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PALYNOLOGY, PALEOENVIRONMENT AND STRATIGRAPHY RELATIONSHIP OF TUNGAN BUZU HILL WITH ADJACENT VALLEY GWANDU FORMATION, SOKOTO BASIN, NORTHWESTERN NIGERIA

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ABSTRACT: *Palynological study of Tungu Buzum Hill was investigated with a view towards determining the age of the outcrop, compare its miospore content with the adjacent Tungu Buzu Valley of carbonaceous shale, their stratigraphic relationship and paleoenvironment of deposition of the litho-sequence. Field study involved litho-description and logging achieved by noting the rock type, mineralogical composition, bed thickness, texture, sorting, roundness, structure, fossil content and diagenetic effect. Palynological slide preparation involved decarbonisation, digestion, sieving, maceral separation using zinc bromide, mounting on slide and petrographic analysis. The litho-sequence is composed sequentially upward of claystone, siltstone, indurated silty claystone, mudstone and ferruginized ironstone characterized by loadcast, fracture, lithification and bioturbation. Palynologically, the litho-section exhibits few marker forms such as Belskipollis elegans, Peregrinipollis nigericus and Retibrevitricolporites obodoensis depictive of early Miocene age. The paleoenvironment was deduced based on the occurrence of peridinacean forms such as Andalusiella sp., Senegalinium sp., Lejeuncysta diversiforma and Paleocystodinium golzowense indicative of marginal marine, while deeper marginal marine forms of gonyaulacacean phytoplanktons present are Micrhystridium sp., Canningia capillata and Dinogymnium sp. There are similarities in palynomorph assemblages of this study and Tunga Buzu Valley section in terms of age and similarity to Gwandu Formation though varied in paleoenvironment in the valley litho-section, marked by continental to marginal marine settings. Field relationship suggests that the Tunga Buzu Hill is stratigraphically overlying the Tunga Buzu Valley, separated by a fault. The Tunga Buzu Hill section represents the footwall while the Tunga Buzu Valley is situated within the hanging wall of a normal fault structure.*

KEYWORDS: Litho-sequence, Marker forms, Deeper marginal marine, Phytoplankton, Footwall and Hanging wall.

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INTRODUCTION

The main interest of study is on Gwandu Formation. The Gwandu Formation continues to attract research study because research investigations on the formation are not abundantly available and previous knowledge on it is scanty and questionable in some aspects. However, there is a recent step-up in the acquisition of geologic information on the Gwandu Formation in different fronts such as geophysics, sedimentology, hydrogeology and biostratigraphy. Despite researchers' keen interest in the formation, it remains inexhaustible especially in the aspect of biostratigraphy and sedimentology. The concentration of the study of Gwandu Formation in Birnin Kebbi is due to the presence of fantastic exposures scattered in both the metropolis and outskirt of the city than other areas in Sokoto Basin.

The Gwandu Formation is the youngest in Sokoto Basin. The geology of Sokoto Basin is sparsely documented compared to other coastal and inland basins in Nigeria. However, the Sokoto Basin was described to have evolved as a result of the separation of South American and African landmasses which resulted in rifting during the Middle Cretaceous. The resultant rifting permitted incursion of the Mediterranean Sea and possibly Gulf of Guinea from the south responsible for sedimentation in the basin. The oldest formation in the basin was given a broad Cretaceous age encompassing Illo and Gundumi formations overlying the Crystalline Basement Complex. These are overlain by Taloka, Wurno and fossiliferous Dukamaje formation of Rima group, dated Maastrichtian age. The Rima group sediments are overlain by Sokoto group facies comprising Dange, Gamba and Kalabaina formations, broadly dated Paleocene. The Paleocene sediments are overlain by the youngest Gwandu formation.

