

CRETACEOUS BIVALVES AND PALAEOENVIRONMENTS OF THE CALABAR FLANK, SE NIGERIA

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ABSTRACT

Bivalves of Albian, Cenomanian, Turonian and Campanian age are documented from the Calabar Flank, SE Nigeria. Benthic megafossils are associated mainly with limestone and marls; thin beds of mudstone, siltstone and shelly layers intercalated within a thick sequence of shales. The latter contain abundant ammonites and planktic foraminifera, while a few of the benthic foraminifera are represented mainly by arenaceous forms. Although the state of preservation of the bivalves is poor and has hindered identification of some specimens to generic and specific levels, it is obvious that diversity is low. Three diminutive forms are however abundant. Integration of the bivalves data with other fossils as well as ichnological evidence has given a better palaeoenvironmental picture. It is shown that the Calabar Flank was subjected to frequent oceanographic fluctuations during the late Lower and the Upper Cretaceous. The Middle-Upper Albian times experienced shallow tropical marine conditions with well aerated bottom while the Cenomanian had long periods of marine oxygen-deficient conditions frequently interrupted by shorter spells of marginal marine oxic bottomed environments. The Turonian witnessed a more uniform shallow sea with oxygenated bottoms while the Campanian rocks show an inner neritic marine setting with occasional arid brackish water environments.

KEYWORDS: Albian-Campanian bivalves, Palaeoenvironments, Calabar Flank, Nigeria

INTRODUCTION

Calabar municipality in southeastern Nigeria situates on a geologic boundary between two major sedimentary basins namely; the Benue Trough and Niger Delta to the north and south respectively. Sedimentary succession in the Niger Delta is mostly of Tertiary age and is considerably thicker than that of the Benue Trough which is dominantly Upper Cretaceous. The SE extension of the Benue Trough (Petters, 1980; Petter & Ekweozor, 1982a) also known as the Calabar Frank (Murat, 1972) fringes the Precambrian basement Oban massif in the north (Fig. 1). The Calabar Flank is of particular geologic importance because it has, except for Angola and Gabon the most complete Cenomanian sedimentary record than any other part of west coastal Africa (Reyment & Dingel, 1986). Sediments in the Calabar Flank dip gently (normally $<10^\circ$) mostly to the southwest. Different formation names have been proposed by many authors (Reyment, 1965; Adeleye & Fayose, 1978; Petters & Ekweozor, 1982a) for this sedimentary succession which ranges from probably early Albian to Recent, without consensus. However bore-hole and outcrop samples show the following succession (Fig. 2): A thick sequence of unfossiliferous fluvio-continental sediments made up of shales, mudstones, sandstones, grits and conglomerates

rests unconformably on the basement and has been named Awi Formation (Adeleye & Fayose, 1978). These clastics are succeeded by karstic algal marine limestones best exposed at Mfamosing quarry. Diverse Late Albian to Early Cenomanian ammonites have been recorded at the top of the quarry of the Mfamosing Limestone (Forster, 1978; Forster & Scholz, 1979) which is unconformably overlain by a thick sequence of grey shales, pyritic at some intervals and intercalated with thin bands of calcareous mudstone, shelly beds and sandstone. These sediments are considered to be Lower to Upper Cenomanian on the basis of the associated ammonites. Zaborski (1985) argued that although some parts of the Middle and most of the Upper Cenomanian appear to be missing in the Calabar Flank as a result of the intra-Cenomanian folding phase in southern Nigeria (Nwachukwu, 1972; Olade, 1975) the presence in his collection of the ammonite *Pseudocaly-coceras* cf. *haughni* (exact position in the road section uncertain) and recording from this area of *Metoicoceras* aff. *ornalum* by Reyment (1955a) indicate the presence of terminal Cenomanian (cf. Kennedy et al. 1981). Above these grey shales is a succession of marls and micaceous calcareous mudstone which according to Petters (1980) and Perch-Nielson & Petters (1981) range from Turonian to Coniacian, although others (Nyong & Ramanathan, 1985) have questioned the

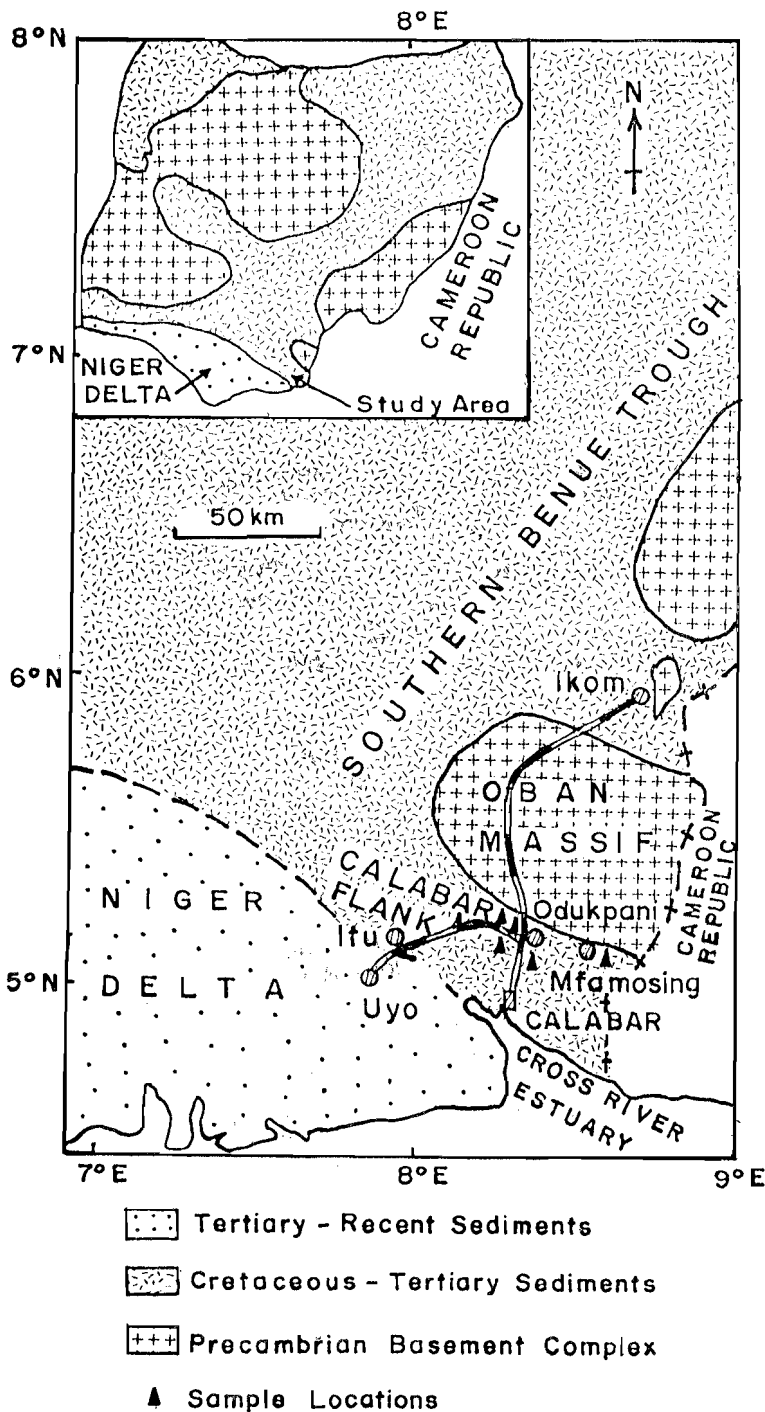


Fig. 1 Sketch geologic map of the study area with fauna locations.

existence of Coniacian sediments in the Calabar region. An important ammonite form in these sediments according to Zaborski (1985) is *Coilopoceras aff. newelli* Benavides - Canceres. In their review of the genus *Coilopoceras*, Kennedy & Wright (1984) believed that this is primarily a late Turonian form. It was on the strength of this that Zaborski (1985) concluded that the shaley limestone and marls in the Calabar Flank are probably Middle-Upper

Turonian. A late Campanian-early Maastrichtian gypsiferous dark shale, rich in the ammonites (*Libycoceras* and *Sphenodiscus*) as well as turtle, fish and reptile bones with intercalations of thin bands of reddish siltstone and limestone which overlie the Turonian sediments with a major hiatus, mark the Cretaceous terminal events. These shales commonly referred to as Nkporo Shale are in turn overlain by the continental sands of late Tertiary and Recent ages.

In the study area, microfossils and ichnofossils have been studied intensively and utilized for biostratigraphy, and palaeoenvironmental interpretations (Petters 1980; 1981; Odebode, 1983; Akpan, 1985, 1990, 1999). Megafossils have however not received much attention save for ammonites (Reyment 1955a, 1965; Zaborski, 1982, 1985), although bivalves, gastropods and vertebrates are common. Early research on fossil bivalves from Nigeria was pioneered by Newton (1922) who was concerned with the systematic documentation of this class from the Eocene Ameki deposits of eastern Nigeria. His work was subsequently reviewed by Eames (1957). In the northern part of the Benue Trough, Cretaceous bivalves were described by Reyment (1955b) and Barber (1958). In their age and stratigraphic correlation of the Upper Cretaceous Gongila and Pindiga formations of NE Nigeria, Popoff, et al (1986) listed bivalves that are associated with these Cenomanian-Turonian sediments. In other parts of Africa, fossil bivalves have been studied. From the western sahara, Cretaceous bivalves have been described (Furon, 1933) while from the Cameroons and Angola, Rennie, (1929) and Freneix et al. (1959) respectively have provided detailed surveys of these molluscs. In the works of Cox (1952) from Ghana, thirty one genera of the Cretaceous and Eocene bivalves have been illustrated and described.

In this report, a systematic survey of bivalves in the Calabar Flank is made. Correlation of some of the fauna with similar forms from other parts of Africa is attempted. The associated bivalves complemented by other mega invertebrates as well as ichnofossils allow the palaeo-oceanographic reconstruction of this basin during Albian to Maastrichtian.

SYSTEMATIC DESCRIPTIONS

All the specimens are housed in the Department of Geology, University of Calabar. Unless otherwise stated, materials described herein are from road cuttings either along the Calabar-Itu or Calabar-Ikom highway in southeastern Nigeria. The locations were

established with reference to their distance from Calabar town using the kilometer post (Fig. 1). Taxonomic study of the forms is plagued with a lot of difficulties. These include inaccessibility owing to the thick tropical vegetation, inadequate exposure and very poor state of fossil preservation resulting in inability to observe most of the diagnostic taxonomic features. In all cases, the original shell materials have been lost through either dissolution or complete alteration by recrystallization. As a result of this, identification of most of the forms to the specific level has been impossible. One of the reasons why only ammonites have been intensively studied and reported from this area is because even though this group of mollusk is preserved mainly as moulds; the suture lines which are diagnostic for the identification and classification of the cephalopods, are normally intact.

