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SOME FOSSIL ANASCAN BRYOZOAN TAXA FROM THE TERTIARY SEQUENCES OF WESTERN KACHCHH, GUJARAT

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ABSTRACT

Fifteen fossil anascan bryozoan species viz. *Biflustra mitiensis* n. sp., *Conopeum gohelaensis*, n. sp., *Herpetopora haimei* n. sp., *Akatopora aidaensis*, n. sp., *Antropora gadhavii*, n. sp., *Nellia quadrangularis* Tewari and Srivastava, 1967, *N. kutchensis* Tewari and Srivastava, 1967, *N. narayani* n. sp., *N. walasaraensis* n. sp., *Vincularia ramwaraensis*, n. sp., *Crepis gurjarensis*, n. sp., *Micropora vredenburgi* n. sp., *Microporina biswasi* n. sp., *Onychocella torquata*, n. sp. and *Floridina pentagonus* n. sp. belonging to 12 genera in eight families are described and illustrated. Stratigraphic ranges of *Nellia quadrangularis* Tewari and Srivastava, 1967 and *N. kutchensis* Tewari and Srivastava, 1967 are revised, and neotypes for these two species have been designated.

Key words: Tertiary, Kachchh, Gujarat, anascan Bryozoa, neotype

INTRODUCTION

The Tertiary sequences of rocks (Table 1) are exposed onland in narrow belts in the western part of Kachchh, Gujarat (Fig. 1) and their major part is extended in offshore areas up to the present continental shelf. The unique feature of this area is the preservation of a condensed 900-meter thick section of rock sequences ranging in age from the Paleocene to Pliocene along the highland of western part of onland Kachchh. Further, the boundaries of litho-, bio- and chronostratigraphic units in Kachchh are somewhat parallel and seldom mutually transgressive (Biswas, 1992).

Table 1 : Tertiary stratigraphy of Kachchh (after Biswas, 1992).

AGE	FORMATION	LITHOLOGY
Middle Miocene-Pliocene	SANDHAN --Unconformity--	Sandstones, minor limestones and shales.
Early Miocene (Burdigalian)	CHHASRA	Silty shales and impure Limestones.
Early Miocene (Aquitanian)	KHARI NADI --Unconformity--	Variegated siltstones and sandstones.
Oligocene (Rupelian-Chattian)	MANIYARA FORT --Unconformity--	Foraminiferal limestones, shales, coral bioherms and lumpy claystones.
Middle to early L. Eocene (Lutetian-Bartonian)	FULRA	Dense foraminiferal limestones.
Early Middle Eocene (Lutetian)	HARUDI --Unconformity --	Claystones/limestones, coquina, etc.
L. Paleocene to E. Eocene (Thanetian-Ypresian)	NAREDI --Unconformity --	Claystones, limestones and gypseous shales.
Early Paleocene (Thanetian)	MATANOMADH --Unconformity--	Volcanoclastics, shales and sandstones.
(Maastrichtian-Danian)	DECCAN TRAP	Basalt

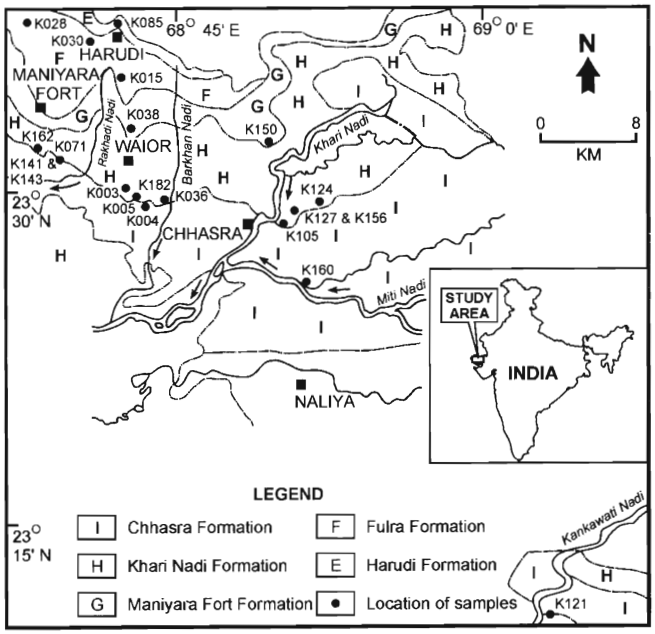

Fig. 1. Geological map of the Tertiary sequence of western Kachchh (after Biswas, 1992) showing the location of samples containing anascan bryozoan species.

