

Original Research Article

## Stratigraphic Status of the Bama Beach Ridge and the Chad Formation in the Bornu Sub-Basin, Nigeria.

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Accepted 30th April, 2015.

This work employed heavy mineral and micropalaeontological procedures to distinguish the Bama Beach Ridge from the Chad Formation in the Bornu sub-basin, Nigeria. Heavy mineral studies show the Bama Ridge samples as consisting of well diversified suite of both opaque and non opaque heavy minerals. These include Haematite, Magnetite, Leucoxene and Ilmenite on one hand and Zircon, tourmaline and rutile on the other. The Chad Formation, however, yielded only four species namely: zircon, rutile, apatite and sphene. Micropalaeontological analyses of several silty clay samples of the Bama Ridge yielded the ostracod species of *Eucypris* sp., *Cypridopsis* sp. and *Darwinula* sp. The Chad Formation samples are found to be effectively devoid of microfossil species. It is thus implied that the Bama Beach Ridge is a separate stratigraphic entity from the Quaternary Chad Formation in the Bornu sub-basin.

**Keywords:** Bama Ridge, Chad Formation, Heavy Mineral, Micropaleontology, Stratigraphic status

### INTRODUCTION

The Bama Ridge is a long and narrow sand ridge. It is a prominent morphological feature overlying the Quaternary Chad Formation in the northeastern part of Nigeria (Fig1) and represents the ancient shoreline of the Mega Lake Chad (Durand, 1982). It was considered to have been formed during the Late Pleistocene when it was left as a distinct feature as the Mega Chad receded (Grove, 1959).

Regionally, the ridge trends roughly NW-SE in a somewhat discontinuous manner for about 160 km. It covers parts of the Cameroun plains, extending through the northern tip of the Mandara Hills in Nigeria, passing through Bama in Borno State to Gashua and Nguru in Yobe State. It ultimately flattens out beneath the sand dunes of the Republic of Niger. The relief surrounding the Bama Ridge (which rises for some 12m through it) is relatively a flat plain (Seneviratae, 1983).

The Bama Ridge in the Nigerian sector of the Chad Basin has never been studied in detail and existing literature only made reports of its existence from geographic and geomorphic angles. Therefore, geological literature from published source is very scanty.

Sedimentological studies on the sediments of the Bama Ridge are scanty. Available information on the geology of this feature is surrounded by a lingering controversy about its origin. Most workers (Mioged, 1924; Grove and Warren, 1968;

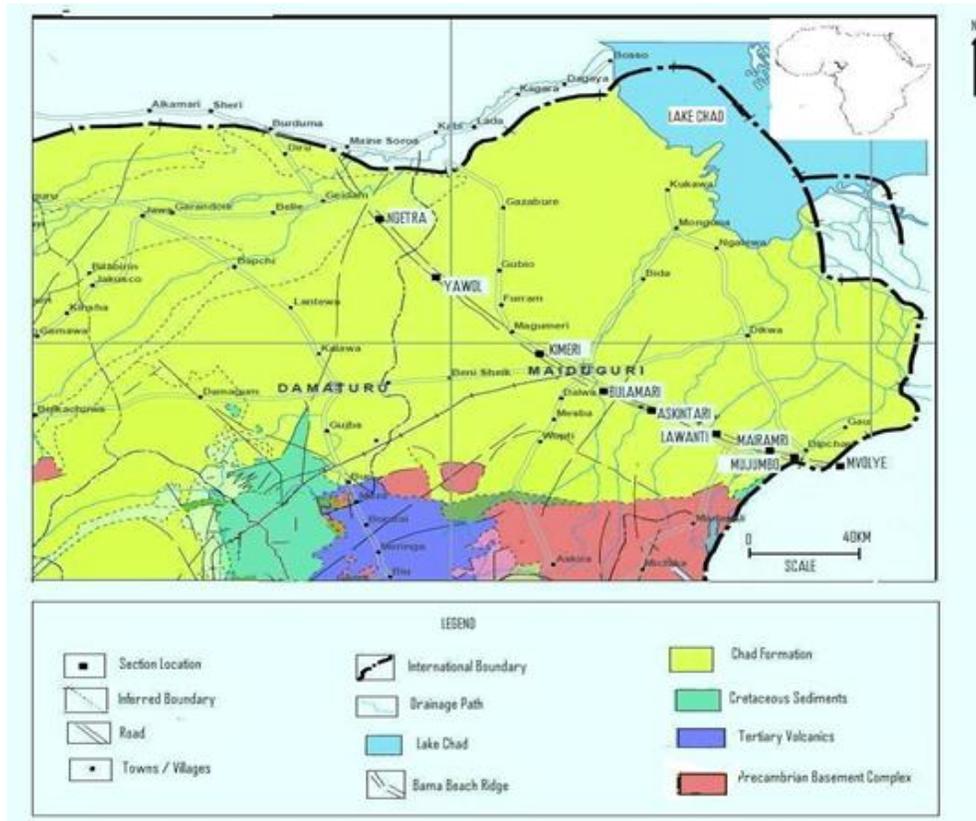
Miller et al., 1968; Iwuagwu, 1991 and Theimeyer, 1993) seem to associate the Bama Ridge with the shoreline of an ancestral Lake Chad. Workers want to know whether these deposits are constituents of the Chad Formation or a separate stratigraphic entity.