Several workers have studied the geology of Sokoto Basin including Kogbe (1972, 1974, 1976, 1989), Adeleye (1975), Obaje (2009, 2013), Obaje *et al*. (2004, 2011, 2014) on the hydrocarbon potential of Sokoto Basin, and Auduson and Onuoha (2020) on the architecture and basement topography using aeromagnetic data of the basin. A number of researches have been carried out on the Gwandu formation, including the works of Wali (2020) on the hydrogeochemical evaluation and mechanisms controlling groundwater. Ozumba *et al.* (2017) described the Gwandu formation sandstone to have good porosity and permeability. Among the recent researches on the Gwandu formation are the works of Ola-Buraimo *et al*. (2018), Ologe *et al*. (2018), Ola-Buraimo and Ologe (2020), Ologe and Ola-Buraimo (2022), Ola-Buraimo and Usman (2022), Ola-Buraimo and Haidara (2022), and Ola-Buraimo and Adamu (2022).

The study area, Tunga Buzu, is located in the northern part of Birnin Kebbi, situated between Longitude $12^0\ 21^l\ 27^{ll}\ 14^0\ 22^l\ 29^{ll}$ and Latitude $4^0\ 16^l\ 24^{ll}\ 8^0\ 18^l\ 27^{ll}$ E (Fig. 1). The investigated area is restricted to the Tunga Buzu Hill. The objectives of study are to date the claystone facies and correlate their palynological assemblages with those obtained from the carbonaceous shale in Tunga Buzu valley from the work of Ola-Buraimo and Haidara (2022), and thereby determine whether it is younger or having same paleoenvironment of deposition and whether it overlies the litho-section in Tunga Buzu Valley.

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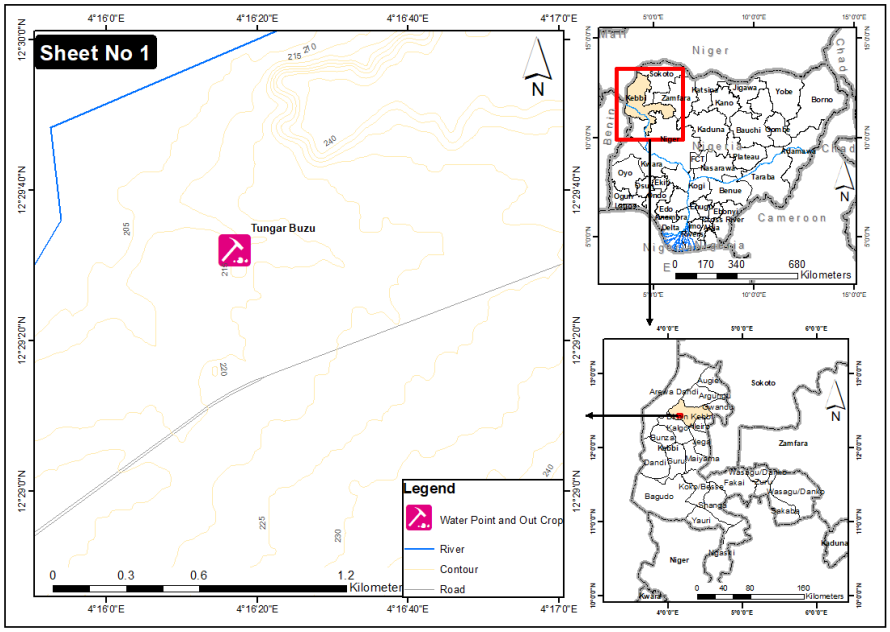

Figure 1: Location Map of the Study Area (This Study)

METHODOLOGY AND MATERIALS

Tunga Buzu Hill was described succinctly from the bottom to the top of the outcrop. Field materials used include GPS, clinometer, measuring tape, hand lens, field note, field map, and 10% dilute hydrochloric acid. Systematic litho-description adopted was after the works of Ola-Buraimo (2020), and Obuseh and Ola-Buraimo (2022) whereby rock types, mineralogical composition, bed thickness, texture, sorting, roundness, structure, fossil content and fabric were determinant factors. Other salient features noted include the presence of accessory minerals and post depositional effects such as diagenesis.

Palynological sample preparation followed the procedure suggested by Ola-Buraimo (2020), and Ola-Buraimo and Haidara (2022). The samples were described, soaked with dilute hydrochloric acid and digested with hydrofluoric acid. The procedure was followed by sieving of samples with 10 µm mesh; maceral was separated from organic matter using zinc bromide. The separated supernatant was mounted on the glass slides for microscopic analysis and photography of preserved forms.

