5
MICROPALAEONTOLOGY

INTRODUCTION

Foraminifera which have representation from a great variety of marine environments also occur with similar abundance in creek environment; their distribution and health are found much controlled by the creek floor morphology, water salinity, pH and energy conditions (Bradshow 1955, Nigam and Khare 1994). The emphasis has been given on foraminifera as the best meiofaunal group as proxies of past marine environments (Nigam and Khare 1995 and 1999). Similarly, in several studies foraminifera have been used for monitoring of developmental pressures on coastal areas (Rao and Bhaskaran 1996, Khare *et al* 1995, Bhalla and Nigam 1986, Banerjee 1989, Nigam and Chaturvedi 2000). In the present chapter a dimension of geo-ecology is attempted by analyzing morpho-groups and species diversity and relating them to water quality, sediment type and micro-geomorphic units of the Meda creek, especially in the downstream area of the barrage. As described previously, the past record of the study area has also been evaluated for their micro-paleontological contents and its significance in the light of present day environment.

METHODOLOGY

The sand size particles were taken for the study of foraminifera. By coning and quartering method the sample size was reduced to one gram. The sample was spread in a contrast colour (black) tray with grid. Known quantity of the sample was then observed under binocular reflection microscope, and total 500 specimens were counted. Total foraminifera numbers (TFN) were then standardized to 1 gm of sample. Relative percentage of each group was counted. Among foraminifera, the percentage of morpho-groups (rounded symmetrical and angular asymmetrical), reworked and fresh foraminifera were also counted. Representative specimens were picked with the help of a fine (0 No.) paintbrush for the documentation purpose.

A genus level classification and systematic has been attempted using the available catalogues and documentation (Loeblich and Tappan 1988, Murray 2003, Buzas and Severin 1982, Debenay *et al* 2001, Nigam and Khare 1999, Rao *et al* 1987, Talib and Faruqui 2007, Kathal 2002, Gandhi *et al* 2002, Juvaux and Scott 2003).

From the washed weighed residue of sand size (> 63 μ) particles, benthic foraminifera specimens were studied. The observation was carried out under a binocular magnifier LABOMDE. Within each sample about 200 up to 300 individuals were picked and identified using the generic classification of Loeblich and Tappan (1988). Total number of foraminifera specimens per species per samples was calculated. The relative abundance was studied by using the total foraminifera number (TFN) standardized to 1 gm of the sample. Following the morphological criteria the foraminifera were classified into angular-asymmetrical and rounded-symmetrical morphogroups and their percentages were computed for each sample. The reworked foraminifera were identified based on their earthy look, abraded, polished and broken surfaces (Nigam and Shetty 1980, Nigam and Chaturvedi 2000). Diversity of the foraminifera (Table 5.1) was analyzed following Shannon–Weiner formula (Simpson 1949).

For the trench and core sediments, attention has also been given to other proxies like Ostracods, Pterapods and Charophytes along with foraminifera. A pollen analysis was also attempted. However except in one sample (depth 42-46 cm) pollens were largely absent. This could be due to high pH, leading to their poor preservation. Therefore, it was not become possible to use pollen as proxies.

MEDA CREEK BOTTOM SEDIMENTS

The micro-palaeontological analysis of the creek bottom sediments indicate that the benthic foraminifera contribute about 98-100% to the total foraminifera number. In fact, only 4 foraminifera, that too reworked, represented planktonic species, and were found in the samples station 5 only.

Systematic Descriptions of Foraminifera

Kingdom **Protozoa** - protozoa
Subkingdom **Biciliata**
Infrakingdom **Rhizaria**
Phylum **Granoloreticulosa**
Class **Foraminifera**
Order **Foraminiferida** Eichwald, 1830
Suborder **Rotaliina** Delage & Hérouard, 1896
Superfamily **Rotaliacea** Ehrenberg, 1839
Family **Rotaliidae** Ehrenberg, 1939
Subfamily **Ammoniinae** Saidova, 1981
Genus **Ammonia** Brünnich, 1772
***Ammonia beccarii* (Linne)**

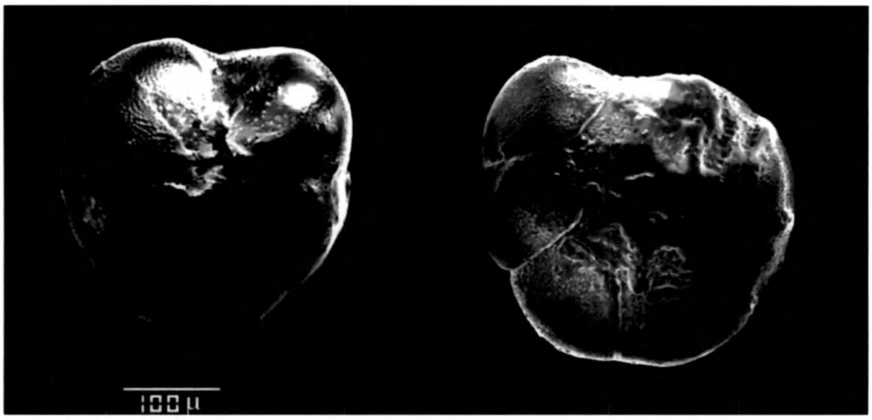

Figure 5.1 SEM photo of the ventral (left) and dorsal (right) views of *Ammonia beccarii*

Ammonia beccarii (Linne) = *Nautilus beccarii* Linne 1758, Systems Naturae. Ed. 10, Holmiae, sewden, vol.1 p. 710.

Strebulus beccarii (Linne)- Ishizaki 1943, v. 14, nos. 3-4, p. 53, pl. 1, fig. 6

Ammonia beccarii (Linnes)- Huang 1964, p. 52, pl.2, fig 6.- Matoba, 1970, p. 41-42, figs. 9 a-c.

Test is biconvex, with low trochospiral coil of 3 to 4 volutions. Spiral side evolute, umbilical side involute. The aperture is an interio-marginal slit. Periphery is rounded; wall is calcareous, optically radial. It shows great tolerance to variation in salinity from 8 to 50 ‰ (Furssenko 1959). Test size decreases with decrease in salinity and increase in temperature (Rao and Subba Rao 1974).

Figure 5.2 SEM photo of the dorsal view of *Elphidium crispum*

Superfamily **Rotaliacea** Ehrenberg, 1839

Family **Elphidiidae** Galloway, 1933

Subfamily **Elphidiinae** Galloway, 1933

Genus **Elphidium** de Montfort, 1808

Nautilus crispum Linne,1758, p.709.

***Elphidium crispum* (Linne)**

Polystomella crispa (Linnaeus), Lamark, 1822, p. 625.- *Elphidium crispum* (Linnaeus), Cushman and Grant, 1927, p.73, pl.7, fig. 3a, b.

Test is lenticular, planispirally enrolled. biconvex and circular in shape with numerous chambers. Deeply incised sutures form interlobular spaces that communicate with an umbilical spiral canal system Wall is calcareous and optically radial. Peripheral margin is acute, umbonal region is raised. Aperture, multiple that consists of numerous pores on the aperture face. Both, megalospheric (mainly reworked) and microspheric forms are present.

This is a cosmopolitan species and can be observed in a salinity range between 19.5 ‰ and 50‰ (Myers 1943). Test size and number of chambers are dependant on nutrition availability .

