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# Aspect of Biostratigraphic and Petrographic Studies of the Late Palaeocene – Eocene sequence of the Eastern Dahomey Embayment, Southwestern Nigeria

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**Abstract**

Petrographic characterization and biostratigraphic distribution of the lithofacies exposed at Ibese and Sagamu were carried out in order to determine the chronology and depositional environment of the associated formations and different microfacies identified with the associated rock units in the embayment. The methods employed include detailed lithostratigraphic description carried out in the field while the carbonate petrography, nannopalae-ontological, palynological and micropalaeontological analyses were carried out in the laboratory. The lithostratigraphy in the Ibese quarry has a thickness of 29.5 m which consist of lower to middle limestone with intercalation of marl with an upper shale and silty sand overburden approximating 2m while the Sagamu quarry has a thickness 30m comprising of lower to middle limestone with an upper shale and lateritic overburden of about 5 m. The limestone intervals assigned to the Ewekoro Formation are dark grayish, fossiliferous and calcitic in some parts, while the shale intervals of the Oshosun Formation are dark and highly fossiliferous. The biostratigraphic results indicate the presence of palynomorphs, calcareous nannofossils and other microfossilsas recovered from the samples in different diversity and abundance. Abundant fossils forms are recorded in some of the samples while others have few and in some cases barren. *Cibicides* spp. are the only foraminifera recovered. *Toweius callosus* and *Coccolithus formosus* are among the calcareous nannofossils retrieved from the samples, while *Monoporites annulatus*is the most abundant of the palynomorph recovered. Petrographic results show two microfacies units. The biomicrite facies is the most re-occurring while, the biosparite facies is sparse. The environment of each microfacies is determined from available data. The presence of *Cibicides* spp. and *Monoporites annulatus* show environments of deposition of the rock units to be open circulated shallow water. The occurrence of *Cruciplacolithus formosus* and *Toweius callosus* dated the Akinbo shale as exposed in Sagamu quarry to be Early Eocene while the presence of *Cruciplacolithus frequens, Cruciplacolithus tenuis* and *Toweius eminens* dated the Akinbo shale as exposed in Ibese quarry to be Late Palaeocene to early Eocene. The abundance of gastropods, pelecypods, scaphopods and diverse microfacies identified suggest quiet shallow marine environment of deposition for the locations. The presence of *Toweius callosus* and *Coccolithus formosus* indicated the age of the Oshosun Formation to be Ypresian (55.8$\pm$0.2 Ma) while the Ewekoro Formation age range from Thanetian (58.7$\pm$0.2 Ma) toYpresian (55.8$\pm$0.2 Ma).

**Key words:** Depositional environment, Biostratigraphy, Petrography, Lithostratigraphy, Calcareous nannofossils, Microfacies.

## Introduction

Dahomey Basin is an arcuate coastal basin lying below the onshore parts of Togo, Republic of Benin and southwestern Nigeria. The basin extends from southeastern Ghana through Togo and Republic of Benin to southwestern Nigeria. The Nigerian sector of the Dahomey Basin is the eastern part of the basin. The basin became increasingly interesting in recent years due to its economic (hydrocarbon) potential. For many decades, most geoscientific research focused on the lithostratigraphy and tectonic framework of the basin and some on hydrocarbon potential. The commercial quantity of limestone deposits in some localities such as Shagamu, Ibese, and Ewekoro in the study area has made way for some cement production factories.

Several wells have been drilled in various structural elements of the basin and this suggests a sediment thickness of approximately 3000m on the basement underlying the basin [1]. Continental drift led to the opening of the Atlantic Ocean during the Mesozoic Era (Fig. 1). The geology, stratigraphy, sedimentology, depositional

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environmental of the different part of the basin have been reported in the literature [2, 3, 4, 5, 6, 7, 8, 9, 10 and others].

At the base of the sedimentary succession is the bitumen-bearing sand of enormous economic potentials [6]. Shallow boreholes have penetrated continuous Late Cretaceous marine shales which are correlated with the Nkporo Shale Formation. Nearer the coast and offshore, the marine beds are older. Lower Tertiary marine units (Palaeocene Ewekoro Limestone Formation and the Eocene phosphatic Oshosun Formation) are exposed in quarries at Shagamu and Ewekoro in Ogun State, and at Onigbolo and Tabligbo in neighbouring Benin Republic. Although the younger Tertiary strata exposed along the coast are non-marine, marine Miocene deposits (ljebu Formation, Afowo Beds) are known in the offshore subsurface. This study is to determine the petrographic and palynologic content of the associated formations, palaeoecology as well as the ages of the different units.

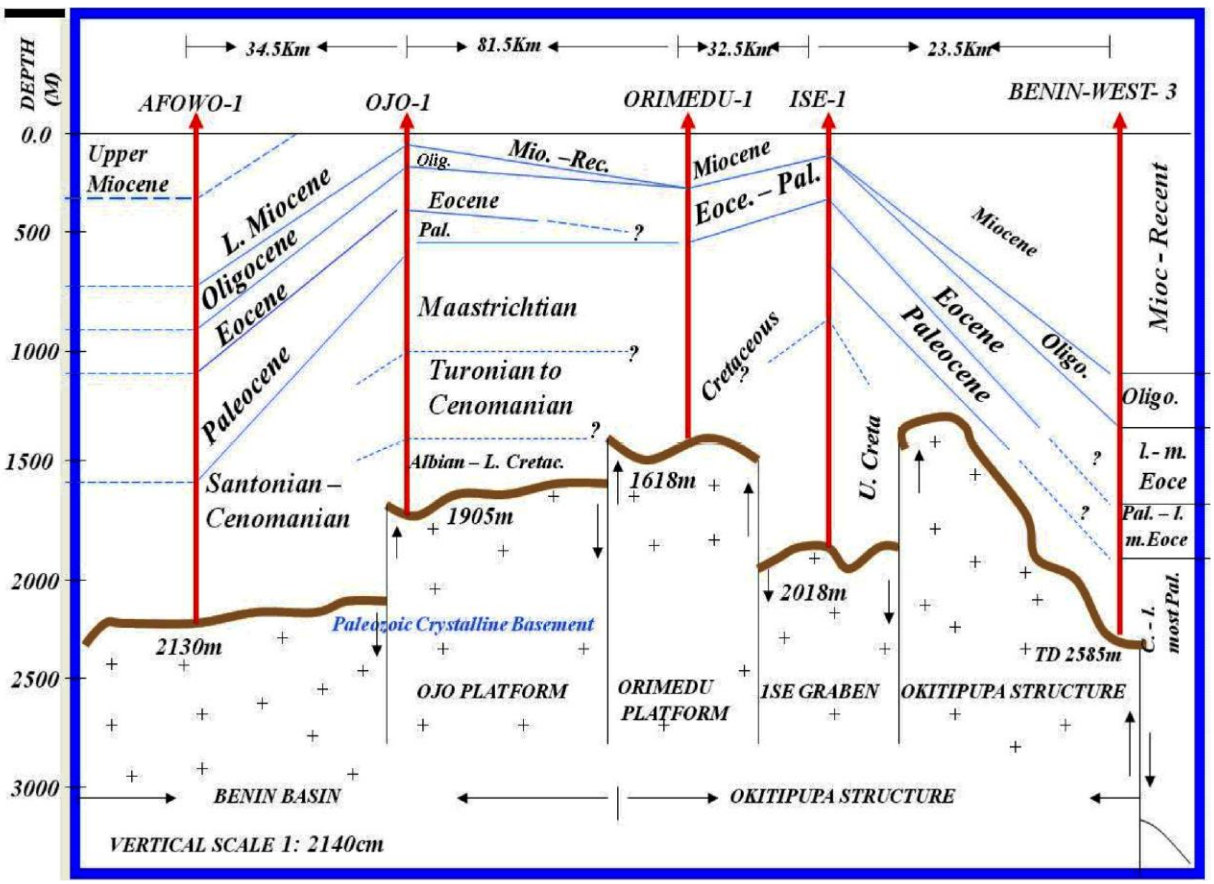
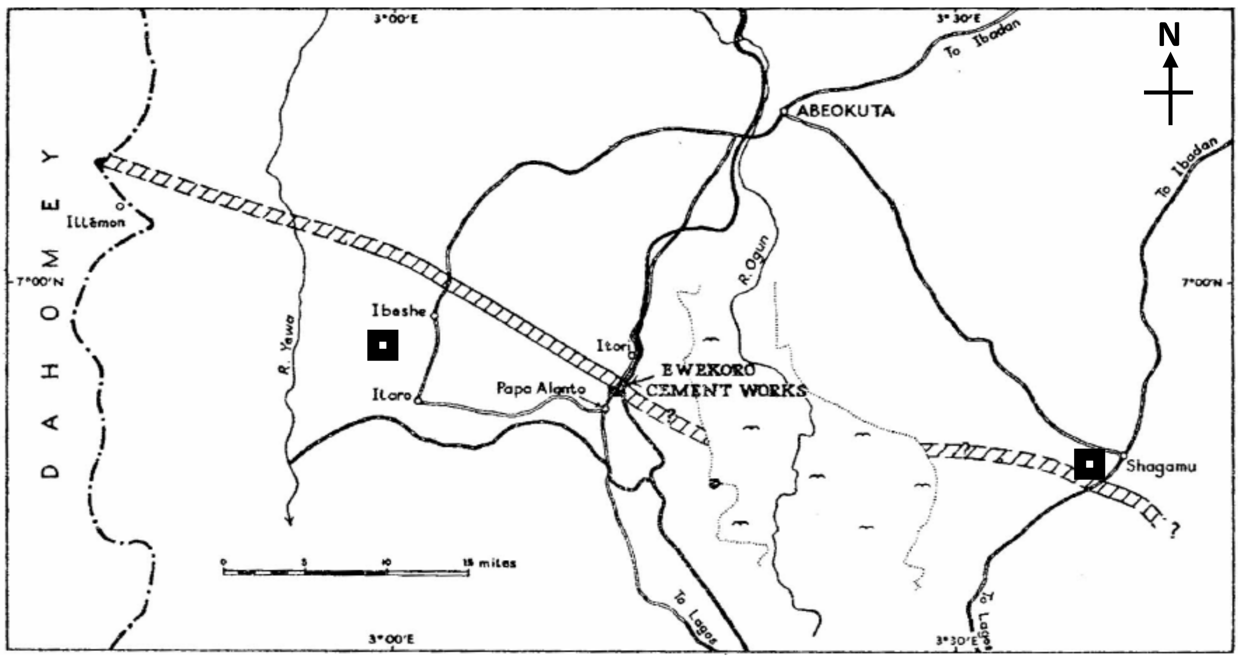



**Fig. 1:** Cross-section of wells drilled in various structural elements of the Dahomey (Benin) Basin (adapted from Coker and Ejedawe 1987).

**Location and Accessibility of the Study Area**

The study area is located in the eastern Dahomey Basin at Sagamu within the longitude $06^{o}$ 49′ 3.30″N and latitude of $03^{o}$37′17.20″E and Ibese which lies within the longitude $06^{o}$59′9.60″N and latitude $03^{o}$4′20.10″E. The samples were collected from the Sagamu and Ibese quarries of Lafarge and Dangote cement factory respectively. Ibese is about 3km from Ilaro and Ilaro is 50km from Abeokuta. Sagamu is about 45km from Lagos (Figs. 2 and 3). The area is accessible by a good network of roads that links the Lagos-Ibadan expressway. The area lies within longitude $06^{o}$49′03.3″ and latitude $003^{o}$37′17.2″.




Study area

**Fig. 2:** Map showing the known extent of Ewekoro limestone in the basin and indicating Sagamu and Ibese study areas (after Jones and Hockey 1964).

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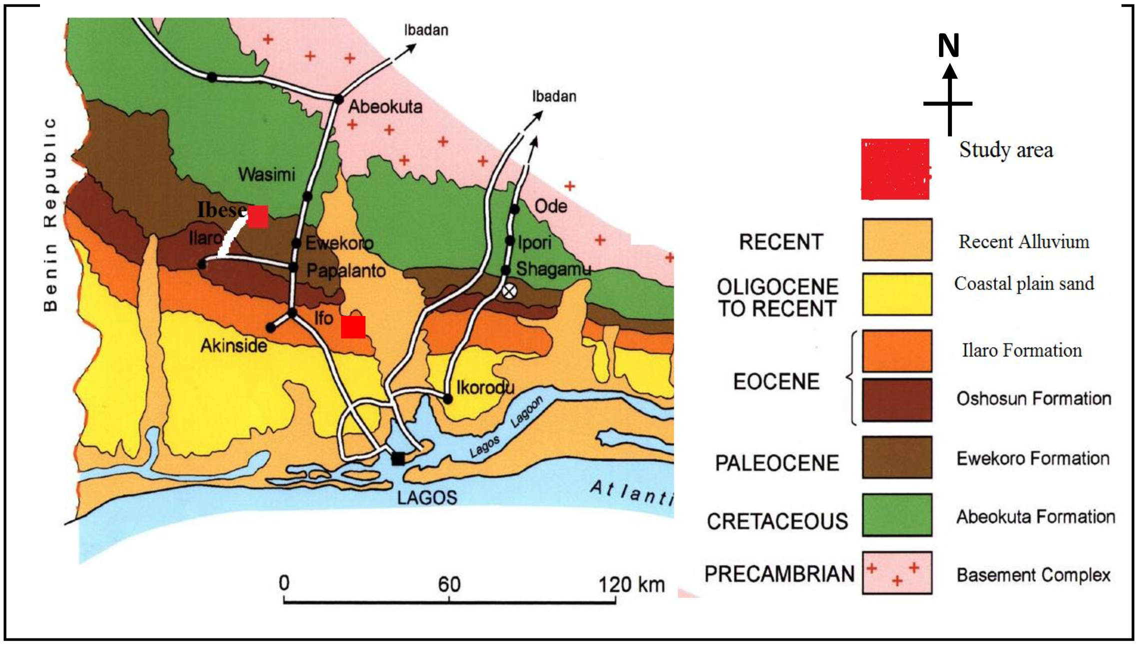


**Fig. 3:** Geological map of the Nigerian part of the Dahomey Embayment showing the study area (modified after Gebhardt et al. 2005).