RESULT AND DISCUSSION

Tungan Buzu Hill is dominated by clay and consists of silt particles and bioturbation across some beds; the total thickness of the outcrop exposure is about 42.8 m. The litho-section at the base consists of variegated claystone, characterized by intense fractures, loadcast and a thickness of 7m thick. It is overlain by loadcast structure, mottled, bioturbated, reddish claystone of 7m thick (Fig. 2). Intercalation layers of fractured, multicoloured purple to yellowish claystone and thin layered siltstones, have a thickness of about 8m. This is overlain

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by indurated, yellowish to brownish silty claystone of intense bioturbation, stratigraphically deposited at the near top of the outcrop. The lower to middle sedimentary facies of different claystones and intercalated siltstone are suggested to be products of marginal marine paleoenvironment of deposition. The upper part of the litho-sequence is composed of continental deposits, and consists of layers of yellowish to brownish coloured mudstone (8.5m thick) and ferruginized ironstone of 7.33m thick as cap rock. The top of the outcrop is flat and extensive in nature with steep sides heavily weathered (Fig. 2).

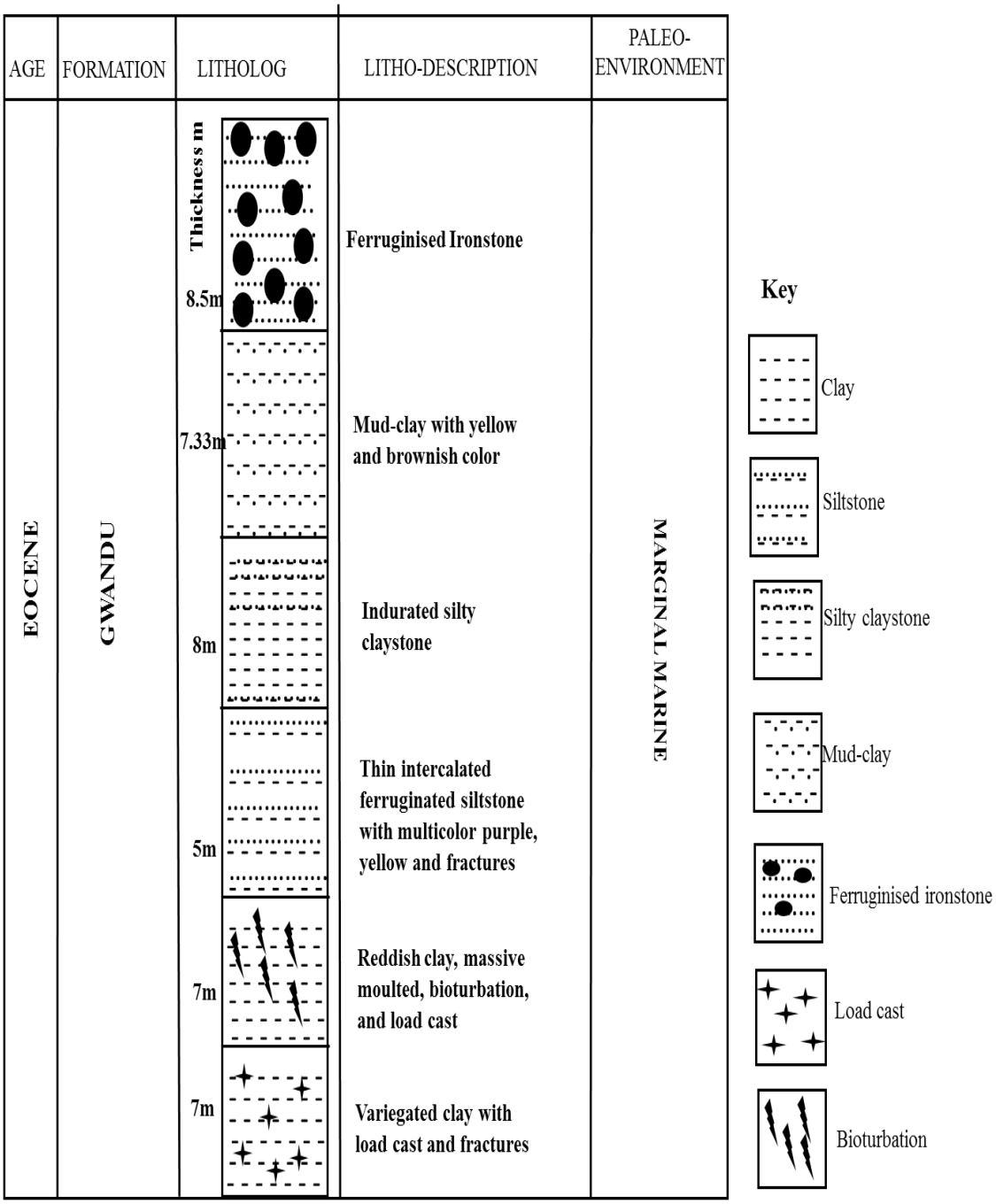

Figure 2: Litholog of Tungan Buzu Hill

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Palynology

Palynological study was carried out on the Tungan Buzu outcrop. Five samples were collected from the outcrop in a sequential order, whereby sample K1 was collected at the bottom of the hill, while K2, K3, K4, and K5 were collected at the middle and upper parts. The sampling interval is irregular as a result of different positions of the clay beds in the outcrop sequence.

Palynozones

The palynological zone erected was compared with the works of Germeraad *et al*. (1968), Evamy *et al*. (1978), Legoux (1978), and Ola-Buraimo and Haidara (2022). The details of the palynological zone, geologic age, palenenvironment of deposition and the basis of their establishments are given below.