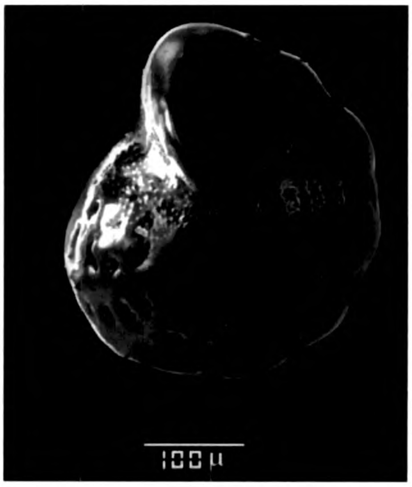

Figure 5.3 SEM photo of the dorsal view of *Elphidium indicum*

***Elphidium indicum* Cushman**

Elphidium indicum Cushman 1936, p83, pl.14, figs. 10a-b - Bhatia, 1956, p. 20, pl.5, figs. 1-5, - Rocha and Ubaldo, 1964 a, p. 417, pl.5, fig2 a-b, 1964b, p.647, pl. 1, figs. 6-7 – Bhalla, 1968, p. 386, pl. 2, figs. 7 a-b.

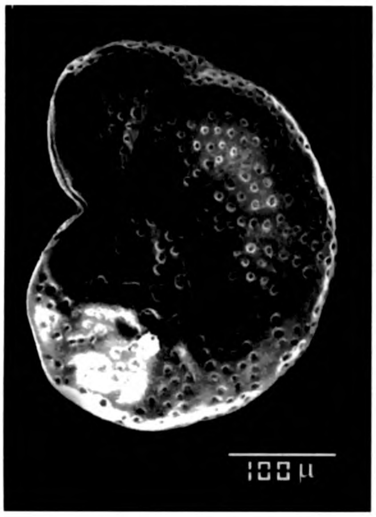

Figure 5.4 SEM photo of the dorsal view of *Cibicides pseudoungeriana*

Test is flat and has many chambers, Sutures are raised with rental processes which bridge the gap between sutures, the area between the sutures are having depressions. Umbilical region has numerous projections.

Suborder **Rotaliina** Delage & Hérouard, 1896

Superfamily **Planorbulinacea** Schwager, 1877

Family **Cibicidae** Cushman, 1927

Subfamily **Cibicidinae** Cushman, 1927

Genus **Cibicides** de Montfort, 1808

***Cibicides pseudoungeriana* (Cushman)**

Truncatulina pseudoungeriana Brady, 1884, vol.9, p. 664, pl. 94 figs. 9 a-c.

Cibicides pseudoungeriana Cushman, 1931, 104 (8), p.123, pl. 22, figs. 3-7;

- Daniel, 1949, p. 114, figs. 114-145; - Sethulekshmi Amma, 1958, p. 34, pl. 32, figs. 49 a-b.

Test circular, planoconvex. Numerous chambers, with 10-11 chambers in last whorl. Sutures are depressed below and limbet above in earlier chambers but become depressed in the last few chambers of the final whorl. Peripheral margin is rounded. Wall is calcareous, coarsely perforated. Aperture is close to the peripheral margin on the ventral side. Coiling dextral and sinisteral, both.

***Cibicides refulgens* Montfort**

Cibicides refulgens de Montfort, 1808, p.122

- Barker, 1960, p. 190, pl. 92, fig. 7-9.

Test is planoconvex with convex ventral side. Chambers are numerous, with eight chambers in last whorl. Vetral sures are deep, dorsal suture are broad. Finely perforated, stout, calcareous wall.

Figure 5.5 SEM photo of the dorsal view of *Cibicides refulgens*

Suborder **Milliolina** Delage and Herouard, 1896
Superfamily **Milliolacea** Ehrenerg, 1839
Family **Hauerinidae** Schwager, 1876
Subfamily **Hauerinidae** Schwager, 1876
Genus **Quinqueloculina** d 'Orbigny 1826
***Quinqueloculina seminulum* (Linne)**

Miliolina seminulum Williamson, 1858, p. 85, pl. 7, figs. 183-185;- Brady, 1884, vol.9, p. 157, pl.5, figs, 6 a-c;- Dakin, 1906, vol.5, p. 299.

Quinqueloculina seminulum Cushman, 1917, 71 (6), p. 44, pl.11, fig. 2; - Goanamuthu, 1943, p. 10, pl. 2, fig 4 a-f.

Figure 5.6 SEM photo of the ventral view of *Quinqueloculina seminulum*

Quinqueloculina seminulum (Linné); Haynes: 1973 p. 74, pl. 7, figs 14, 19; pl. 8, figs 1-3;

Figure 5.7 SEM photo of the dorsal view of *Quinqueloculina tenagos*

Test is oval with rounded peripheral margin. Chambers are half coiled in length. Sutures are depressed, wall is smooth and imperforate. Aperture with single tooth.

***Quinqueloculina tenagos* Parker**

Quinqueloculina costata d'Orbigny, 1826:301.

- Cushman, 1922a:66, 67, pl. 11: fig. 5; 1929a:31, pl. 3: fig. 7.

Quinqueloculina rhodiensis Parker in Parker, Phleger, and Peir- son, 1953:12, pl. 2: figs. 15-17.

Quinqueloculina tenagos Parker, 1962:110.

Specimens are heavily costate; some with a short neck. The aperture is circular and contains a small short bifid tooth. This species is overall shorter and have rounded outline.

***Quinqueloculina vulgaris* d' Orbigny**

Quinqueloculina vilgaris d' Orbigny 1826, p. 302, no. 33.

Sethulekshmi Amma, 1958 pp. 405, pl. 1, fig 5

Ganapti abnd Satyawati 1958, pl.1. figs. 24026; - Antony 1968 p.29. 1.1, fig 22; - Lankford and phleger 1973, pl.2, figs, 1 a-b.

- Kameshwara Rao 1974, pl. 63, fig 12.

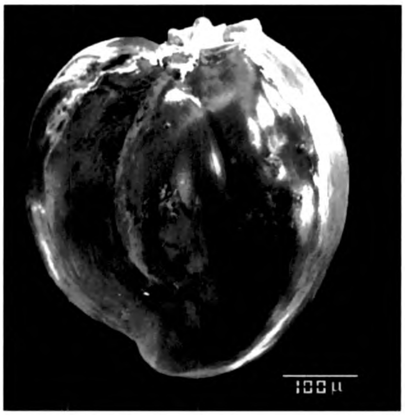

Figure 5.8 SEM photo of the dorsal view of *Quinqueloculina vulgaris*

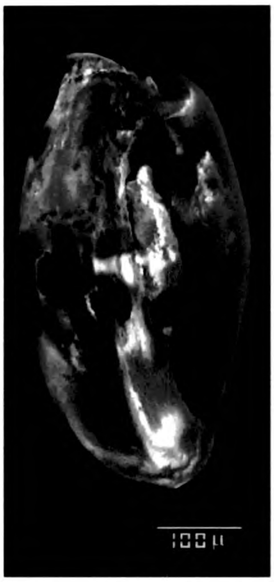

Figure 5.9 SEM photo of the dorsal view of *Quinqueloculina oblonga*

Test is short and stoutly built, the aperture view orbicular and peripheral margin rounded. Suture is depressed and distinct. Wall is smooth and imperforate. Aperture is small with a single tooth bifid at apex. It is a cosmopolitan species occurring from surface to few tens of meters (Ganpati and Styavati 1958, Antony 1968, Kameshwar rao 1974).

***Quinqueloculina oblonga* (Montagu)**

Quinqueloculina oblonga (Montagu) = *Triloculina oblonga (*Montagu); Yassini and Jones, 1995, p. 92, figs. 188-192, 196, 197.- *Quinqueloculina oblonga* (Montagu);6

- Hayward and others, 1999, p. 102, pl. 4, figs. 27, 28

Quinqueloculina sp. 6; Haig, 1997, fig. 4, 14, 15

Vermiculum oblongum Montagu, 1803, p. 179, pl.10, figs. 15-17.

Reworked, abraded specimen with distinct elongated nature. Quinqueloculine chamber arrangement is visible.

***Quinqueloculina curta* Cushman**

Test is short and stoutly built, the aperture view orbicular and peripheral margin rounded. Suture is depressed and distinct. Prominent ridges are present on the wall.