2.1 Supper Family: NUCULANACEA Adams and Adams, 1858

Family: NUCULANACEA Adams & Adams, 1858
Genus: PRAESACCELLA Cox, 1940

Praesaccella sp
Fig. 3a, b & c

Material: Ten specimens, Nos. EBA. 100 - 110

Occurrence: Abundant in the thin band of brown ferruginised siltstone at the top part of Nkporo Shale, Late Campanian; kilometer 36.5, Calabar-Itu Road.

Description: Complete bivalves but weathered shells, average length 8mm, height 6.5mm; width 4mm. Shell is equilateral and equivalve; beak sub-central, weakly projecting and prosogyrate; posterior end tapered more bluntly than anterior. Shell exterior smooth apart from the fine growth lines. Lunular area weakly depressed. Hinge, nuculoid. Adductor scars, pallial line and pallial sinus inconspicuous.

Remarks: The size and outline of shells and

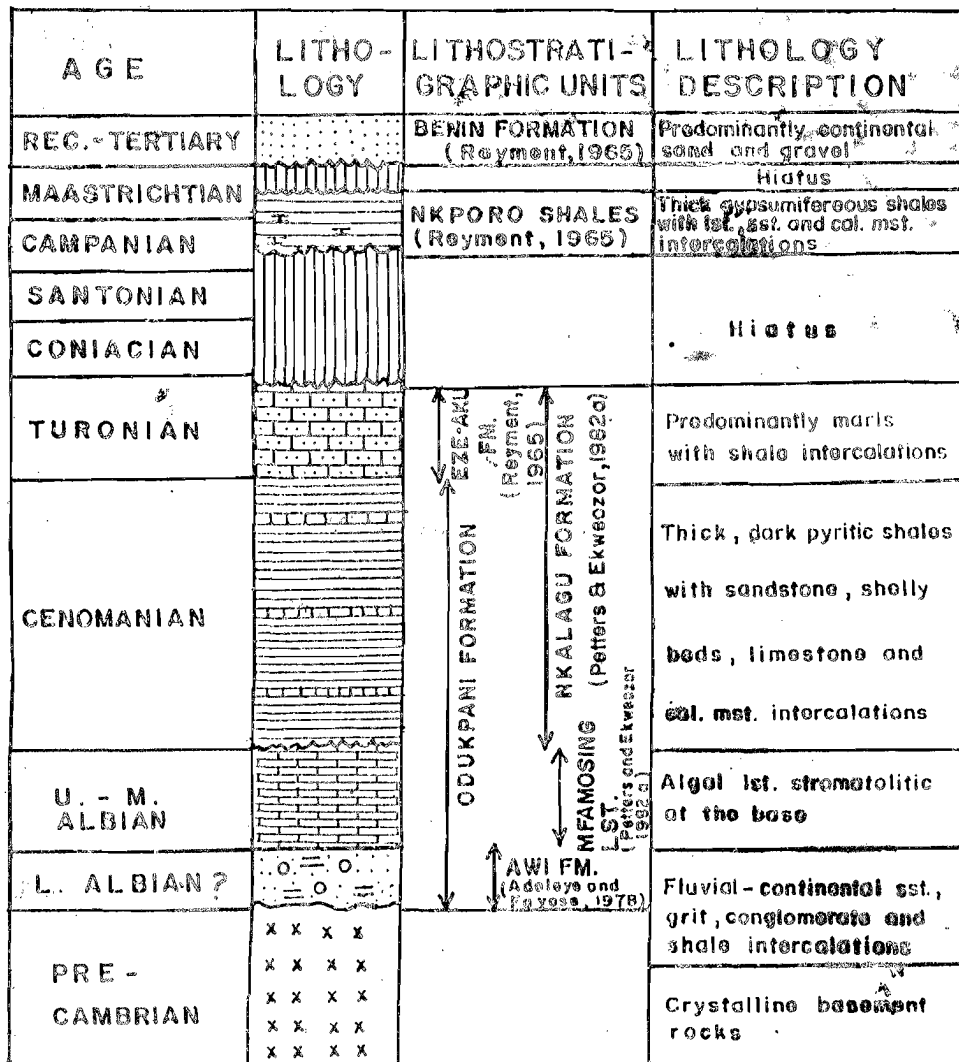


Fig.2 Generalized stratigraphic sequence (not to scale) in the Calabar Flank.

those of internal moulds compare closely with the genus *Praesacella*. In the absence of hinge features and unweathered shell, it is difficult to further identify the specimens.

Genus: ?MESOSACELLA Chavan, 1946

?*Mesosacella* sp.

Fig. 3f & g

Material: Nine specimens, Nos EBA. 111-119

Occurrence: Abundant in the calcareous mudstone bands of Nkalagu (Odukpani), Formation, Middle-Upper Cenomanian; kilometer 28-32, Calabar-Itu Road.

Description: All are internal moulds. Specimens are small in size; length, 6-10mm; height, 4-6mm.

Elongate-subovate in outline; inequilateral but equivalve. Beak, sub-central and fairly prominent. Dorsal margin forms a convex feature upwards.

Remarks: No hinge feature is observable. The state of preservation is very poor, therefore creating uncertainty in identification.

2.2 Superfamily: ARCACEA Lamarck, 1809

Family: ? CUCULLAEIDAE Stewart, 1930

Genus: ?CUCULLAEA Lamarck, 1801

?*Cucullaea* sp.

Fig. 3h & i

Material: Twenty one specimens, Nos EBA. 120 - 140.

Occurrence: Abundant in the calcareous mudstone bands at the top of Nkalagu (Odukpani),

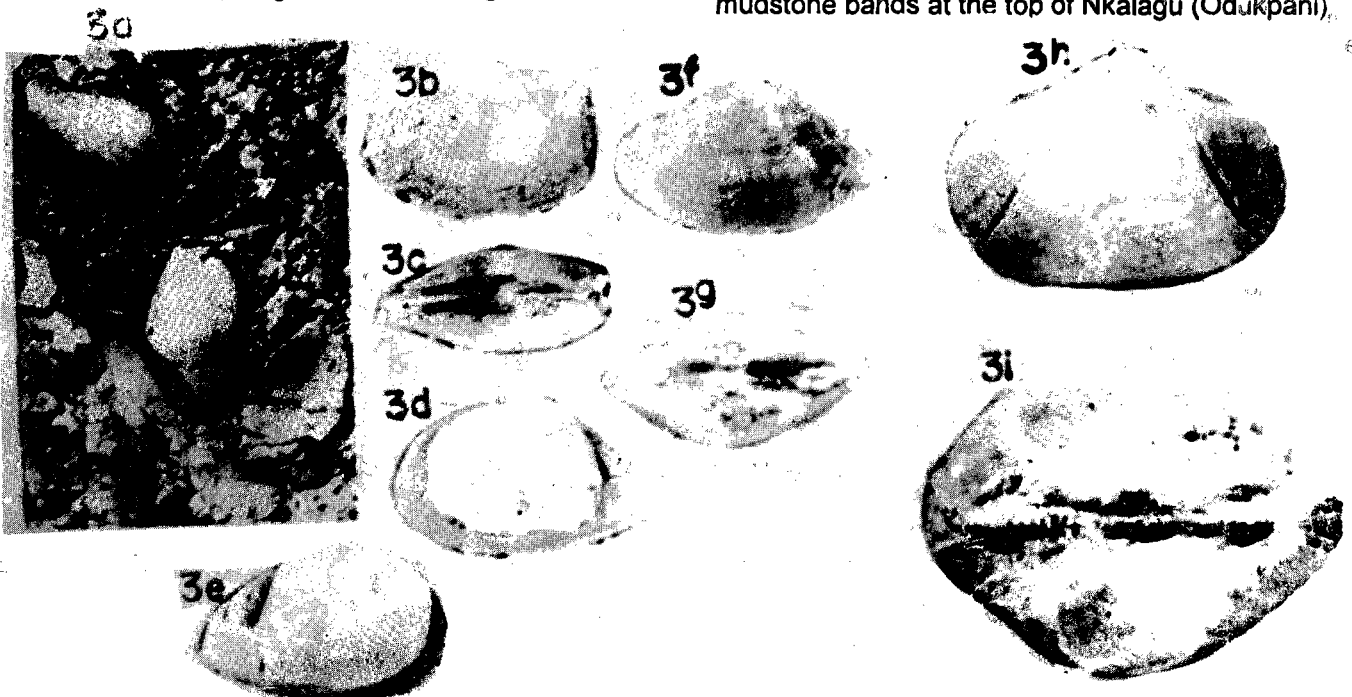


Fig. 3a *Praesacella*, fragile shells and fragments within the siltstone, 36.5km along Calabar-Itu Highway (Upper Campanian), X2.5.

Fig. 3b *Praesacella*, internal mould of left valve from the same locality as 3a, X3.5.

Fig. 3c Same specimen as 3b, dorsal view, X3.5.

Fig. 3d *Parmicorbula rupana*, internal mould of right valve, 32km along Calabar-Itu highway (M. Cenomanian), X5.

Fig. 3e Same specimen as 3d, internal mould of left valve.

Fig. 3f ?*Mesosacella* sp., internal mould, 32km along Calabar-Itu highway (M. Cenomanian), X5.

Fig. 3g ?*Mesosacella* sp., internal mould, . 2km along Calabar-Itu highway (M. Cenomanian), X5.

Fig. 3h ?*Cucullaea* sp., internal mould of right valve, 28km along Calabar-Itu highway (M. Cenomanian), X4

Fig. 3i ?*Cucullaea* sp., internal mould, dorsal view with broken beak, 28km along Calabar - Itu highway (M. Cenomanian), X4.

