

CHAPTER 6: MICROPALEONTOLOGICAL STUDIES

6.1 Introduction

Micropaleontological study is well established technique for reconstructing the palaeo-environments, palaeo-oceanographic, palaeo-climatic changes. The applications of the technique is further extended for inferring tectonic processes such as earthquakes and plate tectonics (Culver, 1988; Bornmalm et al., 1997; Kim and Kennett, 1998; Horton et al., 1999; Edwards and Horton, 2000; Li et al., 2000; Gebhardt et al., 2004; Hayward et al., 2004b; Barbieri et al., 2006; Rossi and Vaiani, 2008; Hayward et al., 2010).

Foraminifera are the most widely studied among microfaunas. Short life cycles and rapid response to environmental changes make Foraminifers an ideal bio-indicator for both short and long term environmental changes. In the marginal marine environments presence of foraminiferal and their diversity plays significant role to understand land-sea interactions. Studies on modern foraminiferal faunal distribution have been used to document Holocene eustatic sea level changes (Gehrels, 1999; Horton et al., 1999; Edwards and Horton, 2000; Gebhardt et al., 2004; Horton and Edwards, 2006; Massey et al., 2006; Woodroffe, 2009), bathymetric related zonation pattern (Culver, 1988) and Holocene tectonic activities (Hayward et al., 2010).

Lower reaches of Narmada Valley have attained remarkable attention in the paleoclimatic and neotectonic activities (Tewari et al., 2001; Chamyal et al., 2002; Raj et al., 2003; Bhandari, 2004a, b; Bhandari et al., 2005; Raj, 2007; Raj and Yadava, 2009; Khadkikar et al., 2010; Laskar et al., 2010), whereas the studies on organic habitats are sparse (Ghosh et al., 2008; Ghosh et al., 2009). Gosh et al. 2008 was first to report occurrence of planktonic foraminiferal species *Gallitella vivans* from the Narmada along a muddy sequence at Ambeta. They also reported intertidal foraminifera in both Narmada and Tapti estuaries. The occurrences of

foraminifers within Narmada channel further traced inland up to 50 km from coast. The present study have identified occurrence of microfaunal assemblage within the muddy facies exposed along Uchediya sequence at two elevation viz., 1.16 m to 1.62 m and 3.50 m to 4.26 m above the present water level in the Narmada channel. Relative with the earlier findings along the Ambheta section, the Uchediya section is 48 km inland whereas, compared to finds within Narmada channel floor, the present site is further 6 km inland.

6.2 Materials and Methods

A standard microfaunal separation method was followed for processing of bulk sample. The bulk sample was wet-sieved through 63 μm size sieve. A fraction of $>63 \mu\text{m}$ was collected and dried in 50 °C for observation under stereoscopic binocular microscope. The samples were scanned for microfauna at magnification maximum up to 32X. A fine 000 brush with only few hairs was used to isolate and transfer the microfaunas. A detailed morphological study has been done using the Scanning electron Microscopic images.

6.3 Results: Foraminiferal Assemblage and their Description

For the present study 2 samples (Depths: 128-130 cm, 142-144 cm) from lithounit 2 and 3 samples (Depths: 360-362cm, 372-374 cm, 386-388 cm) from lithounit 4 were processed for microfaunal recovery. In all 122 micro fanual specimens were picked from 1.7 grams of processed sample from Unit 2 and 158 microfaunal specimens from 2.3 grams of processed sample form Unit 4 (Table 6-). In absence of systematic description of the microfossil assemblages and their description from LrNV, identification of species and description of their taxonomy were derived comparing species with supra generic classification of Loeblich and Tappan (1988). The taxonomic details of microfaual assemblage are discussed below:

Table 6-: Depth wise frequency distribution of Microfossil assemblage

No	Species	Frequency Count					Total	
		Sample	I	II	III	IV		V
		Depth (cm)	670	656	438	426		412
1	<i>Quinquiloculina seminulum</i>			1				1
2	<i>Fissurina cf indica</i>					1		1
3	<i>Gallitella vivans</i>		1			2		3
4	<i>Globigerina bulloides</i>			1	1			2
5	<i>Bolivina pusilla</i>			2			3	5
6	<i>Cassidulina cf laevigata</i>			4				4
7	<i>Bulimina marginata</i>			1	1			2
8	<i>Murayinella murrayi</i>		3	58	14	73	8	156
9	<i>Haynesina simplex</i>					3		3
10	<i>Nonionoides auris</i>		2	23	12	17	6	60
11	<i>Nonionoides gatiloupi</i>			1		2		3
12	<i>Ammonia tepida</i>					4	4	8
13	<i>Elphidium cf excavatum</i>			3	3	11	3	20
14	<i>Elphidium sp.</i>			2				2
Total			6	96	31	113	24	270

Order : MILIOLIDA Delage and Hérouard, (1896)

Superfamily: MILIOLACEA Ehrenberg, (1838)

Family : HAUERINIDAE Schwager, (1876)

Genus: QUINQUELOCULINA D'orbigny,(1826)

Species: *Quinqueloculina seminulum* Linne, (1758)

Plate 6-1: Figure 1

Serpula seminulum Linne, (1758), p. 786.

Miliolina seminulum Williamson, (1858), p. 85, pl.7, fig. 183-185; Brady, (1895), p. 157, pl.5, figs. 6a-c.

Quinqueloculina seminulum (Linne') d'Orbigany, (1826), p.303; Chaturvedi, (2001), p.122, pl. 3, fig. 13, pl.4, fig.1.

Description: Test quinqueloculine, slightly planoconvex to biconvex and various considerably in lateral views from oval, suboval to subrounded.

Remarks: This species is cosmopolitan in occurrence. From the available record it seems that it is the most common species in the recent sediment of the Indian subcontinent. Its recent report is from near shore and subsurface sediments, north-western Gulf of Kachchh (Chaturvedi, 2001); off Karwar, central west coast of India (Nigam and Khare, 1999); from the intertidal deposits of Kuchchh (Reddy, 2006) and from Meda creek of Sourashtra (Lakhmapurkar and Bhatt, 2010). Ruiz et al., (2005) have identified an assemblage of *Quinqueloculina seminulum* and *Elphidium crispum* to sub tidal channel environment near the mouth, with normal marine conditions. This species also survive in an anoxic condition at least for a short period of time (Moodley and Hess, 1992).