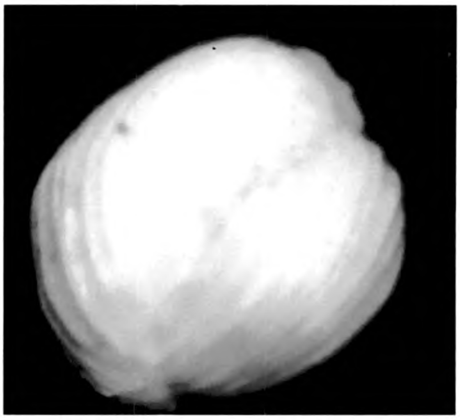

Figure 5.10 Photomicrograph of the ventral view of *Quinqueloculina curta* (length of the photo is 500 µ)

Quinqueloculina undulose-costata Terquem

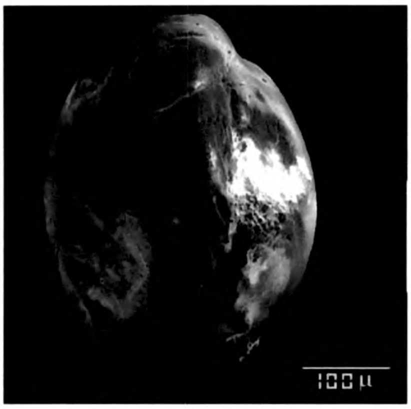

Figure 5.11 SEM photo of the dorsal view of *Quinqueloculina undulose-costata*

Quinqueloculina undulose-costata 1882 Terquem, p. 185 Pl. 20, Fig. 18-19. – Bhatia 1956, p. 17,pl. 2, fig. 9.

Test is medium and stoutly built. Suture is depressed and distinct. Wall is heavily ornamented with two sets undulations criss-crossing each other.

***Triloculina insignis* (Brady)** = *Miliolina insignis* Brady, 1881

Miliolina insignis, Brady, 1884, Rep. Chall. Vol. ix, p .165, pl. iv, Figs. 8,10

A broad test, heavily ridged shell, suture is some what depressed. The species has a wide distribution and a great range in depth.

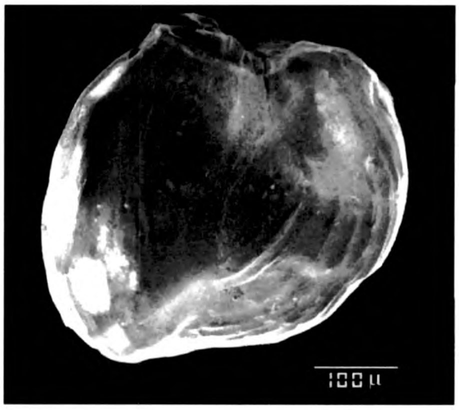

Figure 5.12 SEM photo of the dorsal view of *Triloculina insignis*

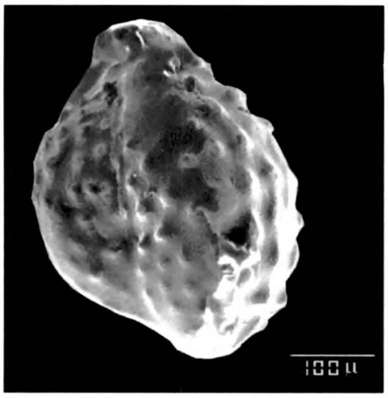

Figure 5.13 SEM photo of the dorsal view of *Triloculina* sp.

***Triloculina* sp.**

Test is spindle shape. Suture depressed. Walls are heavily ornamented with nodes.

Suborder **Rotaliina** Delage & Hérouard, 1896
Superfamily **Discorbacea** Ehrenberg, 1838
Family **Rosalinidae** Reiss, 1963
Genus **Rosalina** d'Orbigny, 1926
Rosalina globularis d'Orbigny

Rosalina globularis d'Orbigny, 1826:271, pl. 13: figs. 1-4.

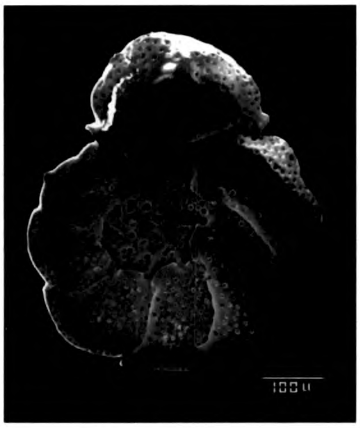

Figure 5.14 SEM photo of the ventral view of *Rosalina globularis*

Discorbis columbiensis Cushman, 1925:43, pl. 6: fig. 13.

Tretomphalus bulloides (d'Orbigny).—Cushman, 1934:86, pl. 11: fig. 2.

Tretomphalus myersi Cushman, 1943:26, pl. 6: figs. 4-6.

Tretomphalus allanticus Cushman.—Bock, 1971:53, pl. 19: figs.1-3.

Test is trochospiral, planoconvex to concavoconvex. All of the rapidly enlarging chambers are visible on the convex spiral side where the depressed sutures are oblique and curved back at the periphery. The final chamber is occupying about one-third of the circumference. Periphery subacute; wall calcareous, surface smooth; aperture near the periphery on the umbilical side, separated by the umbilical

Superfamily **Rotaliacea** Ehrenberg, 1839
Family **Rotaliidae** Ehrenberg, 1939
Subfamily **Ammoniinae** Saidova, 1981
Genus Rotalidium Asano, 1936
***Rotalidium annectens* (Parker and Jones)**

Rotalia beccari (Linnaeus) var. *annectens* Parker an Jones, 1865, p. 387, pl. 19 figs. 11a-c.

Rotalia annectens (Parker and Jones), Millet, 1904, p. 505, pl. 10, figs. 6a-c

Streblus annectens (Parker and Jones), Ishizaki, 1940, p. 58, pl. 3, figs. 12, 13

Ammonia annectens (Parker and Jones), Huang, 1964, pp. 50-52, pl. 2, fig. 3; pl. 3, figs, 1, 2,

Cavarotalia annectens (Parker and Jones), Muller-Merz, 1980, p.28, pl. 13, fig.3.

Rotalidium annectens (Parker and Jones), Loeblich and Tappan, 1988, p. 667, pl. 771, figs. 7-9; pl. 772, figs. 1-7.

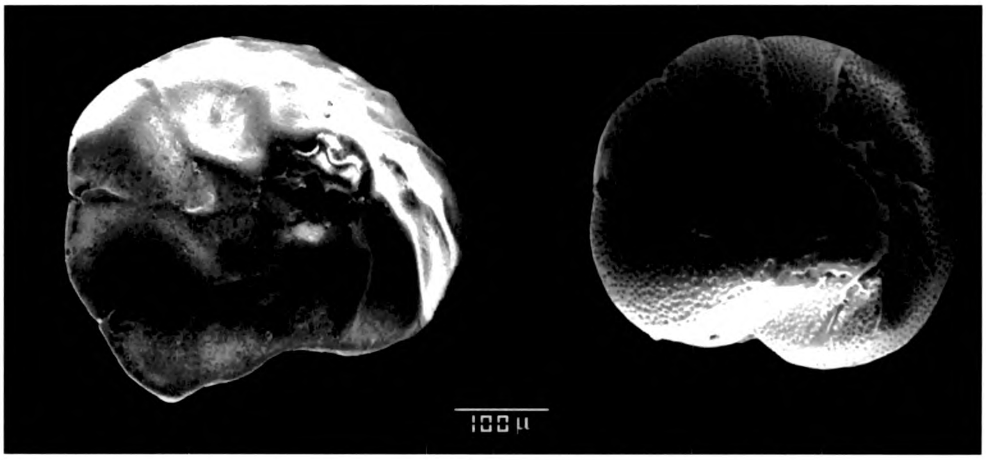

Figure 5.15 SEM photo of the dorsal (left) and ventral (right) views of *Rotalidium annectens*

The test is circular and biconvex. The aperture consists of protoforamen and duetroforamen. Megalospheric forms are quite abundant. 2 to 5 whorls are visible on dorsal side.

