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MACRO INVERTEBRATE FOSSIL FAUNA (MOLLUSCA) FROM QUILON LIMESTONE FORMATION, KERALA STATE: CHARACTERISTICS AND STRATIGRAPHIC IMPLICATIONS

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INTRODUCTION

The Neogene succession, located along the southern coastal stretches of Kerala is represented by the sediments belonging to the Vaikom Formation, Quilon Formation, and the Warkalli Formation (Poulose and Narayanaswamy, 1968; Varadarajan and Madhavan Nair, 1978; Raha *et al.*, 1983, Soman, 1997). These sediments are dated as post Paleocene (Dey, 1962). The Quilon beds bear an important position in Indian stratigraphy as these present evidence of marine transgression along the south-west coast of India during Miocene, similar to the sort of marine deposits along northwestern and western parts of Indian subcontinent (Verma, 1977). The Vaikom and Warkalli Formations are unfossiliferous, while the Quilon limestone Formation bears rich marine fossils belonging to the Miocene (Burdigallian). The carbonate sediments in the Quilon basin rest unconformably over the Vaikom beds (Nair and Rao, 1980).

Geologically, the Quilon beds were referred first by Carter (1854) in connection with reports of fossils from the grey fossiliferous and argillaceous limestones. Later on, W. King in 1882 recognized outcrops of limestones at Padappakara (8^0 58^I N: 76^0 40^IE). This is the type area of the Quilon limestone formation. This was again reported by Logan in 1883. The Padappakara village is situated at about10 Km. NE of Kundara, a town located in the NH 207 at a distance of about 15 Km. from Quilon city (presently Kollam). The type section at Padappakara is represented by a few small outcrops which are not more than 10-25 sq. m. These are *in situ* exposures of irregular shape and without any stratification. The outcrops are partly weathered. The limestone exposures bear enough molluscan fossils of marine habitats. The limestone here is massive and off-white to light grey in colour. It is hard and compact. The outcrops are spatially separated by thick and extensive weathering profiles of laterite or kaolinite rich clay, or sometimes by variegated clay, locally enriched with iron (Fe). In adjoining areas, the Quilon limestone is encountered in open dug wells of about 8-10 m. deep (Foote, 1883; Menon, 1967).

Earlier workers (*viz.*, Jacob and Sastri, 1951, 1952; Sahni and Sastry, 1958; Dey, 1962; Verma, 1977; Padmalal and Seralathan, 1991) reported several fossil forms from the Quilon limestone beds. However, a detailed account establishing an assemblage zone of fossil fauna of the concerned beds was not available. An assemblage zone is based primarily on the combination of available fossil forms in a rock bed. A study is therefore carried out to explore the macrofossil forms from the area to characterize the assemblage zones.

EXTENT AND STRATIGRAPHY OF QUILON LIMESTONE

The Fig. 1 shows the palinspastic map of the Quilon basin prepared during the present study based on the spatial distribution of bed rocks of limestone encountered in open wells and bore

wells. The Quilon limestone basin presently covers an area of about 1200 sq. km. The basin is elongated but irregular in shape, trending NNW-SSE. The basin is about 115 km. long in the N-S direction, from Alapuzha in the North to Edava in the South, and 23 km.wide in the E-W direction from Cherthala in the West to Thakazhi (Lat:09°22`00`` Long:76°25`35``) in the East (Sabu Joseph and Thrivikramaji, 2002).

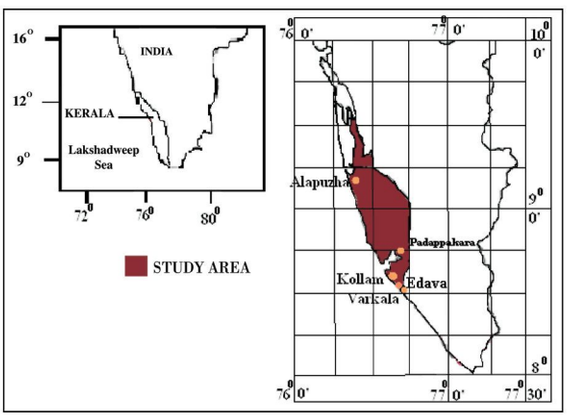

Fig. 1. Schematic map showing the subsurface distribution of the Quilon limestone and the present study area.

A generalized diagram of the succession of Quilon formation prepared from data of bore wells is presented in Fig. 3. The Formation begins with coarse sandstone followed by sandy clay and fine clay on top of that. This clay bed of unequal thickness is overlain by limestone beds. The limestone beds show variable thickness with tongues and lenses at several places. The maximum thickness of the limestone is reported at Nirkunnam (Lat: 09°23`30`` Long:76°19`30``) in Aappuzha district.