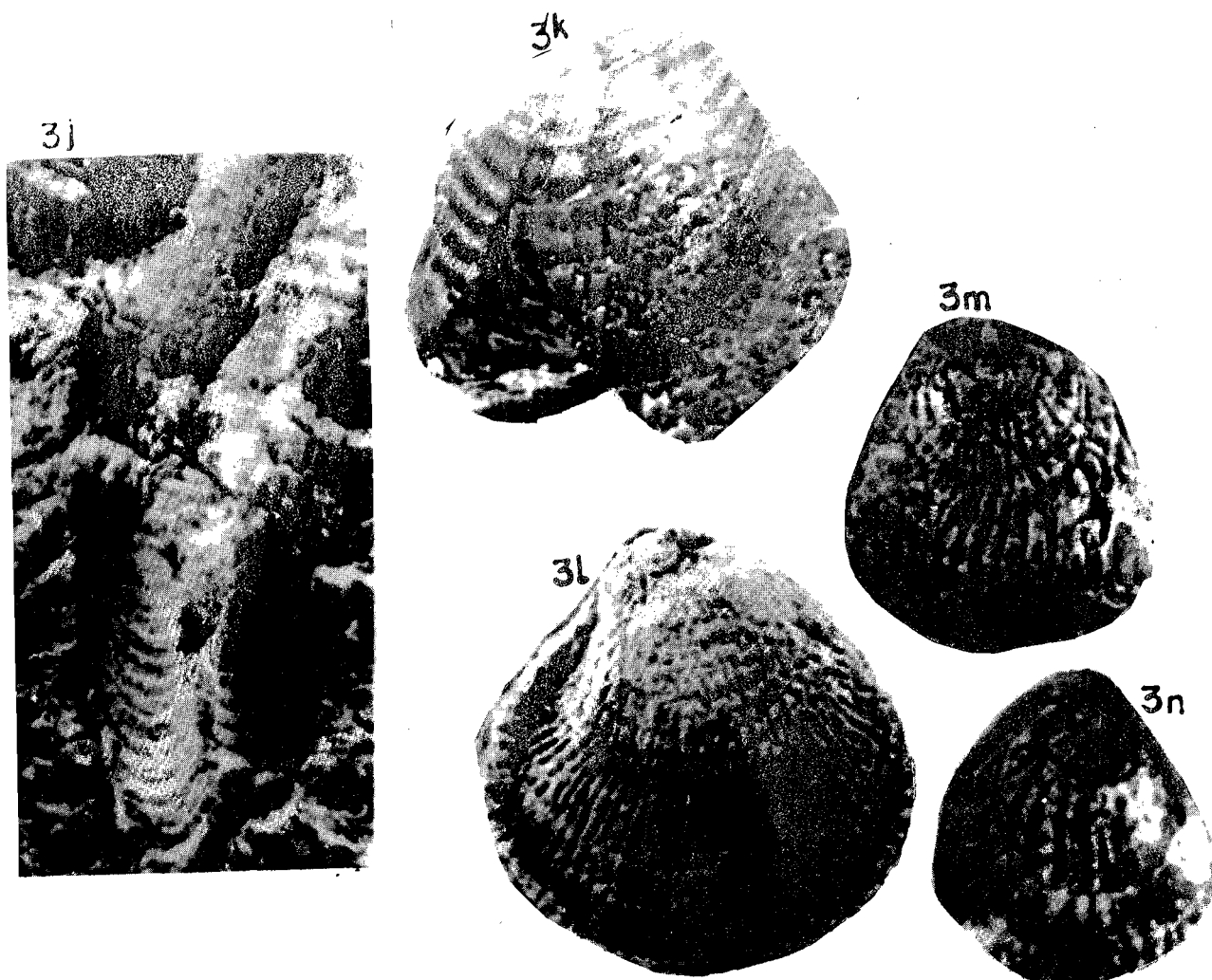


Fig. 3j *Lithophaga* sp; internal and external moulds in the stromatolitic interval of Mfamosing limestone, Upper Albian, X2.5.

Fig. 3k *Endocostea* sp; internal moulds of right valve, 36.5km Calabar-Itu highway (upper Campanian), x 3.

Fig. 3l *Plicatula* sp; 24.8km along Calabar-Ikom highway (L. Cenomanian) X 1.5.

Fig. 3m *Plicatula auressensis*, 24.8km along Calabar-Ikom highway (L. Cenomanian) X1.5.

Fig. 3n Specimen from the same bed as 3m, X1.

Formation, Middle-Upper Cenomanian; kilometer 28 –32, Calabar-Itu Road.

Description : All preserved as internal moulds of articulated valves. Specimens small in size ; length, 9-14mm; height, 7-11mm; highly inflated with maximum just below the beak. Specimens slightly inequilateral and almost equivalve. Beak; subcentral, prominent and incurved. Hinge; long, straight and relatively wide. Evidence of the presence of rows of teeth which appear to be larger in size at the margins than the centre; and fine concentric growth lines. The presence of one or two radial groove(s) close to the posterior and anterior ends of the specimens is remarkable.

Remarks : The identification is based mainly on the general shape of the specimens. It is impossible to be certain in the absence of hinge features. Other groups in this super-family have forms which are strongly inequilateral.

2.3 Superfamily: MYTILACEA Rafinesque, 1815
 Family: MYTILIDAE Rafinesque, 1815
 Genus: LITHOPHAGA Roding, 1798
Lithophaga sp.
 Fig. 3j.

Material : Five specimens, Nos EBA. 141 –145

Occurrence: Common as recrystallized shells in borings of ichnogenus *Gastrochaenolites* and as moulds in the stromatolitic intervals of Mfamosing Limestone (Odukpani Formation) Middle to Late Albian (Akpan, 1992); Mfamosing limestone quarry.

Description: Shell elongate and cylindrical; length, 15-20mm; height, about half of the length, equivalve and tapers on both ends but rather bluntly on the posterior margin. Concentric growth lines are prominent. Hinge features are not observable.

Remarks : The genus contains the best known rock borers in both the ancient and recent environments. Their occurrence in the Mfamosing quarry has been interpreted as indicative of hardground resulting from syndepositionary lithification of the sea floor (Akpan, 1990 & 1991).

2.4 Superfamily: PTERIACEA Gray, 1847
Family: INOCERAMIDAE Giebel, 1852
Genus: ENDOCOSTEA Whitfield, 1877
Endocostea sp
Fig. 3k

Material: Seven specimens, Nos. EBA. 146 – 154
Occurrence: Common in the thin band of brown, ferruginized siltstone at the top part of Nkporo Shale, Late Campanian; kilometer 37 Calabar-Itu, Road.

Description: Internal mould of disarticulated valves. Specimens medium to large in size; length, 80 – 100mm; height, 50 – 70mm; subequivalve and inequilateral. Specimens are ovate in outline; beak is subcentral and weakly projecting. Concentric placations are strong and regular. An important features of this form is the presence of radial groove on the surface of the



Fig. 4a *Exogyra olisiponensis* Sharpe, left valve covering internal mould, 32km, Calabar-Itu highway (M. Cenomanian), X1.

Fig. 4b Same specimen as 4a showing the typical twisted Umbo, X1.

Fig. 4c *Exogyra olisiponensis* Sharpe, outer surface of right valve, 24.8km, Calabar-Ikom highway (L. Cenomanian) X1

Fig. 4d Same specimen as 4c showing inner surface, X1.

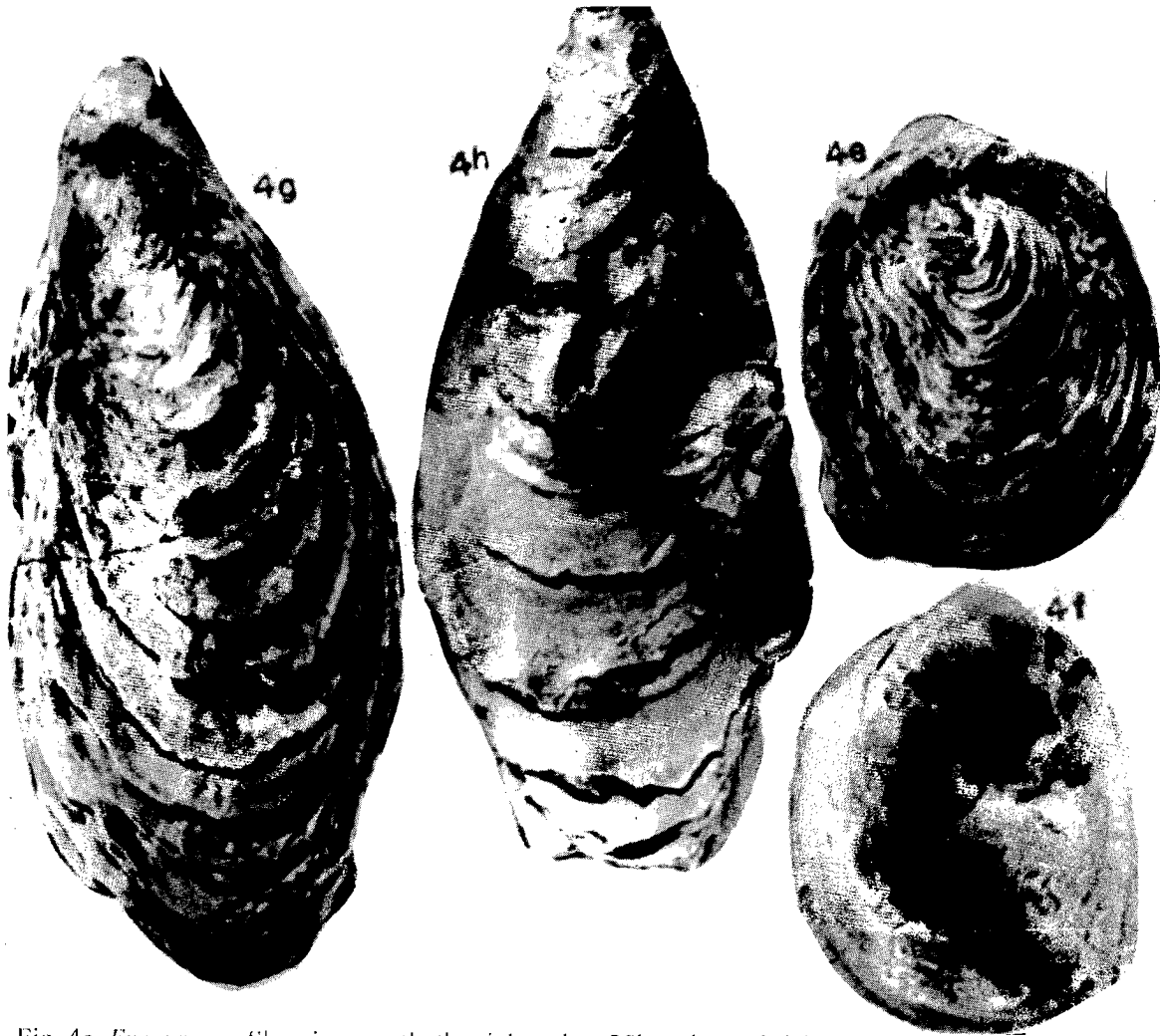


Fig. 4e *Exogyra* sp. Showing mostly the right valve, 28km along Calabar-Itu highway, (M. Cenomanian), X3

Fig. 4f Same specimen as 4e but showing the left valve, X3.

Fig. 4g *Ostrea delettei* Coquand, showing mostly the right valve with small portions of the left valve visible at the extreme of anterior and posterior ends. 32k, Calabar-Itu highway, (M. Cenomanian).

Fig. 4h Same specimen as 4g but showing only the left valve, X1.

internal mould resulting from the existence of rib-like swelling across the interior of the shell diagonally from the posterior side of the beak.

Remarks : Inoceramids are known in most of the upper Cretaceous rocks of Nigeria and the neighbouring Cameroon. Further identification of the specimens from the Calabar Flank is beyond the resolution of the material available.

2.5 Superfamily: PECTINACEA Rafinesque, 1815

Family: PLICATULIDAE Watson, 1930

Genus: PLICATULA Lamarck, 1801

Plicatula auressensis Coquand, 1862.

Fig. 3m & n

1862 *Plicatula auressensis* Coquand, p.222, pl. Xvi, figs. 14-16.

1912 *Plicatula Auressensis* Coquand, Pervinquier, p. 156, pl. xi, figs. 2-18.