The species is considered as an Indo-Pacific species of shallow tropical waters. However, the species shows tolerance to wide range of fluctuations in environmental conditions (Bhatia and Kumar 1976). It occurs all along the east and west coast.

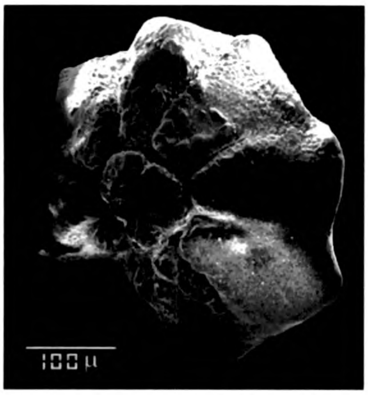

Figure 5.16 SEM photo of the ventral view of *Pararotalia sp.*

Super Family : **Rotaliacea**
Family : **Rotaliidae**
Sub Family :**Pararotaliinae**
Genus :**Pararotalia** Y. Le Calvez, 1949
Pararotalia sp.

Test is trochospiral, planoconvex, dorsal side evolute. Chambers are nearly triangular, centrally elevated on the spiral side, inflated and produced around the umbilicus. Walls are calcareous, perforate, optically radial, with smooth surface. Aperture is interiomarginal, on ventral side. Toothplate is extending to outer margin of the aperture.

Figure 5.17 SEM photo of the dorsal view of *Nonion depressulus*.

Suborder **Rotaliina** Delage & Hérouard, 1896
Superfamily **Nonionacea** Schultze, 1854
Family **Nonionidae** Schultze, 1854
Subfamily **Nonioninae** Schultze, 1854
Genus **Nonion** de Montfort, 1808
***Nonion depressulus* (Walker and Jecob)**

Nonion depressulus (Walker and Jecob) = *Nautilus depressulus* Walker and Jacob 1798, in: Kanmacher, adam's essay on the microscope, ed.2, p 641, fig. 33,

Test is compressed, planispirally coiled, nearly involute. 7-8 chambers from the last whorls. Sutures are depressed. Umblical portion is ornamented with tubercles. Wall is transparent, perforate granular, calcitic. Aperture consists of series of interio-marginal pores, partly obscured by tubercular ornament.

***Nonion scaphum* (Fitchel and Moll)**

Noutilas scaphum (Fitchel and Moll) Cushman 1930, U.S Nat. Mus. Bull. 104, pt. 7 Pl. 2 Figs. 3-4 p.5. Bhatia 1956, Contr. Cush. Found. Foram. Res. Vol. 7, pt. 1, pl. 5 fig. 1-5

Test is circular with 8-10 chambers in the final whorl; last chamber is flaring. Peripheral margin is circular. Aperture is a narrow slit at the base of the last chamber.

Sub Order : **Rotaliina** Delage & Hérouard, 1896
Super Family : **Discorbacea** Ehrenberg, 1838
Family : **Bagginidae**
Sub Family : **Bagginae**
Genus: **Cancris** de Montfort, 1808
Cancris oblonga Montfort

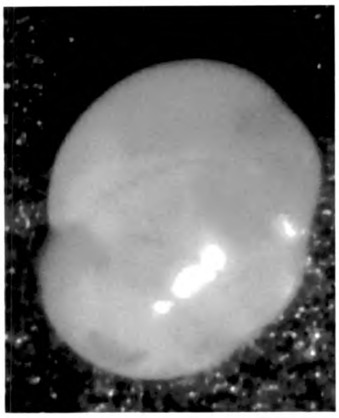

Figure 5.18 Photomicrograph of the dorsal view of *Cancris oblonga* (length of the photo is 300 μ)

Rotalina oblonga – Williamson, 1858 Roy. Soc. p-51, figs. 98-100,

Pulvinulina oblonga – Willamson 1884. Brady, Rep. Voy. Chall. Zool. Vol 5, p.688, pl. 105, Figs. 4, 1884

Pulvinulina oblonga, Cushman 1919 Proc. U.S. Nat. Mus. Vol. 56, p. 631,

Cancris oblonga (Williomson) Phleger and Parker. F.L. Geol. Soc. Amer. Mem. 46, pt. 2, p. 20, pl.9, figs. 17-19. 1951

Test is biconvex. Chambers are a few about seven or eight in the last whorl, the later formed chambers are large in size and length. Wall is calcareous, and optically radial. Peripheral edge is acute and slightly carinate. Suture is somewhat depressed. Wall is granular on the dorsal side and smooth on the ventral side.

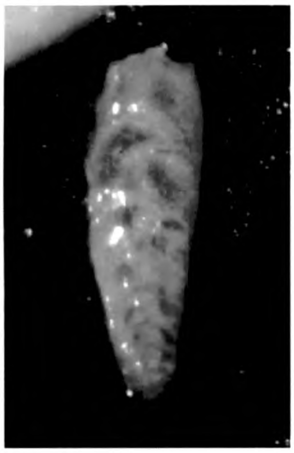

Figure 5.19 Photomicrograph of *Loxostomum* sp (length of the photo is 250 μ)

Sub Order :**Rotaliina**
Super Family :**Loxostomatacea**
Family : **Loxostomatidae**
Genus : **Loxostomum** Ehrenberg. 1854
***Loxostomum* sp.**

Test is elongate, compressed. quadrangular in section, with concave sides and truncate margins. Chambers are biserially arranged and are increasing in relative size as added. The later chambers are arched over the midline with a tendency to become nearly uniserial. Sutures are strongly curved, flush to elevated, thickened, merging into the lateral carinae; wall is calcareous, optically radial. The surface is smooth and aperture basal terminal, slitlike.

Suborder **Rotaliina** Delage & Hérouard, 1896
Superfamily **Bolivinacea** Glaessner, 1937
Family **Bolivinidae** Glaessner, 1937
Genus **Bolivina** d'Orbigny, 1839

Figure 5.20 SEM photo of *Bolivina* sp.

***Bolivina* sp.**

Test is elongate, ovoid to triangular in outline, somewhat compressed. Chambers are broad and low, biserial throughout. Enfolding of the perforate outer wall along the basal margin of the chambers seen. Wall is calcareous, optically radial and perforate. Surface is ornamented with irregularly anastomosing imperforate costae, or costae having pore; aperture is a narrow loop at the base of the apertural face, bordered by a thickened and imperforate rim on one margin.

Foraminifera Distribution

Total 22 benthic forminiferal species has been identified here from the study area, and this distribution within the Meda creek is shown in Table: 5.1.

The foraminifera recorded from the Meda creek bottom sediments are belonging to the suborders Milioliina (*Quinqueloculina, Tiloculina*), Rotaliina (*Ammonia, Cibicides, Rosalina, Astrorotalia, Rotalidium, Elphidium, Nonionella, Nonion*) and Textularina (*Loxostoma, Bolivina*). The *Ammonia* emerges as the most dominating genus contributing to 45 % of the total population. This must due to adaptation of the genus to the large variation in salinity.