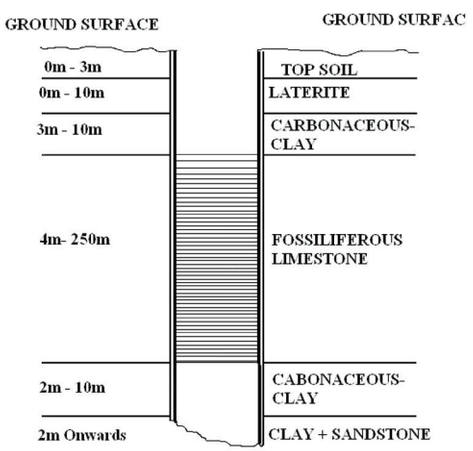

Fig. 2. A generalized diagram of a section of Quilon formation showing fossiliferous Limestone.

MACRO INVERTEBRATE FOSSILS OF QUILON LIMESTONE FORMATION

The Quilon limestone is richly fossiliferous. However, the degree of fossilization has not attained the full extent of petrification. A large number of fossils were collected from open wells and bore-wells dug at places like Mayyanadu (Lat:08°50`00`` Long:76°39`00``), Kottiyam (Lat:08°52`00`` Long:76°35`00``), Thazhuthala (Lat:08°51`00`` Long:76°36`00``), Padappakara (Lat:08°53`02`` Long: 7628`15``)`, Chavara (Lat:08°58`55`` Long:76°31`50``), and Karunagapally (Lat:08°59`45`` Long:76°32`35``), Cherthala(Lat:9° 37′ 50″ Long: 76°19′40″) Kalaikode(Lat:08° 47′40″ Long: 76°41′05″), and other places.

PROCEDURES

All the fossil specimens including broken ones were collected and the details of depth of occurrence were recorded. Morphologically complete and partially broken but recognizable specimens of invertebrate fossils were sorted out and labelled separately. The fossils were soaked in water and cleaned very carefully with a sharp needle and washed gently with water. The specimens are then dried in air, wrapped with cotton and placed in small boxes. Fossils from open wells show complete morphology while bore well samples are generally recognizable but broken. Fossils were carefully collected and labelled at the site itself recording the depth of occurrence and the count of each species. The samples from open wells alone are taken into consideration for vertical zonation. The percentage abundance of the more dominant fossil species in the upper and lower zones are shown in Table.1

Table 1. The percentage abundance of dominant fossil species recovered from open wells .

Location and Vertical Zonation		Dominant Fossil species in Percentage											
		A	B	C	D	E	F	G	H	I	J	K	Others
Thazhuthala (Open well)	Upper zone						45.5	18.18	9.09	9.09	6.06	6.06	6.06
	Lower zone	55.19	16.51	12.73	7.55	5.18							2.83
Kottiyam-1 (Open well)	Upper zone						46.15	20.51	10.26	7.7	7.7	5.12	2.56
	Lower zone	52.58	16.9	14.08	8.45	4.70							3.28
Kottiyam-2 (Open well)	Upper zone						44.4	19.44	11.11	11.11	7.69	2.56	2.56
	Lower zone	57.41	15.31	12.44	6.70	6.22							1.91

A- Rimella ; B- Turritella; C- Strombus; D- Strombus marginatus; E- Serpulorbis; F- Cantharus; G.- Murex; H- Chicoreus; I- Corbula; J- Chlamys; K- Conus.

SYSTEMATICS

The identification of the molluscan macrofossils was carried out by consulting the *Treatise of Invertebrate Palaeontology* (Knight *et al.*, 1964; Cox *et al.*, 1969a,b, 1971), *Compendium of Sea Shells* (Abbott and Dance, 1986) and by comparison of reference material in Zoological Survey of India (ZSI) collection.

Phylum MOLLUSCA,

Class GASTROPODA

Order MESOGASTROPODA,

Family STROMBIDAE

1. ***Strombus marginatus*** Linnaeus, 1758

(Plate I, Figs. 1, 2)

Diagnosis: Shell ovately conical, spire rather high and acuminate; aperture elongate, outer lip not observed (broken), posterior canal extends straight up and adheres to two or three spiral whorls; sculpture consists of numerous axial riblets on apical whorls; a single nodulose and distinct knob on shoulder of body whorl dorsally; colour creamy-white.

Measurements (in mm.) : Height- 39.6, height of last whorl- 28.0, height of aperture- 25.1.