Order : LAGENIDA Delage and Hérourard, (1896)

Superfamily : NODOSARIACEA Ehrenberg, (1838)

Family : ELLIPSOLAGENIDAE A Silvestri, (1923)

Genus : FISSURINA Reuss, (1850)

Plate 6-1: Figure 2

Species: *Fissurina cf indica* Williamson, (1848)

Description: Test free, unilocular, slightly elongated, wall calcareous, hyaline. The specimen is poorly preserved, however the studied specimen exhibits the following characters, ovate in outline, periphery is weakly carinate, wall calcareous, finely perforate, surface granular, the presence of entosolenian tube is noticed. Size ranges from; length 80-90 µm and width 60-70 µm.

Order : GLOBIGERINIDA Lankester, (1886)

Superfamily : HETEROHELICACEA Cushman, (1928)

Family : GUERBELITRIDIIDAE Montanaro Gallitelli, (1958)

Genus : GALLITELLIA Loeblich and Tappan, (1957)

Species: *Gallitella vivans* Cushman, (1934)

Plate 6-1: Figure 3a and 3b

Guembelitra ? vivans Cushman, (1934), p.105, pl. 13 figs. 9, 10.

Guembelitra vivans (Cushman) Collins, (1958) 1958, p. 393, pl. 4, fig 14.

Gallitella vivans (Cushman) Loeblich and Tappan, (1986), p. 249, figs. 9-12; (1988), p.453, pl 485, figs.1-3; Loeblich and Tappan, (1994), p.100, pl. 179, fig. 1-7; Mayenkar, (1994), p.95, pl.9, fig.1; Chaturvedi, (2001), p.140, pl.7, Fig.1.

Description: Test elongate, triangular, tightly coiled and triserial throughout with chamber proliferation in the final stage. Chambers sub angular and rapidly enlarging as added, surface appears to be fine granular and perforated with few numbers of large diameter pores, size varies from; Length 80 μm -100 μm and width 60 μm to 80 μm .

Remarks: In the studied specimen only six well preserved specimens were identified. The enlarged surface view shows very few pores of large diameter, they are randomly oriented and surface appears to be fine-granular. *Gallitella vivans* (Cushman) is the only triserial coiling species among modern planktic foraminifera and living very near to the surface (Kimoto et al., 2009). Because of its small test and very low abundance in both water column and sediment, its distribution and ecology is poorly understood. The occurrence of this species have reported from the Indian subcontinent by Mayenkar, (1994), Chaturvedi (2001), Reddy, (2006), Ghosh et al., (2008) and other part of the world by Collins, (1958); Loeblich and Tappan, (1988); Loeblich and Tappan, (1994); Kimoto et al., (2009).

Order : FORAMINIFERIDA Delage and Hérourard, (1896)

Superfamily : GLOBIGERININAE Carpenter et al., (1862)

Family : GLOBIGERININAE Carpenter et al., (1862)

Genus : GLOBIGERINA D'orbigny, (1826)

Species: *Globigerina bulloides* D'orbigny, (1826)

Plate 6-1: 4a and 4b

Description: Test free, low to medium trochospiral, strongly lobulate, rounded, three chambers in one whorl, chambers spherical to slightly ovoid, well separated, gradual increase in size, sutures deep, wall calcareous, uniformly and

densely perforated, spines simple and with circular cross-sections. Size ranges from; Length 70-80 μm and width 100-110 μm .

Remarks: The specimen is very well preserved and does not show any sign of abrasion or weathering; this type of preservation rules out any role of transportation. The specimen is essentially a planktonic one. The occurrence of this species in intertidal deposits especially in low energy condition highlights the major tidal influenced marine condition may be due to the south west monsoon upwelling (Peeters et al., 2002). The species has been reported from Indian Ocean (Bé and Hutson, 1977) and the south west Indian ocean (Khare et al., 2009). This predominantly subantarctic and transitional species occurs in waters with surface temperatures between 10°C and 18°C., surface salinities less than 35.5 ‰, high in dissolved phosphate and silicate, and where the thermocline is weak and shallow. Its optimal occurrence is in waters of 13.4°C., 34.8‰ salinity, and 1.0 μg at/l phosphate (Bé and Hutson, 1977). The species has reported from Anderson Inlet area in Victoria of south-eastern Australia (Li et al., 2000). Surface water from north-western Arabian sea (Peeters et al., 2002). Li et al., (2000) shows that *Globigerina Bulloides* shows a clear responds to the palaeoenvironmental changes and it indicate a cold water marine environment.

Order: ROTALIIDA Delage and Hérouard, (1896)

Superfamily: BOLIVINACEA Glaessner, (1937)

Family: BOLIVINIDAE Glaessner, (1937)

Genus: BOLIVINA D'orbigny, (1839)

Species: *Bolivina pusilla* Schwager, (1866)

Plate 6-1: Figure 5a, 5b and 5c

Bolivina pusilla Schwager, (1866), p. 254, pl. 7, fig. 101; Mcculloch, (1977), p.257, pl. 105, fig. 11.

Description: Test narrow, elongate, compressed and biserial throughout; surface except the last part of chamber is ornamented by longitudinal striations.

Densely populated pore pits are comparatively larger in size. 8-10 ridges are visible. The upper portion of the chamber showing smooth surface without considerable number of pore pit and no striations are visible. Size varies from; length 200-210 μm and width 50-100 μm .

Remarks: The occurrence of this species is rare. Schwager, (1866) has originally reported this specimen from the Mediterranean Sea. McCulloch, (1977) has recorded it from the Marshall Island of Northeast Pacific. From Indian subcontinent the only report of the species is from the Gulf of Kachhh (Reddy, 2006). The species is originally a deep benthic. The well preserved specimens indicates the effect of interaction between the deep sea marine condition and the inland fluvial environment.