This work thus aims at deciphering the genetic relationship(s), if any, between the Bama Ridge and the underlying Chad Formation in the Bornu sub-basin.

The study area is located mostly in Borno State and covers parts of Bama, Konduga, Maiduguri Metropolitan Council and Magumeri Local Government Areas. The area lies within the 1:50,000 sheets 90 (Maiduguri) and 91 (Mafa/ Bama) and is bounded by latitudes 11°40' – 12° 18' N and longitudes 12° 47'- 13° 41'E. The locations chosen for this study are to the west of the Maiduguri –Yola highway. The ridge runs almost parallel to the road for about 40 km.

The numerous foot /track paths linking the Maiduguri- Yola highway to the ridge make it fairly accessible. During the peak of the rainy season, however, access to the study area becomes difficult as River Ngadda overflows its banks, making most of the area water- logged.

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**Fig 1:** Map of the study area showing the location of sections (Inset is map of Africa showing the location of the study area in Nigeria)

### Stratigraphic Framework of the Study Area

The study area is underlain by a succession of Cretaceous formations overlain by Tertiary and Quaternary formations. The following discussion forms a background to a discussion of the ridge which may be regarded as the youngest geological unit within the Chad Basin.

The study area exhibits platform and trough sedimentation in a geotectonic setting related to rifting (Dike, 2001, 2002b). This has resulted in a series of continental deposition and marine transgressions and regressions (Table 1). Dike (2001, 2002b) and Dike and Bature (1999) estimated a total thickness of about 6000m for the formations from NNPC boreholes. Earlier geophysical (seismic) estimates gave an average thickness of over 10,000 m (Avbovbo *et al.*, 1986).

The Chad Formation, on which the Bama Ridge directly rests, is a variable succession that includes all Quaternary sediments underlying the surface deposits. The formation is a succession of lacustrine and fluvial clays and sands of Quaternary/Pleistocene age (Carter *et al.*, 1963; Dike and Bature, 1999; Dike, 2002a, b). Sediments of the Bama Ridge are considered by some authors (Carter *et al.*, 1963; Matheis, 1976) as a constituent of this formation. It has an average thickness of 400 m.

With respect to water supply, this formation is of great economic significance. It has a thickness of over 700 m in Maiduguri area and, in zones where the fluvio-lacustrine deposit is complete, water-bearing levels consisting mostly of sands and clayey sands are concentrated in three well defined aquiferous horizons (Dike and Bature, 1999; Dike 2002b).

According to Dike (2002b), drilling in the basin has given an insight into the basin's subsurface stratigraphy and shows that large volumes of water exist in the formation. According to data from NNPC boreholes in Maiduguri area (Dike, 2002b), the Chad Formation rests unconformably on the Fika Formation. This has been explained as due to the local uplift/erosion of the post Maastrichtian sediments which affected the northern Benue Trough prior to the sedimentation of the Chad Formation (Dike, 2002 a, b)

### MATERIALS AND METHODS

#### Reconnaissance

This was the first and preliminary stage of field studies, and was used as an aid to locate suitable sites for the field studies and also to determine the accessibility of the study area by locating foot and truck paths. The Nigerian Federal Survey topographic map sheet 90 (Maiduguri / Mafa) and the Agric, Livestock and Technical Services (ALTS, 1976) topographic map of the Ngadda and Yedzaram catchments were used.