Locality : Thazhuthala, Kottiyam

Geological horizon: Lower Miocene (Burdigallian)

2. ***Strombus*** sp. (Plate I, Figs. 3, 4)

Diagnosis : Shell ovately conical, spire moderately high, apex sharp; aperture slightly oblong, columella smooth, with a short blunt projection at the posterior end; siphonal canal slightly recurved; spire whorls sculptured with axial ribs and sharply angular shoulder; shoulder of body whorl rounded and with a few axially lengthened knobs; colour creamy white.

Measurements (in mm.) : Height- 37.2, height of last whorl- 26.1, diameter of last whorl- 16.2, height of aperture- 23.3, diameter of aperture- 4.1.

Locality : Thazhuthala, Kottiyam

Geological horizon : Lower Miocene (Burdigallian)

3. ***Rimella*** (***Varicospira***) sp. nr. ***cancellata*** Linnaeus, 1758 (Plate I, Figs. 5, 6)

Diagnosis : Shell moderately large, solid, fusiform, spire acuminate, outer lip thickened, crenulate, flanked by a deep furrow, extends towards apex covering 2-3 spire whorls; columella with callus, extends over whole length of the body whorl and with outer lip forming a long anal canal; siphonal canal short, aperture and lip lirate; sculptured with axial ribs connected by pitted, spiral grooves giving it cancellate appearance and randomly placed varices.

Measurements (in mm.): Height- 22.2, height of last whorl- 13.34, diameter of last whorl- 11.6, height of aperture- 10.0, diameter of aperture- 2.7.

Locality : Kottiyam, Chavara, Paravur, Thazhuthala.

Geological horizon : Lower Miocene (Burdigallian)

Family TURRITELLIDAE

4. ***Turritella*** sp. (Plate I, Figs. 7, 8)

Diagnosis : Shell long, attenuate with several whorls; earlier whorls convex with many fine spiral ridges, on other whorls two sharp ridges in middle, whorls in the middle sharply angular; aperture somewhat rounded.

Measurements (in mm.): Height- 23.85, height of last whorl- 5.1, diameter of last whorl- 8.4, height of aperture- 4.5, diameter of aperture- 3.3.

Locality : Padappakara, Chavara, Kollam, Paravur, Thazhuthala.

Geological horizon : Lower Miocene (Burdigallian)

Family VERMETIDAE

5. ***Vermetes*** sp. (Plate II, Fig. 18)

Diagnosis : Shell irregularly coiled tube; surface consists of irregular cords; interior of shell glossy.

Measurements (in mm.): Diameter of shell- 6.0.

Locality : Chavara, Thazhuthala, Padappakara.

Geological horizon : Lower Miocene (Burdigallian)

6. ***Serpulorbis*** sp. (Plate II, Fig. 19)

Diagnosis : Long, slender, usually coiling shells resembling 'worm tubules' and growing in clumps.

Measurements (in mm.): Diameter of shell- 1.1.

Locality : Thazhuthala, Chavara, Kottiyam, Padappakara.

Geological horizon : Lower Miocene (Burdigallian)

Order NEOGASTROPODA,

Family MURICIDAE

7. ***Murex*** sp. (Plate I, Figs. 9, 10)

Diagnosis: Shell moderately large, spindle shaped; spire elevated, acute, consists of a few whorls; aperture elongate-ovoid, without anal sulcus, outer lip crenulated, interior slightly lirate, siphonal canal elongate and narrowly open; body whorl large, with low axial ridges; spiral sculpture consists of primary, secondary and tertiary cords.

Measurements (in mm.): Height- 26.69, height of last whorl- 19.55, diameter of last whorl-8.87, height of aperture- 16.0, diameter of aperture 2.76

Locality : Padappakara, Thazhuthala, Chavara, Karunagapally.

Geological horizon: Lower Miocene (Burdigallian)

8. ***Chicoreus*** sp. nr. ***kilburni*** Houart & Pain, 1982 (Plate I, Figs. 11, 12)

Diagnosis: Shell moderately large, broadly rhomboidal, protoconch smooth with two and half whorls, terminally depressed like a cavity, spire elevated with 7-8 post nuclear whorls; body whorl large; aperture large, ovoid-round, anal sulcus inverted V-shaped, outer lip dentate, interior lirate; columella adherent, anteriorly slightly detached; siphonal canal medium-sized, broad narrowly open and recurved upward towards right; body whorl sculptured with three varices, three axial ribs, axial rib on shoulder prominent and knob-like, spiral sculpture with major and minor cords bearing fine nodules, shoulder spine large and branched followed by spines enclosing finer spinelets in between; canal with spines.