SAMPLE: K1

Zone: *Margnastriatites howardii* (after Germeraad *et al*., 1968).

Zone/Subzone: P600/P630 (after Evamy *et al*., 1978).

Zone: C1 zone (after Legoux 1978).

Age: Early Miocene

Characteristics: Palynomorph assemblage in Sample K1 is composed of few diagnostic forms such as *Belskipollis elegans* and *Peregrinipollis elegans*. The pollen is rare in abundance and depictive of Early Miocene age (Germeraad *et al*., 1968; Evamy *et al*., 1978; Legoux, 1978). The relative proportion of terrestrial pollen to dinoflagellate cysts is insignificant. The Sample K1 is dominated by organic walled phytoplankton such as *Andalusiella* sp., undifferentiated dinoflagellate cysts, *Selenopemphix nephroides*, *Senegalinium* sp., *Lejeuncysta diversiforma*, and *Dinogymnium* sp. (Fig. 3; Plate 1). The interval contains pollen similar to those of Tunga Buzu valley carbonaceous shale section, dated early Miocene. It has same paleoenvironment of deposition described to be marginal marine setting (Ola-Buraimo & Haidara, 2022).

SAMPLE: K2

Zone: *Margnastriatites howardii* (after Germeraad *et at*., 1968).

Zone/Subzone: P600/P630 subzone (after Evamy *et al*., 1978).

Zone: C1 zone (after Legoux, 1978).

Age: Early Miocene

Characteristics: The sample K2 contains a grain of *Retibrevitrocolporites* sp. which suggests Early Miocene age deposit. Associated miospores present but not stratigraphically important include *Monosulcites* sp. *Proteacidites* sp. *Monocolpites marginatus* and *Laevigatosporites* sp. The interval is further characterized by moderate diversity of dinoflagellate cysts such as *Nematosphaeropsis labyranthea, Paleocystodinium golzowense*, dinocysts, *Andalusiella polymorpha, Batiacasphaera* sp., *Senegalinium* sp., *Selenopemphix nephroides* and *Micrhystridium* sp. indicative of marginal to deeper marginal marine environment (Fig. 3; Plate

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1). However, the interval further shows appearance of algae (*Botryococcus braunii*) and microforaminiferal wall.