#### Section measurement and description

This exercise was aimed at studying the outcrops in detail by measuring and recording all features of geologic interest such as strikes and dips, sedimentary structures and the azimuths of directional structures. Logging of sections was based on recognition and subdivision of lithologic units such as clay, silt, sand and granulestone.

**Table 1:** Generalized stratigraphic column of northeastern Nigeria (Modified from Carter, 1963; Avbovbo, 1986)

| Age                       | Formation        | Thickness (M) | Description  |
|---------------------------|------------------|---------------|--|
| Quaternary                | Chad             | 400           | Clay with sand interbeds   |
| Palaeocene                | Kerri-Kerri      | 130           | Predominantly iron-rich sandstone and clay with plinth of laterite |
| ----- Unconformity -----  |                  |               |  |
| Maastrichtian             | Gombe            | 315           | Sandstone, siltstone and clay beds                                 |
| Senonian                  | Fika             | 430           | Dark grey to black shale, gypsiferous with limestone beds          |
| Turonian                  | Gongila          | 420           | Alternating limestone and shale with sand beds                     |
| Albian to Cenomanian      | Bima             | 3050          | Poorly sorted, feldspathic sandstone                               |
| Albian                    | Pre-Bima         | 800           | Sand/shale succession  |
| ----- Nonconformity ----- |                  |               |  |
| Precambrian to Cambrian   | Basement Complex |               |  |

This follows the style of Tucker, (1982, 1991, and 2003). After identification of the lithologies, bed thicknesses were measured and details of the attributes were recorded in the field note book.

### Sampling

Systematic collection of outcrop and subsurface samples of the Bama Ridge was undertaken. Subsurface samples were obtained from pits. Hand auger was used for depths of more than half a metre. Ditch cuttings of the Chad Formation were obtained from the NNPC warehouse at Gajiganna. Wells drilled in the area encountered the Chad Formation as the first stratigraphic horizon. The samples are not well preserved, but a total of twenty six representative samples were obtained. A total of 86 samples were collected from both outcrop and the subsurface.

### Laboratory Methods

Heavy mineral study was undertaken to determine the maturity as well as the possible provenance of the sediments of the Bama Ridge. Bromoform was poured directly onto a separation funnel arranged with a collecting flask and a funnel with filter paper placed underneath. Parts of each sample were introduced into the funnel one after the other and constantly stirred with a glass rod until no heavy mineral was observed settling down the separation funnel. The wall of the funnel was washed down with bromoform from a squeeze bottle to ensure that no heavy minerals clung to the wall of the funnel.

The separatory funnel's tap was turned open after achieving a complete separation to allow the settled heavy mineral into the flask underneath the funnel. After separation, the heavy minerals were mounted on slides using Canada balsam while identification was done following the procedures of Krumbein and Pettijohn (1938). The relative abundances of

the heavy minerals were estimated from the slides using a combined fleet and ribbon method (Glaehouse, 1971) on a flat stage. Heavy minerals from 66 samples of the Bama Ridge and 10 of the Chad Formation were studied.

### Microfossil studies

Forty (40) samples of silty clays of the Bama Ridge and 13 of the Chad Formation were subjected to microfossil analysis. 100 grammes of each sample was measured and boiled in a solution of  $\text{Na}_2\text{CO}_3$  for about 40 minutes in a pot of stainless steel, while constantly stirring with a stirring rod to disaggregate the particles. After boiling, the solution was allowed to cool and then poured into a set of sieves of mesh sizes 20, 40, 60, 80 and 100 microns.

Mesh size 20, which retained few large grains, was discarded. The retains on each sieve mesh were washed gently with running water, the meshes were then oven-dried. The residues were then labeled and stored in a fume cupboard for observation. The content of each sieve was observed under the binocular microscope. Two types of picking trays were used: one with a coloured background, the other with a white background. By gently tapping, using a sharp - pointed needle, suspected microfauna were picked for identification.