1937 *Plicatula Auressensis* Coquand, Trevisan, p. 60, pi. iii, figs. 5-10.

1943 *Plicatula Auressensis* Coquand, Schneegans, p. 93, pl. i, figs.5-8

1952 *Plicatula auressensis* Coquand, Cox, p. 15, pl. ii, figs. 5 & 6.

Material : Fourteen specimens, Nos. EBA. 155-168.

Occurrence: Abundant and form compact shell bed about 30cm thick within a shaley section,

Nkalagu (Odukpani) Formation (Middle Cenomanian); kilometer 29 -30, Calabar-Itu Road.

Description: Some consist of articulated valves, flat and ovate in outline. Specimens are between 33 and 37mm in height and 25 and 30mm in length. Shell outer surface has numerous straight or slightly sinus radial riblets which are separated by furrows of about the same width. Radial riblets are crossed by concentric growth lines which occasionally bear weak spines. Important feature is the circular area at the umbo with concentric rugae without radial riblets or some that are very poorly developed.

Remarks: *Plicatula auressensis* is said to be typical of the Cenomanian in Northern Africa and Sicily and is common in the Cenomanian of Palestine (Cox, 1952). This species has been recorded from the Cenomanian of Niger Republic and Ghana. The specimens in this report agree very well with Cox's (1952, Pl.11, figs. 5&6) and Coquand's (1862, pl.xvi, figs. 14 - 16) in the overall morphology. The concentric growth lines of Cox's specimens are less conspicuous because they represent resin casts of external moulds.

Plicatula
Fig. 31.

Material: One specimen, No. EBA. 169

Occurrence: Rare. The only specimen was collected from a shale bed, Nkalagu (Odukpani) Formation; Early Cenomanian; kilometer 24.8, Calabar-Ikom Road.

Description: Specimen; suboval in outline, narrowing slightly at the umbonal region. The shell slightly compressed. Length 35mm, height 37mm. Equivalve and inequilateral. Numerous radial riblets bending slightly at major growth stages. Concentric growth lines closely packed and regular.

Remarks: The specimen resembles *P.fourneli* in size and general outline except that Coquand's (1982) figured *P.fourneli* and the BM(NH) specimen L 10766 have fewer and relatively widely spaced radial ribs with two or three smaller striations in between. This species is said to be common in the Cenomanian-Turonian sequence of NE Nigeria.

2.6 Superfamily: OSTREACEA Rafinesque, 1815

Family: OSTREDAE Rafinesque, 1815
Genus: EXOGYRA Say, 1820

Exogyra olisiponensis Sharp 1850
Fig. 4a - d

1850 *Exogyra Olisiponensis* Sharpe, p.

185, pl. 19, figs. 1 & 2

1869 *Ostrea Olisiponensis* (Sharpe),
Coquand, p. 125, xix, figs. 1 -7.

1872 *Ostrea Olisiponensis* (Sharpe),
Larlet, p. 59 pl. xi, figs 1& 2.

1890 *Ostrea Olisiponensis* (Sharpe),
Peron, p. 114 pl. xxiii, figs. 14 -18.

1902 *Ostrea (Exogyra) Olisiponensis*
(Sharpe), Choffat, p. 66, pl. vi figs.
17-19.

1904 *Ostrea (Exogyra) Olisiponensis*
(Sharpe), Fourteen, p. 283, figs. 3 - 5.

1905 *Ostrea (Exogyra) Olisiponensis*
(Sharpe), Choffat, p. 44 pl. 1, figs. 4 & 5.

1911 *Ostrea (Exogyra) Olisiponensis*
(Sharpe), Woods, p. 277, pl. xx
figs. 1-3.

1912 *Exogyra Olisiponensis* (Sharpe),
Pervinquier, p. 174, pl. xiii, figs. 4,
5a-c.

1918 *Exogyra Olisiponensis* (Sharpe),
Greco, p.5, pl. 1 fig. 12 -14.

1929 *Exogyra Olisiponensis* (Sharpe),
Rennie, p. 15, pl. iii, fig. 8

1929 *Exogyra Olisiponensis* (Sharpe),
Resside, p. 268, pls. LXV-LXVIII, LXIX,
figs. 1 - 4.

1933 *Exogyra Olisiponensis* (Sharpe),
Weir, p. 405 pl. xxxvii, figs. 1, 2, 4
pl. XXXVIII, figs. 1 - 4; pl. XXXIX,
figs. 1 - 4.

1935 *Exogyra Olisiponensis* (Sharpe),
Furon, p. 52, Pl. ii, figs. 7a & b

1937 *Exogyra Olisiponensis* (Sharpe),
Trevisan, p. 66 p. iv, fig. 2 - 6

1943 *Ostrea (Exogyra) Olisiponensis*
(Sharpe), Schneegans, p. 96.

1952 *Exogyra olisiponensis* Sharpe, Cox
p. 16, Pl. li, fig. 12

1957 *Exogyra olisiponensis* Sharpe,
Reyment, pl. 7, fig. 14

1965 *Exogyra olisiponensis* Sharpe,
Reyment, pl. vi, fig. 25.

Material : Fifteen specimens Nos. EBA. 170 - 184, consisting of five larger lower left valves and ten smaller upper right valves.

Occurrence : Common; seven of the ten right valves are from Nkalagu (Odukpani) Formation, Early Cenomanian, kilometer 24.8, Calabar-Ikom Road where the oyster forms shelly beds at some levels and occurs within the shale sections (Fig. 7). Other specimens occur within calcareous mudstone bands of Nkalagu (Odukpani) Formation, Middle-Upper Cenomanian; kilometer 28-32, Calabar-Itu-Road.

Description: Shells are disarticulated, recrystallized, some of them pyritized. Medium-large in size; left valves 53-100mm and right

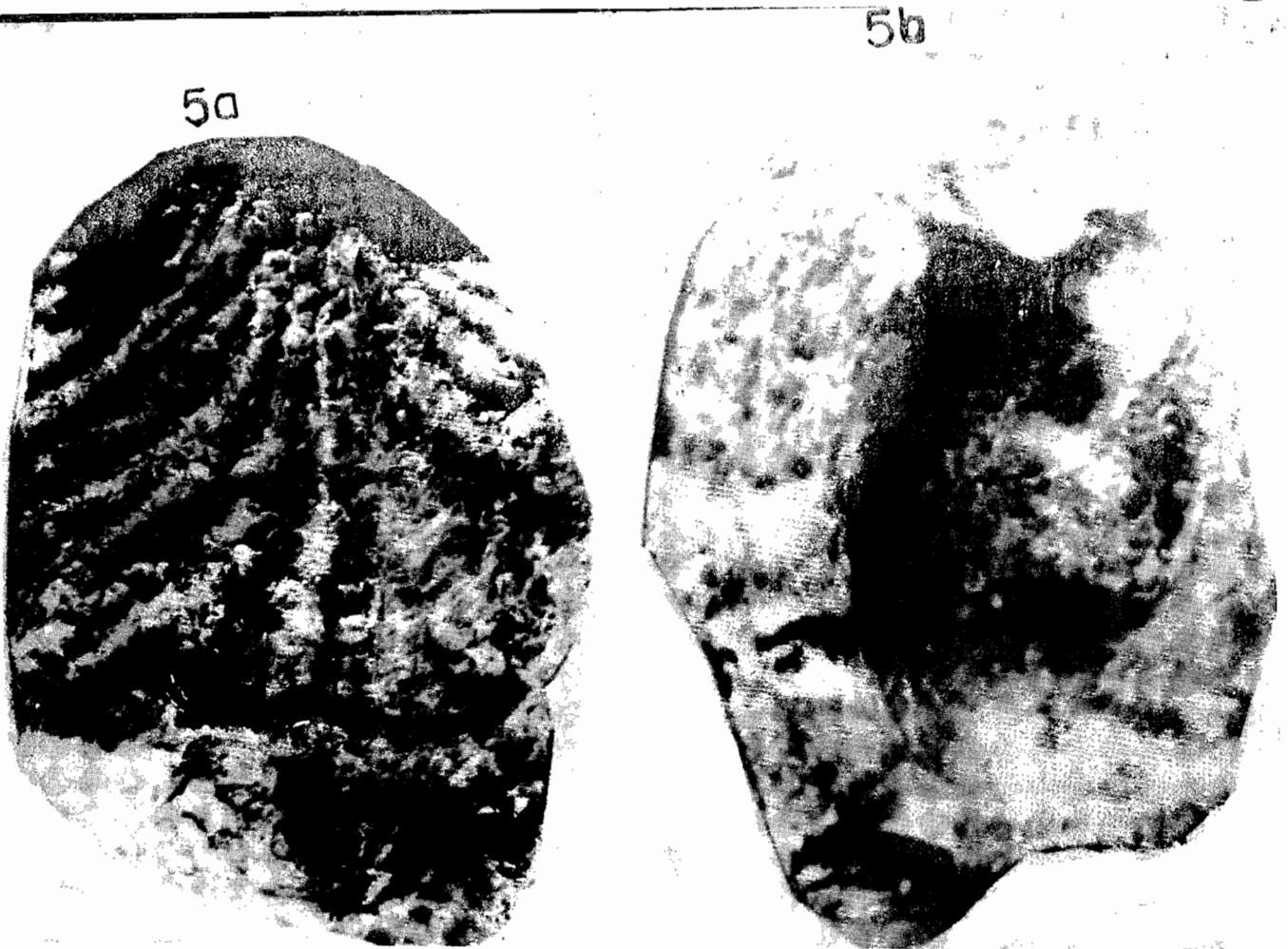


Fig. 5a *Lopha semiplana*, right valve, highly recrystallized with deep, v-shaped radial folds. Locality and age, uncertain. X. 5.

Fig. 5b Same as 5a; inner surface with single muscle scar. X. 5.

valves. 32–65mm in height; strongly inequivalve and inequilateral. Right valves roughly flat from external surface with more or less oval outline. The left valves are convex from outer surface, nearly orbicular in shape. Their inner surfaces contain hard calcareous mudstone. The posterior part of disk regions of the outer surface of the right valves are relatively smooth and almost surrounded by a crowded and upturned foliaceous growth squamae which run parallel to the shell outline covering entirely the anterior margin. The adductor muscle scars of the right valves are subtriangular in shape. The left valve is characterized by a prominent and twisted umbo. The radial ribs are variable but trend generally from the umbonal region to the central end. They are discontinuous and narrow compared to the wide furrow in between. Node-like structures occur on some of the radial ribs and are likely to have carried some spines.