The interval is correlatable with established works of Germeraad *et al*. (1968), Evamy *et al*. (1978) and Legoux (1978), dated early Miocene age. The palynomorph assemblage is also correlatable with the assemblages of established reports on the palynological study of Gwandu Formation at Dukku Claystone Type Section (Ola-Buraimo & Adamu, 2022) and also similar to Gwandu Formation Carbonaceous Shale at Tunga Buzu Valley (Ola-Buraimo & Haidara, 2022). The presence of microforaminiferal wall lining in the interval could suggest deposition of the sediment in a deeper marginal marine environment compared to the interval that overlies it.

SAMPLE: K3

Zone: *Margnastriatites howardii* (after Germeraad *et al*., 1968).

Zone/Subzon: P600/P630 subzone (after Evamy *et al*., 1978).

Zone: C1 zone (after Legoux, 1978).

Age: Early Miocene

Characteristics: The palynomorph assemblage of Sample K3 does not contain diagnostic forms that could suggest early Miocene age. However, the suggested age was based on the stratigraphic position of the interval within the stratigraphic column. Pollen and spores present are *Longapertites marginatus*, *Proteacidites* sp., *Cingulatisporites ornatus*, *Verrucatosporites* sp., *Leiotriletes* sp. and *Monosulcites* sp. (Fig. 3) Organic walled phytoplankton of peridinacean type present include the undifferentiated dinocyst, *Selenopemphix nephroides*, *Andalusiella polymorpha*, *Batiacasphaera* sp. and *Canningia capillata* in association with rare occurrence of gonyaulacacean form like *Canningia capillata* (Fig. 3; Plate 1). They are paleoenvironmental markers of marginal marine setting (Ola-Buraimo, 2020; Ola-Buraimo & Ehinola, 2021).

SAMPLE: K4

Zone: *Margnastriatites howardii* (Germeraad *et al*., 1968).

Zone/Subzone: P600/P630 (after Evamy *et al*., 1978).

Zone: C1 zone (after Legoux, 1978).

Age: Early Miocene

Characteristics: The Sample K4 is characterized by rare occurrence of non-diagnostic forms such as *Longapertites marginatus*, *Monosulcites* sp. and *Auriiculidites* sp. (Fig. 3; Plate 1). They are pollen with long stratigraphic age range, neither restricted nor having offshoot in the early Miocene period. Therefore, the interval is not concisely defined but tentatively dated early Miocene age based on the stratigraphic interval position in the outcrop section. The sediments were deposited in the marginal marine paleoenvironmental setting based on the occurrence of peridinacean forms such as *Andalusiella* sp., dinocyst, *Senegalinium* sp., rare occurrence of gonyaulacacean form like *Micrhystridium* sp. and fluviomarine algae form like

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Botryococcus braunii (Ola-Buraimo, 2020; Plate 1). Therefore, the Sample K4 is suggested to have been deposited in a marginal marine environment like the overlying interval.

SAMPLE: K5

Zone: *Margnastriatites howardii* (after Germeraad *et al*., 1968).

Zone/Subzone: P600/P630 subzone (after Evamy *et al*., 1978).

Zone: C1 zone (after Legoux, 1978).

Age: Early Miocene

Characteristics: The interval with Sample K5 is at the bottom of the Tunga Buzu Hill. It is relatively deficient in pollen and spore; in contrast it has relative abundance of organic walled phytoplankton (Fig 3; Plate 1). The only marker fossil present is rare in occurrence—*Belskipollis elegans*, suggestive of early Miocene age (Germeraad *et al*., 1968; Evamy *et al.*, 1978; Legoux, 1978; Ola-Buraimo & Adamu, 2022; Ola-Buraimo & Haidara, 2022). The paleoenvironment of deposition is marginal marine system based on the occurrence of dinoflagellate cysts (Ola-Buraimo, 2020; Ola-Buraimo & Ehinola, 2021).

