was suggested to vary from fluviatile to a prograding deltaic setting at the bottom (Ola-Buraimo *et al*., 2018).

However, the geologic age and distinctive paleoenvironment of deposition of the Tunga Buzu Carbonaceous Shale Type Section has not be carried out or documented to suggest whether the carbonaceous shale constitutes another member of the Gwandu Formation or forms part of underlying older formation. Thus, this study was intended to establish a correlation of pollen and spores recovered from this study with other established work on Gwandu Formation based on the similarity in their constituent palynomorph assemblages.

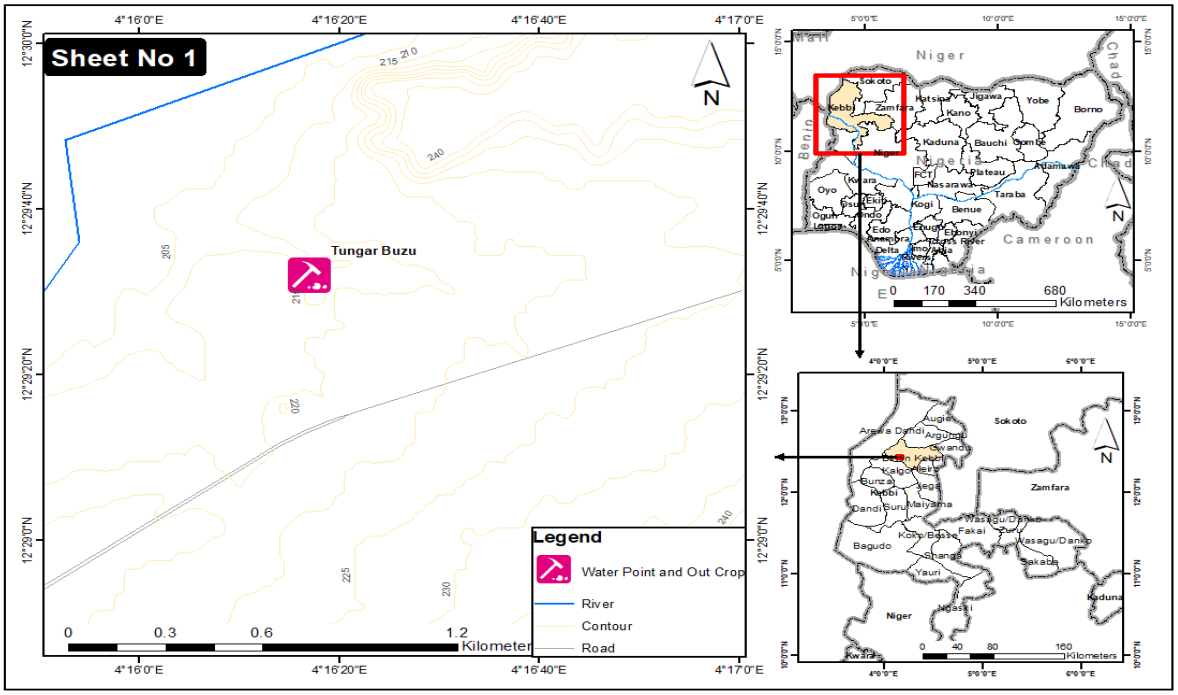

Figure 1. Location map of the study are

METHODOLOGY AND MATERIALS

Field study was undertaken to collect samples from both the overlying claystone beds and the underlying carbonaceous shale bed for comparison of palynomorph assemblages. The outcrop was described sequentially by distinguishing adjacent lithofacies based on colour, composition, texture, fossil content, structure and effect of post depositional diagenetic effect.

The claystone and shale samples were subjected to laboratory procedure of preparing palynological slides. The samples were crushed with mortar and pestle in order to enhance the processes of chemical decarbonisation and digestion. The crushed samples were initially treated with dilute hydrochloric acid (HCl) in order to decarbonise the samples. Further, the samples were digested using hydrofluoric acid (HF) for a complete breakdown of the shale particles. Samples were soaked overnight with hydrofluoric acid; stirred intermittently towards achieving complete digestion.