D'Archiac and Haime (1853: cited by Tewari & Srivastava, 1967) first noted the occurrence of bryozoans in the Tertiary sequences of Kachchh. Tewari *et al.* (1960) reported two new free-living bryozoan taxa, and Tewari and Srivastava (1967) reported nine new bryozoan species from these sequences. Recently a diverse bryozoan assemblage comprising 99 species placed under 62 genera and 38 families has been reported from the Lutetian (middle Eocene) to Burdigalian (early Miocene) horizons (Table 1) of this area (Guha and Gopikrishna, 2005a). Of these 99 species, the order Cheilostomata is repre-

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sented by 92 species under 55 genera in 33 families. In general, the diversity of taxa and density of colonies under the anascan and ascophoran subdivisions of cheilostomes are somewhat comparable. Guha and Gopikrishna (2004a, b, 2005b, c) have described 25 anascan cheilostome species (including 24 new species) from these sequences. The present paper describes and illustrates 15 more species (including 13 new species) in this group belonging to 12 genera in eight families. Neotypes for *Nellia quadrangularis* Tewari and Srivastava, 1967 and *N. kutchensis* Tewari and Srivastava, 1967 are designated and stratigraphic ranges of these two species have been revised.

MATERIAL AND METHODS

A total of 1237 bryozoan colonies or their fragments have been retrieved from 21 rock samples (indicated in Fig. 1). Usual practice of cleaning of bryozoan colonies including the use of an ultrasonic cleaner was followed. Since the area belongs to the tropical climatic zone, the surface of bryozoan colonies bears the mark of diagenetic changes that have often masked finer morphologic features. For scanning electron microscopy, the specimens were photographed at 10 kv after coating with gold. Measurements of various parameters (Lz - zooecial length, wz - zooecial width, ha - apertural height, wa - apertural width, Lav - length of avicularium, wav - width of avicularium, hov - height of ovicell, wov - width of ovicell, Lkz - kenozooecial length, wkz - kenozooecial width) of adult zooecia (excluding the ancestrular part) were carried out with a WILD MMS 235 digital measuring unit fitted to a WILD M3C microscope. The ranges of such measurements with mean ($\bar{x}$) and sample size (N) are noted for holotype specimens for each taxon.

For systematic classification, Bassler (1953) along with the revision (Working list for Treatise) suggested by Gordon (2005) has been used. The suborder Anasca Levinsen, 1909 originally included several divisions such as Malacostega, Levinsen, 1902, Inovicellata Jullien, 1888, etc. (see Bassler, 1953). In the revision suggested by Gordon (2005), all anascan bryozoan taxa have been grouped under three suborders (Malacostegina Levinsen, 1902, Inovicellina Jullien, 1888, Scrupariina Silén, 1941) and one infraorder Flustrina Smitt, 1868 (under suborder Neocheilostomina d'Hondt, 1985). For preliminary identification of individual taxon, comparison has been made with published work of Canu and Bassler (1920, 1929), Berthelsen (1962), Tewari and Srivastava (1967), Gordon (1984, 1986), Taylor (1987), Moissette (1988), Badve and Sonar (1995), Guha and Nathan (1996), Taylor and Monks (1997), Tilbrook (1998) and Grischenko, *et al.* (2002) and figures available at the Bryozoa homepage of P. Bock <www.civgeo.rmit.edu.au/bryozoa>. Type material and illustration for each species were sent to Dr. D. P. Gordon of NIWA, Wellington, New Zealand for his comments.

Repository: The Holotype and Neotype specimens are preserved in the Central Fossil Repository Unit of the Geological Survey of India, Kolkata - 700 016, India and the paratypes are preserved in the museum of the Department of Geology and Geophysics, Indian Institute of Technology, Kharagpur 721 302, India.

SYSTEMATIC DESCRIPTION

Phylum **Bryozoa** Ehrenberg, 1831
Class **Gymnolaemata** Allman, 1856
Order **Cheilostomata** Busk, 1852
Suborder **Malacostegina** Levinsen, 1902
Superfamily **Membraniporoidea** Busk, 1852
Family **Membraniporidae** Busk, 1852
Genus ***Biflustra*** d'Orbigny, 1852

Biflustra mitiensis n. sp.
(Pl. I, figs. 1-2)

Material examined: Holotype - GSI Type No. K60/771, colony encrusting a high-spired gastropod shell. Paratypes - K156/026/002 - 011; 10 colonies.

Dimensions of holotype (in mm): Lz -$\bar{x}$ = 0.402, 0.348-0.473; wz -$\bar{x}$ = 0.271, 0.235 - 0.344; ho - x= 0.252, 0.219 - 0.293 and wo -$\bar{x}$ = 0.179, 0.151- 0.224 (N = 25).