Palynostratigraphic correlation establishes that the palynomorph assemblages in this study and Tunga Buzu Valley Carbonaceous Shale outcrop section is similar, and belong to same *Magnastriatites howardii* zone of Germeraad *et al*. (1968), P600 zone and P630 subzone of Evamy *et al*. (1978), and zone C1 of Legoux (1978), dated Early Miocene age. They as well belong to the same paleoenvironment of deposition, marginal marine and deeper marginal marine in Tunga Buzu Hill but vary from continental to marginal marine settings in Tunga Buzu Valley Carbonaceous Shale section deposit. It is here established that both the hill and the valley stratigraphic sections belong to Gwandu Formation. Field relationship suggests that the Tunga Buzu Hill is stratigraphically overlying Tunga Buzu Valley, but separated from each other possibly as a result of faulting whereby the hill section is an upthrow corresponding to the footwall and the valley section is a downthrown equivalent to the footwall of a faulted structure.

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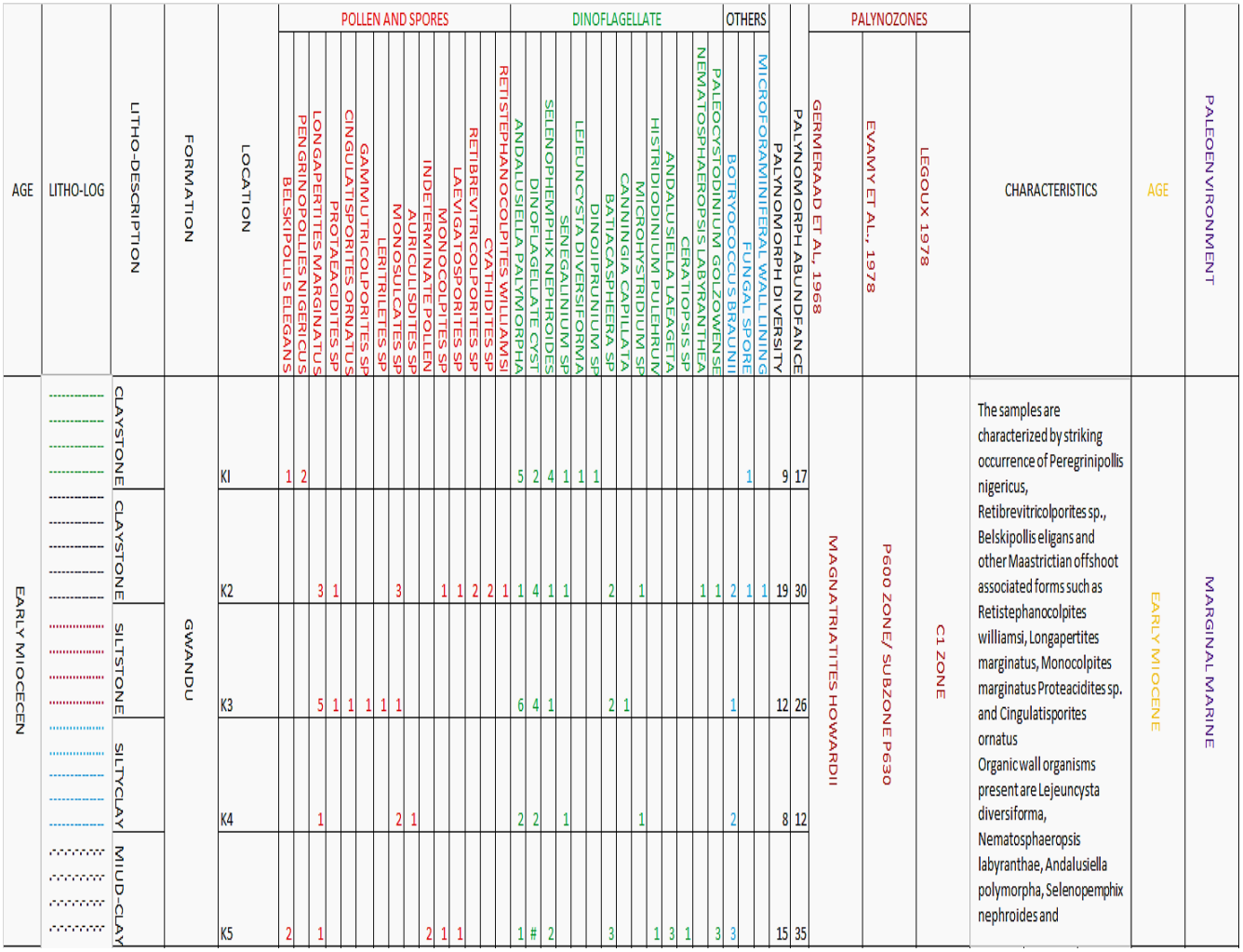
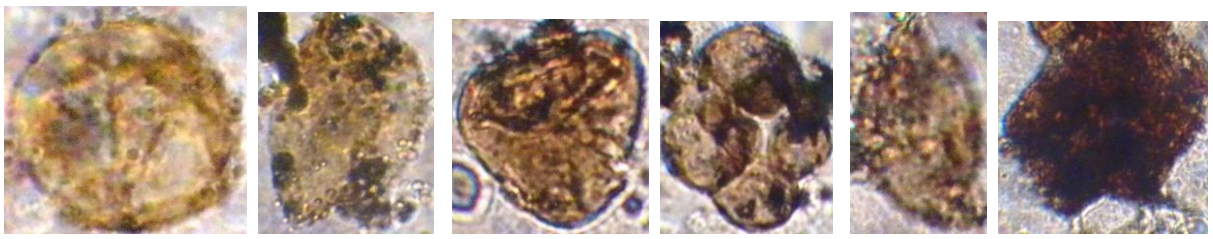