Remarks : Although only the internal moulds of the left valves of *E.olisiponesis* were figured by

Cox (1952) from the Cenomanian of Ghana, these specimens are generally similar in morphology to the one in this report. *E.olisiponesis* was first featured from the SE Nigeria by Reyment (1957) but without an exact location. This species has been reported by Reyment (1955b) and Popoff et al (1986) from the Lower Turonian and Cenomanian respectively of NE Nigeria. Apart from the variation which is known in the radial ribbing of the left valves from the Portuguese type locality (see Sharpe, 1850, p.19, figs. 1 & 2), there is variation in the ornamentation of the flattish right valves because some have radial ribs cutting across the concentric squamae while others are devoid of these ribs. There is no radial ribbing on any of the right valves described in this report. *Exogyra olisiponesis* shows a wide geographic distribution during the Upper Cenomanian as well as the Lower Turonian and has been reported from many parts of Northern Africa, Central Sahara, Central West Africa and European Mediterranean coasts (Furon, 1933). It has been described from

South America and the United States but it shows a tethyan (non-polar) distribution.

Exogyra sp

Fig. 4e & f

Material: Three specimens Nos. EBA. 185-187 consisting of one articulated and two disarticulated valves.

Occurrence: Rare; Collected from a calcareous mudstone band of Nkalagu (Odukpani) Formation, Middle Cenomanian, kilometre 28, Calabar-Itu Road.

Description: The specimens are of medium size; length, 15mm, height 19mm. The articulated specimen is inequivalve, inequilateral with suborbicular outline. Umbo is prominent and slightly twisted. Outer surface of upper valve is covered with concentric growth squamae which are moderately spaced.

Remarks: Material available does not allow identification to be made with certainty beyond this generic level. The specimen resembles *E. africana* and *E. mermeti*, both of which are common in the Cenomanian rocks of North Africa and are known from the Upper Cenomanian of NE Nigeria.

Ostrea delectrei Coquand, 1862.

Fig. 4g & h

1862 *Exogyra delectrei* Coquand, p. 244, pl. xviii, fig. 1-7.

Material: A single specimen No. EBA 188 consisting of articulated valves inside which is internal mould.

Occurrence: Rare; collected from mudstone band of Nkalagu (Odukpani) Formation, Middle Cenomanian, kilometre 32, Calabar-Itu Road.

Description: The specimen is large and elongated; length, 51mm, height, 130mm. The articulated valves are recrystallized. Inequivalve and slightly inequilateral. The internal calcareous mould covered by the valves are also recrystallized. The right valve is slightly less convex than the left counterpart and its outer surface is characterized by prominent terrace-like posteriorly plunging growth ridges which are widely spaced at the centre but fused at the shell edge immediately beyond the hinge axis.

Remarks: This species was first described with seven specimens (Coquand, 1862, Pl. xviii, figs. 1-7) from the Cenomanian of Algeria. Some specimens from this locality have been examined in the BM (NH), London and it is observed that the BM(NH) specimen L 8075 and those figured by Coquand as 1 & 2 are closest in comparison although they are slightly smaller in size than the specimens described herein from SE Nigeria.

Genus: LOPHA Bolten MS; Roeding 1798

Lopha semiplana (J. de C. Sowerby)

Fig. 5a & b

1825 *Ostrea semiplana* (J. de Sowerby), p. 144, Pl. cccclxxxix, fig. 3

1869 *Ostrea semiplana* Sowerby, Coquand, p. 74, pl. xxviii, figs. 1 - 15, pl. xxxv, figs. 1 & 2, pl. xxxviii, figs. 10 -12.

1912 *Alectryonia semiplana* Sowerby, Perivinquiere, p. 208, Pl. xiii, fig. 3a & b.

1913 *Ostrea semiplana* Sowerby, Woods p. 379, Pl. 1vi, fig. 17 - 19, pl. 1viii, figs. 1- 5.

1952 *Lopha semiplana* Sowerby, Cox p.15, pl. 1, figs. 5 & 6.

Material: A single specimen No. EBA 213 which is the right valve.

Occurrence: Collected by a student during a field trip in the Calabar Flank; exact locality uncertain.

Description: The shell right valve is large; about 160mm in height and 110mm in length and highly recrystallized. Suborbicular to oval in outline with strong radial placcations which are formed into deep, v-shaped folds.

Remarks: This specimen which is well preserved resembles the ones described by Woods (1913) from the Upper Turonian and Upper Senonian of England. *Lopha semiplana* has been described from a younger formation (Campanian) of Ghana by Cox (1952).

2.7 Superfamily: CARDIACEA Lamarck, 1809

Family: CARDIIDAE Lamarck, 1809

Genus: PROTOCARDIA Beyrick, 1845

Protocardia cf. *aurillitoralis* Cox, 1952

Fig. 6c

c.f. 1952 *Protocardia aurillitoralis* Cox, p. 21, pl. ii, Figs. 3a b & 4.

Material: A single specimen, No. EBA 189.

Occurrence: Rare; the only specimen is apparently a thin left valve whose preservation is enhanced by accumulation and cementation of calcareous mud in the concave inner surface of the shell. Found within the base of the shale section of Nkalagu (Odukpani) Formation; Lower Cenomanian, kilometer 24.8, Calabar-Ikom Road.

Description: This specimen is moderate in size; length, 32mm and height, 35mm. It is subequilateral and suborbicular in outline; beak is subcentral but prominent. The posterior margin of the outer surface has the characteristic radial riblets which occupy about 1/5 of the total length of the shell. Concentric growth lines are present but rather faint.

Remarks: The specimen described above differs from Cox's (1952) type specimens which are internal and external moulds in its

height/length ratio. In the latter, the length is generally greater than the height. This aspect of its dimension agrees with the long ranging and widely distributed *P. hillana* (Sowerby) which apart from its abundance in the Albian of Britain is known in Angola and Southern Africa from the Senonian (Rennie, 1929, p. 35, p. 11, fig. 1) and the Upper Cretaceous (Newton, 1909, p. 76, pl. v. fig. 1b) respectively. *P. cf. aurilitoralis* differs because of its apparent less prominent concentric growth lines and riblets.

Protocardia sp

Fig. 6e, f & g

Material : Seven specimens Nos. EBA. 190- 196

Occurrence: Fairly common as internal moulds of articulated valves in the same horizon as the *P. aurilitoralis* described above.

Description: Specimens are equivalve but inequilateral, average length 63mm, height 64mm and convexity 38mm. Specimens typically subtrigonal in outline being longer at the posterior than anterior margin. Anterior and posterior adductor muscle scars are prominent and roughly oval in shape; beak conspicuous. Where the ghost of the shell was observed, faint impressions of the posterior radial riblets were common as well as concentric growth lines.

Remarks: The specimens described above differ from *P. aurilitoralis* (Cox, 1952) from the Cenomanian of Ghana in a number of ways. The Ghananian examples are generally smaller in size, show greater length/height ratio and tended towards a quadrate outline. The state of preservation of the specimens under discussion does not permit observation of sufficient features to warrant further identification. Some specimens

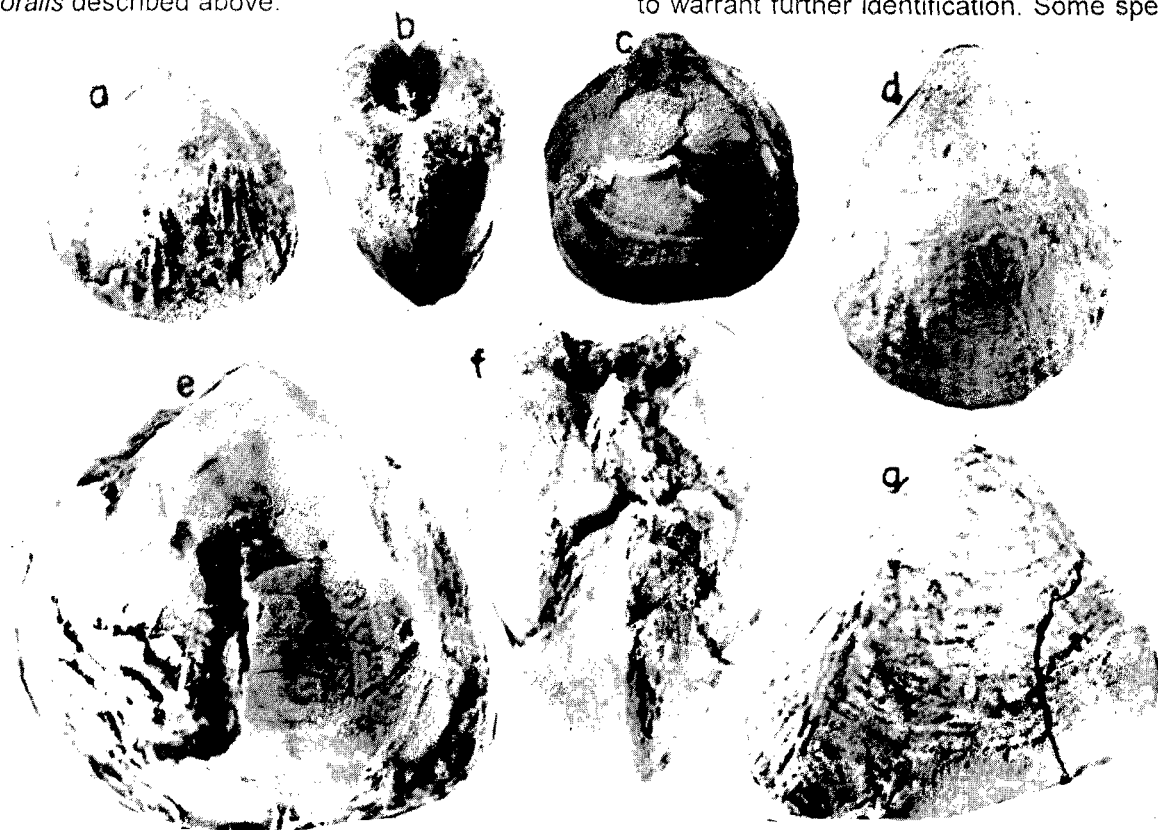


Fig. 6a *Cardium* cf. *anressense* Coquand, internal mould of right valve with remnants of shell, 28km along Calabar-Itu highway, (M. Cenomanian), X1.5.

Fig. 6b Same specimen as 6a, anterior view, X 1.5.