Measurements (in mm.): Height- 31.9, height of last whorl- 19.9, diameter of last whorl- 12.75, height of aperture- 18.3, diameter of aperture- 5.3.

Locality : Kollam, Chavara, Mayyanadu, Thazhuthala.

Geological horizon : Lower Miocene (Burdigallian)

Family BUCCINIDAE

9. ***Cantharus*** sp. (Plate I, Figs. 13, 14)

Diagnosis: Shell moderately large, thick and horny; body whorl higher than spire, constricted towards base; aperture moderately broad, outer lip thickened, with 5-6 strong teeth and anterior most forming a ledge entering the aperture; columella calloused, with lirations on the parietal wall and two prominent teeth on lower half; sculptured with broad axial ribs prominently crossed by sharply raised spiral cords.

Measurements (in mm.): Height- 23.85, height of last whorl- 15.5, diameter of last whorl- 14.4, height of aperture- 13.85, diameter of aperture- 4.95.

Locality:Thazhuthala,Kottiyam,

Geological horizon: Lower Miocene (Burdigallian)

Family CONIDAE

10. ***Conus*** sp. (Plate I, 15-17)

Diagnosis: Shell moderately large, cone-shaped with an elongate body whorl; spire convexly flat, slightly elevated, distinctly striate, pointed apically; aperture long, narrow and extending along whole body length, inner lip and outer lip run almost parallel.

Measurements (in mm.): Height- 21.4, height of last whorl- 15.5, diameter of whorl- 10.5, height of aperture- 17.5, width of aperture- 1.5.

Locality: Kollam, Chavara, Karunagapally, Thazhuthala.

Geological horizon: Lower Miocene (Burdigallian)

Class BIVALVIA
Subclass PTERIOMORPHA
Order PTERIOIDA
Family PECTINIDAE

11. ***Chlamys*** sp. (Plate II, Figs. 20, 21)

Diagnosis : Both valves (RV and LV) convex, higher than long, somewhat oblique; auricles clearly delimited, large, byssal notch large; sculpture of radial ribs; margin scalloped.

Measurements (in mm.): Length- 18.0, height- 21.4.

Locality : Thazhuthala.

Geological horizon: Lower Miocene (Burdigallian)

Subclass HETERODONTA,
Order MYOIDA,
Family CORBULIDAE

12. ***Corbula*** sp. (Plate II, Figs. 22-24)

Diagnosis : Moderate-sized sturdy shell, valves similar in size and shape, moderately inflated, concentrically ribbed, rostrum bordered by keel

Measurements (in mm.): Length- 11.65, height- 7.76, inflation- 5.56.

Locality : Padappakara, Chavara

Geological horizon : Lower Miocene (Burdigallian).

DISCUSSION

The Quilon limestone bears dominantly fossils of molluscs, foraminifers, and occasional corals, crabs, echinoids, etc. The Lower Miocene age for lower stratigraphic horizons and the Upper Miocene age for uppermost stratum indicate the time range of these marine sediments. The prevalence of black clays, sandstone, bluish grey brackish water shell limestone and nodular limestone signify the deposition in a lagoonal condition (Rajan and Kumar, 2005). Borehole data (CGWB, 1999) showed that the basin has variable depth at places suggesting an irregular relief for the floor of the basin. The basin attains maximum depth around Alappuzha and Cherthala and the depth diminishes towards the north, east, south and southeast. The maximum thickness of the limestone bed measuring about 298 m. has been found at a borehole drilled at Nirkunnam (Lat. 09°23´45? Long. 76°21´15?) and the average thickness of the limestone deposit is about 30 m. At many places the limestone bed is lens-shaped with tongue-like extensions where the bed shows large perforations of irregular shapes.

The molluscan forms recovered from the Quilon beds are either similar or closely related to species still in existence. They are primarily shallow marine forms and the depth of water may not be more than 40 m. as most of these forms are not generally found below that depth. Verma (1977) on the basis of recovered fossilized crabs stated that the animal forms of the bed were characteristic of near-shore

environment with a temperature range of 25 ° -30 °C, salinity range of 27-40 ppm and bathymetric range of surface to 20 m. The molluscan species show clear similarity with the fauna of the Indo-Pacific region. Dey (1962) demonstrated the affinity of the most molluscan forms with those of the Gaj and Karikal beds of India, and some show similarity with the Miocene and Pliocene forms of Java. According to him the fauna of Quilon and Miocene fauna of Ceylon (Sri Lanka) are of same age.