Figure 3: Distribution Chart of Palynomorphs Recovered from Tungan Buzu Hill

Magnification ×800



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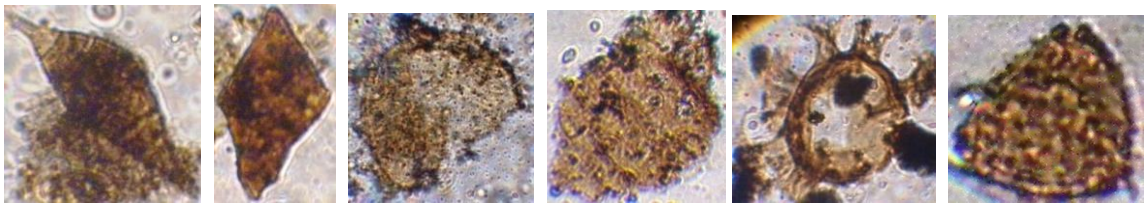

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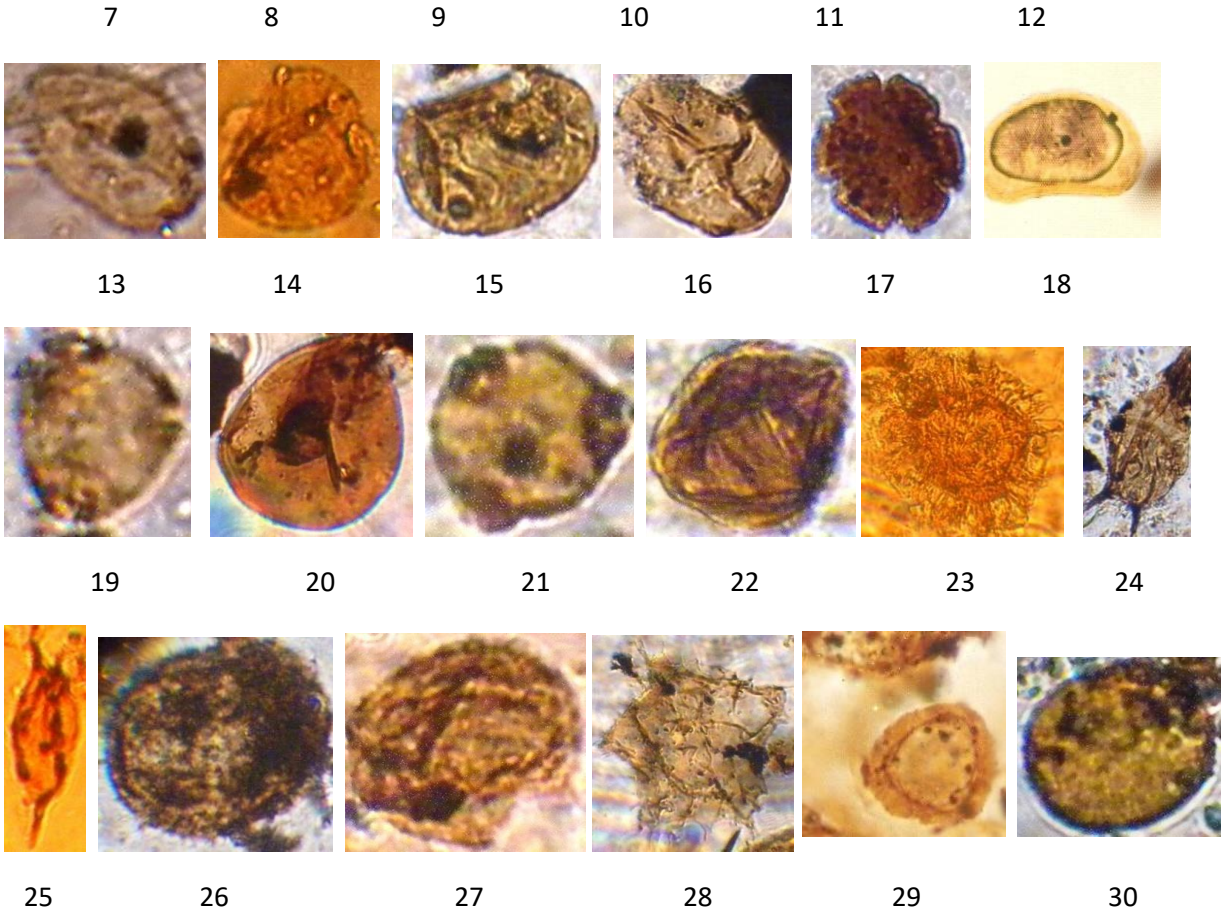

Plate 1: Assemblage of Some Recovered Palynomorphs in Gwandu Formation at Dukku Hill

1 *Batiacasphaera* sp.

2 *Longapertites marginatus*

3 *Cyathidites* sp.

4 Microforaminiral wall lining

5 *Auriculiidites* sp.

6 *Senegalinium* sp.

7 Fungal spore

8 *Andalusiella polymorpha*

9 *Caningia* sp.

10 *Botyroccus braunii*

11 *Oligosphaeridium pulcherrimun*

12 *Proteacidites* sp.

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13 *Monocolpites marginatus*

14 *Monosulcites* sp.

15 *Laevigatosporites* sp.

16 *Monosulcites* sp.

17 *Retistephanocolpites williamsi*

18 *Verrucatosporites* sp.

19 *Retibrevitricolporites* sp.

20 *Leiotriletes* sp.

21 *Retibrevitricolporites obodoensis*

22 *Selenopemphix nephroides*

23 *Nematosphaeropsis labyrinthea*

24 *Ceratiopsis diabelii*

25 *Paleocystodinium golzowense*

27 *Lejeuncysta* sp.

28 *Wetzeliella* sp.

29 *Cingulatisporites ornatus*

CONCLUSION

Lithostratigraphy of Tunga Buzu Hill consists mainly of claystone, siltstone, indurated silty claystone, mudstone and ferruginized ironstone. The lithofacies are characterized by loadcast, fracture, lithification, bioturbation and ferruginization. The analyzed claystone facies are composed of few key miospores such as *Retibrevitricolporites obodoensis*, *Peregrinipollis nigericus* and *Belskipollis elegans*, indicative of early Miocene age belonging to Gwandu Formation.

Field relationship shows that the palynomorph assemblage of the Tunga Buze Hill is similar with that of the Tunga Buzu Valley carbonaceous shale section. The study outcrop varies from marginal to deeper marginal marine environment compared with Tunga Buzu Valley that varies from continental to marginal marine setting. Stratigraphically, the Tunga Buzu Hill overlies the Tunga Buzu Valley but they are separated by a fault; Tunga Buza Hill is the footwall while the Tunga Buzu Valley is the hanging wall of the normal fault in the area.

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