## RESULTS AND DISCUSSIONS

### Results

#### Heavy Minerals

Using optical characteristics exhibited by mounted specimens on slides, several species of heavy minerals were identified. Results indicate that the Bama Ridge has both the opaque and non-opaque heavy minerals (Fig. 2). The opaques are volumetrically more abundant than the non-opaques.

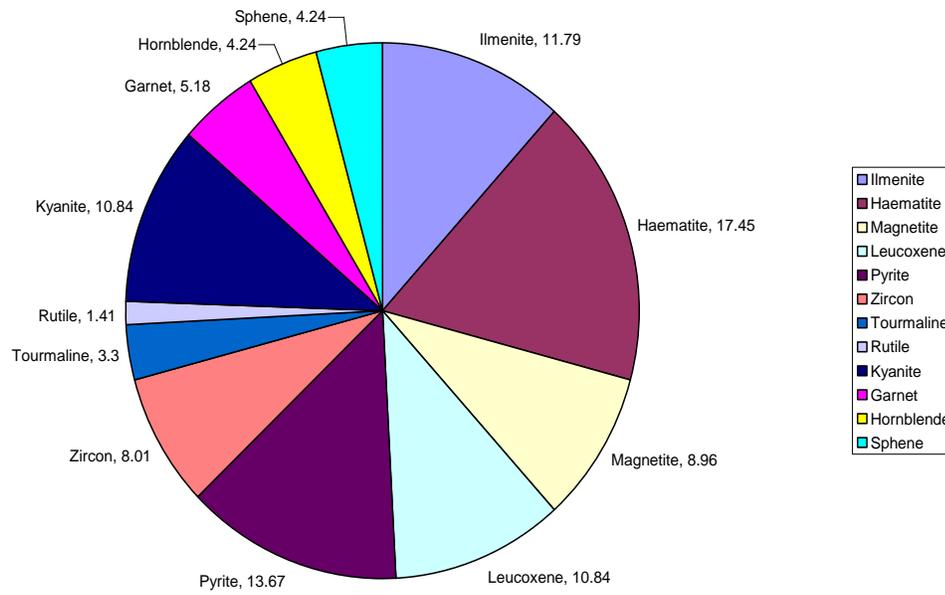


Fig 2: Frequencies of the suite of heavy minerals in the Bama Ridge facies

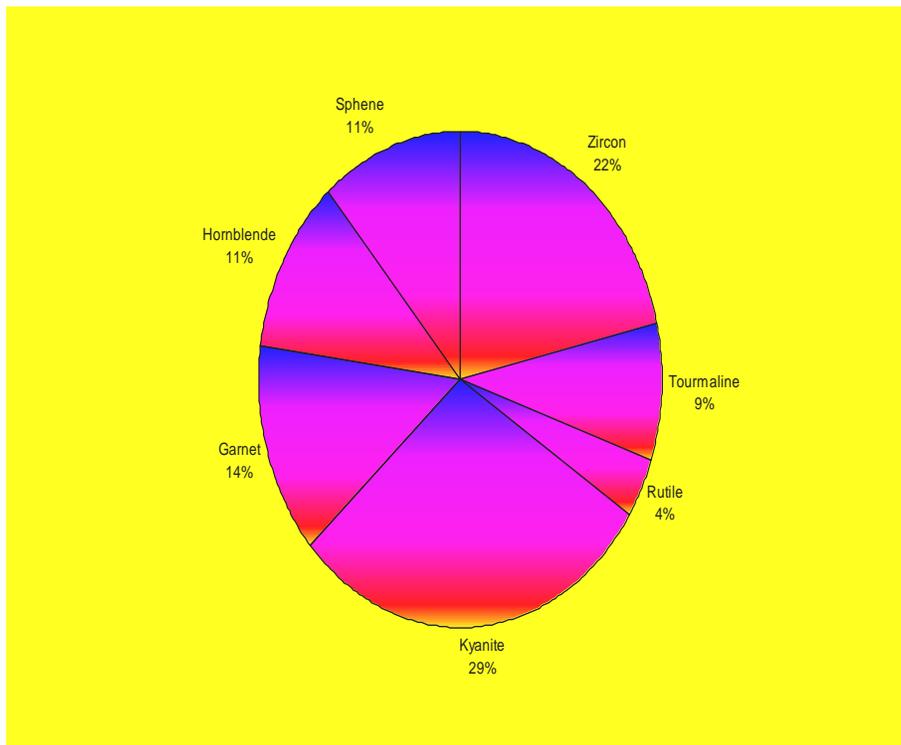


Fig 3: Frequencies of the non opaque heavy minerals of the Bama Ridge

The opaques include haematite, magnetite, leucosene, ilmenite and pyrite. The non-opaques (Fig. 3) consist of both the ultrastable and the metastable heavy minerals. Zircon, tourmaline and rutile (ZTR) constitute about 34% of the non-opaques and make up the ultrastables while the metastables are kyanite, garnet, hornblende and sphene.

The Chad Formation samples on the other hand yielded only the subrounded minerals zircon and rutile, along with apatite and sphene. The Rutile occurs as euhedral crystals and subrounded grains.

### Microfossil Distribution

Forty samples of silty clays of the Bama Ridge and the Chad Formation were subjected to microfossil analysis. 29 samples yielded results while 11 did not (Table 5). Samples of the Chad Formation did not yield any microfossil, except for what is apparently a remnant of foraminifera specimen observed from Mbeji well at about 545m, a horizon transitional between the Chad and the underlying Fika Formation. Species of ostracods identified in the Bama Ridge are classified and described below (Tables 2,3 and 4). A total of 59 counts (Table 5) were made of which *Eucypris* sp. was observed 29 times. *Cypridopsis* sp. and *Darwinula* sp. Were counted 17 and 13 times, respectively.

### Discussions

Relations between Bama Ridge and Chad Formation have long been a subject of speculation, and no comparative study has been undertaken to distinguish their stratigraphic status. Generally the heavy minerals of the various facies of the Bama Ridge (Fig. 2) point to a sediment that is mineralogically immature, due to presence of suites of less stable minerals. Also the relative abundance of the opaque minerals mainly the iron oxide may reflect the oxidizing nature of the ridge. The seven species of the non-opaques (Fig. 3) -zircon, tourmaline, rutile, kyanite, garnet, hornblende and sphene (*garnet, hornblende and kyanite are the less stable species*) further indicate a basement origin and mineralogical immaturity. Hubert (1962) and Omali et al. (2011) used Z. T. R index to further classify sandstone maturity.