The molluscan fossils showing high frequency of occurrence in Quilon limestone are: *Strombus marginatus, Chicoreus, Rimella, Turritella, Murex* and *Conus*. The distribution of fossils shows systematic variation as the depth increases, but shows remarkable similarity horizontally. Fossils recovered during the present study suggest that on the basis of assemblage the Quilon limestone formation can be divided into an upper and lower biostratigraphic zones (see Tale 1).

It has been seen that the upper division is dominated by *Rimella , Turritella, Strombus, Strombus marginatus, Serpulorbis* and the lower zone is marked by the dominance of mollucs represented by *Cantharus, Murex, Chicoreus, Corbula, Chlamys, Conus*, etc.

During the present study fossils were recovered from several open wells and bore wells. However,for systematic analysis samples from three open wells only are taken. The percentage distribution of dominant fossil species are shown in Figs. 5 to 10.

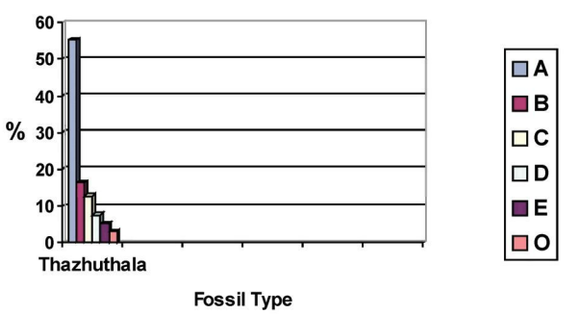

Fig. 5. Histogram showing distribution of dominant fossil species in the lower zone at Thazhuthala

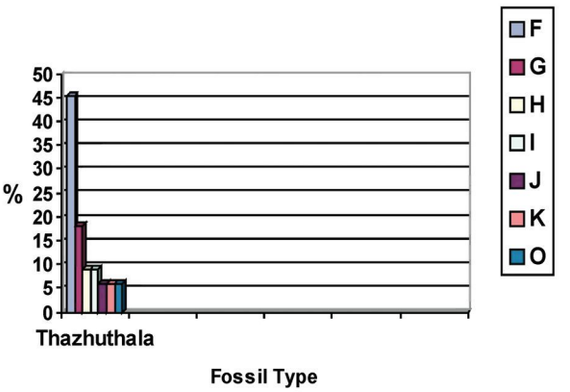

Fig. 6. Histogram showing distribution of dominant fossil species in the upper zone at Thazhuthala

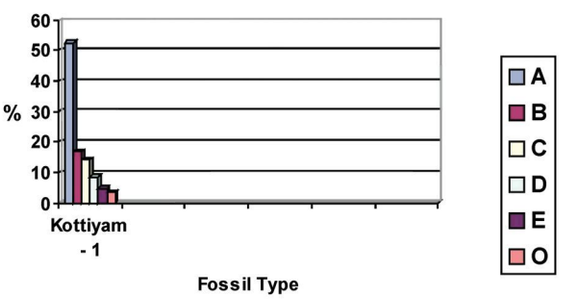

Fig. 7. Histogram showing distribution of dominant fossil species in the lower zone at Kottiyam -1

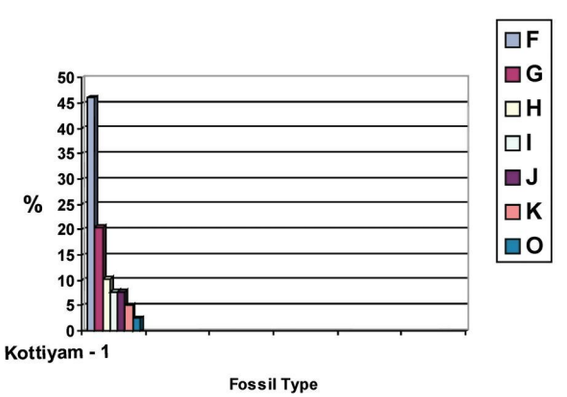

Fig. 8. Histogram showing distribution of dominant fossil species in the upper zone at Kottiyam-1

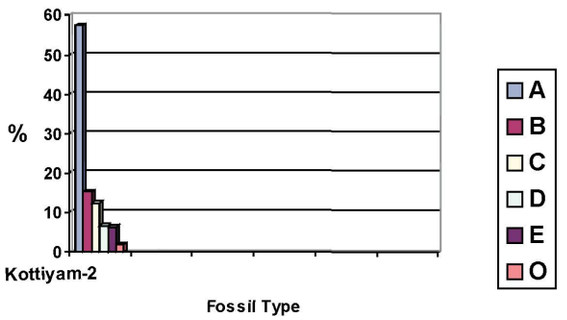

Fig. 9. Histogram showing distribution of dominant fossil species in the lower zone at Kottiyam-2