Order : ROTALIIDA Delage and Hérouard, (1896)

Superfamily : CASSIDULINACEA D'orbigny, (1839)

Family : CASSIDULINIDAE D'orbigny, (1839)

Genus: CASSIDULINA D'orbigny, (1826)

Species: *Cassidulina cf laevigata* D'orbigny, (1826)

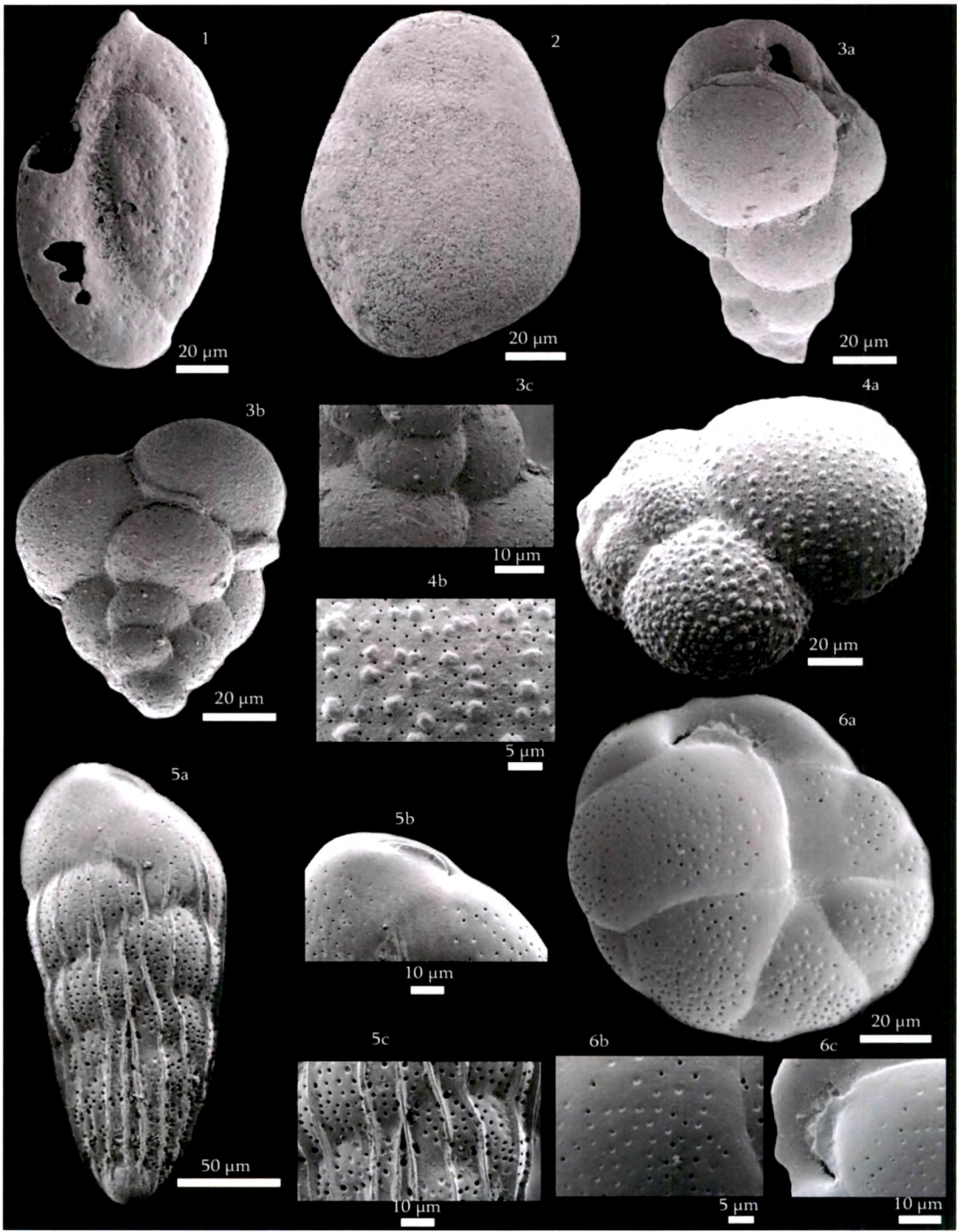
Plate 6-1: Figure 6a, 6b and 6c

Cassidulina cf laevigata D'orbigny, (1826), p.282; Lolelich and Tappan, (1987), p504, pl.555, figs 1-8.

Description: Test free, calcareous, circular, planispiral, periphery gently lobulate, wall smooth, semihyaline, periphery angular but not keeled, test biconvex with 5 pairs of chambers per whorl. Central portion of the test is excavated and sutures are depressed and curved. The pores are of big size but their concentration is not seen in the region located along the suture. Size ranges from Length 90-100 μm and width 90-100 μm .

Remarks: The side view of the studied specimen shows 6 chambers moderately enlarged in size. The central portion of the test is excavated and sutures are depressed and curved.

Palte 6-: *Quinquoluculina seminulum* , *Fissurina cf indica*, *Gallitellia vivans*, *Globigerina bulloides*, *Bolivina pusilla* and *Cassidulina cf laevigata*



Order : ROTALIIDA Delage and Hérouard, (1896)

Superfamily : BULIMINACEA Jones, (1875)

Family : BULIMINIDAE Jones, (1875)

Genus : AMMONIA Brünnich, (1872)

Species : *Bulimina marginata* D'orbigny, (1826)

Plate 6-2: Figure 1

Bulimina marginata D'orbigny, (1826), p.269, pl.12, figs. 10-12.

Description: Test elongate triangular, triserial throughout, chambers rapidly enlarging in height as added, strongly overlapping and slightly inflated; the lower most acute margin of the chambers ornamented by short spines. Size ranges from; length 90-100 µm, width 50-60 µm.

Remarks: *Bulimina marginata* is described and named by Orbigny (1826) is one of the most common species in most outer shelf upper slope environment (Burgess and Schnitker, 1990). This species is widely distributed in the recent sediments of the Indian Region. Its recent reports are from North-western Gulf of Kachchh (Chaturvedi, 2001), off Central west coast of India (Nigam and Khare, 1999), off Karikkattukuppam near Chennai, east coast (Rao, 1998) and from the intertidal deposits of Kachchh (Reddy, 2006). In the studied specimen the species shows a low frequency, only one specimen is collected from the lithounit 1. This may be due to its sustainability in a low temperature range. Laboratory analysis of the species shows that the species reproduces and calcifies between 6-14°C with an optimum between 8-12°C temperature (Barras et al., 2009).