Table: 5 1 Foraminifera species distribution in the Meda creek

Sr. No.	Species	Sampling stations 1	2	3	4	5
1	*Triloculina insignis* (Brady)	-	2.5	1.3	4.2	-
2	*Quinquiloculina curta* Cushman	6.1	19.0	7.8		5 8
3	*Quinqueloculina tenagos* Parker	4 5	3.8	5.2	4 2	3.8
4	*Triloculina transversestriata* (Brady)	1.5	2 5	3 9	8 5	1.9
5	*Quinqueloculina vulgaris d' Orbigny*	4.5	-	5 2	8 5	3.8
6	*Quinquiloculina reticulata* (d' Orbigny)	-	1.3	1.3	1.4	-
7	*Q oblonga* (Mintagu)	6.1	-	2 6		-
8	*Q seminulum* (Linne)	-	-	-	2.8	-
9	*Bolivina sp*	-	-	-	1.4	-
10	*Loxostomum sp.*	-	-	-	1.4	-
11	*Elphidium crispum* (Linne)	4.5	6.3	2.6	15.5	13.5
12	*Elphidium indicum* (Cushman)		6.3	-	-	13 5
13	*Ammonia beccarii* (Linne)	60.6	30.4	39.0	26.8	19.2
14	*Ammonia sp.*	6.1	12.7	19.5	5.6	5.8
15	*Cibicides pseudoungerianus* (Cushman)	-	-	-	1.4	-
16	*Rosalina globularis* d' Orbigny	-	1.3	-	-	1.9
17	*Pararotalia sp.*	1.5	5.1	3.9	7.0	7.7
18	*Nonion scaphum* (Fichtel and Moll)	-	1.3	-	-	-
19	*Cibicides refulgens* Montfort	-	2.5	1.3	-	-
20	*Nonion depresulus* (Walker and jecobs)	-	-	1.3	1.4	-
21	*Cancris oblonga*	1.5	1.3	-	-	-
22	*Rortalidium annectens* (Parker and Jones)	3.0	3.8	5.2	9.9	23.1
	Species	11	15	14	15	11
	Symmetrical /Asymmetrical	5.2	3.1	3.5	2.9	10.6
	Total Foraminifera Number	**187**	**216**	**198**	**173**	**107**
	Reworked foraminifera %					
	From Miliolite	**2.82**	-	**1.14**	**48.94**	**1.33**
	Recent	**16.9**	**29.94**	**27.27**	**14.89**	**13.33**
	Diversity	**2.209**	**3.224**	**3.529**	**3.506**	**2.686**

It also prefers fine sediments and a shallow depth (Goldstein and Moodley 1993) and so, finds this creek as a favourable habitat. This is followed by the *Quinqueloculina* sp, contributing about 15 % of the total population, which indicate low energy conditions of the Creek. These are followed by *Elphidium*

(11%), *Triloculina* (9%) and *Rotalidium* (8%), indicating that the habitat conditions are favourable to both, Miliolidae and Rotalina.

Stations 2 (TFN 216) and 3 (TFN 198) with silty clay bottom have been found most favoured by the foraminifera, followed by the Stations 1 (TFN 187) and 4 (TFN 173) having clayey silt. TFN has been recorded minimum (107) at station 5 with the sandy bottom.

Foraminifera Morpho-groups

The significance of morpho-groups has been identified by various workers (Phleger 1956, Khare *et al* 1995). The sediment turbulence caused by various factors like currents, depths, morphology of shores and monsoon, controls the distribution of morphogroups of foraminifera (Jayaraju and Reddi 1997, Raj and Chamyal 1997 and 1998). The angular asymmetrical forms indicate less energy whereas, rounded symmetrical forms indicates turbulent environment. Though rounded symmetrical forms dominate the creek, angular asymmetrical forms have also shown their significant presence at stations 2, 3 and 4. Rounded symmetrical forms have been found maximum (ten times high) at station 5 which is right on the mouth on the creek, indicating higher energy conditions and influence of the sea waves. The same forms have shown five times higher occurrence at station 1 close to the fishermen jetty of Miyani which is frequently traversed by boats. Geomorphically, the station lies on the lagoon terrace where breaking of waves might be leading to an increase in turbulence. These facts further substantiate the relationship between rounded symmetrical forms and the higher energy conditions. There is also a positive correlation between clay content and angular asymmetrical forms. The stations marked by higher percentage of angular asymmetrical forms have also shown a lower percent of reworked foraminifera.

Reworked Foraminifera

The reworked foraminifera, have shown highly polished and severely abraded nature, indicative of their transport by waves and currents. Interestingly, two types of reworked foraminifera have been found in the study area; 1) reworked fossilized foraminifera eroded from surrounding miliolite rocks, 2) recently dead forms with intra basinal transportation.

The older foraminifera could be easily distinguished with smooth rounding of the test so as difficult for the identification of structures (Nigam and Shetty 1980). Also, there was filling of secondary material and secondary mineralisation occurred due to diagenetic processes. This type of forams recorded maximum at station 5, the inner most station of the creek. The reworked foraminifera are found belonging to the genus *Quinqueloculina, Cibicides* and *Ammonia*.

Recently reworked foraminifera show relatively less earthy colour, polished and partly broken tests indicative of short distance transport. Station 2 has recorded maximum (29.94 %) number of reworked forms followed by station 3 (27.27 %). Whereas, station 5 and 4 have recorded lower percent of reworked foraminifera. The creek being a sheltered lagoon, where fine sediments can be easily deposited in general the presence of reworked forms could be more.

Species Diversity and Richness

Species diversity indicates overall impact of the creek environment on the foraminifera. Species diversity has been recorded lowest at station 1, and 2 and maximum at station 3 closely followed by the station 4. There could be several reasons for this but, the most prominent are lower salinity due to fresh water discharge and high TSS indicating turbid water. Sensitive species were either absent or in fewer number at station 1. In contrast, sturdy *Ammonia beccarii* has dominated contributing to 60% of the total population.

While integrating distribution of foraminifera with geomorphic unit, sediments characters and water quality, it can be concluded that none of the parameters singularly control the distribution of foraminifers. Therefore, foraminifera as a proxy of environment point towards more than one geo-ecological variable.

SHALLOW SUBSURFACE SEDIMENTS

The micropaleontological study of the subsurface profile samples from the upstream of barrage has shown that. Foraminifera, Ostracods, Pterapods and Charophytes are the major groups contributing to the total microfossil in the sediments. Table 5.2 presents relative abundance of these.

Table 5.2 Relative abundance of the microfauna in the subsurface sediments.

Sample Number	depth cm	Foraminifera %	Ostracods %	Pterapods %	Charophytes %	Total
1	15	61.74	24.6	7.6	6.1	100
2	30	48.76	8.5	23.3	19.4	100
4	42	54.80	23.8	7.1	14.2	100
6	54	10.38	38.7	34 9	16.0	100
8	66	48.80	28.0	6 4	16.8	100
11	84	91.91	2.9	2.3	2.9	100
14	102	47.87	8.5	4.3	39.4	100
17	120	80 00	4.0	4.0	12.0	100
20	138	52 33	12.8	5.2	29.7	100
23	156	78.26	21.1	0.0	0.6	100
26	174	59.46	23.4	16.2	0.9	100
29	192	76.53	13.0	9.0	1.5	100
32	210	88.73	7.8	2.0	1.5	100
35	228	93.85	6.2	0.0	0.0	100
38	240	87.50	12.5	0 0	0.0	100
41	264	91 75	8.2	0 0	0.0	100
44	282	92.12	6.7	1.2	0.0	100
45	290	84.00	13.1	2.9	0.0	100

The group collectively known as ''pteropods'' has also been encountered in the sub surface samples. These are holoplanktonic shelled opisthobranch gastropods (order: Thecosomata) which are planktonic snalis. The Pteropods have shown a distinct absence between 2.5 to 2.65 m with low abundance beyond 2 m depth. Pteropods genus found are *Creseis* sp, *Limacina* sp (3 species), *Peraclis* sp (Figure 5.21). Pteropods are found again beyond 2.8 m depth.