Based on this index of 34%, generally considered low, the sediments of the Bama Ridge can be considered mineralogically immature. The mineralogical immaturity is further confirmed by the bulk of the light coloured minerals represented by ultrastable quartz mineral in the ridge. The use of Q/F+L ratio of Pettijohn (1975) gave a mineralogical index of 6.24%. This index indicates a mineralogically immature sediment which is as a result of the 29% feldspar content. Though Winkler (1974) postulated a low grade metamorphic source for staurolite in a sediment, this can be interpreted as indicative of diagenetic effects. Hornblende, however, is indicative of nearness to source. Only four species of heavy minerals zircon, rutile, apatite and sphene were observed from the Chad Formation.

This indicates low species diversity usually associated with older rocks, as against the well diversified distribution of minerals of both opaques and the non-opaques described from the Bama Ridge. This is in consonance with Pettijohn (1941) that in a given environment, younger sediments display a greater variety of heavy minerals. Among the heavy minerals of the Bama Ridge are the unstable species which include sphene, hornblende and kyanite. These have a low order of persistence as developed and put forward by Pettijohn (1941) corresponding to a low degree of survival under the impact of

intrastratal solutions. This also contrasts with the minerals of the Chad Formation whose positions (1, 2 and 6) in the order of persistence scale of Pettijohn (1941) indicate that they should be expected in older sediments. However, the presence of sphene is considered an anomaly. The minerals of the Chad Formation are generally subrounded indicating some degree of recycling. However, rutile observed both as euhedral and as subrounded grains may imply a multiplicity of sources.

Ostracods are by far the most complex organisms studied in the field of micropaleontology. They are found today in almost all aquatic environments including springs and caves, semiterrestrial environments and in both fresh and marine waters. They are also highly diverse. For instance, for genus *Darwinula* alone, Kempf (1980) listed about 363 species, including a few sub-species in his well accepted ostracod database. Since then many other new species have been added. This underlines the substantial difficulty concerning the ostracods and their employment in palaeoenvironmental studies.