Order: ROTALIIDA Delage and Hérouard, (1896)

Superfamily: GLABRATELLACEA Loeblich and Tappan, (1964)

Family: GLABRATELLIDAE Loeblich and Tappan, (1964)

Genus: MURRAYINELLA Farias, (1977)

Species: *Murrayinella murrayi* Heron-Allen and Earland, (1915)

Plate 6-2: Figure 2a, 2b, 2c and 2d

Rotalia murrayi Heron-Allen and Earland, (1915), p. 721, pl. 53, figs. 27-34.

Description: Test low trochospiral coil of 2½-3 whorls, 11-12 chambers gradually enlarging in size. Surface is unevenly granular showing remnants of tubercles. The distinct character of this reported species is that, the specimen of

this locality has open umbilical and the final chamber of the test is provided with short, low apertural flap. The central portion is pitted in nature. Size varies from; Length- 80 µm -90 µm and width 100 µm-120µm.

Remarks: This species is the most frequent in the studied sample. The species are reported from shore-sand from Sandoway, Arakan Coast, Burma, and also in shallow water at Segaar, New Guinea (Heron-Allen and Earland, 1915). The species reported from the Thailand Gulf (Melis and Violanti, 2006) forms the most frequent species (17.6 %) in the assemblage. From India, the only report of this species is from the Kachchh region of western India (Reddy, 2006). Melis and Violanti, (2006) noted that the species had a wide environmental tolerance and can be used as a marker for monitoring fluvial influence and pollution.

Order : LIIDA Delage and Hérouard, (1896)

Superfamily: NONIONACEA Schultze, (1854)

Family: NONIONIDAE Schultze, (1854)

Genus: HAYNESINA Banner and Culver, (1978)

Species: *Haynesina simplex* Cushman, (1933)

Plate 6-2: Figure 3a, 3b, 3c, 3d, 3e, 3f, 3g and 3h

Elphidium simplex- Cushman, (1933), p.52.pl.12, figs. 8,9.

Elphidium simplex – Cushman, (1939), p.62. pl.17, fig.10.

Elphidium simplex- Albani, (1968), p.113, pl.10, fig. 4.

Discription : This species is very rare in the studied assemblage.

Order : ROTALIIDA Delage and Hérouard, (1896)

Superfamily : NONIONACEA Schultze, (1854)

Family : NONIONIDAE Schultze, (1854)

Genus : NONIONOIDES Saidova, (1975)

Species: *Nonionoides auris* D'orbigny, (1839)

Plate 6-2: Figure 4a, 4b and 4c

Valvulina auris D'orbigny, (1839), p.47, pl.2, fig. 15-17.

Nonionella auris (D'Orbigny) Cushman, (1939), p. 33, pl.9, fig. 4; Setty and Nigam, (1980), p-421.

Nonionoides auris (d' Orbigny) Saidova, (1975), p. 248; Loeblich and Tappan, (1994), p. 158, pl.345, figs. 5-16.

Distinguishing characters: Test oval to elongate oval in outline, a low trochospiral coil of two convolutions; the umbilical end of the last chamber extending into the umbilicus on the ventral side. Size varies from; Length 100-110 μm and width 60-70 μm .

Remarks: A total of eight chambers are visible. On the dorsal side sutures are straight and slightly depressed. At some places microbial boring are seen. Fine pores in the surface are randomly oriented. The surface shows narrow straight depressed suture. Small pores are also seen across the suture. This species is originally described by D'orbigny, (1839) from the coast of Chile. Cushman, (1939) reported this species from the Payta, Piementel and Eten coasts of Peru and off British Columbia. Off the Forkland Island by Heron-Allen and Earland, (1932). In the Sahul Shelf, Loeblich and Tappan, (1994) have recorded it from the Van Diemen Rise eastern Timor Sea at 111.25 m depth and the western Van Diemen Rise of Central Timor Sea at a depth of 54.84 m depth. From India the species have been reported occurrence from the western coast (Setty and Nigam, 1980; Mayenkar, 1994; Chaturvedi, 2001; Reddy, 2006).

Order : ROTALIIDA Delage and Hérourard, (1896)

Superfamily : NONIONACEA Schultze, (1854)

Family : NONIONIDAE Schultze, (1854)

Genus : NONIONOIDES Saidova, (1975)

Species: *Nonionoides gatiloupi* D'orbigny, (1826)

Plate 6-3: Figure 3a and 3b

Nonionina gatiloupi D'orbigny, (1826), p 294

Nonionoides Saidova, (1975), p. 248

Description: Test weakly trochospiral, followed by planispiral, chambers enlarging gradually, biumbilicate, periphery sub angular to rounded, wall calcareous, hyaline, finely perforate, surface smooth, aperture low and interiormarginal. Size varies from; Length 100-110 μm and width 75-80 μm .

Remarks: This is a Holocene species present in sublittoral regions, Atlantic, Caribbean and Pacific regions. In the studied sediments it has a low frequency.

Plate 6-2

1. *Bulimina marginata*

- a. Side view showing triserial arrangement of chambers. Specimen had moderate preservation. View X450.

2. *Murayinella murrayi*

- a. Ventral view showing six chambers in all gradually enlarging in size. View X800.
- b. The central portion of the species is pitted in character. View X2500.
- c. Showing remnants of tubercles. View X3300.
- d. Dorsal view showing the moderately increasing chamber diameter. The specimen shows 2.5-3 whorls consisting of 11-12 chambers. View X700.