**Physiography and Drainage Patterns**

Jones and Hockey [2] classified the topographic elements of the eastern Dahomey Basin into the northern upland, southern upland and Ewekoro Depression at the centre. The northern upland consists of plateaus rising to maximum height of 213.5m northwest of Abeokuta. The ground elevation is high probably due to the rugged terrain which is underlain by the basement rocks. The northern uplands fall away southwards to a low lying marsh standing about 30.5m above sea level.

South of the northern upland is the low laying Ewekoro Depression, which forms the lowland area. The Ewekoro Depression has been regarded as an extension of the Lama Depression in the Republic of Benin and Togo to the west. The Ewekoro Depression is wider at the Nigeria-Republic of Benin border, it thins out eastward and finally, disappears beyond Ijebu-Ode [2]. Further southward, the Ewekoro Depression is succeeded by the low, gently sloping southern uplands. The southern uplands reach a maximum height of about 122m near Ilaro and drop gently southwards to the Coastal Plains.

The three major rivers in the study area are rivers Ogun, (Central part), Yewa, (West) and Ona, (East). These rivers drain southwards in a sub-dendritic and dendritic pattern and finally joined the Coastal Lagoon [2]. Other rivers like Yemoji, Owuru, Ewekoro and Iju also flow southward. Around the northern uplands, centrifugal and radial drainage systems dominate, particu-larly south of Abeokuta, while the Ewekoro Depression and the southern upland display dendritic patterns (Fig. 4).

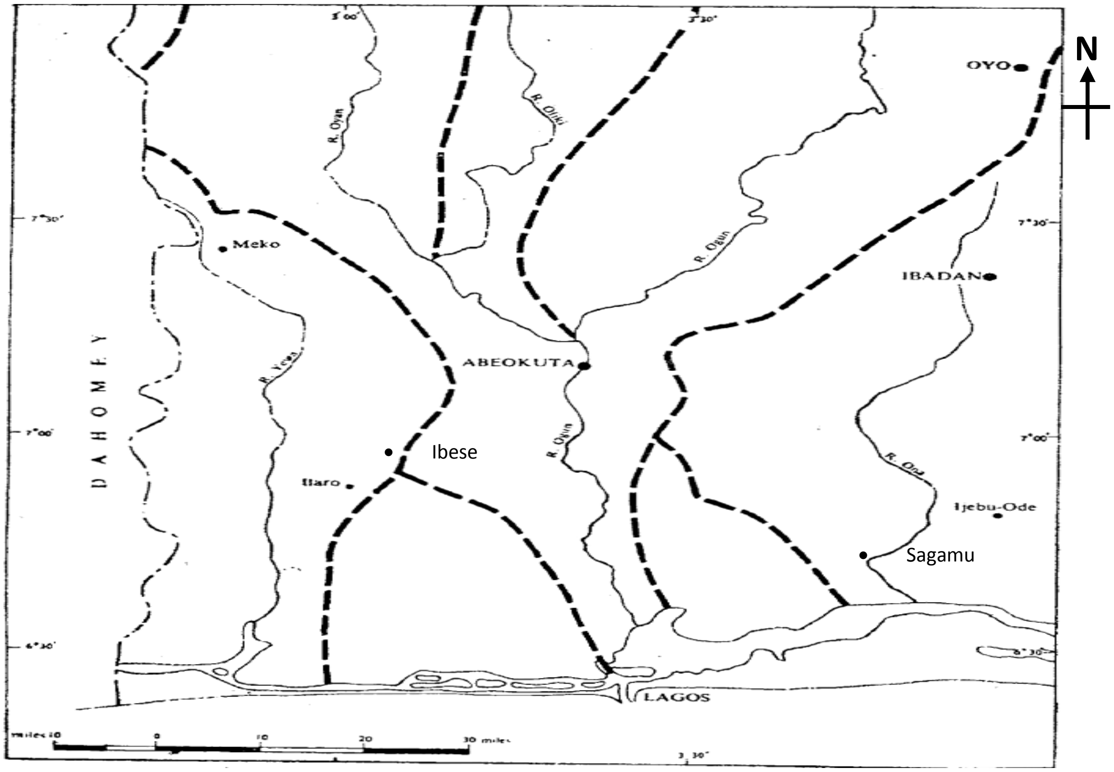


**Fig. 4:** Drainage of the study area (after Jones and Hockeys 1964).

**Previous Work**

Geological investigation of the Cretaceous sediments of the Dahomey Embayment has been done by various workers. The earliest work on the eastern part of the basin (Nigerian Sector) was initiated by the Geological Survey of Nigeria in 1919, when a survey for railway was being carried out. The strip of the country extending 16km to each side of the railway was mapped on a scale of 1:250,000.

After this, most workers have come up with various documentations with regards to the age, lithology and structure of the basin. They also focus their attention on geochemical investigation with works on the industrial importance of limestone. Jones and Hockey [2] carried out an extensive work on the Ewekoro Formation. They established the name Abeokuta Formation for mainly arenaceous strata with mudstone, silt, clay and shale interbeds that crop out onshore and assigned a Late Senonian age to it. The Eocene age assigned is due to the fact that the Abeokuta Formation underlies the Palaeocene Ewekoro Formation [2].

Billman [11] subdivided the Abeokuta Formation into three lithostratigraphic units: the "Unnamed Older Folded Sediments", "Unnamed Albian Sands" and Abeokuta Formation. On the basis of age equivalence, he referred the remaining Cretaceous strata to the Awgu and Nkporo Shales. Omatsola and Adegoke [12] proposed three new lithostratigraphic units namely Ise (Unnamed Older Folded Sediments equivalent and the Unnamed Albian Sands), Afowo (Abeokuta Formation equivalent) and Araromi Formations (Awgu and Nkporo Shales equivalent).

Reyment [13] described a new type of locality based on the exposures at the Ewekoro and Shagamu quarry. He regarded the Ewekoro Formation as a lateral equivalent of the Imo Shale and assigned an Upper Palaeocene age to it. Adegoke [14] sub-divided the limestone into three microfacies; algal biomicrite, shelly biomicrite and sandy

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biomicrite and also accepted the Palaeocene age earlier proposed [2]. Other workers include Okosun [15], Ogbe [16] and Fayose and Azeez [17] who studied the micro-palaeontological characteristic of the Ewekoro Formation. Recent study of the sandstone in some part of the Dahomey Basin regarded it as greywacke [4]. Gebhardt et al. [18] study foraminiferal assemblage of the Oshosun Formation of the Dahomey Basin where biostratigraphy was used to trace the onset of the Carbon Isotope Excursion (CIE) at the Palaeocene - Eocene boundary in the Gulf of Guinea region. This was the first ever of such work. Other studies and the work of Adeonipekun and other workers used bio-sequence stratigraphy within the eastern Dahomey Basin and recognized three zones namely *Apectodinium* Zone (middle-late Palaeocene) *Apectodinium homomorphum* Zone (Late Palaeocene) and *Areoligera senonensis* Zone (Eocene) [9, 19, 20, 21].

## Stratigraphy of the Eastern Dahomey Basin

The stratigraphy of the eastern Dahomey Basin has been discussed by various workers and different classification schemes have been proposed [2, 5, 7, 10, 13, 16, 19, 22] among others. However, these classifications are not without controversies on age assign-ments and nomenclatures of the different lithological units found within the basin (Fig. 5).

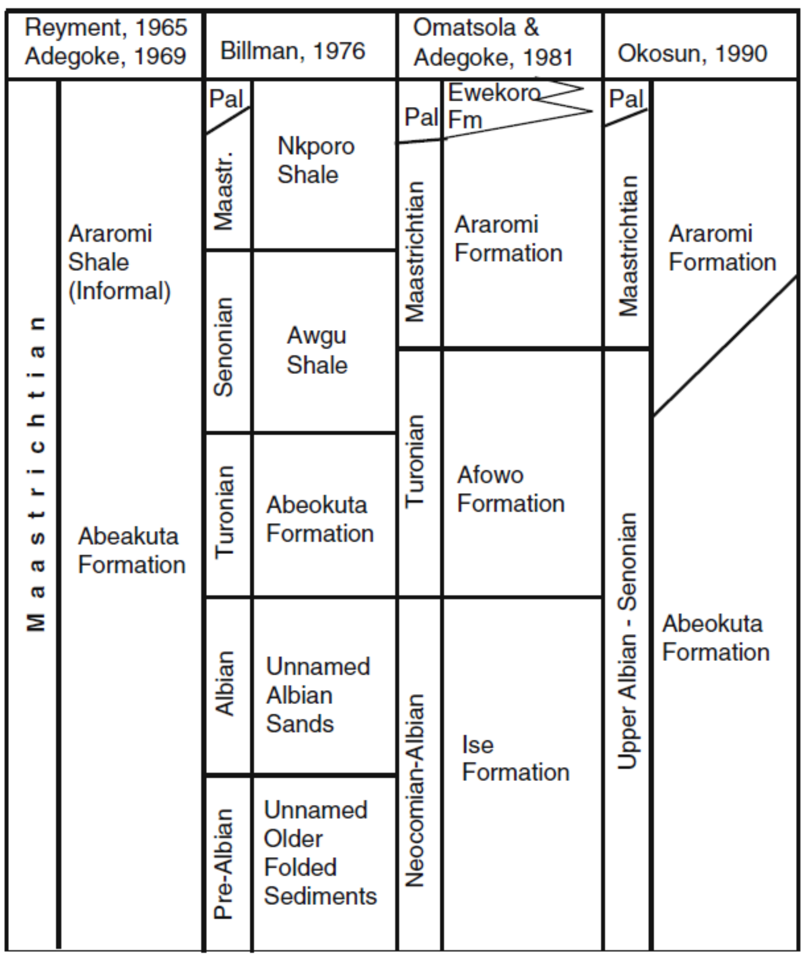


**Fig. 5:** Stratigraphic succession of Dahomey Basin (after Obaje 2009).

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Omatsola and Adegoke [5] following the disagreement with the nomenclature of Billman [22] proposed the Cretaceous sequence in the eastern Dahomey Basin as beginning with the Abeokuta Group, made up of three formations from oldest to the youngest namely; the Ise, Afowo and Araromi Formations. Overlying the Abeokuta Group is the Ewekoro, Akinbo, Oshosun and Ilaro Formations and the youngest stratigraphic sequence in the eastern Dahomey Basin is the Benin Formation.

**Geology of the Study Area**

The study area is characterized by extensive sedimentation which fully represents the stratigraphy of the eastern Dahomey Basin. Some lithologic units, essentially the Benin and Ilaro Formations outcrop at some locations within the study area. The study area is underlay with the Ewekoro Formation and the Ilaro Formation that characterizes the top soil. Sagamu and Ibese quarries are located in northeastern part of Dahomey Basin. The top soil comprises of silt, clay and sands which is about 3m and the intercalated shale in Sagamu is 3m and 5m in Ibese quarries. The Sagamu quarry is located pseudo-parallel to the West African coast while Ibese quarry is located within the continental region of West Africa.

**Materials and Methods**

Representative samples were collected through stratigraphic intervals, exposed via excavation and blasted surfaces in the quarry sites at Sagamu and Ibese. The samples obtained are limestone, shale and sand (Figs. 6 and 7). The laboratory analyses include petrography, calcareous nannofossil, palyno-logical, and micropalaeontological analyses. The palynological, nannofossil and micropaleontological analyses were carried out at Crystal Age Limited, Lagos, Nigeria while the carbonate petrography was carried out at the Thin Section Laboratory, Department of Geology, University of Ibadan.