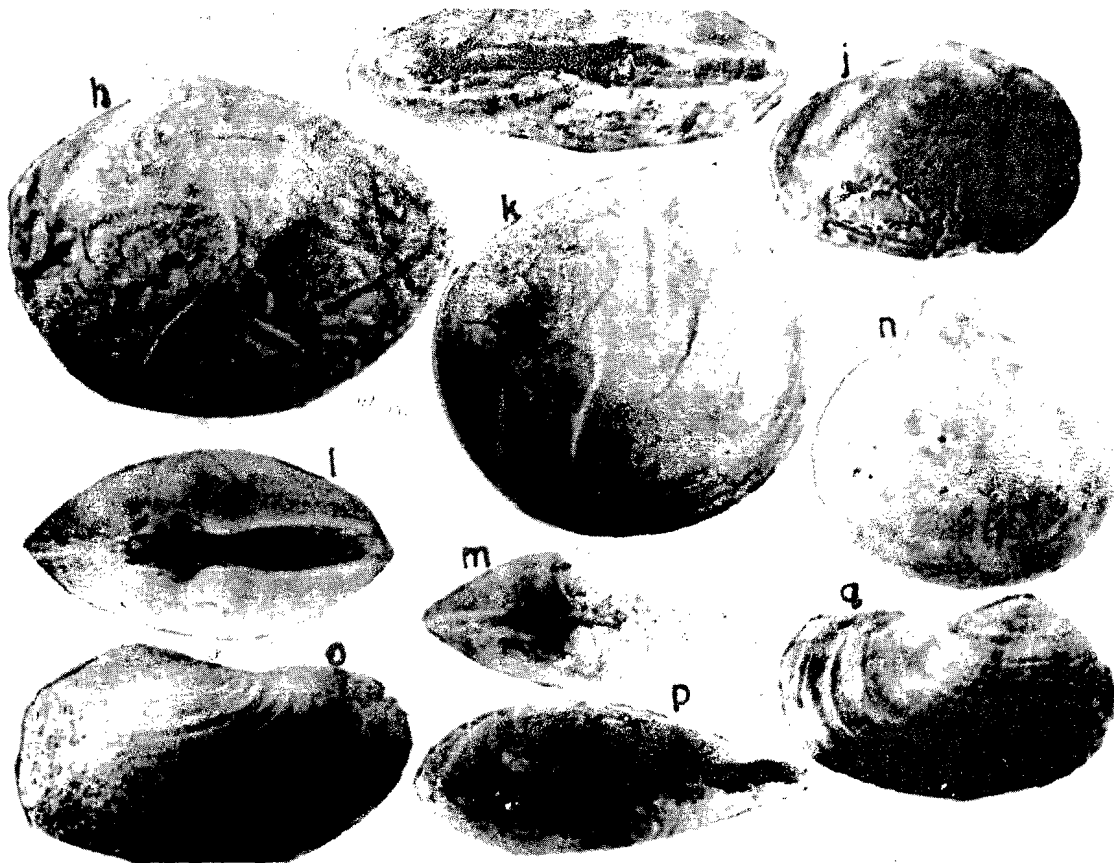
Fig. 6c *Protocardia* cf. *aurilitoralis* Cox, right valve, 24.8km along Calabar-Ikom highway, (L. Cenomanian), X1

Fig. 6d *Trachycardium* sp. Internal mould. 28km along Calabar-Itu highway, (L. Cenomanian), (X1.5)

Fig. 6e *Protocardia* sp. Internal mould, 24.8km along Calabar-Ikom highway, (L. Cenomanian), X1.

Fig. 6f *Protocardia* sp. Internal mould, 24.8km along Calabar-Ikom highway, (L. Cenomanian), X1.

Fig. 6g ? *Protocardia* sp., internal mould, compressed and found in the same locality as 6e above, X1.



- Fig. 6h A tellinid, broadly resembling *Tellina rivana*, 24.8km along Calabar-Ikom highway (L. Cenomanian), X1.
- Fig. 6i A tellinid, broadly resembling *Tellina rivana*, 24.8km along Calabar-Ikom highway (L. Cenomanian), X1.5.
- Fig. 6j A tellinid, broadly resembling *Tellina parkerana*, 24.8km along Calabar-Ikom highway (L. Cenomanian), X1.5.
- Fig. 6k ?*Tenea* sp., internal mould showing right valve, 24.8km along Calabar-Ikom highway (L. Cenomanian), X1.5
- Fig. 6l ?*Tenea* sp., internal mould showing right valve, 24.8km along Calabar-Ikom highway (L. Cenomanian), X1.5.
- Fig. 6m ?*Aphrodina* (*Mesocallista*) cf. *riedeli* Reymont, internal mould, dorsal view, 24.8km along Calabar-Ikom highway (L. Cenomanian), X 1.5.
- Fig. 6n Same as 6m, view of left valve.
- Fig. 6o *Pleuromya* sp., internal mould, Mfamosing limestone quarry, Upper Albian XI.
- Fig. 6p *Pleuromya* sp., internal mould, Mfamosing limestone quarry, Upper Albian XI.
- Fig. 6q *Pholadomya* cf. *pedarnalis* Roemer, internal mould 21.8km, Calabar-Itu highway, Turonian, XI.

(Fig. 6g) occurring in a bed above the described form which although markedly flatter, have the same trigonal outline. There is a strong indication of the presence of posterior radial riblets and concentric growth lines. It is very difficult to determine whether or not the two sets of specimens are the same species because the latter appear to have been badly squashed with umbonal and hinge areas very poorly preserved.

Genus: CARDIUM Linne, 1758
Fig. 6a & b.

Material: Three specimens Nos. EBA. 187-189
Occurrence: Fairly common in the calcareous mudstone bands in the middle part Nkalagu (Odukpani) Formation, Middle Cenomanian; kilometer 28, Calabar-Itu Road.

Description : Internal moulds of articulated valves with fragments of shell on them. Specimens of medium size, average length 22mm, height 24mm, convexity 16mm. Nearly orbicular from top of the valve and heart-shaped if articulated valves are viewed from either the posterior or anterior margin. Specimens are equivalve but inequilateral; posterior margin being slightly longer than its anterior counterpart. Shell fragments attached to the internal mould possess numerous, evenly spaced radial ribs. The latter are about 1mm wide while the intervening depressions are twice this width. Beaks are prominent and incurved.

Remarks: Although the nature and state of preservation do not allow the study of some of their features, these specimens agree in shape and size with *Cardium auressense* (BMNH, L10864) described and figured by Coquand (1862) from the Cenomanian of Algeria.

Trachycardium sp
Fig. 6d

Material: Six specimens Nos. EBA. 190- 196.

Occurrence: Fairly common mainly as internal moulds with remnants of shell attached. They occur in the same horizon as the *Cardium* sp described above.

Description : Specimens are of medium size, subovate outline and inflated. Inequilateral but almost equivalve; average length 24mm, height 28mm. Beaks are about central in position prominent and strongly incurved. The anterodorsal slope is generally lower than its posterior counterpart although it is more excavated towards the beaks. The posterior and good proportion of the anterior margin are rounded. Patches of shell fragments preserved show that the external surface was covered by about prominent regularly spaced spinose radial ribs.

Remarks; Further identification is difficult because of poor preservation. The hinge features are not observable. Morphologically, the specimens resemble *Cardium* (*Trachycardium*) *incomptum* Sowerby described from the Cretaceous of Southern India by Stoliczka (1870, p. 216, pl. xi, figs. 3 -7). *Cardium* (*Trachycardium*) *tinninense* Stephenson (1952, p.102, pl. 24, figs. 1-7) is essentially different because of the number of ribs said to range from 55 - 65. *Cardium* (*Trachycardium*) *production* J. de C. Sowerby occurs in the Lower Turonian rocks of North-eastern Nigeria (Barber, 1958).

2.8 Superfamily: TELLINACEA de Blainville, 1814

Family: TELLINIIDAE de Blainville, 1814
Figs. 6h, i & j

Material : Two sets of specimens; Nos. EBA. 197-200 and 201 - 203.

Occurrence: The specimens are all internal moulds, rare, occur within the shales at the top of the road section, Nkalagu (Odukpani) Formation, Lower Cenomanian, kilometer 24, 8, Calabar-Ikom Road.

Description: The first set (Fig. 6j) is of medium size; inequilateral but equivalve, slightly compressed. It is elongated-subelliptical; average length 41mm, height 27mm. Beaks not prominent, hinge inconspicuous with the dorsal and ventral margins convex upwards. Concentric growth lines are faint. The second set (Fig. 6h & i) has an average length and height of 39mm and 30mm respectively. Specimens strongly inequilateral and subequivalve, strongly compressed. Beaks, less conspicuous but subcentrally placed. Dorsal margin show a v-shaped upward appearance. The angle of slope from the beak to the anterior side being steeper than that to the posterior. Ventral and posterior margins are broadly rounded while the anterior margin is sharply rounded. Pallial sinus is wide and prominent forming a badly written letter U from the posteroventral margin, more than half the distance towards the anterodorsal margin.

Remarks : In the absence of well preserved specimens and hinge features, it is impossible to determine with certainty what genera these specimens belong. Although pallial sinus and hinge features are not apparent in the first set of specimens (Fig. 6j), the general outline is comparable to "*Tellina rivana* (Stephenson, 1952, p. 114, pl. 29, figs. 17 - 21) described from the Cenomanian of Texas. The second set of specimens are similar in outline and shape of the pallial sinus to "*Tellina*" *parkerana* Stephenson (1952, p.114, pl. 28, figs. 1-5) from the Cenomanian of Texas and *Tellina* (*Palaemoera*?) *whitei* Stanton, (1893, p.112, pl.25, figs. 4 - 7) from the Cretaceous of the Colorado Formation. "*Arcopagia*" *dopressa* Coquand (1862; p. 191, fig. 8, pl. vi) from the Cenomanian of Tunisia has a broadly similar outlook although the specimen is larger, the left valve more convex with a broader posterior margin.

2.9 Superfamily: ARCTICACEA Newton, 1891
Family: ARCTICIDAE Newton, 1891
Genus: TENEA? Conrad, 1870
Tenea? sp
Fig. 6k & l

Material : A single specimen No. EBA. 204.

Occurrence: Rare; the only specimen is an internal mould of articulated valves from the base of the road-cut, Nkalagu (Odukpani) Formation, Lower Cenomanian, kilometer 24.8, Calabar-Ikom Road.

Description: Internal mould of medium size, length 35mm, height 34mm; subcircular in outline.

Inequilateral but equivalve; beak prominent pointing to the anterior and subcentral in position. Positions of the lunule and escutchean are represented by fairly deep depressions. Impressions of the concentric growth lines are faint. Only a portion of the pallial sinus is preserved.

Remarks: From the general outline and the visible portion of the pallial sinus, the described specimens from SE Nigeria resembles specimens L2415, UF 1657 housed in the BM (NH) and named *Tenea inflata* (Cobb) of probably Campanian age from the Bee Cayon Santa Ana mountains of U.S.A. The only other form broadly similar to it is the venerid *Anofia aro* Reymont (1955b) from the Maastrichian of Afikpo in the SE Nigeria. In this circumstance where there is only one specimen, no details of the hinge features

preserved, absence of muscle scars and only partially preserved pallial sinus, its assignment to the genus *Tenea* is but tentative; most importantly as this genus is known elsewhere only from rocks of younger age (cf. Stephenson 1941 p.217).

2.10 Superfamily: VENERACEA Rafinesque, 1815

Family: VENERIDAE Rafinesque, 1815

Genus: APHRODINA? Conrad, 1869

Aphrodina? (*Mesocallista*) cf. *riedeli* Reymont Fig. 6n & m

cf. 1955b *Aphrodina* (*Mesocallista*) *riedeli*

Reymont, p. 147, pl. iv, fig. 6a & b, tex fig. 2

Material: A single specimen No. EBA. 205

Occurrence: Rare; the only specimen is an internal mould of articulated valves from a road section of the Nkalagu (Odukpani) Formation, Lower Cenomanian; kilometer 24.8, Calabar-Ikom Road.