Fresh water ostracods tend to have in general smooth, thin, weakly calcified simple bean-shaped carapaces. The moderately well preserved fossil ostracods of the Bama Ridge, especially *Eucypris* sp. and *Cypridopsis* sp. include a range of carapace sizes 0.3 mm to 1.7 mm. This indicates that juveniles and adults were coexisting and were not transported in from elsewhere or reworked from older deposits. *Darwinula* sp. is however rather poorly preserved and only adult specimens were found.

The three species of ostracods (Fig.4) generally imply continental environment. *Eucypris* is a common constituent of fresh water temporary ponds but may tolerate elevated salinities. The normal habitat of *Cypridopsis* is water bodies with rich vegetation and temperatures of 15-20°C (Holmes et al., 1999). *Cypridopsis* is also very intolerant of low oxygen concentrations and is an active swimmer that feeds by grazing periphyton. *Cypridopsis* has been associated with moderately saline environments. *Darwinula* sp. is mostly found in ponds, lakes and slow flowing streams and is limited to waters that are well oxygenated with salinity range of up to about 15 percent and where salinity values are stable. It is usually associated with less saline water of up to 2 percent.

Unfortunately, none of these species tells much about the stratigraphic age of the deposit. According to Davies (1971), Upper Cretaceous to Recent is the range for *Eucypris* and *Cypridopsis* species, and Upper Carboniferous to Recent for *Darwinula* sp. This is a rather long age range.

The Chad Formation is effectively devoid of microfossils. None of the samples analysed yielded any microfossil. This absence has earlier been reported by Simon-Robertson (1991). What was apparently a foraminifer from the Mbeji well is interpreted as a foreign material mixed into the samples of the Chad Formation from the Fika Shale horizon. This contrasts with the Bama Ridge which has a fair representation by the presence of three species of freshwater ostracods (*Eucypris* sp., *Cypridopsis* sp. and *Darwinula* sp.).

Furthermore, although Robertson Research Group (1989) proposed no palynological zonation for the Chad Formation, the pollen assemblages recorded indicate a Miocene to Pleistocene age. This contrasts to the various zones recognized for the other formations in the stratigraphy of the Bornu sub-basin. Also samples of Chad Formation analysed for Ngamma East well by Simon-Robertson (1991) yielded taxa such as *Verrucatosporites usmensis*, *Spirosyncolpites bruni* and *Retibrevitricolporites obodoensis* that indicate Oligocene or younger age.

**Table 2:** Classification of *Cypris*

| Classification | Name          |
|----------------|---------------|
| Phylum         | Crustacea     |
| Class          | Ostracoda     |
| Order          | Podocopida    |
| Sub-order      | Podocopina    |
| Super family   | Cypridacea    |
| Family         | Cyprididae    |
| Genus          | <i>Cypris</i> |

This species is observed as smooth, relatively large with subtriangular outline and fairly convex. Ventral margin is more or less concave. The posterior end is more sharply rounded (Fig.4a) than the anterior end.

**Table 3:** Classification of *Cypridopsis*

| Classification | Name               |
|----------------|--------------------|
| Phylum         | Crustacea          |
| Class          | Ostracoda          |
| Order          | Podocopida         |
| Sub-order      | Podocopina         |
| Super family   | Cypridacea         |
| Genus          | <i>Cypridopsis</i> |

This species (Fig.4c) has some faint pittings on its surface; the anterior end is more narrowly rounded than the posterior and the right valve slightly larger than the left and overlaps it.

**Table 4:** Classification of *Darwinula*

| Classification | Name             |
|----------------|------------------|
| Phylum         | Crustacea        |
| Class          | Ostracoda        |
| Order          | Podocopida       |
| Sub-order      | Podocopina       |
| Super family   | Darwinulidae     |
| Genus          | <i>Darwinula</i> |

This species is characterized by an elongate outline which is slightly higher posteriorly (Fig.4b). The right valve is larger in size than the left valve.