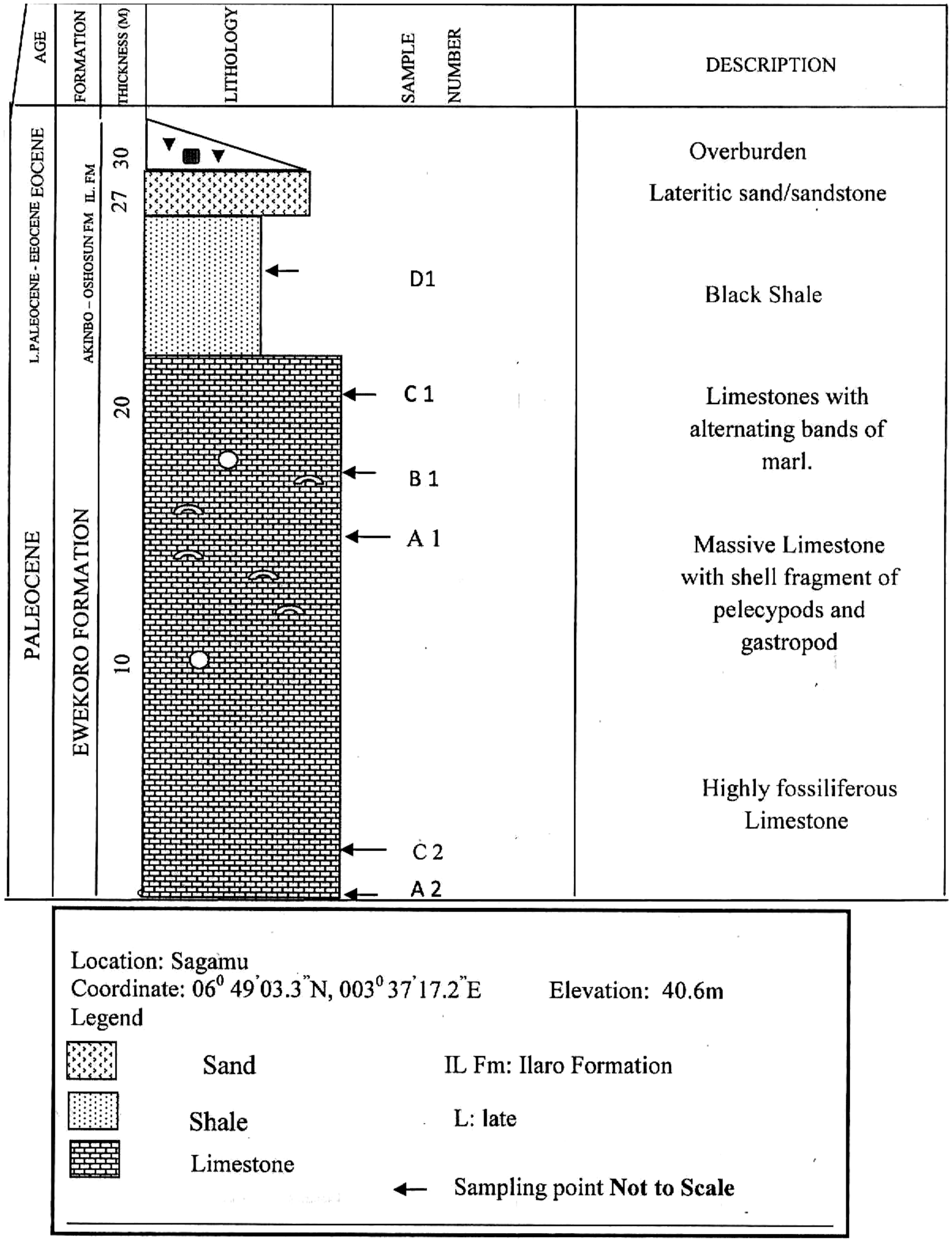


**Fig. 6:** Lithostratigraphy of Sagamu quarry.

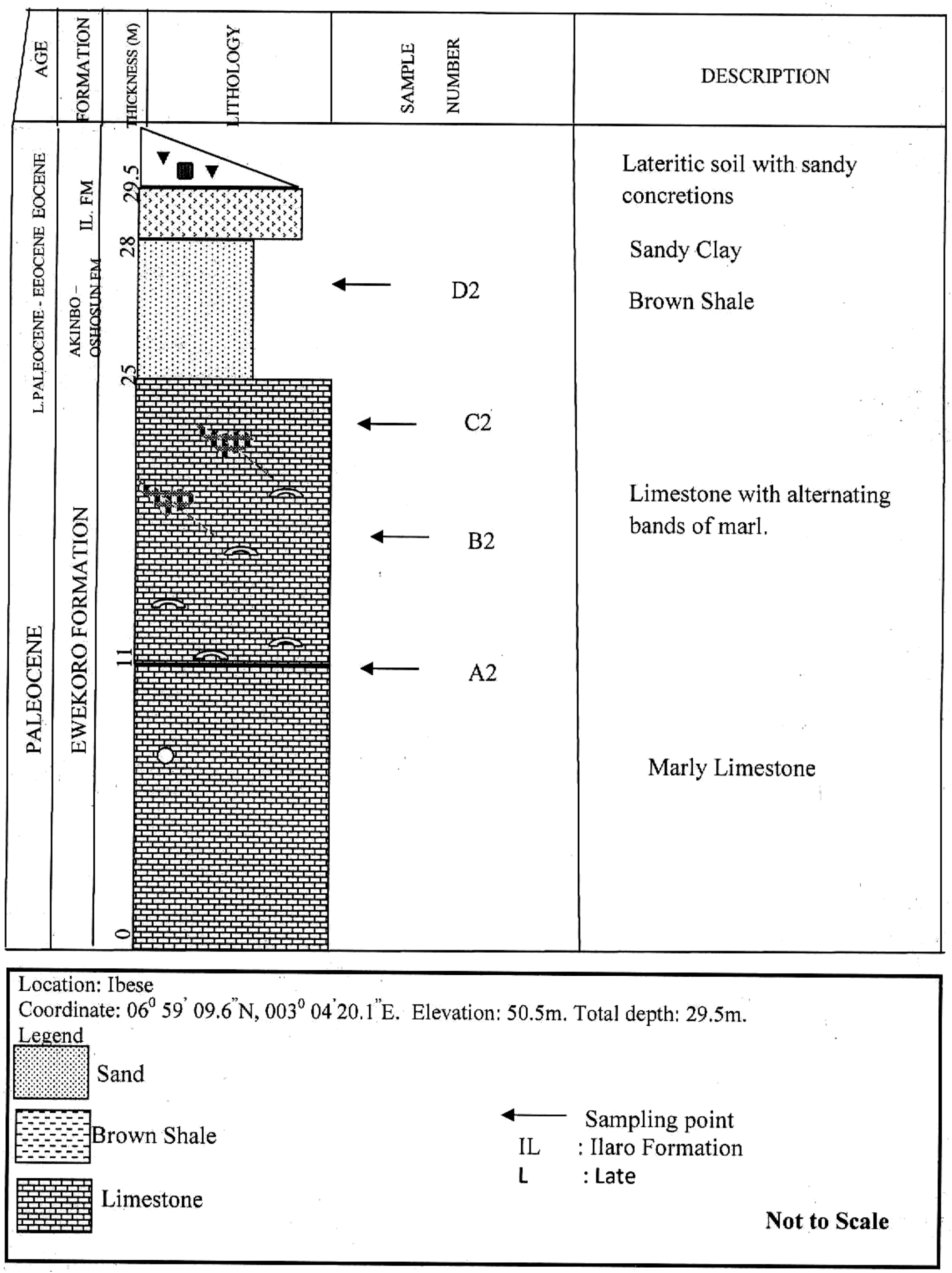


**Fig: 7:** Lithostratigraphy of Ibese quarry.

## Results and Interpretation

The results of the various analyses carried out have been used in making inferences on the age of the various units where index fossils were identified, the environment of deposition and the different microfacies identified.

## Carbonate Petrography

Carbonate microfacies were named on the basis of recognised depositional texture [23]. There are six different carbonate microfacies recognised in the study. The microfacies common to the carbonate rock as exposed in Ibese quarry are *Bio-Intramicrite*, Intra-*biomicrite* and *Shelly Biomicrite*. The carbonate rocks as exposed in Sagamu quarry, the recognized microfacies are *Bio-Pelmicrite*, *Bio-Pelsparite* and *Bio-Intrasparite*.

### *Shelly Biomicrite*

The shelly biomicrite microfacies are common only to the carbonate rock as exposed in Ibese quarry. The rock occurs in the upper part of Ibese quarry section. The rock contains fossil embedded in a micrite matrix (Fig. 8). The micrite matrix contains substantial amount of mud which fills the space between the allochems, containing smooth rounded fragment of pelecypods, echinoids and coral packed in clay size particle.

The complete rounded fragment of gastropods was observed in the thin section with internal micritization of some of the fossil fragment been observed in the gastropod. Their identification is based on structures known from the best preserved material. Recrystallizations of the bioclast into micro-spar in a micrite calcite matrix are evident with the modal composition of the rock showing the distribution of the entire carbonate constituent (Fig. 8b). Longitudinal section of high spiralled gastropod and pelecypods are visible with internal micritization and recrystallization (Fig. 8a). Also observed are non-bioclasts component especially peloids formed from decayed bioclasts (Table 1, Fig. 9). The presence of the shelly biomicrite suggest quiet water environment with micrite as the dominant matrix which is supported with Folks classifications of the carbonate rock [23].

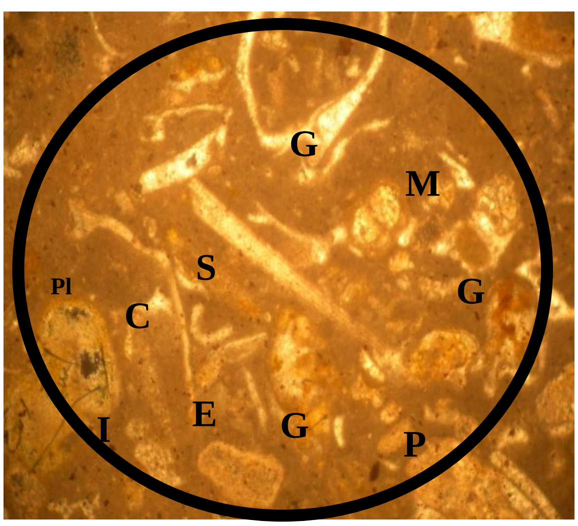


**Fig. 8a:** Photomicrograph of *shellyBiomicrite.* Notice the gastropod (G) pelecypods (P) intraclast (I) echinoiderm (E) micrite(Mi) sparite (S) pellet(Pl) corals (C).


Mag. ×40

**Fig. 8b:** Photomicrograph of Shelly*Biomicrite. Note* the recrystallization of the bioclasts and other fossil present.

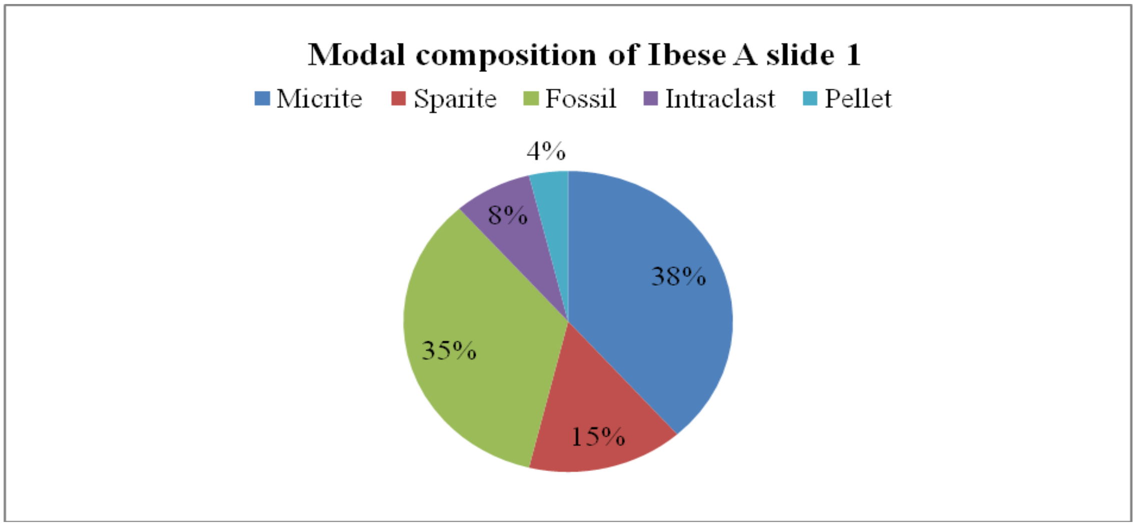


**Fig. 9:** Chart showing the modal composition of Shell Biomicrite carbonate rock as exposed in Ibese quarry.

**Table 1: Modal Composition of Ibese A Slide 1**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 38% | It supports most of the allochems such as fossil and shell fragments. The mud like clay size material embedded as cement within the fossil. |
| Sparite | 15% | Sparry calcite has undergone recrystallization as noticed on the shell fragment and the fossil present. |
| Fossil | 35% | Fossils present include gastropod, pelecypods, coral echinoderms and shell fragment. |
| Intraclast | 8% | It is noticed as in fill in the shell fragment and gastropods. |
| Pellet | 4% | Very few embedded and scattered in the micrite matrix. |

**Table 2: Modal Composition of Ibese B Slide 2**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 40% | It supports some allochems such as shell fragments |
| Sparite | 10% | Sparry calcite has undergone recrystallization in some parts |
| Fossil | 27% | Fossils present include gastropod, pelecypods, shell fragment |
| Intraclast | 20% | Rounded to sub-rounded and they are replacement of the fossil. They are largely represented in the section. |
| Pellet | 3% | Occur as dark sub-spherical to spherical body. |

***Bio-Intramicrite***

This microfacies is observed in the middle part of the carbonate rock 15m (limestone) as exposed in Ibese quarry. The rock consists of both bioclastic and non-bioclastic in Intramicrite matrix. The middle part of the section as shown below indicates a high composition of the rock in intraclast allochems (Fig. 10a). The articulating gastropods and pelecypods are not altered significantly. A noticeable increase in the intraclast within the micrite matrix was observed towards the centre of the slide, this suggest that the carbonate is deposited as conglomerate which was subsequently filled with micrite cement (Fig. 10a). Some peloids, cup like corals and spiralled echinoderms bioclast are observed in longitudinal and transverse sections. The internal parts are in filled by drusy microspar calcite cement. The echinoid and gastropods are recrystallized to sparry calcite and micritization respectively (Fig. 10b, Table 2 and Fig. 11).