The next stage of the preparation was sieving, using 10µm sieve mesh. Clay particles were removed, thereby permits concentration of organomacerals. The recovered organic debris was later treated with concentrated nitric acid (HNO_3) in order to bleach and enhance sculptural elements of the palynomorphs. This process will improve the identification of the miospores, dinoflagellates and other stratigraphically important forms present in the slide under the microscope view. Further laboratory procedure involved separation of macerals from the unwanted organic debris through liquid phase separation, using zinc bromide. The floated maceral was separated, rinsed with ethanol (alcohol) before it was finally mounted on glass slides; analysed for palynomorph content using Will microscope with attached camera. The

camera was used in taking photographs of well-preserved diagnostic miospores, dinoflagellates, algae and other important forms.

RESULTS AND DISCUSSIONS

The claystone facies have been described in details in the work of Ola-Buraimo *et al*., (2018), the underlying carbonaceous shale was described here lithologically to be light grey in colour, fissile in nature, non-fossiliferous but carbonaceous. The light grey colour suggests deposition of the shale in anoxic environment, relatively rich in organic materials (Plate 1). The carbonaceous shale is slightly bioturbated and fairly ferruginized (Plate 1).

Plate 1. Carbonaceous shale

The claystone deposit is light to dark brown in colour, structurally, no distinctive bedding, massive in nature, characterized by joint structure having infilling grout (Plate 2)

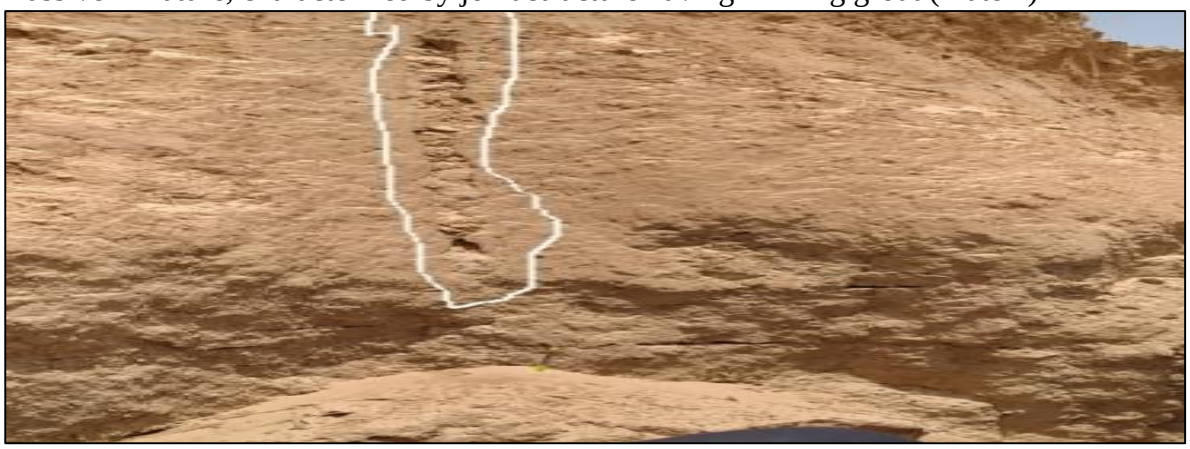

Plate 2. Claystone deposit with infilling grout joint

Palynology
The palynological interpretation follows standard method whereby result obtained was compared with established palynological studies from Pantropical regions and Nigerian sedimentary basins as documented in the works of Germeraad *et al*., (1968), Evamy *et al*., (1978), Legoux (1978), Ola-Buraimo (2020), Ola-Buraimo and Adamu (2022, in press). The analysed samples were described and characterized below into palynological broad zones and subzone

Palynozones
The interpretation of the analysed samples was carried out on each sample, samples N1 to N3 are claystone facies while sample N4 is the carbonaceous shale. The details of the palynological zones and subzone erected were based on the characteristics given below.