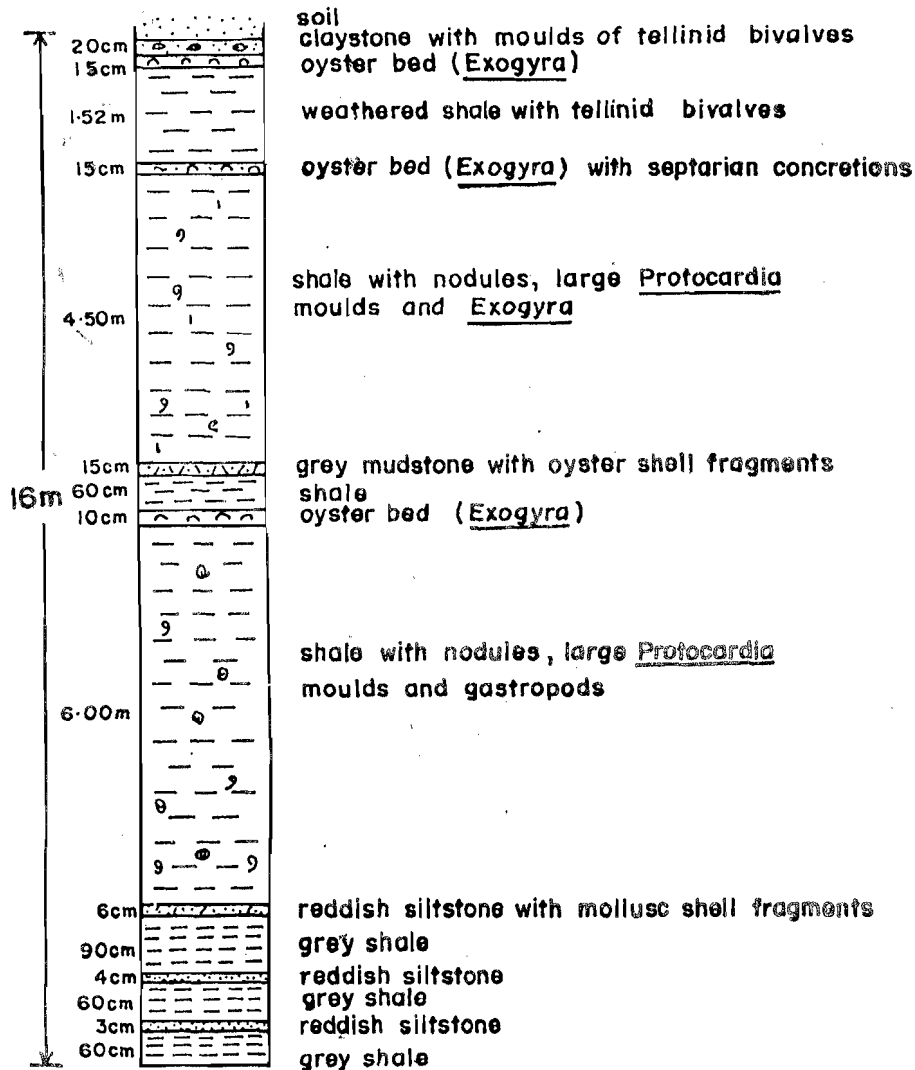
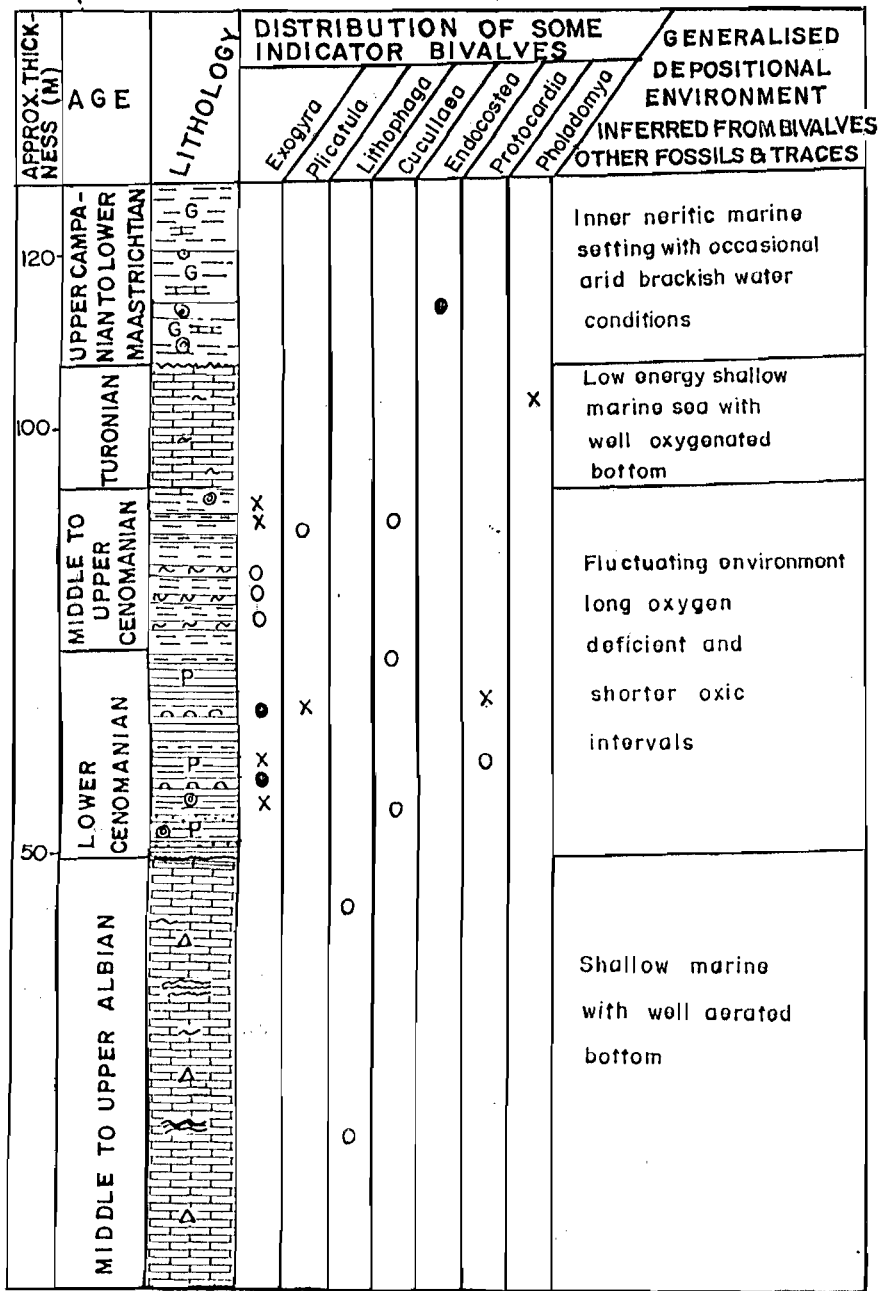


Fig. 7 Lithostratigraphic section at Odukpani hill (24.8km) along Calabar-Ikom highway (L. Cenomanian) showing occurrence of important bivalves.



- siltstone
- calcareous mudstone
- marly limestone
- shale with nodules
- calcareous alga
- stromatolitic structure
- oyster bed
- trace fossil (mainly Thalassinoides)
- X = Present
- O = Common
- = Abundant
- G = Gypsum
- P = Pyrite

Fig. 8 Composite lithostratigraphic section of exposed Cretaceous sediments in the Calabar Flank showing the distribution of some indicator bivalves and the different depositional environments broadly inferred from the associated mollusks, other fossils and lithology.

Description: Specimen of medium size; subtrigonal in outline; length 27mm, height 26mm; inequilateral but equivalve. Beak is prominent; slightly displaced and pointed to the anterior end. Position of the lunule show a reasonably deep depression but without any sign of the escutcheon. The mould is smooth apparently without concentric growth lines. Pallial line and sinus are not observable and no details of the hinge are preserved.

Remarks: The diagnostic features are not observable and as such its precise taxonomic affinity cannot be certain. However, from the general morphology, this specimen has the shape of *Aphrodina (Mesocallista) reideli* described by Reyment 1955b, p. 147, pl. iv, fig. 6a & b) from Agwu Formation (Coniacian) of Nigeria. Many species of *Aphrodina* are known in Europe, America, Africa and New Zealand in rocks of Albian-Tertiary ages.

- 2.11 Superfamily: MYACEA Lamarck, 1809
 Family: CORBULIDAE Lamarch, 1818
 Genus: PARMICORBULA Vojcs, 1944
Parmicorbula rupana Stephenson 1952
 Fig. 3d & e.

1952 *Parmicorbula rupana* Stephenson,
 p. 33, figs. 9 – 12.

Material: Five specimens Nos. EBA. 206-210.

Occurrence: Abundant as internal moulds in the calcareous mudstone band within a shale section of Nkalagu (Odukpani) Formation; Middle -? Upper Cenomanian, kilometer 32; Calabar-Itu Road.

Description: The form is small; average length 6mm; height 4mm with strong inflation; the greatest being at the anterior end. The mould show that the right valve is larger than the left and hence show inequivalve and inequilateral condition. Umbo is well defined but displaced towards the posterior region of the dorsal margin. Adductor muscle scars are unequal; the posterior appear to have been larger. Concentric growth lines are very faint.

Remarks: The genus *Parmicorbula* is known from Aptian to Eocene and has been reported from Europe, North America, Asia and Africa. The specimens referred to in this report are quite comparable to the internal mould of Stephenson, 1952, (pl. 33, fig. 12) from the Cenomanian of Texas in terms of size and general morphology.

- 2.12 Superfamily: PHOLADOMYDAE Gray,
 1847

Family: PHOLADOMYIDAE Gray, 1847
 Genus: PHOLADOMYA Sowerby, 1823

Pholadomya cf. *pedernalis* Roemer, 1852.

Fig. 6q

- cf. 1852 *Pholadomya pedernalis* Roemer,
 1852
 1913 *Pholadomya pedernalis* Roemer,
 Pervinquier, p. 288, pl. xxi, fig. 5

Material: A single specimen No. EBA. 211.

Occurrence: Rare; the only specimen is an internal mould of articulated valves preserved within a marly limestone, Nkalagu (Odukpani) Formation, Middle Turonian; kilometre 21.8, Calabar-Itu Road.

Description: Specimen of medium size, length 45mm, height 29mm; roughly elliptical in outline; strongly inequilateral but almost equivalve. Umbo is prominent, almost rounded and placed very close to the anterior side. The latter bulges out to form a 'U' shaped outline while the posterior counterpart has a 'V' shaped pattern. Ventral margin, moderately convex; hinge area concave close to the Umbo. The surface of this internal mould bears numerous concentric growth lines with not less than ten very faint, almost equally spaced radial ribs occurring mostly around the anterior area. The growth lines bend in a 'U' fashion upwards at the posterior part of the specimen.