***Intrabiomicrite***

This microfacies present in the carbonate rock at the basal part of the section. The abundance of gastropods, echinoderms and pelecypods are observed. The gastropods structures indicate both longitudinal and transverse in the section. The radial pattern of the echinoderm shows internal rim cement (Figs. 12, 13 and Table 3). The intraclast occur as pocket in the section which show that the deposition of carbonate as conglomerate is minimal. The abundance of micrite matrix indicates quiet water deposition of the carbonate.

***Bio-spar-micrite***

The bio-sparmicrite microfacies occur at the upper part of the Sagamu quarries. This rock type consists of shell fragment, echinoderms and gastropods with peloids. Other bioclasts include highly spiralled corals, pelecypods and shell fragment. The gastropods show internal micritization but are partly dissolved in some part which are replaced by the conglomerate of carbonate of intraclast (Fig. 14a). The pelecypods, echinoderm and corals grains are partly replaced by drusy calcite cement. The Bio-spar-micrite indicates a sparry calcite cement of the bioclasts in a micrite matrix (Fig. 14b). This suggests a quiet environment of deposition with little agitation as a result of the intraclast (Fig. 15 and Table 4).

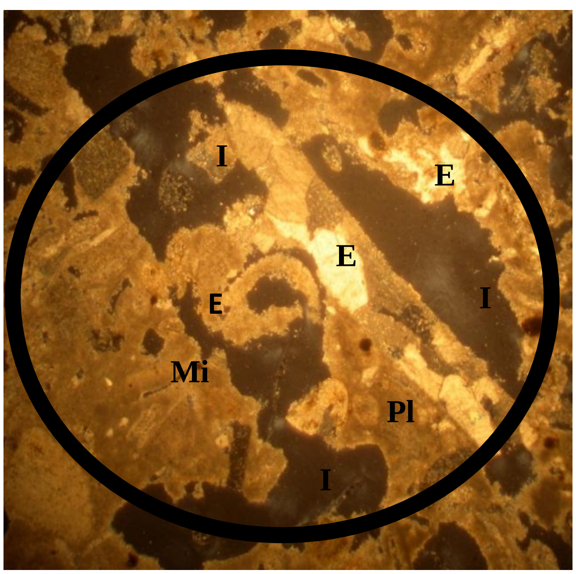


**Fig. 10a:** Photomicrograph of *Bio Intramicrite*. Gastropod (G) pelecypods (P) intraclast (I) echinoderms (E) micrite (MI) sparite (S) pellet (Pl) and corals (C). The rock is intraclast supported in a micrite matrix. (Mag×40)

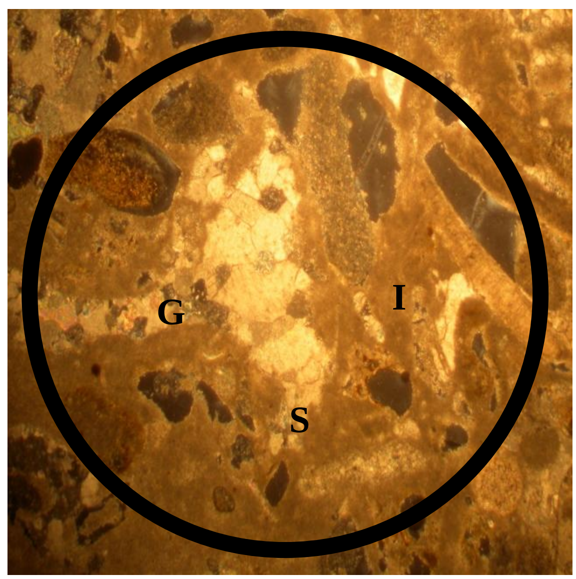


**Fig. 10b:** Photomicrograph of *Bio Intramicrite*. Notice the Sparry calcite cement on the gastropods and the micritization of the echinoderms. (Mag×40)

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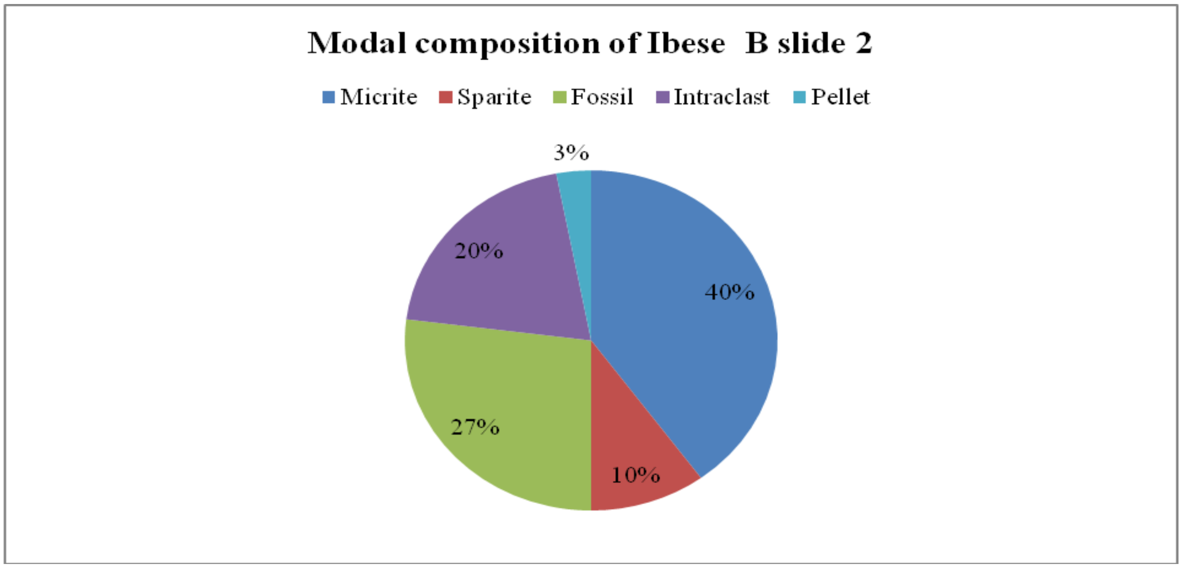



**Fig. 11:** Chart showing the Modal composition of Ibese B slide 2.

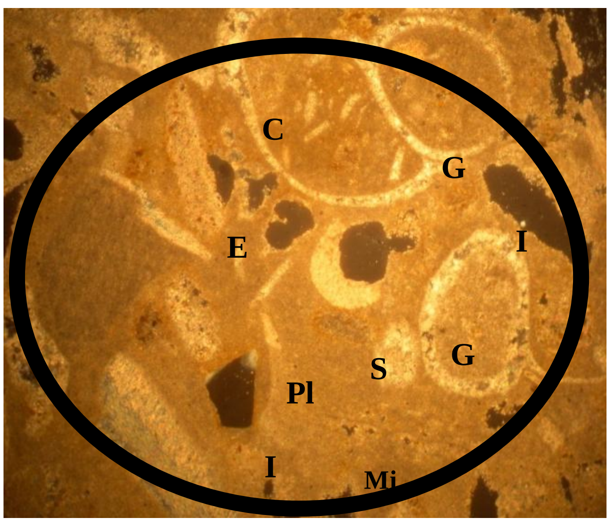



**Fig. 12a:** Photomicrograph of *Intra biomicrite* showing gastropod (G) pelecypods (P) intraclast (I) echinoderms (E) micrite (Mi) sparite (S) pellet (Pl) and corals (C).The allochems are highly supported by a mud like matrix with pocket of intraclast. (Mag×40)

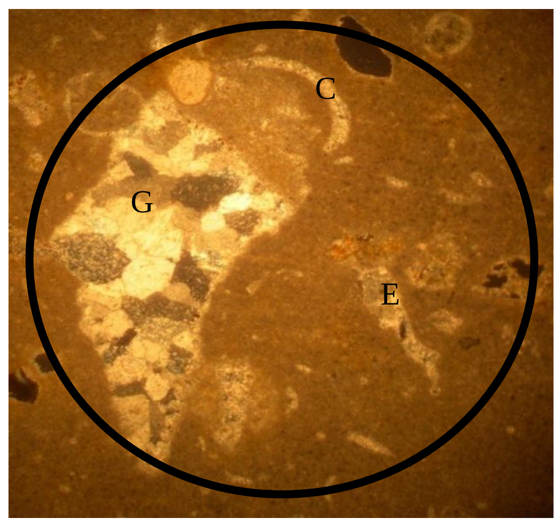



**Fig. 12b:** Photomicrograph of *Intra biomicrite*. The Sparry calcite cement of the gastropods, coral and echinoderms embedded in a micrite matrix. (Mag×40)

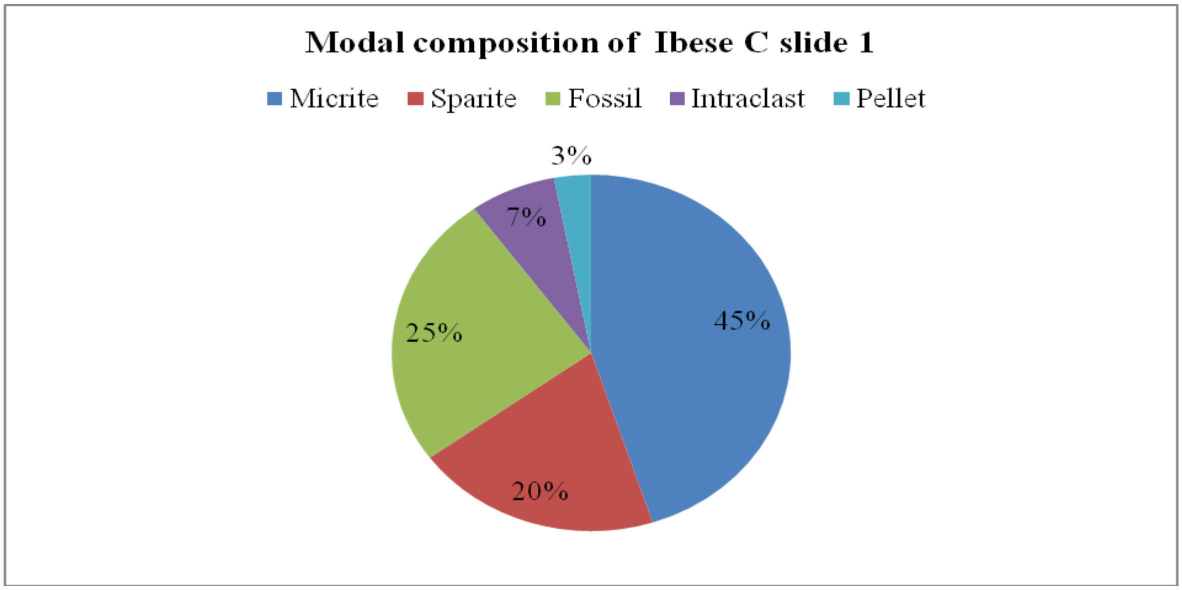



**Fig. 13:** Chart showing the Modal composition of Ibese C slide 1.

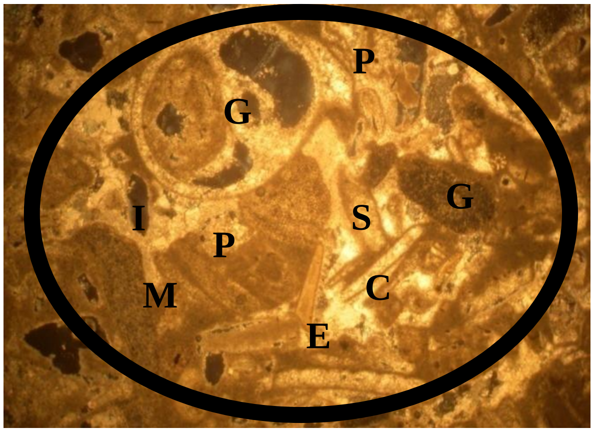



**Fig. 14a:** Photomicrograph of *Bio spar micrite* microfacies. Gastropod (G) pelecypods(P) intraclast (I) echinoid (E) micrite(Mi) sparite(S) pellet(Pl) corals(C). Mag×40 echinoderms embedded in a micrite matrix. (Mag×40) (Mag×40)

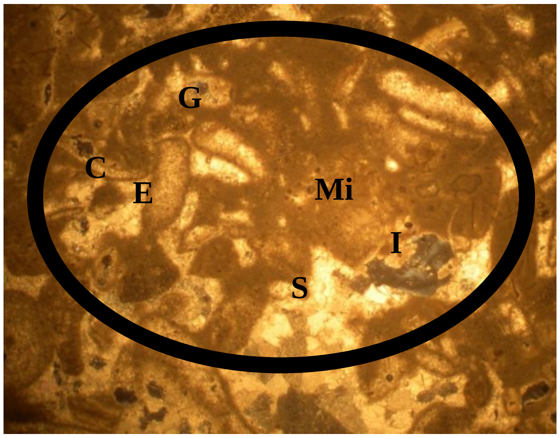



**Fig. 14b:** Photomicrograph of Bio-spar-micrite facie showing the sparry calcite of the bioclast and the micrite matrix with the infill of the intraclast within the matrix. Mag×40
Mag×40 echinoderms embedded in a micrite matrix. (Mag×40)