Sample: N1
Zone: *Margnastriatites howardii* Zone (Germeraad *et al*., 1968).
Subzone: P600 Zone/P630 Subzone (Evamy *et al*., 1978).
Zone/Subzone: C1 Zone (Legoux, 1978).
Age: Early Miocene
Characteristics: Sample N1 was dated Early Miocene age based on the co-occurrence of *Striamonocolpites laevigatus*; relative quantitative occurence *Verrutricolpites* sp. and rare appearance of *Retibrevitricolporites obodoensis* in relatively high frequency. However, the appearance of *Retibrevitricolporites obodoensis* and *Striamonocolpites* sp. in the slides classify the assemblage to belong to *Magnastriatites howardi* zone of Germeraad *et al*., (1968), P600 zone and P630 subzone of Evamy *et al*., (1978) and C1 zone of Legoux (1978) belonging to Early Miocene age. Palynomorph assemblage of sample N1 is similar to miospore assemblage recovered from Dukku Claystone Type Section of Gwandu Formation (Ola-Buraimo and Adamu, 2022). The paleoenvironment of deposition of the claystone is suggested to be fluviatile based on the rare co-occurrence of *dinoflagellate cyst* (7.14 %) and Botryococcus braunii (7.14 %) compared to terrestrial miospores (85.72 %) retrieved from the sample (Ola-Buraimo and Ehinola, 2021). The interval belongs to period of low water level, active river processes under a Lowstand Systems Tract (LST; Fig 2).

Sample: N2
Zone: *Margnastriatites howardii* Zone (Germeraad *et al*., 1968).
Zone/Subzone: P600 Zone/P630 Subzone (Evamy *et al*., 1978).
Zone: C1 Zone (Legoux, 1978).
Age:Early Miocene
Characteristics: The sample N2 was dated Early Miocene based on the occurrence of *Retibrevitricolporites* sp., *Proteacidites* sp., *Peregrinipollis nigericus* and quantitative occurrence of *Verrutricolpotires* sp. (Fig.2) The co-occurrence of these forms belong to subzone P630 of Evamy *et al*., (1978) and Zone C1 of Legoux (1978). The assemblage of miospores here is in tandem with those for claystone member of Gwandu Formation dated Early Eocene age in Dukku Claystone Type Section (Ola-Buraimo and Adamu, 2022). Organic walled forms recovered include undifferentiated dinoflagellate cysts, *Andalusiella* sp. and *Selenopemphix nephroides* (Plate 7). A higher percentage of dinoflagellates cysts (57.14 %) to terrestrial pollen (42.86 %) suggests deposition in marginal marine environment (Ola-Buraimo, 2020a, b; Ola-Buraimo and Ehinola, 2021). A comparison of the percentage of palynomorph

diversity in sample N1 with sample N2 depicts a gradual deepening in the deposition of the sediments from the continental to marginal marine system. Therefore, a prograding system of a deltaic setting is suggested for the Gwandu Formation.

Sample: N3
Zone: *Margnastriatites howardii* Zone (Germeraad *et al*., 1968).
Subzone: P600 Zone/P630 Subzone (Evamy *et al*., 1978).
Zone: C1 Zone (Legoux 1978).
Age: Early Miocene
Characteristics: The sample N3 is characterized by the appearances of *Retibrevitricolporites obodoensis* and relative increase in the quantity of recovered *Verritricolporites* sp (Fig. 2). The pollen percentage recovered is quantitatively small in population and diversity; characterized by no recovery of dinoflagellate cyst (Fig. 2). The sample was dated Early Miocene based on the occurrence of marker fossils such as *Retibrevitricolporites obobdoensis and Striamonocolpites laevigatus* (Germeraad *et al*., 1968; Evamy *et al*., 1978 and Leqoux, 1978). The palynomorph assemblage is similar with pollen and spores recovered in claystone sediments of Dukku Claystone Type Section dated Early Miocene age (Ola-Buraimo and Adamu, 2022). The paleoenvironment of deposition of the sample N2 is suggested to be fluviatile based on the occurrence of non-appearance of dinoflagellates cysts and rare occurrence of *Botryococcus braunii*. (Ola-Buraimo, 2020; Ola-Buraimo and Ehinola, 2021). Therefore, the interval belongs to a period of low seal level whereby there was active fluviatile processes of continuous progradation of the deltaic setting of a Lowstand Systems Tract (Fig.2)