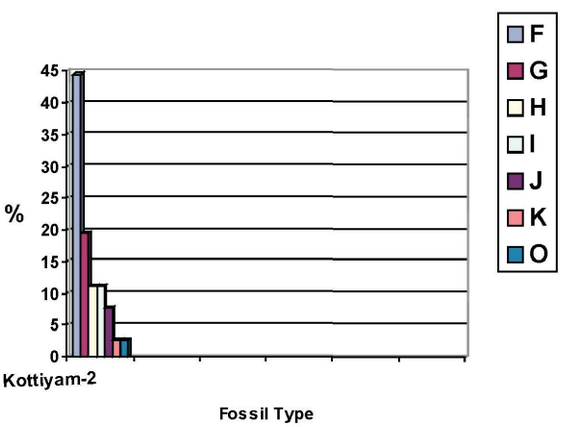

Fig. 10. Histogram showing distribution of dominant fossil species in the upper zone at Kottiyam-2A

One of the remarkable features of the Quilon limestone fauna as noted by Dey (1962) is the predominance of the gastropod molluscs. This is also evident from the samples collected during the present study. There has been a practice of deducing age among the palaeontologists of the Tertiary fauna from the proportion of the extant species and the extinct species. The limitations of the practice has however been pointed out by Dall (1904), Vaughen (1924). Van Der Vlerk (1931) worked out a percentage of the Tertiary fauna of the Indo-Pacific region for different periods.

It is considered that the evolutionary rate since early Tertiary in that region has been slower than in Mediterranean and North American Tertiary provinces. Relying upon Van Der Vlerk's deduction Dey (1962) opined that Quilon bed is of Upper Miocene or Vindobonian in age. Eames (1950) considered Quilon fauna belong to Upper Gaj (Burdigallian) age because of presence of several typical Gaj species in the fauna. Jacob and Sastri (1952) referred the foraminiferal forms from 170-280 ft. below surface in a borehole at Chavara (near Quilon) to Burdigallian age. These faunal forms are probably from a lower fossiliferous horizon than the Quilon bed exposed on the backwaters.

The diversity and vertical zonation of the fossil molluscs in the Quilon limestone bed shows that the fossil fauna bears biostratigraphic significance for an upper and lower division character. It is presumed that there was significant change in palaeoclimate and ecological factors that supported the fauna. It is interesting to note that associated carbonaceous beds of the Quilon formation are devoid of macroinvertebrate fossils. The rich fossil fauna in the Quilon bed is an indication of favourable oxygen concentration, transparency of the aquatic medium, nutrients, basin stability, etc. existed for a faunal community only during a limited period of time. This shows that the Late Miocene marine transgression during which the Quilon limestone deposited was of a short time span. During this time the basin was perhaps completely isolated from terrigenous sedimentation and that the present drainage patteren of the area developed after the uplift of the basin. It may be inferred that the palaeoclimate during which the limestone deposition took place was without much precipitation and a tendency of dryness and higher palaeo- temperature prevailed.

SUMMARY

The Neogene deposits of South Kerala sedimentary basin located along the southern coastal stretches of Kerala are represented by the sediments belonging to the Vaikom, Quilon and Warkalli Formations. These sediments apparently rest unconformably over the Archaean metamorphosed crystalline basement. While the older Vaikom and the younger Warkalli beds are unfossilliferous the Quilon limestone beds, sandwiched between them, are rich in marine macrofossils. These comprise several species of Mollusca. This fauna and available information of other biota indicate a Burdigallian age for the carbonaceous beds. The present paper incorporates a systematic account of the macro invertebrate fossils recovered from the limestone beds that show dominance of Gastropoda followed by Bivalvia

(Pelecypoda). The biostratigraphic correlation and palaeo-environmental conditions for the growth of these fauna have also been discussed.

Based on the abundance and pattern on distribution of macrofossils species with depth, the Quilon limestone formation can be divided into an upper and a lower zone. In each zone a particular fossil species appears to dominate numerically. The present study identifies and gives morphological description of the available species. The vertical variation in the frequency of major fossil species in the two biozones indicate changes in the paleo-ecological conditions in the sedimentary basin during the Tertiary period.