The distribution of the ostracods in the Meda creek has been described by Khosla *et al* (1982). Accordingly, their distribution has been found controlled by the creek bottom physiography. In the present study, however ostracods were studied from the subsurface sediments, which are similar to those of the active Meda creek representing marine conditions. The main genus of ostracods encountered include *Caudites* sp, *Phlyctenophora* sp., *Tanella* sp., *Pectocythere* sp., *Rugieria* sp., *Loxocorniculum* sp., *Hemicytheridea* sp., *Cypridies* sp., *Cyprinotus* sp., *Cypris* sp., *Praecipura* sp., *Atjehella* sp., *Ruggeieria* sp., *Paradoxostoma* sp., *Cytherelloidea* sp. and *Propontocypris* sp. (Figure 5.22)

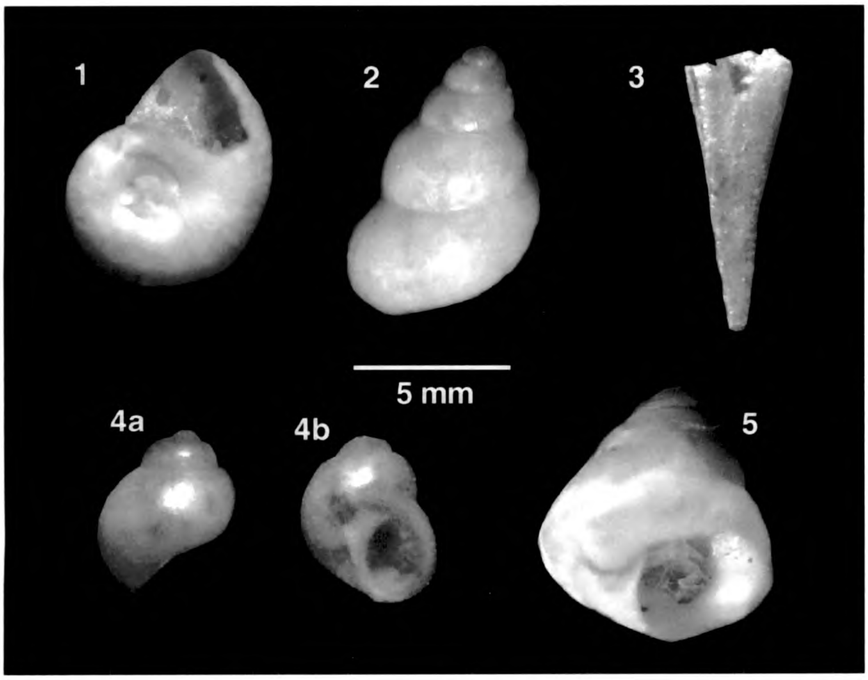

Figure5.22 photomicrograph of Pteropods; (1) *Limacina inflate*, (2) *Limacina bulimoides*, (3) *Creseis* sp, (4 a&b) *Peraclis* sp. and (4) *Limacina trochiformis*

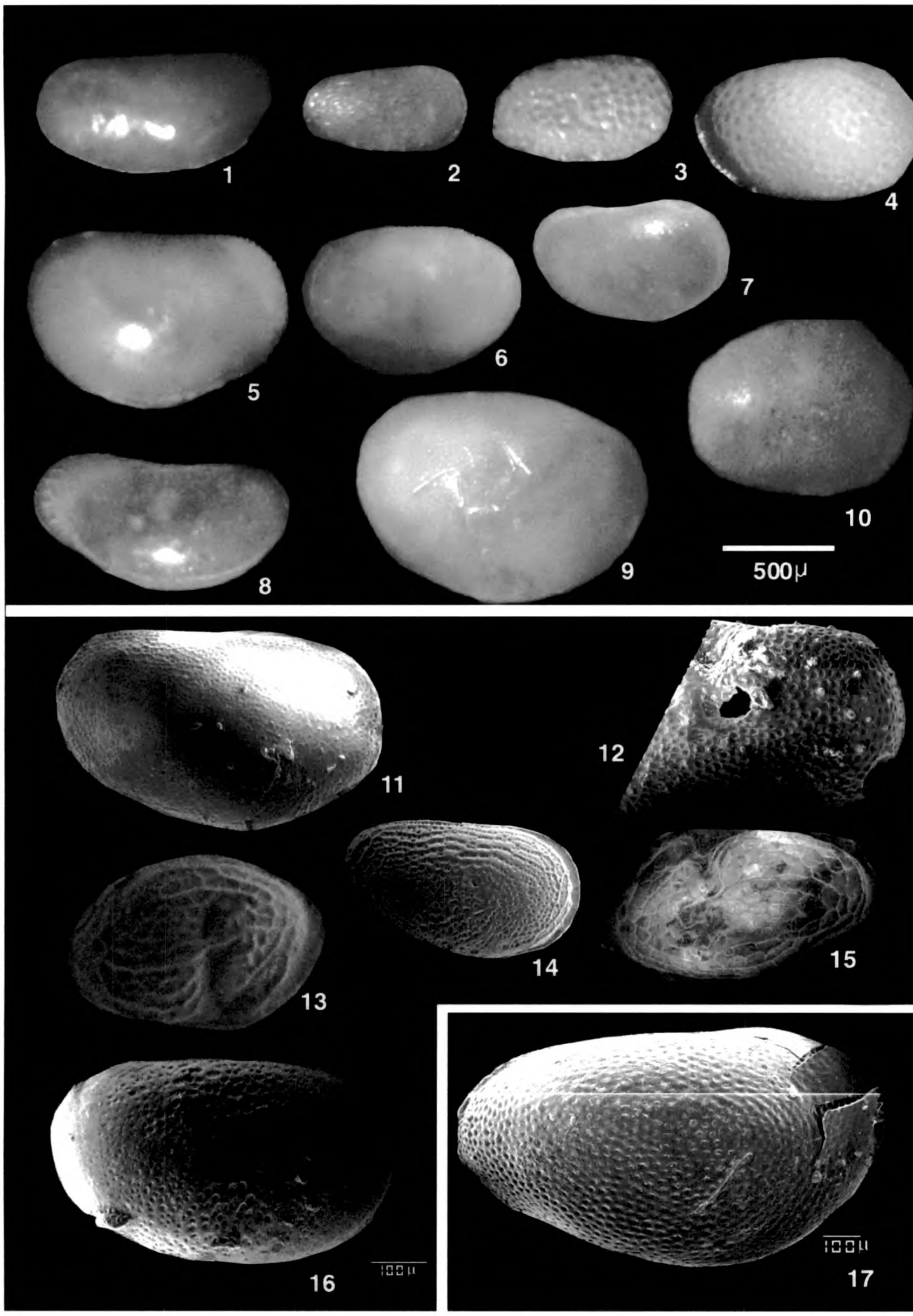

Figure 5.23 photomicrograph of Ostracods; (1) *Phlyctenophora* sp., (2) *Tanella* sp., (3) *Pectocythere* sp., (4) *Loxocorniculum* sp., *(5) Cypridies* sp., (6) *Cyprinotus* sp., (7) *Cypris* sp., (8) *Atjehella* sp., (9) *Paradoxostoma* sp., (10) *Cytherelloidea* sp. (11) *Cytherelloidea* sp. (12) *Praecipura* sp., (13) *Rugieria* sp., (14) *Hemicytheridea* sp., (15) *Ruggeieria* sp, (16) *Caudites* sp,. and (17) *Propontocypris* sp

Foraminifera

Foraminifera have remained as the dominating group through out the section, with the most dominating genus being *Ammonia*. The other genuses mainly belong to the suborder Rotaliina and Milioliina.

The dominating genus *Ammonia* range from 56 to 95% among the total foraminifera with in general increasing trend towards the top (Table 5.3).