Sample: N4
Zone: *Margnastriatites howardii* Zone (Germeraad *et al.*, 1968).
Zone/Subzone: P600 Zone/P630 Subzone (Evamy *et al.*, 1978).
Zone: C1 Zone (Legoux 1978).
Age: Early Miocene
Characteristics: Sample 4 is the carbonaceous shale that was particularly investigated for this study by comparing the palynomorph assemblage contained in it with the pollen, spores and dinoflagellate cysts recovered from the overlying claystone beds. The shale is relatively rich in pollen, rare in spore and very abundant in dinoflagellates. Diagnostic pollen that are stratigraphically important and present in the sample include *Striamonocolpites laevigatus*, *Retibrevitricolporites obodoensis*, *Longapertites* sp, *Proteacidites* sp, *Praedapollis* sp., *Peregrinipollis nigericus* and *Belskipollis elegans* (Fig.2). The only recovered spore is *Laevigasporites* sp. in rare quantity. The palynomorph to dinoflagellate cyst percentage ratio is 35.94:64.06 % respectively.

The assemblage of palynomorphs recovered in the carbonaceous shale is similar with those obtained from Samples N1, N2 and N3. The assemblage of miospores recovered in the shale is also similar with those forms recovered from claystone of Dukku Claystone Type Section and the overlying claystones in this study, dated Early Miocene age (Ola-Buraimo and Adamu, 2022). Dinoflagellate recovery is relatively high compared with the overlying claystone member that does not have a record of dinocyst recovery. The relative increase in dinoflagellate to terrestrial miospores is an indication of gradual deepening deposit of the carbonaceous shale in a marginal marine environment away from the continent. The change in the paleobathymetry from continental to marine environment was as a result of increase in sea level incursion during

Transgressive Systems Tract; characterized by retrogradational depositional system (Fig. 2). Dinoflagellates that appeared in the sample N4 are *Andalusiella* sp., *Selenopemphix nephroides*, *Senegalinium* sp., *Andalusiella polymorppha*, *Oligosphaeridium* sp., *Spinidium* sp., *Batiacasphaera* sp. and rare occurrence of algae of Botryococcus braunii type (Fig.2, Plate 7). The preponderance of Peridinacean forms over the gonyaulacacean forms, and high pollen abundance and diversity are indicative of Transgressive Systems Tact regime of a rising sea water level in a marginal marine setting (Adebayo *et al*., 2015; Ola-Buraimo, 2020; Ola-Buraimo and Ehinola, 2021).