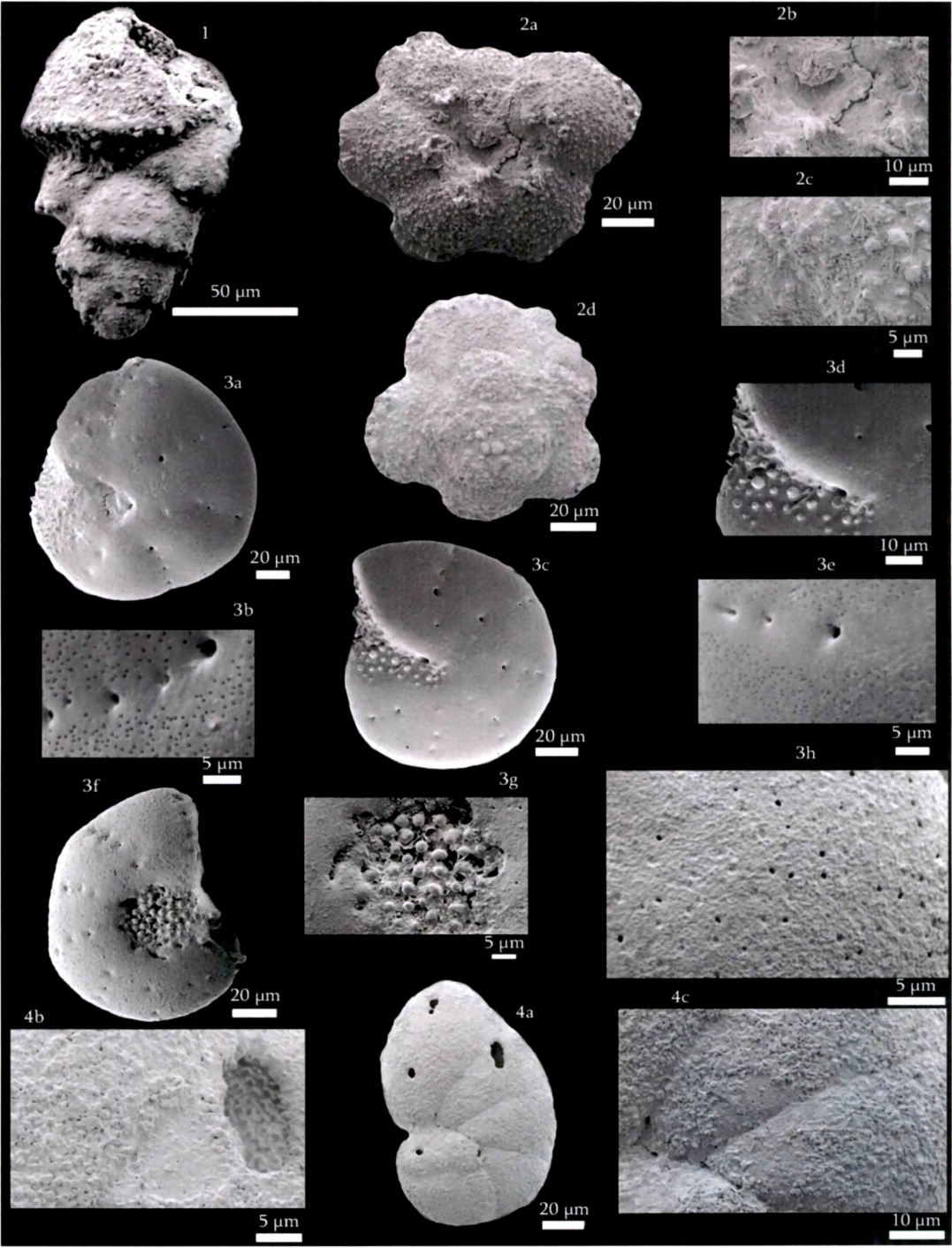
3. *Haynesina simplex*

- a. Side view showing the rounded and gradually increasing chambers. Sutures are characterised by septal bridges. Papillate structure is absent. View X550.
- b. Enlarged surface view showing fine perforations closely placed and large septal bridges. View X4300.
- c. The specimen is characterized by papillate structure near the umbilical area. The suture is curved and radial. The Septel Bridge is very few and ranges from 2-4 bridges distantly placed. In all the side view exhibit several chambers. Very gradually increasing size. View X600.
- d. Papillate structure includes tuburcle and small cone like structure. The surface is densely populated with fine pores. View X1700.
- e. Surface showing dense small pores and septal bridge. View X3500.
- f. Side view showing well developed papillate structure. View X850.
- g. Central portion exhibit distinct papillate structure. View X2700.
- h. Enlarge surface showing randomly oriented distinctly placed pores. View X4500.

4. *Nonionoides auris*

- a. Dorsal view. In all 8 chambers on the dorsal side sutures are straight radial and slightly depressed. At some places microbial borings are also seen. This might have been resulted by the activity of bacteria. View X550.
- b. Enlarged portion showing microbial borings. View X3700.
- c. Enlarged portion showing randomly oriented fine pores. View X200.

Palte 6-: *Bulimina marginata*, *Murayinella murrayi*, *Elphidium simplex* and *Nonionoides auris*.



Order : ROTALIIDA Delage and Hérourard, (1896)

Superfamily : ROTALIACEA Ehrenberg, (1839)

Family : ROTALIIDAE Ehrenberg, (1839)

Genus : AMMONIA Brünnich, (1872)

Species: *Ammonia tepida* Cushman, (1927)

Plate 6-3: Figure 2a, 2b, 2c, 2d, 2e and 2f

Rotalia beccarri var. *tepida* Cushman, (1927), p.79, pl.1;

Ammonia tepida (Cushman) Seibold, (1975), p.191-192;

Ammonia tepida in Hayward et al., (2003), p.353, fig. 1-8.

Description: Test small; low trochospiral; periphery rounded to slightly sub angular; broadly developed; Test walls perforated ; pores rounded; size varies from; length- 90 µm to 100µm and width- 90 µm to 100µm .

Remarks: *Ammonia tepida* is a cosmopolitan species, colonizing marine to brackish-marine environments (Almogi-Labin et al., 1992). The species have sustainability in a salinity range of 0.2–70 psu (Bradshaw, 1957; Reddy and Jagadiswara Rao, 1984; Almogi-Labin et al., 1992). The recent reports stated the restriction of this morpho-type to tropical, equatorial region (Hayward et al., 2003; Hayward et al., 2004a) and indicative of a clear fresh water influence (Melis and Violanti, 2006). The presence of this species have also been reported from inland brackish lake (Wennrich et al., 2007). The surface enlargement of the studied specimen showing comparatively large, randomly oriented pores located within the granular surface with distinctly placed pores. The species have a reported occurrences form east and west coast of India (Rao and Rao, 1974; Nigam, 1984) and also reported from the Holocene section ($\sim 30 \pm 10$ and $\sim 90 \pm 10$ ka) from the Narmada estuary (Ghosh et al., 2008).