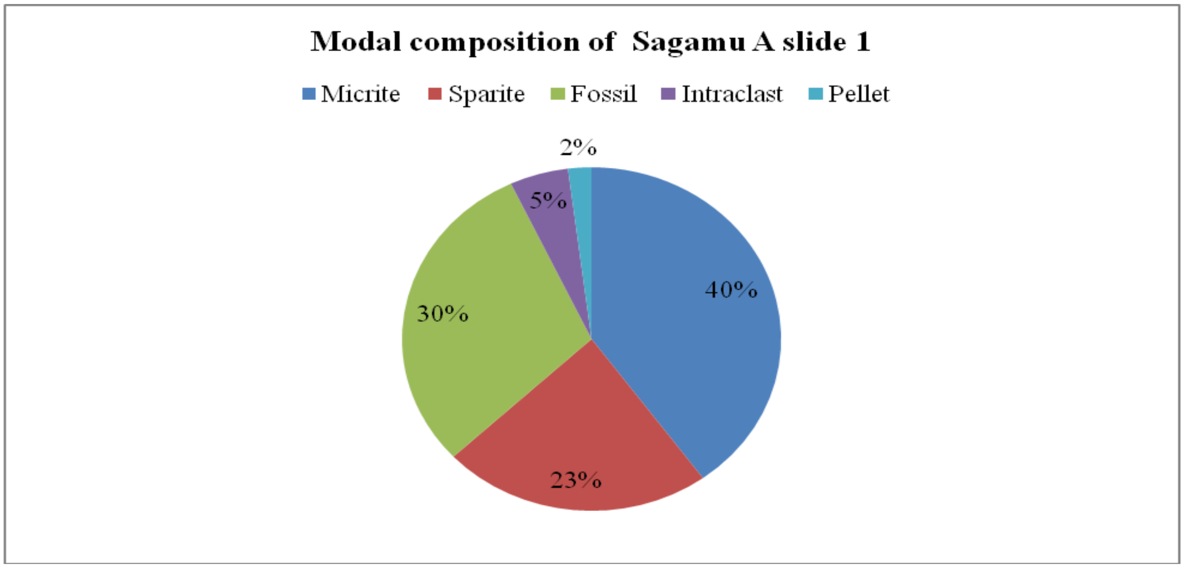



**Fig. 15:** Chart showing the modal composition of *Bio-spar-micrite* microfacies (Sagamu).

**Table 3: Modal composition of Ibese C slide 1**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 45% | It supports most of allochems such as gastropods, corals and shell fragments |
| Sparite | 20% | Sparry calcite has undergone recrystallization in some parts. |
| Fossil | 25% | Fossils present include gastropod, pelecypods, corals and shell fragment. |
| Intraclast | 7% | It is lenticular in the section and occurs as in fill. |
| Pellet | 3% | They occur as tiny dark sub-spherical to spherical body. |

**Table 4: Modal Composition Slide 1 Sagamu A**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 40% | It is matrix that supports some allochems such as shell fragments. |
| Sparite | 23% | Sparry calcite has undergone re-crystallization in some parts. |
| Fossil | 30% | Fossils present include gastropod, pelecypods, corals, algae, shell fragment. |
| Intraclast | 5% | Occur as in-fill of the dissolved bioclast. |
| Pellet | 2% | Occur as dark sub-spherical to spherical body. |

**Table 5: Modal Composition of Sagamu B Slide 2**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 60% | It supports some allochems such as shell fragments. |
| Sparite | 10% | Sparry calcite has undergone recrystallization in some parts. |
| Fossil | 10% | Fossils present include gastropod, pelecypods, coral and shell fragment. |
| Intraclast | 9% | It occurs as replacement for the dissolved micrite within the fossil in the section. |
| Pellet | 11% | Occur as dark sub-spherical to spherical body scattered in the section. It is fairly represented in the section |

**Table 6: Modal Composition of C Slide 1 (Sagamu)**

| Component | Percentage | Remark |
|---|---|---|
| Micrite | 15% | It supports some allochems such as shell fragments. |
| Sparite | 15% | Sparry calcite has undergone recrystallization in some parts. |
| Fossil | 15% | Fossils present include gastropod, pelecypods, coral and algae. |
| Intraclast | 50% | It serves as the main matrix in which the allochems attached. It is due to the sand grain component in the rock unit |
| Pellet | 5% | Occur as dark sub-spherical to spherical body. |

***Bio-Pelmicrite***

The microfacies are essentially present in the carbonate rocks exposed at Sagamu quarry at the middle part of the section. The abundance of pellets scattered around the micrite matrix indicate agitation during the deposition. The bioclasts are fully micritized and some bioclast are completely replaced by sparry calcite. The gastropod, corals and echinoderms are drusy calcite in a micrite matrix. The intraclast occur towards the wall of the section. The micritization of gastropod and echinoderms are observed in the section. Non-bioclastic component especially peloids formed from decayed bioclast and faecal pellets are also observed. This microfacies suggests a more agitation during the deposition and recrystallization of the fossils (Figs. 16, 17 and Table 5).

***Bio-Intrasparite***

The bio Intra-sparite microfacies occurred at the basal part of the section of Sagamu quarry. The rock consists of abundant sparry calcite in an intraclast matrix with few portions of micrite and peloids. It consists of gastropods, echinoderms and algae in sparry calcite cement. The micritization of the gastropods and corals is observed (Fig. 18). The intraclast is bind to the bioclasts present in the section. Both the longitudinal and transverse section of the echinoderms, coral and gastropods are observed. The coralline algae and flat lying like leaf is observed in the section (Fig. 18a) also two generation of cement is observed, micrite and sparite. The coral and echinoids are forming loosely connecting tubes mostly in the section. Non-bioclastic component like peloids are observed. Heavy mineral and quartz grains were observed embedded in the sparry calcite matrix (Fig. 19 and Table 6).

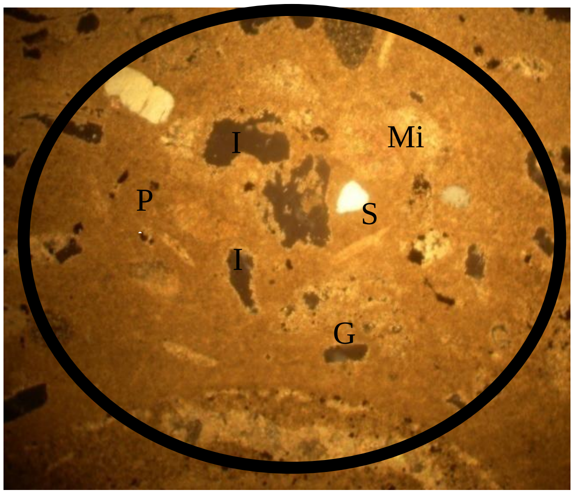



**Fig. 16a:** Photomicrograph of *Bio-Pel-micrite* microfacies. Gastropod (G) Pelecypod (P) Intraclast (I) Echinoderm (E) Micrite (Mi) Sparite (S) Pellet (Pl) Corals (C). Mag ×40

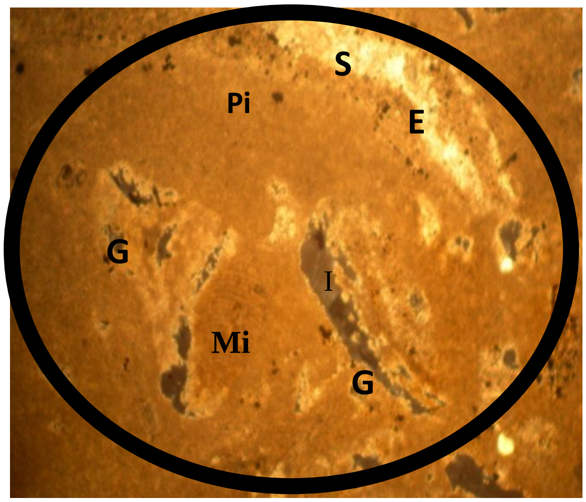



**Fig. 16b:** Photomicrograph showing the sparry calcite cement of the echinoderms (E) and micritization(Mi) of gastropods (G) and the intraclast(I) replacement of the dissolved bioclast. Mag×40

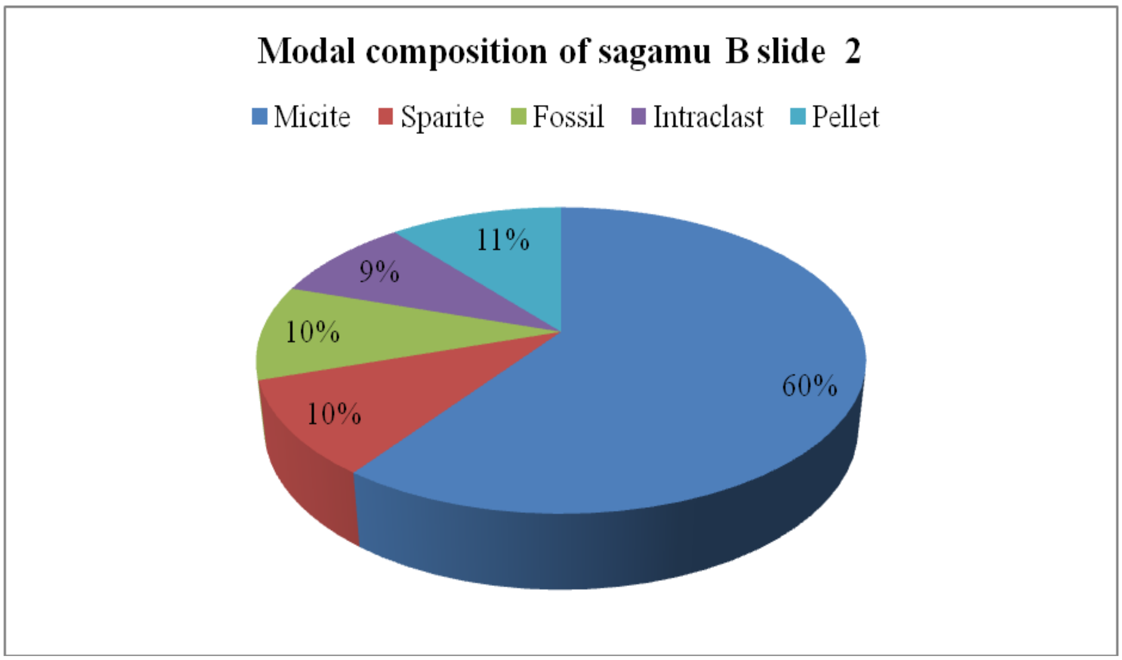



**Fig. 17:** Chart showing the modal composition of Sagamu B slide 1.

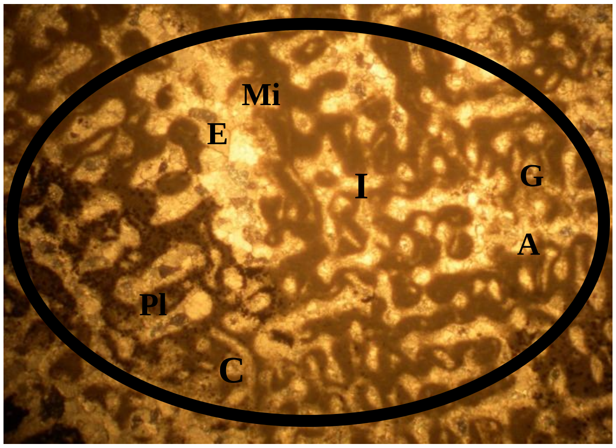



**Fig. 18a:** Photomicrograph of *Bio-Intra-sparite*. Gastropod (G) pelecypods (P) intraclast (I) echinoderm (E) micrite (Mi) sparite (S) algae (A) pellet (Pl) coral (C). Mag×40

Mag×40
echinoderms embedded in a micrite matrix.
(Mag×40)

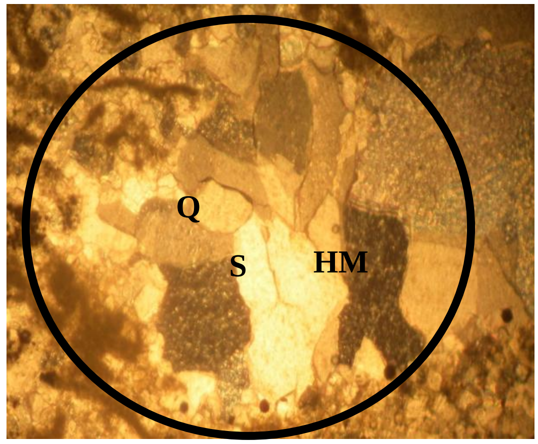



**Fig. 18b:** Photomicrograph showing the recrystallization of the calcite with other component like quartz and heavy minerals Quartz (Q) Heavy minerals (HM) Sparry calcite (S). Mag×40

Mag×40
echinoderms embedded in a micrite matrix.
(Mag×40)
(Mag×40)

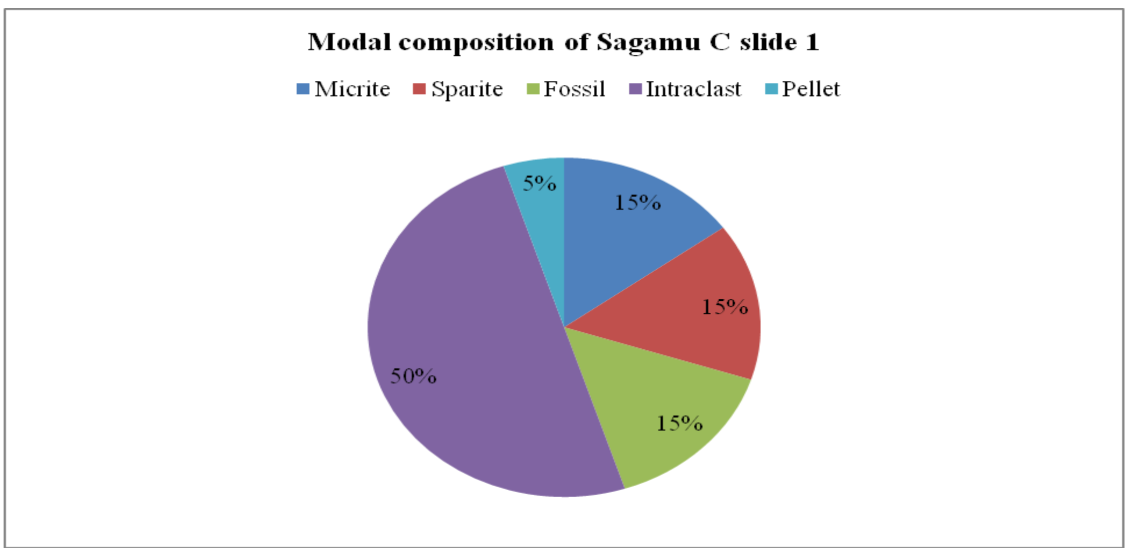



**Fig. 19:** Chart showing the modal composition of C slide 1(Sagamu).

***Micropalaeontology***

The result of the foraminifera recovered from the samples collected from the rock units at varying depth in both location shows varying degree in abundance and diversity. The microfossils species recovered were very rare and the microfossils recovered are dominated by pelecypods and gastropod with both belonging to the phylum Mollusca (Fig. 21). Scaphopod resembling forms were also seen in the samples of both locations. The result of the microfossil in each rock unit from both locations are presented in Table 7 and Figure 20. The presence of *Lenticulina inornata* and *Cibicides* sp. are observed in the samples B1 and D2 respectively.