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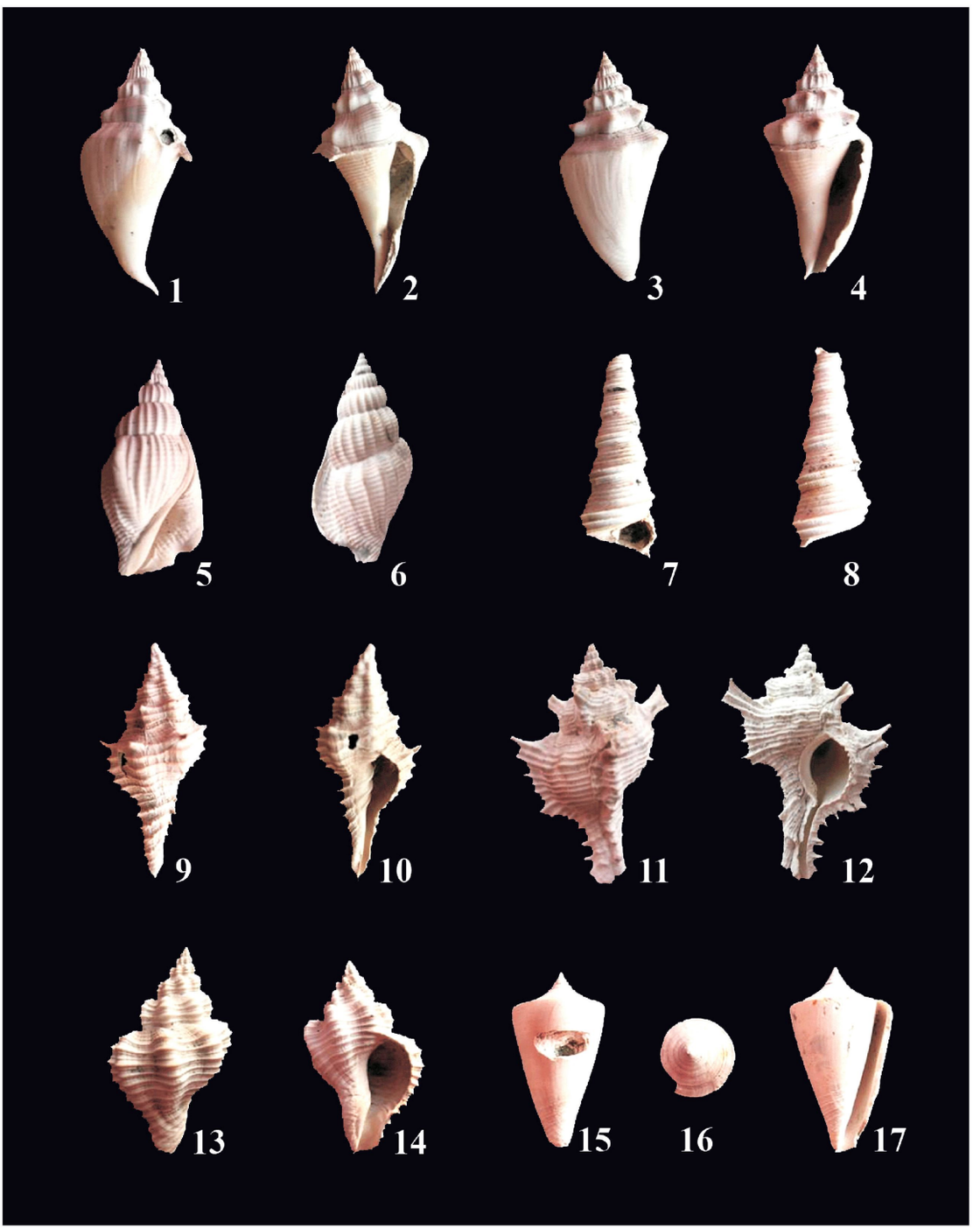
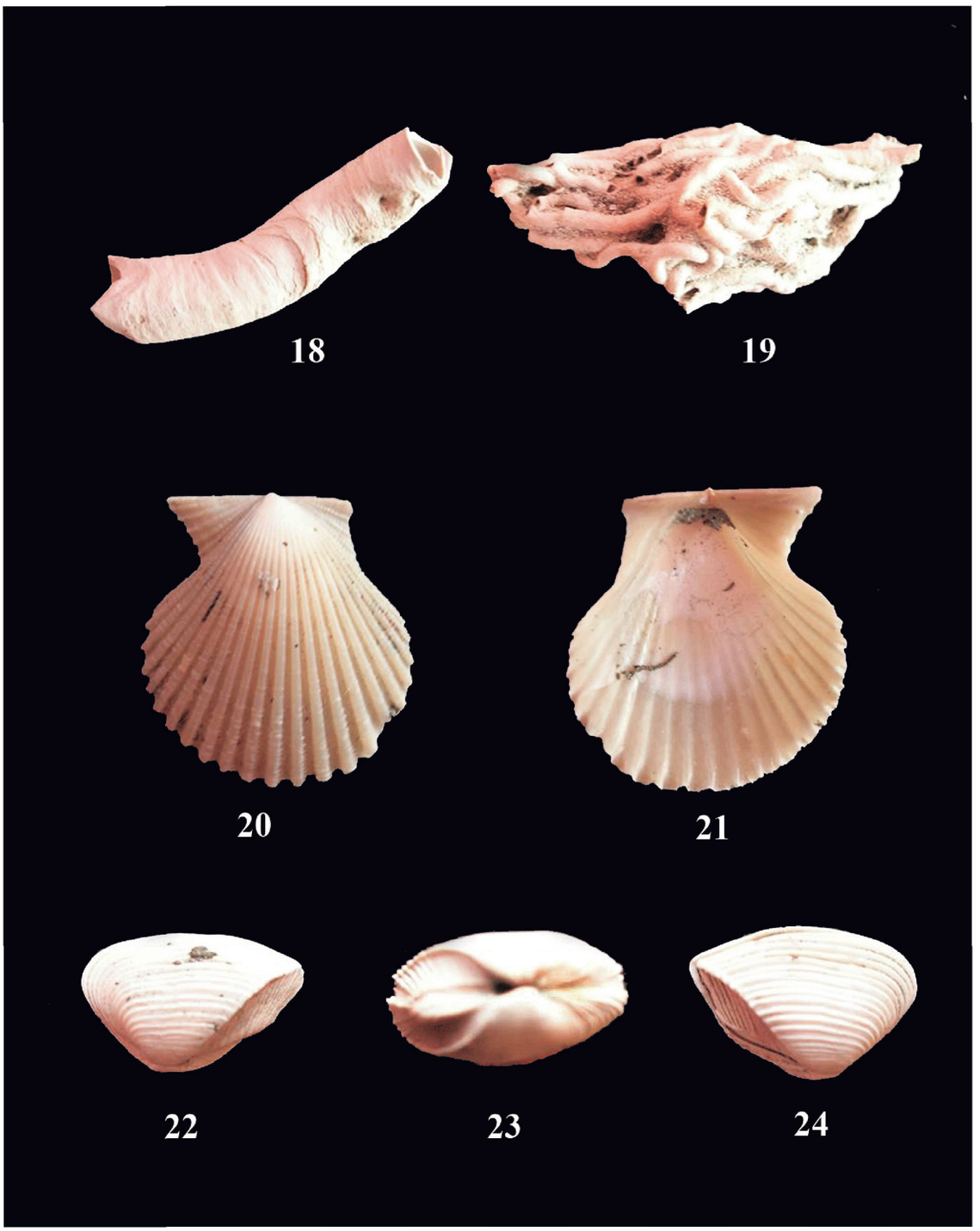
PLATE I