Type Horizon and locality: Argillite horizon of the Khari

EXPLANATION OF PLATE I

(Unless otherwise stated, all figures are SEM images)

1-2. ***Biflustra mitiensis*** n. sp. 1. General aspect of the Holotype colony (GSI Type No. K60/771, early Miocene - Aquitanian). 2. Close-up view showing prominent tuberose cryptocyst and a pair of well-raised tubercles marked with arrows).

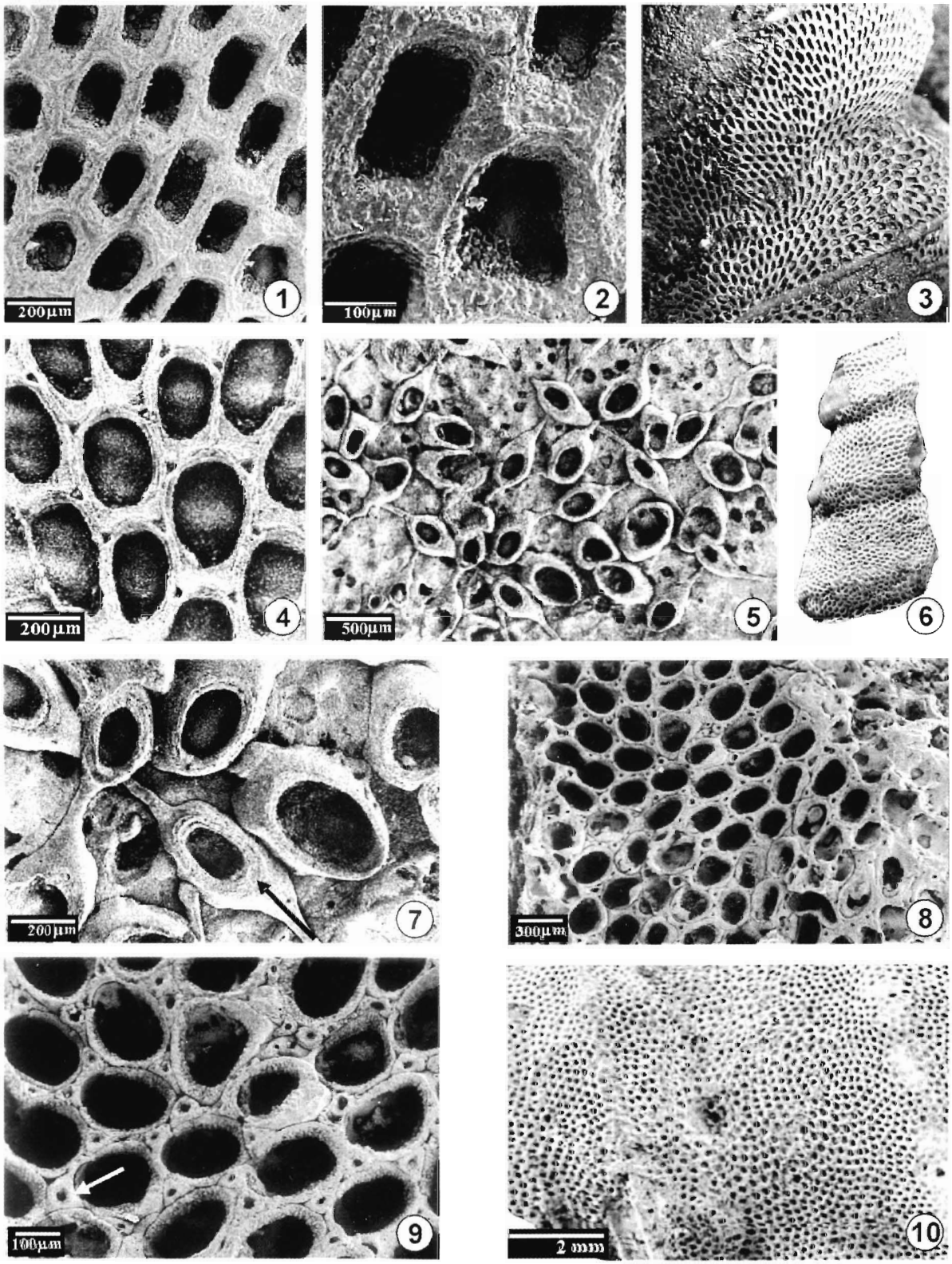
3-4. ***Conopeum gohelaensis*** n. sp. 3. General view of the Holotype colony (GSI Type No. K60/772, early Miocene - Aquitanian) encrusted on a high-spired gastropod shell X 10 (photoautomat image). 4. Details of zooecia and interopesial cavities.

5-6. ***Herpetopora haimei*** n. sp. 5. General view of the Holotype colony showing uniserial zooecia (GSI Type No. K60/773, middle Eocene - Lutetian). 6. Details of autozooecial features, regenerated mural rim (black arrow) and large uniporous septula (white arrow).