SAMPLE NO.	LITHOLOGY	LITHO-DESCRIPTION	POLLEN AND SPORES									DINOFLAGELLATE CYSTS									ALGAE	PALYNOMORPH ABUNDANCE	PALYNOMORPH DIVERSITY	DINOFLAGELLATE ABUNDANCE	ALGAE ABUNDANCE	SYSTEMS TRACT	PALYNOZONATION			CHARACTERISTICS	AGE	PALEOENVIRONMENT
			STRIAMONOCOLPITES LAEVIGATUS	VERRITRICOLPORITES SP.	RETIBREVITRICOLPORITES OBODOENSIS	PROTEACIDITES SP.	PEREGRINIPOLLIS NIGERICUS	LONGAPERTITES SP.	LAEVIGATOSPORITES SP.	PRAEDAPOLLIS SP.	BELSKIPOLLIS ELEGANS	DINOFLAGELLATE CYSTS	ANDALUSIELLA SP.	SELENOPEMPHIX NEPHROIDES	SENEGALINIUM SP.	LEJEUNCYSTA SP.	ANDALUSIELLA POLYMORPHA	OLIGOSPHAERIDIUM SP.	SPINIDIUM SP.	BATIACASPHAERA SP.	WETZILIELA SP.	BOTROCOCCUS BRAUNII						GERMERAAD *ET AL.* (1968)	EVAMY *ET AL.* (1978)	LEGOUX (1978)			
N1		DARK BROWN CLAYSTONE	2	5	1							1									5	14	5	1	5	LST	MAGNASTRATITES HOWARDII ZONE	P600 ZONE/P630 SUBZONE	C1 ZONE	**The interval is charaterized by the co-occurrence of *Striatricolpites laevigatus, Retibrevitricolporites obodoensis, Verrutricolporites sp., Peregrinipollis nigericus, Praedapollis sp.* and rare occurrence of *Belskipollis elegans* indicative of Early Miocene age.**	EARLY MIOCENE	FLUVIAL
N2		LIGHT BROWN BIOTURBATED CLAYSTO-	2		1							1	2	1								7	5	4	0	TST						MARGINAL MARINE
N3		DARK BROWN CLAYSTONE		6	1	1	1														1	10	5	0	1	LST						FLUVIAL
N4		LIGHT GREY CARBONACEOUS FISSILE SHALE	3		5	4	3	8	1	1	1	10	2	2	1	12	2	1	1	2	8	1	64	19	41	1	TST						MARGINAL MARINE

FIGURE 2. CHECKLIST OF PALYNOMORPH APPEARANCE WITH DEPTH, LITHO-DESCRIPTION, PALYNOZONES, SYSTEMS TRACT, AGE AND PALEOENVIRONMENT OF DEPOSITION

Figure 2. Checklist of palynomorph appearance with depth, litho-description, palynozones, systems tract, age and paleoenvironment of deposition

The sequence stratigraphic relationship between the samples as indicated in sample N1 and N3 belong to LST while samples N2 and N4 belong to TST regimes. Such phenomenon and sequence stratigraphic relationship was as a result of eustatic changes in sea level and other geologic factors (Ogala *et al*., 2009; Ola-Buraimo *et al*., 2010; Adebayo *et al*., 2015; Ola-Buraimo, 2020; Ola-Buraimo and Ehinola, 20211; Ola-Buraimo and Adamu, 2022).