Remarks: This specimens is similar to *P. pedernalis* first described by Roemer (1852, p.45, pi. vi, fig. 4a & b) from the Albian of Texas and subsequently recognized from the Lower Turonian of Tunisia by Pervinquier (1912, p. 288, pi. xxi, figs. 5-7) and from a similar horizon of the French Congo by Lombard (1931, p.312, pl. xxxiii, fig. 2). The present specimen however has a greater number of radial ribs which are less conspicuous. It has the same shape as *Pholadomya liveriensis* BM (NH) L 12856 from the ?Maastrichtian of France, although the latter is much greater in size with coarser radial ribs but apparently less pronounced concentric growth lines. The holotype of *P. nauliensis* described from the Campanian of Ghana by Cox (1952, p.25, pl. ii, fig. 7) is also larger. The Cenomanian-Turonian limestone of the Gongola Formation in Northern Nigeria is known (Barber, 1958; Carter et al, 1963; Popoff et al, 1986) to contain *Pholadomya* aff. *pedernalis* Roemer.

Family: PLEUROMYDAE Dall, 1900

Genus: PLEUROMYA Agassiz, 1842

Pleuromya sp.

Fig. 6 o & p

Material : A single specimen No. EBA. 212.

Occurrence: The only specimen is an internal

mould of articulated valves on the top of Mfamosing Limestone, Upper Albian, at Mfamosing quarry, 30km NE of Calabar.

Description: The specimen is of medium size; shows equivalve and inequilateral conditions; length 51mm, height 39mm, moderately inflated and elongated in outline. Gape appears to have been narrow. Beak is prominent, incurved and located at about one third of the length to the anterior of the dorsal margin. Ventral margin is convex and the dorsal counterpart is somewhat undulating. The surface of mould show distinct concentric lines. Hinge features are not observable.

Remarks: This specimen is similar in size and shape to *Pleuromya subelongata* d'Orb. (BMNH, L 39101) from the Great Oolite, White Limestone of England. *Panopaea orientalis* Forbes from the Upper Cretaceous of S. India (BMNH L 56612) is also similar in shape but show stronger concentric lines apart from indicating occurrence of moderate gape. The genus *Pleuromya* is known from Triassic-Lower Cretaceous.

PALAEOECOLOGICAL CONSIDERATIONS AND CONCLUSIONS

The distribution of bivalves described herein has been influenced by the Cretaceous palaeo-oceanographic events (Reyment, 1980; Reyment & Dinger, 1987) which affected the Benue Trough as well as the manifested local crustal instability in the Calabar Flank.

Middle-Upper Albian Mfamosing Limestone

This represents the initial marine flooding of SE Nigeria; the transgression which succeeded the linkage together of both the North and South Atlantic Oceans. *Lithophaga* and *Pleuromya* of Mfamosing Limestone are benthic forms. Whereas, the latter was a burrower in soft unconsolidated bottom, it is known that many species of extant *Lithophaga* live exclusively as borers in hard calcareous substrates of shallow sublittoral zone in warm seas (Yonge & Thompson 1976; Kleemann 1980; Kobluk & Lysenko, 1986). At the Mfamosing quarry, *Lithophaga* are restricted to the stromatolitic intervals of the limestone where they created superimposed elongated flask-shaped borings of ichnogenus *Gastrochaenolites* in closely spaced beds with no surface of erosion. The proof of *Lithophaga*'s creation of the borings is further enhanced by the fact that they all fit tightly and there are no examples of multiple occupancy. However, the whole sequence contains plenty of unidentifiable fragments of invertebrates and calcareous algae *Lithophyllum*

sp. *Neomeris* sp and *Cayeuxia* sp as well as bioturbation structures of the *Cruziana* ichnofacies (cf. Seilacher 1967). The bivalves and their activities indicate that the limestone was formed in a shallow tropical sea with well aerated bottom which at certain intervals (stromatolitic horizons) underwent syndimentary lithification (cf. Heckel, 1972; Akpan, 1985, 1990, 1991). This inference has support from the associated biogenic sedimentary structures and calcareous algae. The latter are all tropical forms (cf. Wray, 1977).

3.2 Cenomanian shales with intercalations of calcareous mudstone, siltstone and shelly beds.

These sediments were deposited during the Early to Late Cenomanian times. Petters and Ekweozor (1982b), Nyong and Ramanathan (1985) utilized micro-fossils from only the shaly intervals and drew a conclusion of an anoxic bottom condition during this time interval. This interpretation was based on the prominence of arenaceous foraminifera and complete absence of benthic forms in some sections.

Apart from the heterogeneity of the facies, rapid vertical changes is a rule rather than an exception for this sequence. The recovering and analysis of bivalves from all the facies in this study has thrown more light on the bottom oxygen condition of the Cenomanian sea. It is clear that the depositional environment fluctuated between long oxygen-deficient and shorter oxic intervals. The former, which in the section is represented by the dark organic-rich shales show at the lower sections exaerobic biofacies (0.1 to $0.2 \text{ m}^{-1} \text{ O}_2$) of Savrda and Bottjer (1987). These interpretations have support from other benthic microfossils and trace fossils. Whereas bivalves and other macroinvertebrates as well as ichnofossils are common in the thin beds of siltstone and mudstone intercalations in the entire Cenomanian sequence, a few layers of the Early Cenomanian shale unexpectedly contain large moulds of articulated valves of the bivalve *Protocardia* spp (Fig. 8). Evidence of any disarticulation is lacking. Although the original shell material is not preserved, ribbings on the moulds (Fig. 6e, f & g) indicate that the shells were robust. All available evidence indicates that the bivalves are *insitu* and obviously required some amount of oxygen for survival. *Plicatula* shells and oysters also form distinct beds at some locations. The fossil characteristics of the mudstone/siltstone are (1) low diversity, (2) abundance of two or three small sized bivalve individuals and (3) prominence of oyster.

At approximately 32km (Middle-Upper

Cenomanian) along Calabar-Itu highway, about 50 individuals of *Parmicorbula rupana* which are hardly greater than 6.0mm in length and 4.0mm in height were often recovered from about 1kg of mudstone. Also in association with the *Parmicorbula* were diminutive? Messosacela and neogastropods of uncertain family and genus.

The entire Cenomanian sediments (shales, mudstone/siltstone and shelly beds) yielded less than 20 species of bivalves from sample area covering at least 3000m². The low diversity, absence of stenohaline forms like echinoderms and corals even within the fossiliferous horizons of the mudstone/siltstone and the prominence of oyster *Exogyra olisiponensis* in the shelly beds are pointers to marginal environments with reduced salinity associated with their origin.

The vertical changes in facies evident in the Cenomanian sediments of the study area probably reflects fluctuation (at that time) in the hydraulic and bathymetric related parameters necessitated by local crustal instability within this basin, the internal structure which consisted of step-like NW-SE trending horsts and graben (Simpson, 1954).

Palaeobathymetry of the Calabar Flank in the Cenomanian when these shales accumulated as given by Odebode (1983) and Iwobi (1989) varies between 10-50m. the calcareous mudstone and shelly beds represent very shallow (<10m) nearshore environment. It has been argued (Kauffman, 1969) that most cemented epifaunal forms in the families of Ostreidae and Plicatulidae including *Exogyra* and *Plicatula* (constituents of the mudstone and shelly beds in the study area) were capable of living in the inner sub-littoral benthic zone but would commonly prefer exposed or semi-exposed, stable substrate surfaces subjected to periodical wave and current actions, good lighting and food supply. Although the shales were generally deposited under an anoxic bottom condition (Petters & Ekweozor, 1982b; Nyong and Ramanathan 1985) there appear to have been short-lived episodes of oxygen amelioration during the Early Cenomanian as demonstrated by horizons (see Fig. 7 & 8) containing *insitu* calcified macro-benthic invertebrates notably large *Protocardia* spp. Occurrence of these bivalves is apparently directly analogous to the existence of large moulds and casts of *Anadara montereyana* bivalve within layers of the Monterey Formation of California whose oxygen content at the time of deposition was estimated at between 0.1 to 0.2mll⁻¹ (exaerobic biofacies of Savrda and Bottjer 1987) compared to <0.1mll⁻¹ and >1.0mll⁻¹ for anaerobic and aerobic bottom conditions

respectively (Savrda and Bottjer, 1987 & 1989). These authors postulated a symbiotic relationship between the bivalve and sulphur-oxidizing bacteria where the latter provided a chemosynthetic food source for the former. The exaerobic biofacies is probably coincident with periods of increased bottom water circulation of otherwise almost stagnant oxygen-deficient warm bottom waters of epicontinental seas such as existed in the Calabar Flank at this time.

3.3 Turonian marls and calcareous mudstone:

The marls and calcareous mudstone form low hills which have been truncated by the Calabar-Itu highway at about 21.8km and 34km respectively. These sediments are intensively bioturbated. The major ichnofossil is the *Thalassinoides* (cf. Akpan, 1985) of the *Cruziana* ichofacies (Seilacher 1967) which is indicative of formation in a shallow oxygenated environments with medium to slow rate of deposition. These traces are normally associated with shrimps like *Callinassa* and *Upogebia* which in Recent times create burrows in fine and coarse grained, well oxygenated sediments of the sublittoral zone (Campbell, 1976). Both the bivalve *Pholadomya* and the echinoid *Hemiaster founcli* (Akpan & Ramanathan, 1985) that are associated with these sediments are infaunal forms whose 'relative' today burrow in well aerated sediments of shallow seas. Benthic organisms are absent or scarce in anoxic bottoms because of the indispensibility of oxygen to living organisms. Therefore, both the body fossils; the bioturbation structures as well as their preservation, suggest life in a shallow oxygenated marine bottom with slow rate of sedimentation, abundant food resource and stable substrate.

3.4 Upper Campanian - Lower Maastrichtian shales with Intercalations of Bonebeds, Bands of siltstone and limestone

These sediments which constitute part of the Nkporo Shale of Reyment (1965) and encountered in outcropping sections at 36-37km, 41m and 42m along Calabar-Itu highway marked the end of Cretaceous palaeo-oceanographic event in the Calabar-Flank. It is reckoned (Reyment, 1980b; Kogbe, 1981; Wozny & Kogbe, 1983) that during the Upper Campanian-Maastrichtian transgression when the Nkporo Shale formed, the Equatorial Atlantic sea had a brief link across the Sahara to the Tethys just as in the Cenomanian-Turonian times. Only the section at 36.5 - 37km which is regarded as Upper Campanian yielded identifiable bivalves. In terms of mega-fauna and sedimentology, this

section is similar broadly to the Dukamaje Formation (Maastrichtian) of the southern Iullemeden Basin (cf. Kogbe, 1981).

The thick carbonaceous *Libycoceras* and *Sphenodiscus* rich shales with occasional bands of gypsum, beds of reptiles, turtles, fishes bones, ferruginized siltstone in which are embedded the inoceramids and nuculanids are reasonable indications of shallow marine setting interrupted occasionally by warm marginal conditions.

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