**Table 7a: The Frequency of Microfossils Recovered from the Rock Units**

| **A1** | **Frequency** |
|---|---|
| Pelecypods | 4 |
| Gastropods | 3 |
| ?Scaphopods | 2 |
| Broken/indeterminate microfossil | 7 |
| **A2** | |
| Pelecypods | 25 |
| Shell fragment | 8 |
| Gastropods | 3 |
| Broken shell fragment | 7 |
| **B1** | |
| Pelecypods | 5 |
| Cibicides species | 1 |
| Gastropods | 1 |
| ?Scaphopod | 2 |
| **B2** | |
| ?Scaphopods | 1 |
| Gastropods | 1 |
| Pelecypods | 10 |
| Broken shell fragment | 1 |
| **C1** | |
| Scaphopod | 19 |
| **C2** | |
| Gastropods | 1 |
| Indetermenate miscellaneous microfossil | 1 |
| **D1** | Barren |
| **D2** | |
| Lenticulina inornata | 1 |

**Table 7b : The Distribution of Recovered Microfossil in Sagamu and Ibese Study Area**

| **Foraminifera** | **Sagamu** | **Ibese** |
|---|---|---|
| Broken shell | 0 | 8 |
| *Cibicides* spp | 1 | 0 |
| Gastropods | 4 | 5 |
| Indeterminate miscellaneous microfossils | 7 | 1 |
| *Lenticulina inornata* | 0 | 1 |
| Pelecypods | 9 | 35 |
| Scaphopod | 19 | 0 |
| ?Scaphopod | 4 | 1 |
| Shell fragment | 0 | 9 |

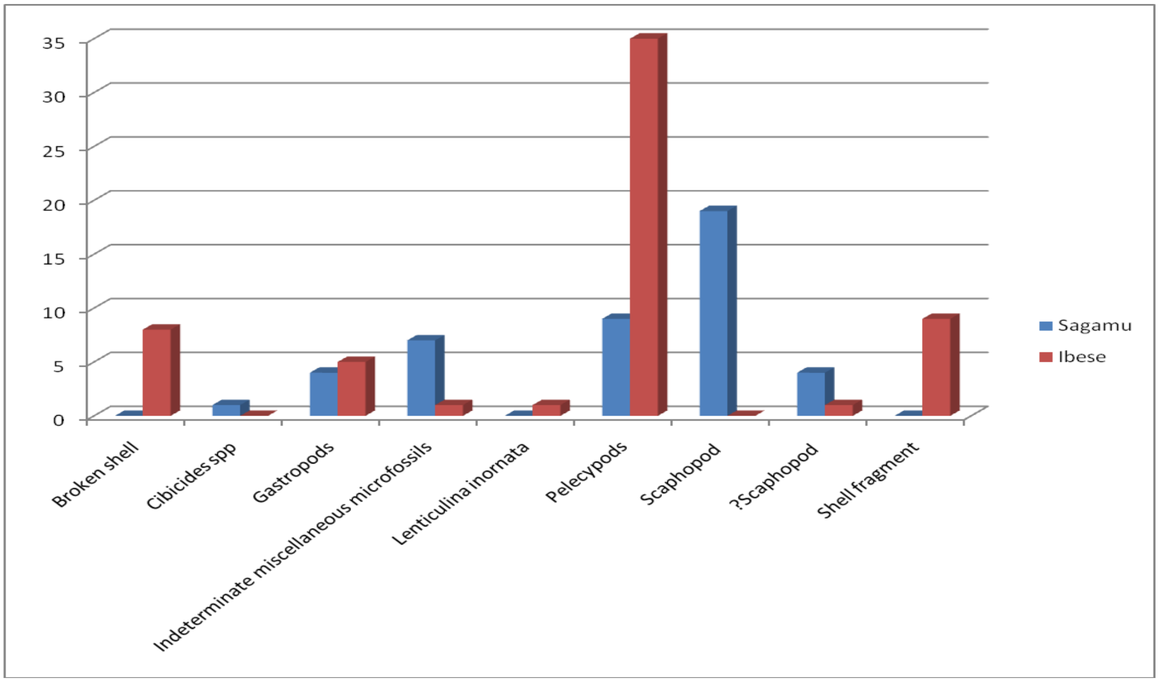
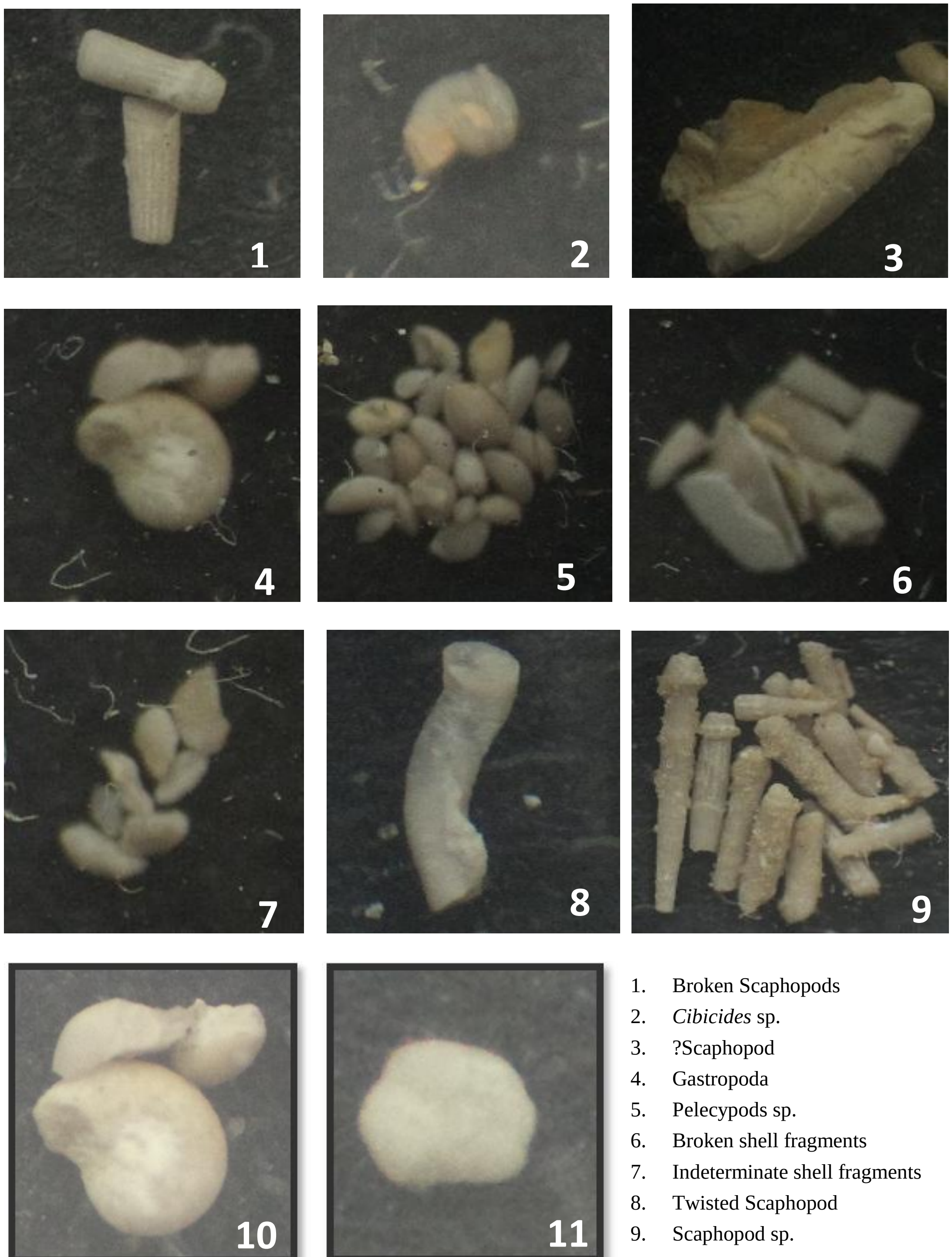



**Fig. 20:** The variation of individual microfossil in Sagamu and Ibese quarries.



1. Broken Scaphopods
2. *Cibicides* sp.
3. ?Scaphopod
4. Gastropoda
5. Pelecypods sp.
6. Broken shell fragments
7. Indeterminate shell fragments
8. Twisted Scaphopod
9. Scaphopod sp.
10. *Lenticulina inornata*
11. *Cibicides* sp.

**Fig. 21:** Photomicrograph of the recovered microfossils.

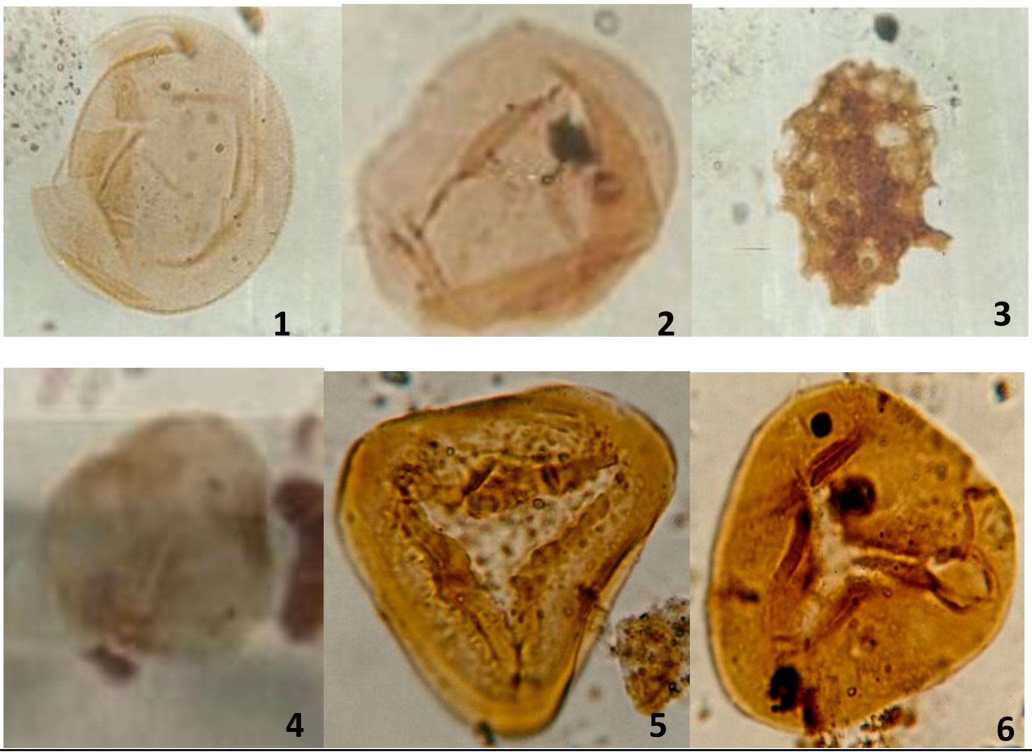
***Palynology***

The palynological result showed various forms of palynomorphs although some rock units are barren. The slide from which palynomorphs were observed was the slide labelled D1, which corresponded to Sagamu shale (black). The assemblages were dominated by land derived sporomorphs particularly *Monoporites annulatus*, *Laevigatosporites* spp., *Acrostichum aureum, Zonocostites Ramonae* and *Pteris* spp. Others recovered include *Gemmamonoporites* spp., *Psilatricolporites crassus* and *Peregrinipollis nigericus*. Most of the sporomorphs recovered are terrestrial with few marine forms. Some of these species are presented (Fig. 22). *Acrostichum aureum, Zonocostites ramonae* and *Laevigatosporites* spp. are fresh water forms found in swampy environment. These were appreciably abundant in the D1 horizon. *Psilatricolporites crassus*is is the most significant marine form that was recovered in this horizon. The presence of marine sporomorphs in the D1 horizon indicate marine environment for the whole sequence in the location. Also, the preponderance of terrestrial forms suggests a transition from a marine to terrestrial environment. This transition could have been due in part to the tectonic evolution of the Dahomey Basin during the early Cretaceous. It could also have been as a result of the transgression and regression phases of the Atlantic Ocean during this period. This assumption is supported by the preponderance of *Monoporites annulatus* in the D1 horizon which suggests the final closing stage of a marine transgressive phase and the beginning of a regressive phase.