Table 5.3 Relative abundance of various genus of foraminifera in subsurface samples

Sample. No.	Nonion %	Ammonia %	Elphidium %	Para rotalia %	Rotali dium %	Quinque loculina %	Cibicides %	Rosellina %
1	1 2	95.1	-	-	1.2	2.4	-	-
2	1.5	93.3	-	-	4.5	0.75	-	-
3	0.6	94 2	-	-	3.2	1.95	-	-
5	4.5	81.8	4.5	-	4.5	4.5	-	-
8	4.8	85 4	2.4	-	-	4.9	-	2 4
11	0.8	96.1	1.6	-	-	-	-	1.6
14	4.3	82.6	2.2	-	6 5	2.2	0.0	2.2
17	3.3	70.0	-	-	3.3	20.0	3.3	-
20	2.0	96.6	-	-	-	-	1.4	-
23	2.5	83.8	-	-	1.3	10.0	2.5	-
26	4.5	85.1	-	-	3.0	6.0	1.5	-
29	5.9	86.8	-	-	1.5	2.9	1.5	1.5
32	15.9	79.8	-	-	-	1.1	-	3.2
35	5.1	88.8	1.3	1.3	-	2.5	-	1.3
38	15.7	76.4	2.2	1.1	-	2.2	1.1	1.1
41	14.5	72 7	5 5	3.6	-	3.6	-	-
44	11.2	76.6	2.8	0.9	0 9	5.6	0 9	0.9
45	26.7	56.7	1 1	3.3	2.2	6.7	1.1	2.2

Ammonia sp and *Nonion* sp are the most dominating species followed by *Quinqueloculina* sp. Most of the other genus shows their profound presence in samples from lower depth indicating more favorable conditions for a variety of forams with the depth.

To understand the energy conditions, ratio of rounded symmetrical forms to angular asymmetrical forms, and compact to abraded forms of foraminifers were obtained (Table 5.4)

Table 5 4 Relative abundance of foraminiferal morphogroups

Sample No	Intact tests (I) %	Reworked (R) %	Rounded symmetrical forms (S) %	Angular asymmetrical forms (A) %
1	85.7	14.3	96.8	3.2
2	86.3	13.7	96.1	3.9
4	87.5	12.5	96.4	3.6
5	72.7	27.3	90.9	9.1
8	87.5	12.5	95.8	4.2
11	83.9	16.1	98.9	1.1
14	79.2	20.8	97.9	2.1
17	82.5	17.5	80.0	20.0
20	55.4	44.6	94.6	5.4
23	72.7	27.3	89.6	10.4
26	85.0	15.0	93.3	6.7
29	81.4	18.6	94.3	5.7
32	83.3	16.7	97.8	2.2
35	73.4	26.6	97.9	2.1
38	66.7	33.3	97.7	2.3
41	60.9	39.1	97.8	2.2
44	62.0	38.0	93.5	6.5
45	66.3	33.7	92.8	7.2

Accordingly a large number of reworked specimens at lower part of the core indicate low energy conditions leading to a decrease in flushing out mechanism that finally facilitate only the intrabasinal (local) transportation and deposition of the particles.

Charophytes

Gyrogonites, a fossil remnant of filamentous algae called charophytes (Family Characeae), has been encountered in the profile samples.

The Charophytes are green macroscopic algae that occurs in fresh and brackish water environment. There are six genera in this family (Characeae) viz., *Chara* L. and *Nitella* Ag. which are widespread and abundant, *Lamprothamnium* J. Gr. and *Tolypella* A. Br. have a few species each, and *Nitellopsis* Hy and *Lychnothamnus* (Rupr.) Leonh. which is represented by a single species.

Charophytes lack true leaves. It has leaf-like branchlets of equal length grown in whorls around the stem (Fig 5.24). It also lacks true stems. Instead, it possesses a round stem-like structure. Instead of flower microscopic one-celled sex organs called oogonia are formed. These tiny organs and patterns in the cases that surround them are used to distinguish between species.

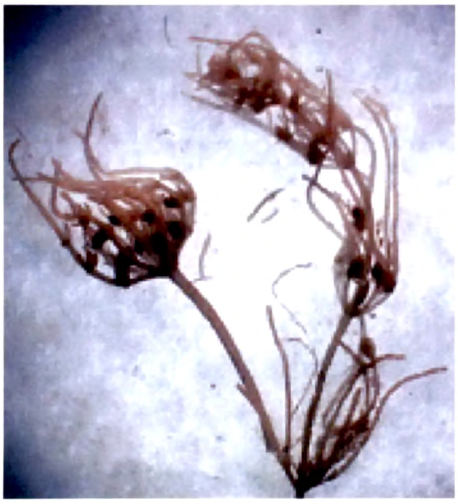

Figure 5.23 A typical morphology of modern charophyte plant.

Tiny spores are produced in fruiting bodies. In some species the fruiting bodies are orange and very conspicuous. The plant remains attached to the bottom by root-like structures called holdfasts. Propagation of the species is through spores carried by water and waterfowl; plant fragments. These plants are important food source for waterfowl particularly ducks, and provide valuable protection for young fish and invertebrates.

The charophyte grows in fresh to brackish water, inland and coastal, in both shallow and deep water. Some species found in alkaline lakes and slow-moving streams (Garcia 1994).

The charophytes are used in studying paleoenvironment due to profound preservation of its body part called gyrogonite. The gyrogonites are calcified female reproductive bodies or oogonia which are generally spherical, subspherical or elliptical in shape, and their size ranges from 0.5 mm to over 1.0 mm in diameter. The oogonia are borne on short branches (Figure 5.25) and contain a single egg cell which is surrounded by few spiral tube cells. Mostly, oogonia get calcified with calcium carbonate during their lifetime and after falling from the parent plant, they become part of the sediment and fossilize. Sometimes, these oogonia get transported by streams and are deposited also in shallow nearshore marine sediments, obviously in specific areas and less abundance.

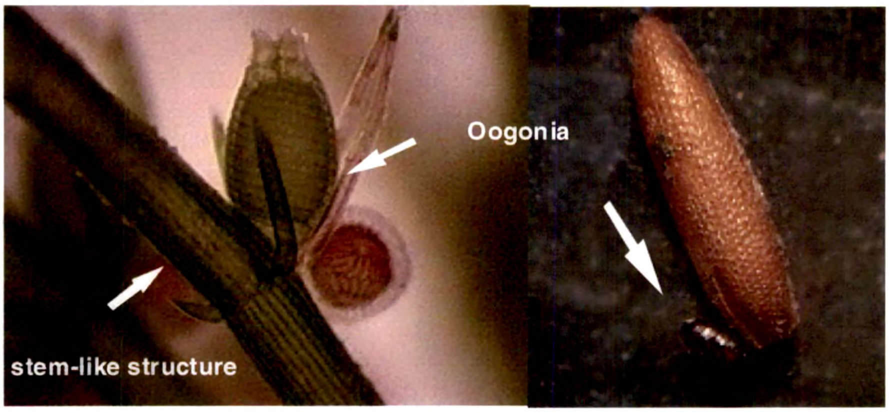

Figure 5.24 Details of modern charophyte plant.

The basic structure of all recent gyrogonites consists of strictly five enveloping cells that twist around the inner egg cell in a clockwise direction. Because the spirals appear in lateral view to climb upwards from right to left, this type is conventionally called sinistral or "sinistrorse".

Recent studies have shown that the charophytes usually fructify only at depths of less than 4 m, so when found in large numbers indicate shallow waters (Becker *et al* 2002). As a group, the Charophytes are normally regarded as indicators of healthy clear water ecosystem (Sille *et al.* 2004). They are also among the first colonizing pioneers in large water bodies after a disturbance event (Crawford 1977 and Wade 1990). This is often due to the ability of the gyrogonites to lie dormant in sediments for a large period of time before germination (Simons *et al* 1994, Beltman and Allegrini 1997).

The palaeobotaical systematics of the charophytes is based on the gyrogonites. However, the living charophytes are classified according to characters of the plant which are not preserved in the fossil state. Study at the interface (Extant/Fossil) has shown that the living genera display very distinctive fructifications and can be accurately determined from their gyrogonites even in absence of plant remains (Soulié-Märsche, 1989). At species level, the parallelism is more difficult to establish because the gyrogonites display morphological variation in response to environmental differences. In order to determine correctly the subfossil and Quaternary gyrogonites that are related to still living taxa, the range of ecological variation has to be calibrated through the study of abundant gyrogonite populations from modern lakes and ponds with various physico-chemical conditions. The knowledge of the range of inter-population variation that a given modern species is able to produce shows that many fossil morphologies distinguished as separate species potentially could have belong to one species and should be grouped together (Soulié-Märsche, 2005).