Order : ROTALIIDA Delage and Hérourard, (1896)

Superfamily : ROTALIACEA Ehrenberg, (1839)

Family: ELPHIDIIDAE Galloway, (1933)

Genus: ELPHIDIUM Denys-De-Monfort, (1808)

Species: *Elphidium excavatum* Terquem, (1875)

Plate 6-3: Figure 3a, 3b and 3c

Elphidium excavatum (Terquem) forma *clavata* Cushman Plate 1, figures 1-9; plate 2, figures 1-9

Description: Test planispiral, involute, periphery rounded, size gradually increasing as added, suture depressed, sutures usually closed before reaching the umbilical region. The illustrated specimen is characterised by broadly rounded periphery without any keel. The umbonal area is shallowly depressed, excavated, septal bridges are irregular and walls finely perforated. The specific identification is made by limited number of specimens. In view of the character exhibited by this specimen the species is tentatively comparable with *excavatum*. Size; Width 60-70 μm , Length 80-90 μm .

Remarks: In the studied samples, the species is present in all two units. This species have also reported in Indian subcontinent from central west coast of India , from Gulf of Khambath, north eastern part of Arabian Sea, gulf of Kutch, east coast of India and from the Saurashtra coast (Kameswara Rao, 1971; Nigam, 1984; Nigam and Khare, 1999; Rao et al., 2000; Rao and Srinath, 2002). This species can survive in an anoxic condition at least for a short period of time (Moodley and Hess, 1992).

Order : Rotaliida Delage and Hérouard, (1896)

Superfamily : Rotaliacea Ehrenberg, (1839)

Family: Elphidiidae Galloway, (1933)

Genus: *Elphidium* Denys-De-Monfort, (1808)

Species: *Elphidium* sp.

Plate 6-3: Figure 4a and 4b

The illustrated specimen is comparatively small, with sub rounded periphery. The sutures are depressed and curved. The septal bridges are obscured by the strongly reticulated surface shows recrystallization. More material is needed for detail examination.

Plate 6:3

1. *Nonionoides gatiloupi*

- a. This illustrated specimen distinctly showing 9 chambers in the final whirl, suture is straight depressed. The chambers are gradually increasing in size. However the last chamber is comparatively smaller than the penultimate chamber. View X600.
- b. The surface enlargement shows numerous pores, randomly oriented in a fine matrix. View X2500.

2. *Ammonia tepida*

- a. Ventral view of *Ammonia tepida*. View X500.
- b. Enlarged surface view exhibiting very fine pores, very closely spaced and visible only at very high magnification. The enlarged surface also shows the presence of pores of large diameter. However in a unit area they are very few. For eg the picture shows only two pores. View X2700.
- c. Surface enlargement of the *Ammonia tepida* showing comparatively large randomly oriented pores located within the granular surface. View X14000.
- d. Ventral view of the *Ammonia tepida*. View X400.
- e. Enlarged umbilicus view. View X1000.
- f. Enlarged surface view showing the arrangement of pores and their absence in the suture area. View X1300.