A) *Eucypris* sp.B) *Darwinula* sp.C) *Cypridopsis* sp.D) *Eucypris* sp.**Fig.4:** Photomicrographs of identified ostracods (Mg X100)

Table 5: Summary of identified Ostracods in the Bama Beach Ridge and the Chad Formation  
(Chad Formation samples in Bold)

| S/N       | Sample No.   | <i>Eucypris</i> sp | <i>Cypridopsis</i> sp | <i>Darwinula</i> sp | Unidentified |
|-----------|--------------|--------------------|-----------------------|---------------------|--------------|
| <b>1</b>  | <b>L1S2</b>  |                    |                       |                     |              |
| 2         | L1S5         |                    | 1                     |                     |              |
| 3         | L2S2         | 1                  |                       |                     |              |
| 4         | L2S5         | 1                  |                       | 1                   |              |
| 5         | L2S7         |                    | 2                     |                     |              |
| <b>6</b>  | <b>L3S2</b>  |                    |                       |                     |              |
| 7         | L4S1         | 2                  |                       |                     |              |
| 8         | L4S4         | 1                  |                       | 1                   |              |
| <b>9</b>  | <b>L5S1</b>  |                    |                       |                     |              |
| <b>10</b> | <b>L6S2</b>  |                    |                       |                     |              |
| 11        | L6S5         |                    | 2                     | 1                   |              |
| 12        | L7S1         | 1                  |                       |                     |              |
| <b>13</b> | <b>L7S4</b>  |                    |                       |                     |              |
| <b>14</b> | <b>L8S2</b>  |                    |                       |                     |              |
| 15        | L8S5         |                    |                       | 1                   |              |
| 16        | L9S1         | 1                  |                       |                     |              |
| <b>17</b> | <b>L10S2</b> |                    |                       |                     |              |
| <b>18</b> | <b>L10S6</b> |                    |                       |                     |              |
| 19        | L11S2        | 1                  |                       | 1                   |              |
| 20        | L12S1        |                    | 1                     |                     |              |
| 21        | L12S4        |                    |                       |                     | 1            |
| <b>22</b> | <b>L13S3</b> |                    |                       |                     |              |
| 23        | L13S6        | 1                  | 1                     |                     |              |
| 24        | L14S2        | 2                  | 1                     |                     |              |
| 25        | L15S2        | 2                  |                       | 1                   |              |
| <b>26</b> | <b>L16S1</b> |                    |                       |                     |              |
| 27        | L17S2        | 2                  | 1                     |                     |              |
| 28        | L18S1        |                    |                       | 2                   |              |
| 29        | L19S3        | 1                  | 1                     | 1                   |              |
| 30        | L20S2        | 1                  | 1                     |                     |              |
| 31        | L20S5        | 1                  | 1                     |                     |              |
| 32        | L21S2        | 2                  |                       |                     |              |
| 33        | L21S5        | 1                  |                       | 1                   |              |
| 34        | L22S1        |                    | 1                     |                     | 1            |
| 35        | L23S1        |                    | 2                     |                     |              |
| 36        | L24S3        | 3                  |                       | 1                   |              |
| 37        | L25S4        | 2                  | 1                     | 1                   |              |
| 38        | L26S1        | 2                  |                       | 1                   |              |
| 39        | L26S4        |                    | 1                     |                     |              |
| 40        | L27S3        | 1                  |                       |                     |              |

Specimens of *Praedapollis flexibilis* and *Peregrinipollis negericus*, found as caving within the underlying Fika Formation also suggest Oligocene or younger age for the Chad Formation. These data based solely on palynology comprise assemblages that are entirely of non-marine taxa, mainly fresh water algae such as species of *Pediastrum*, together with angiosperm pollen and fern spores. On this basis, a non-marine lacustrine setting is implied.

## SUMMARY AND CONCLUSION

Controversy as to whether the Bama Beach Ridge is a constituent of the Chad Formation in the Bornu sub-basin has been lingering for long. Heavy mineral studies show that the Bama Beach Ridge is highly diversified in both the opaques and the non-opaque heavy minerals. The Chad Formation has a limited occurrence of Zircon, rutile, apatite and sphene only. Three species of ostracods: *Eucypris* sp., *Cypridopsis* sp. and *Darwinula* sp. characterized the silty clay facies of the Bama Beach Ridge, whereas the Chad Formation is found to be effectively devoid of microfossils. The stratigraphic status of these intimately associated units was thus distinguished.

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