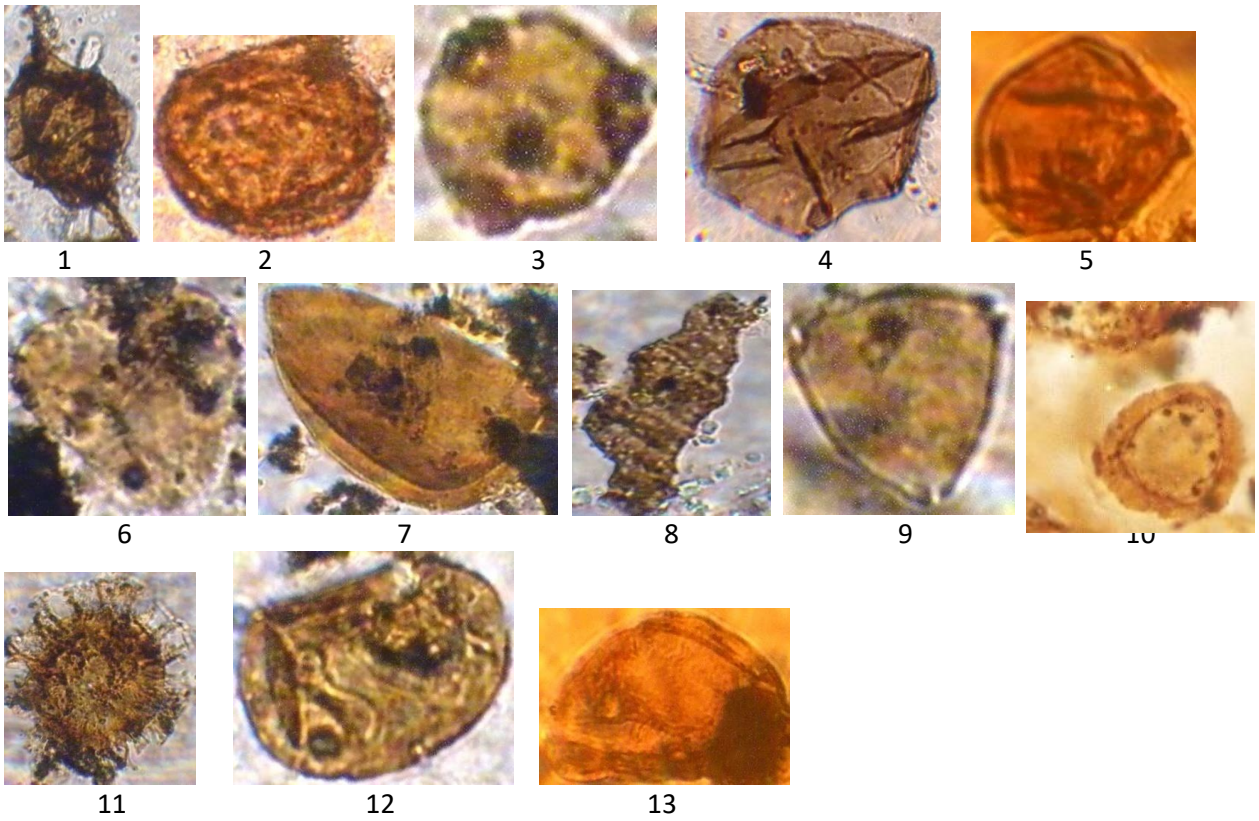

Plate 7. Assemblage of some recovered Palynomorphs in Gwandu Formation at Dukku Hill

1 *Andalusiella polymorpha*
2 *Batiacasphaera* sp.
3 *Retibrevitricolporites obodoensis*
4 *Andalusiella laevigata*
5 *Phelodinium* sp
6 Cyathidites sp.
7 *Longapertites microfoveolatus*
8 *Botryococcus braunii*
9 *Proteacidites* sp.
10 *Cingulatisporites ornatus*
11 *Histrichosphaeridium turocona*
12 *Laevigatosporites* sp.
13 *Longapertites marginatus*

CONCLUSION

Outcrop section of the study area indicated a basal carbonaceous shale and overlying claystone facies. The carbonaceous shale is light grey in colour, bioturbated, and slightly ferruginized. The vertical arrangement of the lithofacies based on the palynomorphs recovery shows gradual deepening and relative increase in palynomorph abundance and diversity. The miospores forms present in the carbonaceous shale are similar with those recovered from the overlying claystone beds. They are composed of *Retibrevitricolporites obodoensis*, *Striamonocolpites laevigatus*,

Verritricolporites sp., *Praedapollis* sp. and *Belskipollis elegans*; indicative of Early Miocene sediment, deposited in the continental and marginal marine paleoenvironments.

The main controlling factor in the deposition of the Gwandu Formation was the eustatic change in sea level, whereby Lowstand Systems Tract (LST) was responsible for the deposition of continental claystone deposit while the Transgressive Systems Tract (TST) resulted in the deposition of marginal marine claystone and carbonaceous shale. These assertions are based on the paucity and preponderance of peridinacean dinoflagellates. Therefore, the Tunga Buzu Carbonaceous Shale Type Section constitutes a member and belongs to the Early Miocene Gwandu Formation in Sokoto Basin, northwestern Nigeria.

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