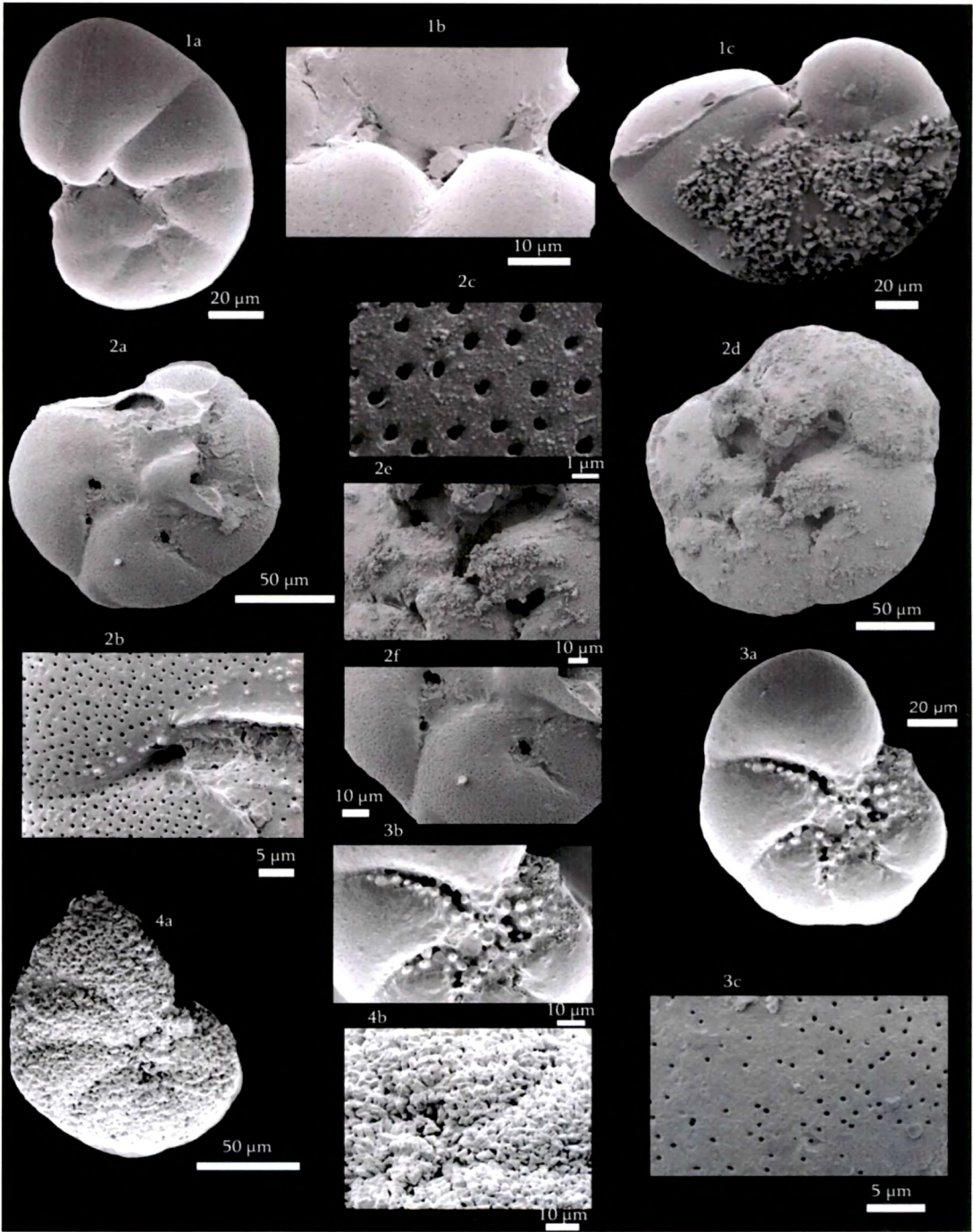
3. *Elphidium cf excavatum*

- a. Side view showing planispiral, involute, rounded periphery and gradually increasing chambers. Suture is depressed, broadly rounded periphery without keel. The umbonal area is shallowly depressed, excavated, septal bridges are irregular and walls finely perforated. Specimen shows distinct papillate structure along the surface and also near the umbilical region. View X600.
- b. Distinct papillate structure along the suture and near the central region. View X1400.
- c. Enlarged surface view showing randomly oriented closely placed pores. View X5000.

4. *Elphidium* Species

- a. Side view showing granular surface structure, rounded periphery and gradually increasing chambers as added. View X430.
- b. Enlarged view shows tightly held elongated grains. View X1400.

Palte 6-: *Nonionoides gratiloupi*, *Ammonia tepida*, *Elphidium cf excavatum* and *Elphidium* species.



6.4 Discussion

The micro-paleontological analysis of the sediment from the two levels, that is lithounit 2 (152-342 cm) and lithounit 4 (344-416 cm) reveal the presents of foraminifera and ostracods (Table 6- and Figure 6-). Both the units have a Total Foraminifera Number (TFN) are comparatively lower than the Total Microfossil Number (TMN). From the taxonomic point of view, assemblage of foraminifera is well preserved and most of the forms are tiny. In majority the assemblage is juvenile in nature and the frequency is very low. The presence of abraded forms is very low as compared to the well preserved forms. The sample also shows a very low diversity and are represented by benthic forms *Ammonia tepida*, *Murayinella murrayi*, *Nonionoides auris*, *Nonionoides gatiloupi*, *Bulimina marginata*, *Bolivina pusilla*, *Quinqueloculina seminulum*, *Cassidulina cf laevigata*, *Haynesina simplex*, *Elphidium cf excavatum*, *Elphidium sp.*, *Fissurina cf indica* and planktonic forms *Gallitella vivans*, *Globigerina bulloides*. In general, these benthic foraminiferal assemblages can be interpreted to a shallow water intertidal marine origin. The occurrence of Planktonic foraminifera of *Globigerina bulloides* and *Gillitella vivans* indicates strong events of tidal/storm environments, which is responsible for the deposition of planktonic forms. This is also supported by the present day occurrence of planktonic foraminifera in the beach rocks of west coast and present day intertidal deposits of Narmada and Tapti estuary (Ghosh et al., 2009). The two intertidal layers are (lithounit 2 and 4) separated by sandy fluvial sediments (Figure 6-). Both these levels have identical foraminiferal assemblage and thereby, do not differ from each other. Along with the foraminiferal assemblage a rich number of ostracod is also reported.

The presence of foraminifera and ostracode assemblage in the Late Holocene sediments confirms the activity of marine fluvial interface inland up to 56 km in the past. But the major question arises here is level of unit 4, which is 3.5

to 4.2 meter above the present water level. It coins three possible explanations for the deposition, viz. Eustatic sea level change, monsoonal upwelling of western coast (Ghosh et al., 2008) or a base level change.