***Nannopalaeontology***

Calcareous nannofossils recovered from these areas are very rare and moderately to poorly preserved. Detailed identification of species was made of all taxa encountered in each slide. The result shows varying degree in occurrence and diversity. Species recovered include *Toweius* spp., *Coccolithus pelagicus*, *Sphenolithus* spp., *Coccolithus formosus*, *Toweius callasus*, and other indeterminate coccoliths. There was co-occurrence of *Toweius callasus* and *Coccolithus formosus* in the D1 horizon. The rare species are *Coccolithus formosus, Toweius occultatus, Toweius eminens,* indeterminate *Coccolith, Cruciplacolithus frequens, Cruciplacolithus tenuis, Toweiu scallosus* and *Toweius pertusus* (Fig. 23 and Table 8).

The presence of *Toweius callasus and Coccolithus formosus* suggests Eocene for D1 horizon and according to the standard zonation schemes [24 and 25], the occurrence of *Toweius callasus* and *Coccolithus formosus* suggests CP11 - CP13 and NP12 - NP15 Zones and CP9-CP17 and NP11-NP23 Zones respectively. Based on the recovered forms as well as the similarities with the assemblages in CP10 - CP13/NP11 - NP15 Zones [24 and 25], D1 (Sagamu) and D2 (Ibese) horizons are assigned to early Eocene age (52.8Ma - 46.1Ma) (Figs. 24 to 28).




Mag x1300

1. *Laevigatosporites* sp.
2. *Monoporites annulatus*
3. *Peregrinipolis nigericus* (corroded)
4. *Zonocostites ramonae*
5. *Pteris* sp.
6. *Acrostichumaureum*

**Fig. 22:** The photomicrograph of the recovered palynomorphs.

**Table 8: The Results of the Nannofossils recovered from each Samples**

| | |
|---|---|
| **A1** | Barren |
| **A2** | Barren |
| **B1** | Barren |
| **B2** | Barren |
| **C1** | Barren |
| **C2** | Barren |
| **D1** (Sagamu) | Frequency |
| *Coccolithus formosus* | 1 |
| *Coccolithus pelagicus* | 6 |
| *Indeterminate coccoliths* | 2 |
| *Sphenolithus* spp. | 1 |
| *Toweius callosus* | 1 |
| *Toweius* spp. | 2 |
| **D2 (Ibese)** | **Frequency** |
| *Coccolithus formosus* | 3 |
| *Coccolithus pelagicus* | 23 |
| *Cruciplacolithus frequens* | 1 |
| *Cruciplacolithus tenuis* | 1 |
| *Sphenolithus moriformis* | 5 |
| *Toweius callatus* | 55 |
| *Toweius eminens* | 2 |
| *Toweius occultatus* | 3 |
| *Toweius pertusus* | 1 |
| *Toweius* spp. | 35 |

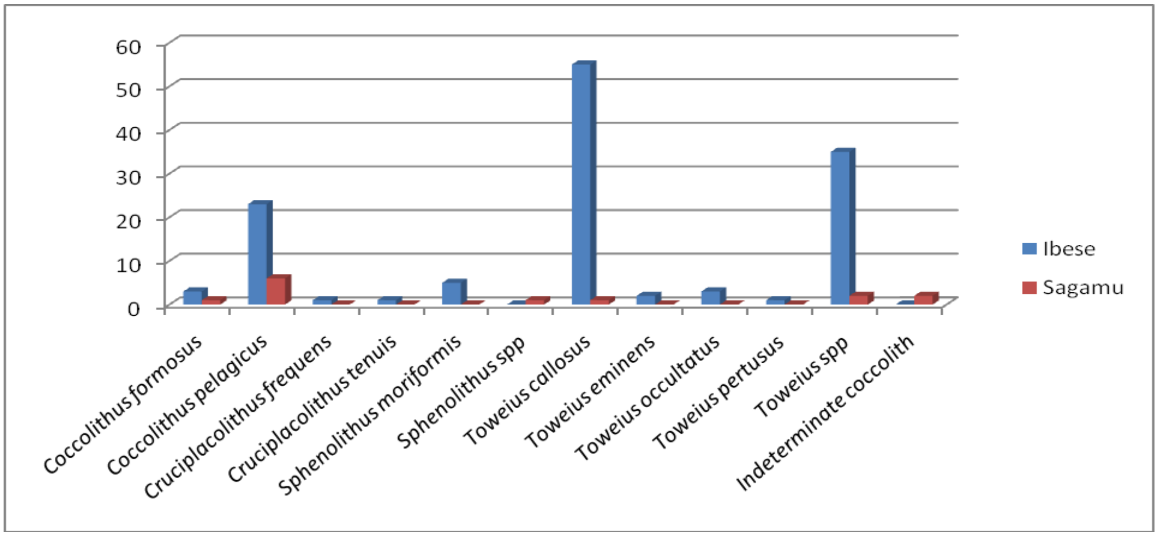
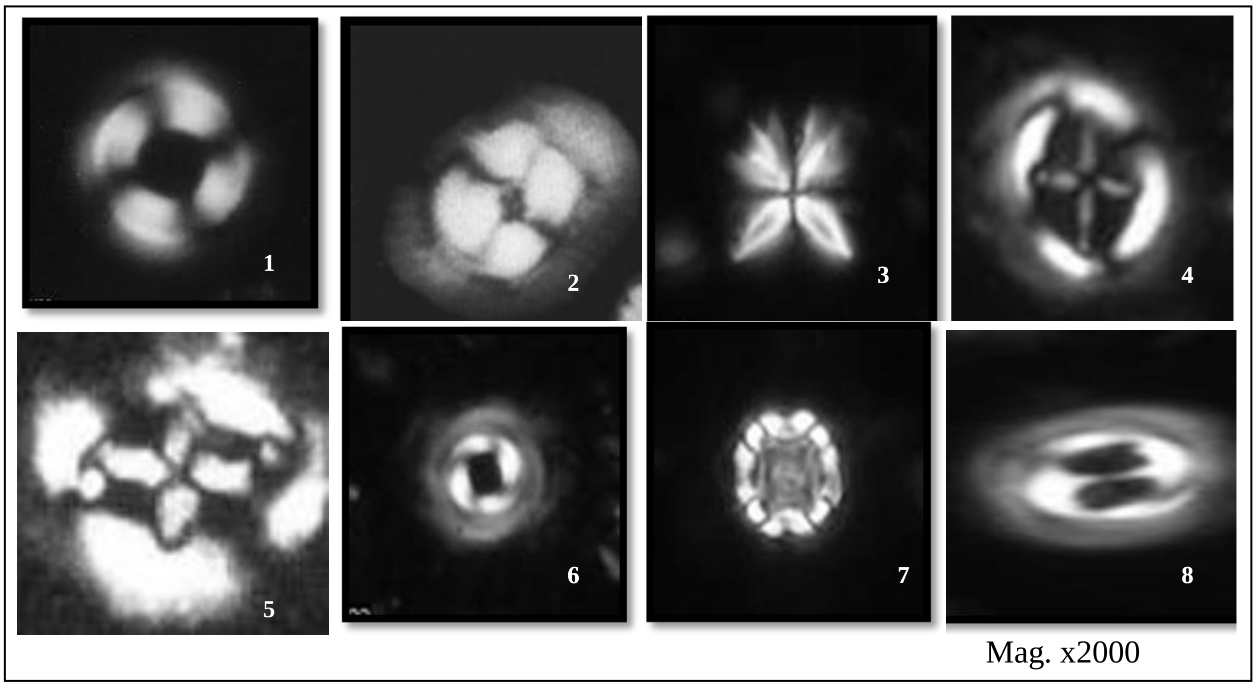



**Fig. 23:** The variation of individual Nannofossils recovered from Sagamu and Ibese quarries.




1. *Coccolithus formosus*
2. *Coccolithus pelagicus*
3. *Sphenolithus moriformis*
4. *Cruciplacolithus frequens*
5. *Toweius* spp.
6. *Toweius pertusus*
7. *Toweius callatus*
8. *Toweius occultatus*