Figs. 1-17. 1-2, *Strombus marginatus* Linnaeus: 1, Adapertural view (1.3X), 2, Apertural view (1.3X); 3-4, *Strombus* sp.: 3, Adapertural view (1.3X), 4, Apertural view (1.3X); 5-6, *Rimella* (*Varicospira*) sp. nr. *cancellata* Linnaeus, 5, Apertural view (2.1X), 6, Adapertural view (2X); 7-8, *Turritella* sp. : 7, Apertural view (1.8X), 8, Adapertural view (1.8X); 9-10, *Murex* sp.: 9, Adapertural view (1.7 X). 10, Apertural view (1.8 X); 11-12, *Chicoreus* sp. nr. *kilburni* Houart & Pain: 11, Adapertural view (1.59X), 12, Apertural view (1.56X); 13-14, *Cantharus* sp.: 13, Adapertural view (1.8X), 14, Apertural view (1.7X); 15-17, *Conus* sp.: 15, Adaprtural view (1.6X), 16, Apical view (1.4X), 17, Apertural view (1.8X).

PLATE I



Figs. 18-24. 18, *Vermetes* sp. (2.5X); 19, *Serpulorbis* sp. (3.1X); 20-21, *Chlamys* sp.: 20, External view of left valve (2.9X), 21, Internal view of left valve (3X); 22-24, *Corbula* sp.: 22, External view of right valve (4X), 23, Lateral view, umbonal area (5X), 24, External view of left valve 4.2X).