In the present study only preliminary description of charophyte is attempted. Total four types have been identified while describing forms of gyrogonite an attempt has been made to indicate probable genus of the gyrogonite.

Form A

Gyrogonites are white to off-white and robust in nature. Shape is ovoidal to subglobular, apex slightly convex and base truncated. Spiral cells are smooth without ornamentation, numbering 8-10 in lateral view. Opercular cells are 5 in number and in contact with corresponding spiral cells. Basal pore is large. Form resembles to genus *Chara* sp.

Figure 5..25 SEM photo showing the morphological details of the gyrogonite of *Chara* sp.

Form B

Gyrogonites are white to off-white and robust. Shape is globular to subglobular, with obtuse and rounded apex. Spiral cells joined at summit. Total 10-12 spiral cells on lateral view are broad and convex and joins at summit. Base is broad and with wide and concave basal pore. Form resembles to genus *Lamprothamnium* sp.

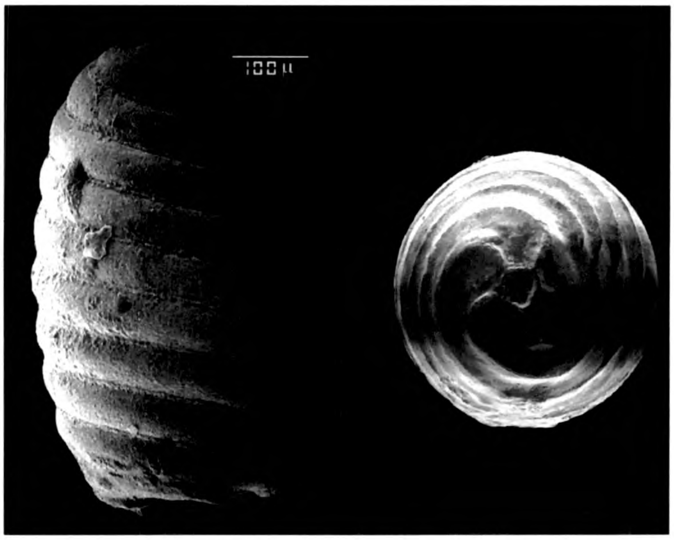

Figure 5.26 SEM photo showing lateral and basal views of *Lamprothamnium* sp.

Figure 5.27 SEM photo showing the morphological details of the gyrogonite of *Lychnothamnus* sp.

Form C

Gyrogonite are white to off-white robust and ovoid to sub-globular shape. Rounded apical zone and protruding basal zone give overall a spindle-shape appearance. Spiral cells, 8-10 on lateral view, are concave, having sharp edges. Basal pore is large. Form resembles to genus *Lychnothamnus* sp.

As only one species of *Lychnothamnus* is known to exist that is *Lychnothamnus barbatus* is rare a species, even declared as endangered in Australia. The species is known to have tolerance for alkaline water, prefers calcium rich environment and is reported from 1 to 4 m water depth (Casanova *et al* 2003). Species has been reported from various water bodies like shallow and deep lakes, ponds and running waters (Pal *et al* 1962). The species requires water level fluctuations (including drought, spell of dryness) for its survival (Casanova *et al* 2003).

Form D

Gyrogonites are dull dirty white in colour. Shape is flat circular. Apex and base, both are obtuse. Opercular cells are 10 in number. Spiral cell is concave, having sharp edges with 6-8 spire visible on in lateral view. Form resembles to genus *Nitella* sp.

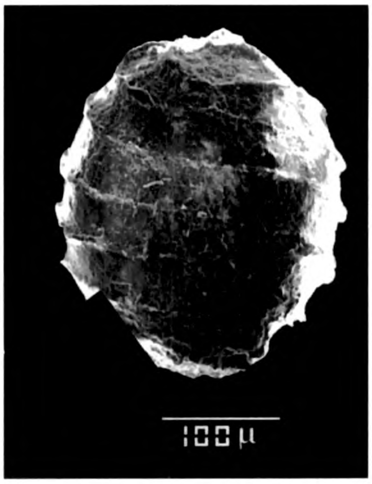

Figure 5.29 SEM photo showing the morphological details of the gyrogonite of *Nitella* sp

Presence of Charophytes along with foraminifera of shallow depth nature in the samples indicates brackish water environment. Their disappearance beyond the depth of 2.3 meter indicates prevalence of much saline conditions in the past.

Pollens Grains

The subsurface sample were analysed for palynological contents by adopting standard method. However, only the shallow depth samples (top 50 cm) have yielded the pollen grains in poor amount which did not permit a detailed quantitative or semi-quantitative analysis of the same. The spore and pollen grain composition mostly represents brackish water grass and wetland plants like charophytes, pteridophyte, convolvulaceae and cyperaceae (Figure 5.30).

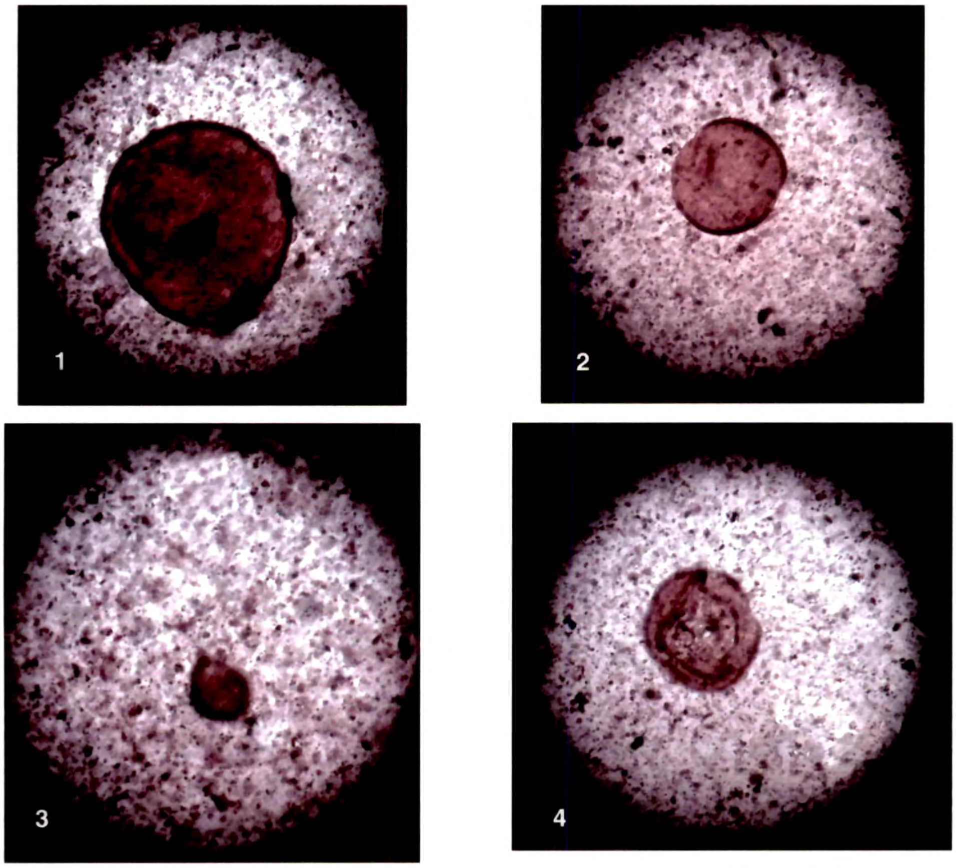

Figure 5.29 Microphotographs of (1) *Cherophyte* spore (2) Pteridophyte spore (3) Convolvulaceae pollen and (4) Cyperaceae pollens (length of photographs is 300 μ)