**Fig. 24:** Some calcareous nannofossil species recovered from samples.

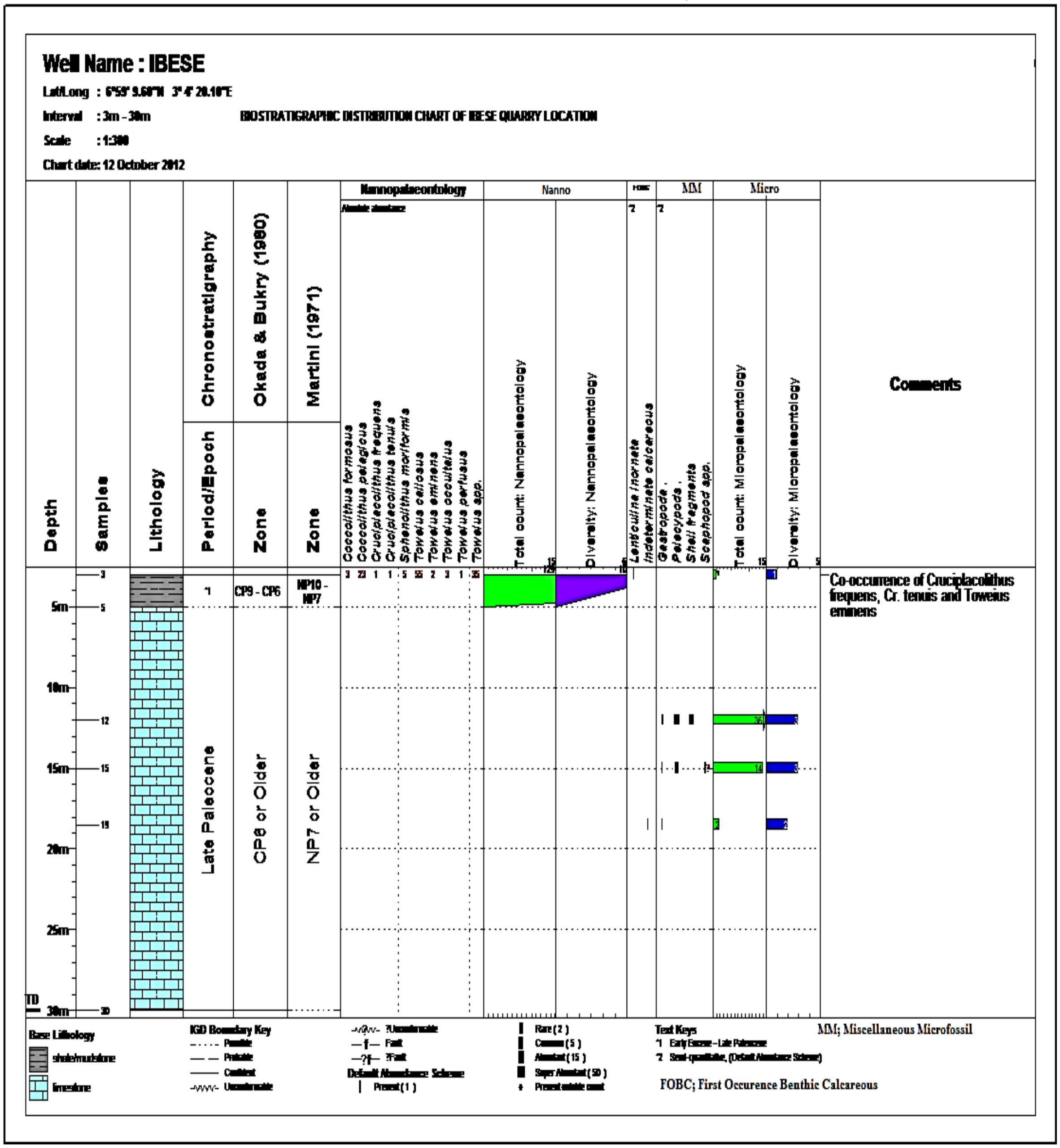



**Fig. 25:** Distribution chart of the different fossils recovered from Ibese study area.

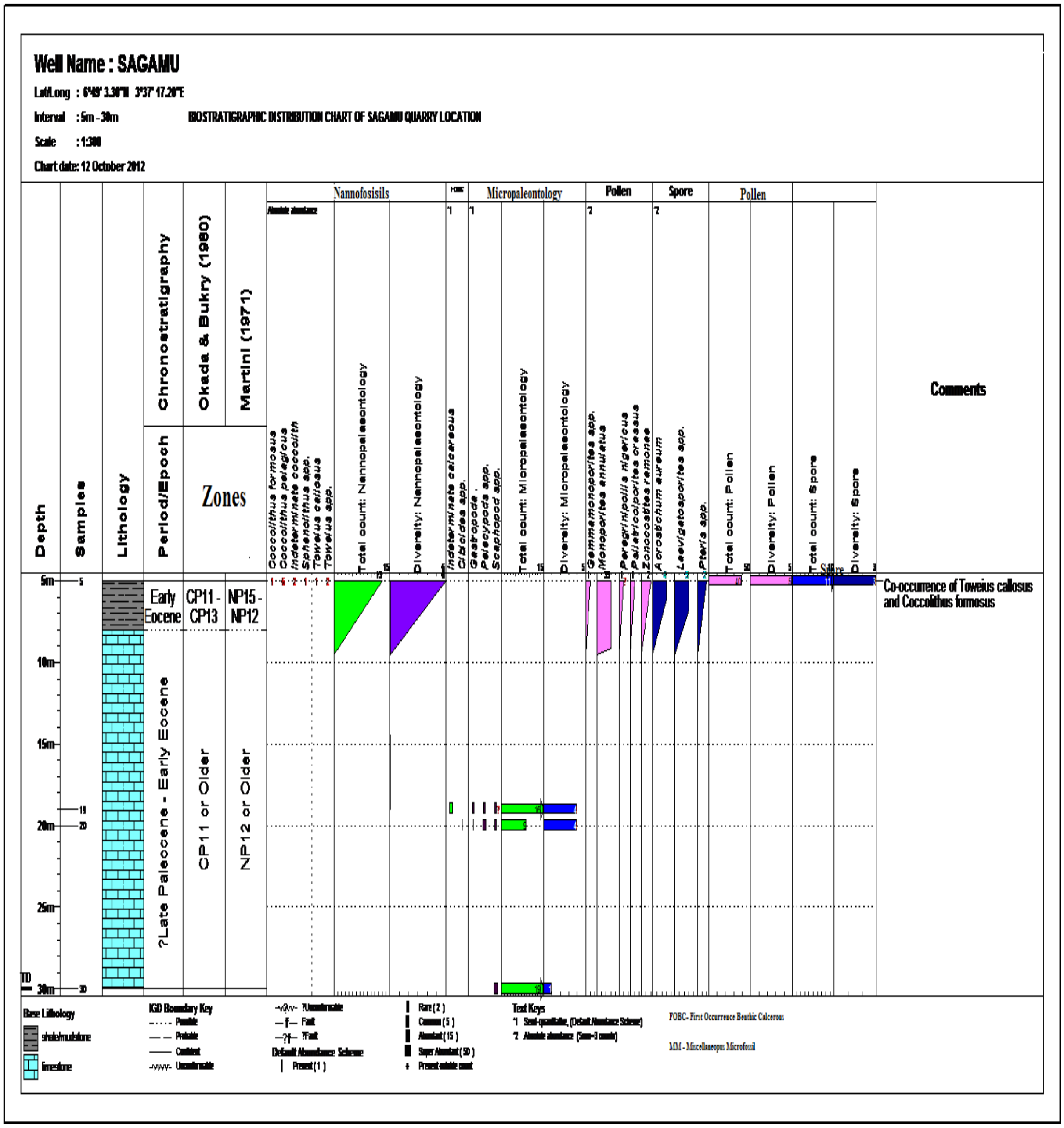



**Fig. 26:** Distribution chart of the different fossils recovered from Sagamu study area.

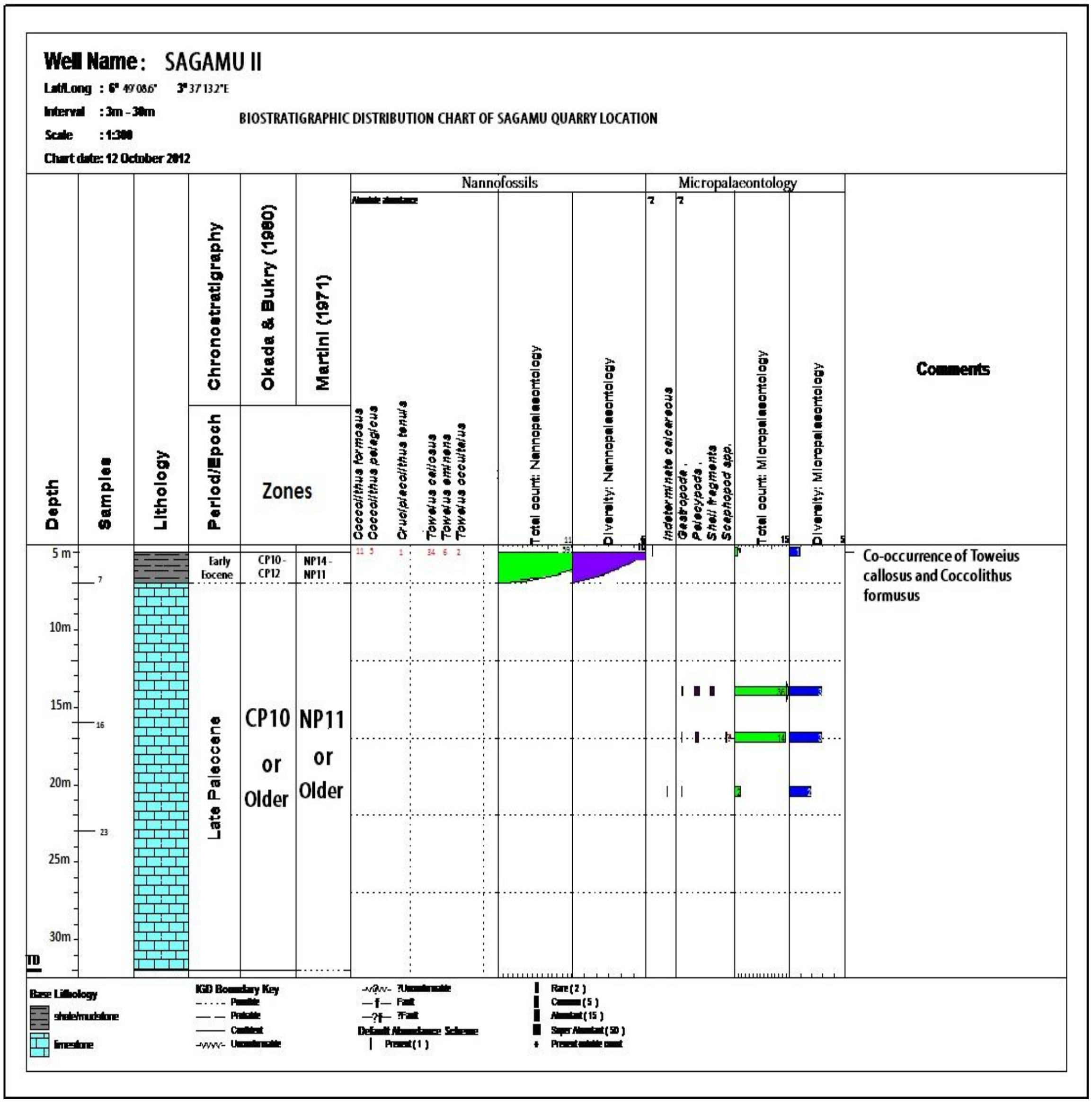



**Fig. 27:** Distribution chart of the different fossils recovered from Sagamu study area.

## Biostratigraphy

The calcareous nannofossil exhibits high diversity and abundance. The assemblages from Sagamu showed abundant *Coccolithus pelagicus.* Rare species are *Toweius* spp., *Sphenolithus* spp., *Coccolithus formosus*, *Toweius callosus* and indeterminate Coccolith. Based on these recovered fossils, using the standard zonation of Martini [25] (NP15-NP12) for *Toweius callosus*, *Coccolithus formosus* (NP11-NP23) and Okada and Bukry ([24] for *Toweius callosus* (CP11-CP13) and *Coccolithus formosus* (CP9-CP17), the rock units fall within the CP10-CP13 and NP11- NP15 Zones, hence dated early Eocene (52.8 Ma - 46.1Ma).

The nannofossil assemblages from Ibese (D2) showed abundant *Coccolithus pelagicus*, *Coccolithus formosus Toweius* spp., *Toweius callatus* and *Toweius occultatus*. Rare species are *Cruciplacolithus frequens, Cruciplacolithus tenuis, Toweius pertusus* and *Toweius eminens*. Sequel to the recovered species, *Cruciplacolithus frequens*

(NP6-NP9), *Cruciplacolithus tenuis* (NP3-NP9) and *Toweius eminens* (NP7-NP10) with respect to *Toweius callosus* (NP12-NP15) and *Toweius occultatus* (NP12-NP13), *Cruciplacolithus frequens* (CP5-CP8A), *Cruciplacolithus tenuis* (CP2-CP8a) and *Toweius eminens* ( CP 6- CP9a) with respect to *Toweius callosus* (CP10- CP13a) and *Toweius occultatus* (CP10- CP11) [24 and 25], the presence of *Cruciplacolithus frequens*, *Cruciplacolithus tenuis* and *Toweius eminens* show that the rock units fall within CP6 - CP9 and NP7 - NP10 Zones [26 and 27] suggesting late Palaeocene to early Eocene age. However, the presence of *Toweius callosus*, *Toweius occultatus* and *Coccolithus formosus* show that the zone is long ranged which may extend to CP9 and NP11, hence suggesting Late Palaeocene - Early Eocene (55.6Ma – 46.1Ma) for D2 unit.

**Palaeoecology**

This was based on the recovered calcareous nannofossils, and they have several good ecological diagnostic species. *Coccolithus pelagicus* thrive well in cold (nutrient rich surface water between $7^{o}C$ to $14^{o}C$. This categorises them as good palaeoclimate indicators [26, 27]. Rahmann and Roth noted that *Coccolithus pelagicus,* a long-ranging species, provides paleoclimatic information for Middle Miocene to Pleistocene [28]. The presence of *Coccolithus pelagicus* in D1 (Sagamu black shale) and D2 (Ibese brown shale) horizons indicate a deposition in cooler marine water condition. Although, it is well known that *Coccolithus pelagicus*is a resistant species to the carbonate dissolution and this could improve its relative frequency [28].The *Sphenolithus* species are considered to be paleo-bio-indicators for warm oceanic water suggesting that the Akinbo shales at the top of Ewekoro Formation was a cooling phase stage of deposition [29].

**Depositional Environment**

The co-occurrence of marine and land-derived sporomorphs in the D1 shale horizon suggests a transition from marine to terrestrial environment of deposition. The pre-ponderance of land derived palynomorphs from the D1horizon indicates deposition in a near-shore environment. The water level in the near-shore environment must have probably reduced drastically to a very low level. This is confirmed by the presence of *Monoporites annulatus,* which indicates the commencement and closing of marine transgressive and regressive phases.

The foraminifera recovered from the lower B1 horizon corroborates deposition in shallow waters. This is also supported by the presence of *Cibicides* spp., gastropods and pelecypods in this horizon and other units below it. This suggests that the limestone was formed in a shallow water environment.

The Biomicrite unit is formed in shallow neritic water of open circulation at or just below wave base [30, 31]. Sediments containing fragments of various organisms and the bioclasts are micritized. This unit may indicate that the fossils are sedentary and also that current was calm in the depositional environment and the microcrystalline ooze did not get winnowed from shelly materials.

This facies formed as a result of ineffective winnowing and calm current actions peculiar to protected shallow lagoon or shallow platforms on the leeside of barriers, where the great width of the platform prevents any permanent removal of lime mud. The standard facies belt of the biomicriteis, the open marine platform facies characterized by burrowing traces. This facies has the highest number of occurrence in the petrographic studies of the limestone samples A1, B1 and C1 collected from the Shagamu quarry.

The Biosparite unit is associated with shoal environment in disturbed water. This unit has the winnowed platform edge sands as its standard facies belts which are formed in shoals, beaches, offshore tidal bars in fans or belts, or dune islands [30]. This facies had a less frequency of occurrence in the limestone units from the Shagamu quarry.

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**Conclusions**

The biostratigraphic studies which involved nannofossils analysis, micropaleontology, palynological and petrographic studies have been carried out on the shale and limestone lithofacies collected from rock unit exposed in Sagamu and Ibese. Evidence from the fossil assemblages recovered from the samples showed a transition from marine to terrestrial depositional environment. *Cibicides* spp. recovered from the limestone horizon (B1) together with molluscs (gastropod and pelecypod) recovered from the other limestone horizons (A1) and C1 indicate a shallow water environment. This suggests that the limestone of the Ewekoro Formation was deposited in shallow water conditions. The dominance of terrestrial palynomorphs coupled with few marine forms in the D1 horizon shale indicates a transitional environment of deposition for the shale of the Oshosun Formation. The abundance of *Monoporites annulatus* in the shale samples indicates the beginning of a marine regressive phase during the formation of the shale. The occurrences of *Toweius callosus* and *Coccolithus formusus* suggests an Early Eocene age (Ypresian =55.8 $\pm$0.2 Ma) for the Oshosun Formation from which these fossils were recovered. Also, an age range of ?Late Palaeocene (?Thanetian = ?58.7$\pm$ 0.2 Ma) to Early Eocene (Ypresian = 55.8 $\pm$ 0.2 Ma)was assigned to the underlying limestone of the Ewekoro Formation.

The petrography of the limestone units from Shagamu has revealed two microfacies units of shelly biomicrite and shelly biosparite. The limestone samples A1, B1, A2 were dominated by the biomicrite microfacies units, while the limestone sample C1 and B2 were dominated by the biosparite microfacies units. The shelly biomicrite facies indicate deposition in shallow neritic water of open circulation at or just below wave base while, the shelly biosparite facies indicates agitated shoal environment (High energy). There are evidences from the result that the limestone of the Ewekoro Formation has undergone four stages of diagenesis. After deposition, the limestone constituents (allochems) were cemented by carbonate mud matrix. This led to micritization which in turn caused the compaction of the constituents, which led to the growth of several sparry calcite cement. These diagenetic processes led to the formation of the whole mass of limestone of the Ewekoro Formation in the eastern Dahomey Basin.

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