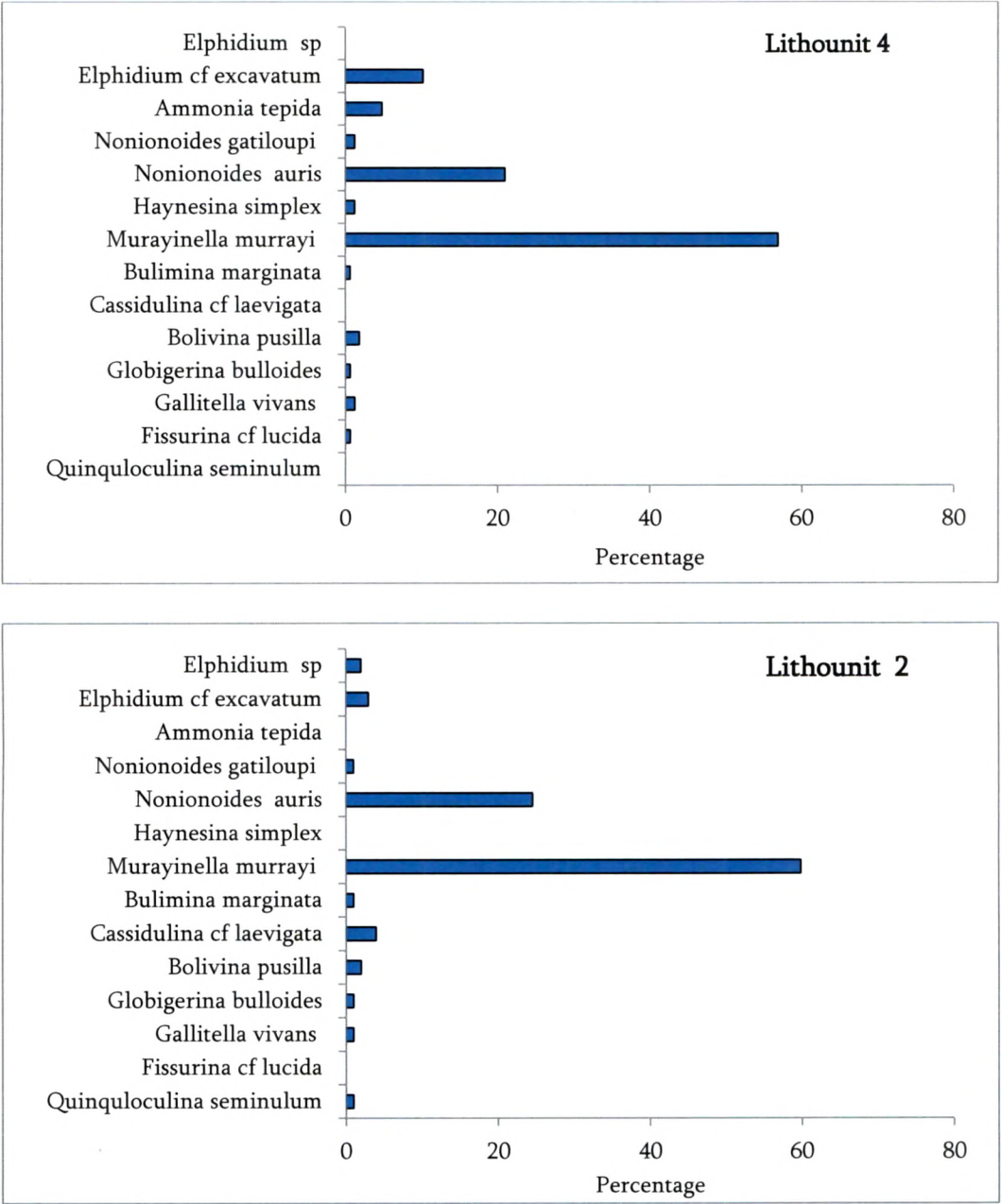


Figure 6-: Histogram showing relative percentages of foraminiferal species at lithounit 2 and lithounit 4.

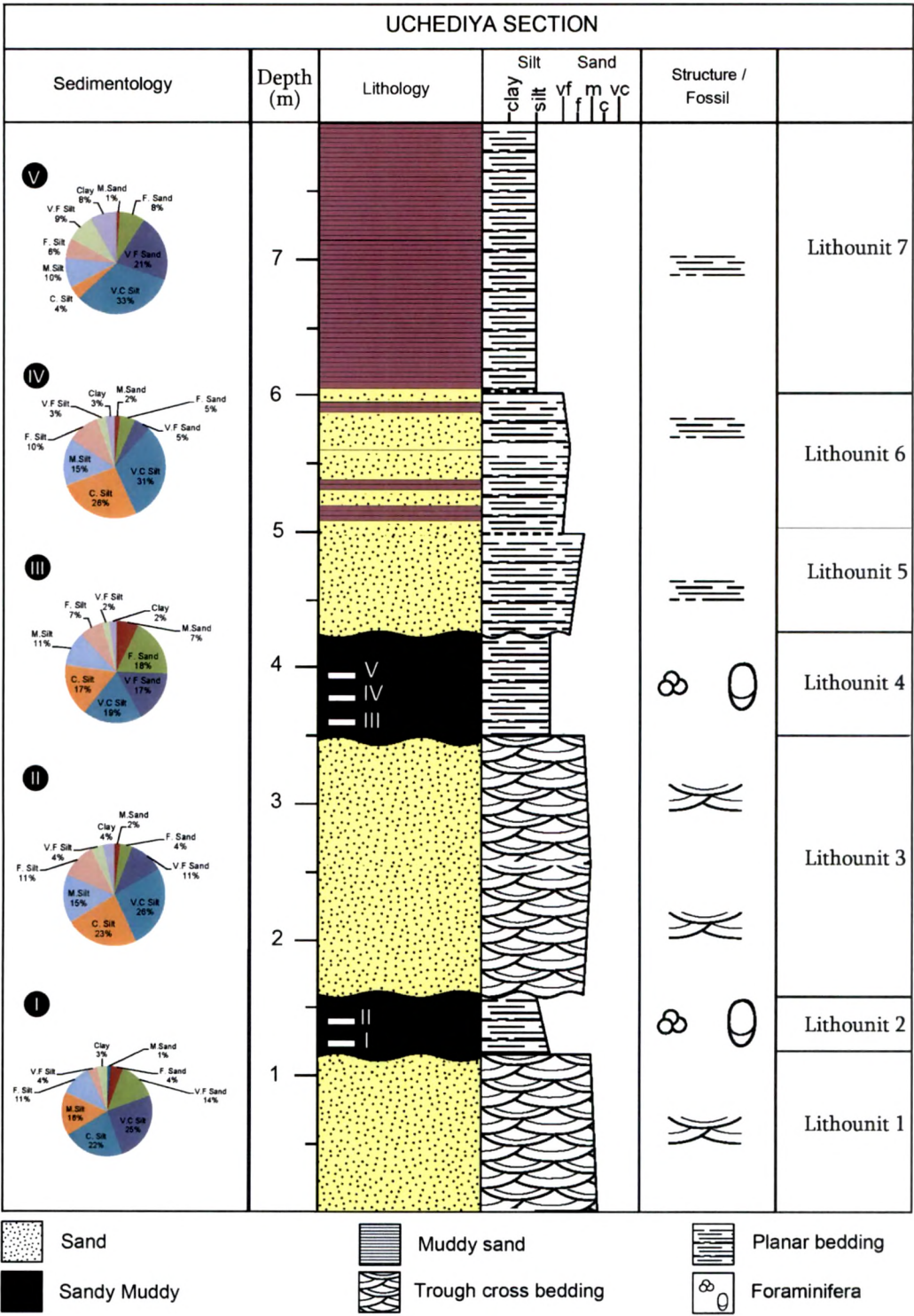


Figure 6-: Litholog of Uchediya sequence showing sedimentological characteristics of foraminifera bearing lithounits.

In the present stand point of view and considering chronology of the section there is no evidence to prove the sea level change or a base level change in a short period of ≈ 500 years. However, considering occurrence of planktonic and benthic foraminiferal assemblage, lower-upper bounding surfaces and the sedimentological characteristics together suggests that these muddy facies were deposited during catastrophic monsoonal storm with coastal upwelling.

6.5 Inferences

1. The late Holocene section exposed at Uchediya village in the southern bank of Lower reaches of Narmada preserve evidence of marine influences.
2. The present finding of foraminiferal assemblage at two levels above the present channel reveals occurrence of repeated palaeo-storm events in the lower reaches of Narmada valley through Arabian Sea.
3. The presence of *Bulimina marginata*, a low temperature marine fauna indicate a low temperature in the period during the deposition of the lower lithounit 2.
4. Presents of *Gallitella vivans*, a planktonic verity in the intertidal deposit indicate a post monsoonal upwelling of Gulf of Khambath and it has significantly modify the morphological setting of fluvial environment at the part of Lower reaches of Narmada.