7-9. ***Akatopora aidaensis*** n. sp. 7. The Holotype colony (GSI Type No. K60/774, early Miocene - Aquitanian) on gastropod shell, X 10 (photoautomat image). 8. General aspect. 9. Details of autozooecia, avicularia, kenozooecia and mural septula (ovicell marked with white arrow).

10. ***Antropora gadhavii*** n. sp. 10. General aspect of the Holotype colony (GSI Type No. K60/775, early Miocene - Aquitanian).

Plate I



Nadi Formation near the Haripar village, 10km south of Goyela village along the Matanomadh-Naliya road.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name 'mitiensis' is after the Miti River near the type locality.

Diagnosis: Encrusting unilaminar colonies with autozooecia having parallel lateral walls and arched distal and proximal margins; cryptocyst prominent, coarse, tuberose with one or two rows of tubercles descending into opesia; opesia longer than wide. A pair of well-raised tubercles at the proximolateral corners of each zooid. Avicularia and ovicells not observed.

Description: Colonies encrusting, unilaminar; autozooecia arranged in regular alternating rows. Autozooecia subrectangular arched distally. Cryptocyst well developed proximally, coarsely tuberose and narrowed along the lateral walls with one or two rows of tubercles descending into the opesium. Lateral walls rise a little above the autozooecial surface, margins indistinct. Gymnocyst indistinct, represented by a pair of prominent knobs located at the proximolateral corners of each zooid. Opesia large, distally placed with a thin crescentic tuberose rim. Avicularia and ovicells not observed.

Remarks: This species resembles *Biflustra denticulata* Smitt, 1873 in having tuberose cryptocyst and tubercles. However, *B. denticulata* has a smooth well-developed gymnocyst whereas the Kachchh taxon lacks a prominent gymnocyst and has parallel lateral walls with one or two rows of tubercles descending into the opesia. *Biflustra tenuis* (Desor, 1848) as redescribed by Badve and Sonar 1995, p. 328, pl. 45, figs. 4, 5 & 6) has autozooecia closely resembling the present taxon but differ in having an asymmetrical proximal cryptocyst.

Distribution: Eleven colonies from the type locality.

Family **Electridae** d'Orbigny, 1851

Genus ***Conopeum*** Gray, 1848

Conopeum gohelaensis n. sp.

(Pl. I, figs. 3-4)

Material examined: Holotype - GSI Type No. K60/772, unilaminar colony encrusting on high-spired gastropod shell. Paratypes - K156/025/002 - 003, K127/001 - 004, K127/006 - 009; 10 colonies.

Dimensions of holotype (in mm): Lz -$\bar{x}$ = 0.451, 0.392 - 0.513; wz -$\bar{x}$ = 0.265, 0.228 - 0.312; ho -$\bar{x}$ = 0.354, 0.600 - 0.399 and wo -$\bar{x}$ = 0.220, 0.177 - 0.249 (N = 15).

Type horizon and locality: Argillite horizon of the Khari Nadi Formation at Haripar village, 10km south of Gohela village along the Matanomadh-Naliya road.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name 'gohelaensis' is after the Gohela village near the type locality.

Diagnosis: Unilaminar encrusting colonies with oval to elliptical autozooecial outline. Cryptocyst distinct, narrow, finely rugose; opesia large with finely crenulated margins; mural rim flat; interopesial cavities small, triangular, one each on the distolateral corners of the zooid. Avicularia, spine bases and ovicells not observed.

Description: Unilaminar colonies encrusting high-spired gastropod shells. Autozooecia arranged in alternating series; oval to elliptical in outline; cryptocyst distinct, narrow, finely granular, thin laterally, widened proximally; gymnocyst indistinct. Lateral walls medium; zooecial margins marked by fine grooves; septulae indistinct. Opesia large; outline as that of respective autozooid; occupying about 90% of total zooecial frontal; mural rim smooth with fine crenulations descending into the opesia. Small interopesial cavities, triangular in outline, one each on the distolateral corners of the zooid. Avicularia, spines and ovicells not observed.

Remarks: Though the present taxon is very much similar to *Jellyella tuberculata* (Bosc, 1802) redescribed by Taylor and Monks (1997, p. 46, figs. 14-15), the presence of distinct cryptocyst and absence of spines around the opesium rules out the placement of this taxon under *Jellyella* Taylor and Monks, 1997. Owing to the triangular interopesial cavities along with absence of avicularia, spines and ovicells the present taxon is placed under the genus *Conopeum* Gray, 1848. The present taxon is much similar to the Recent *Conopeum reticulum* (Linnaeus, 1767) illustrated by Grischenko *et al.*, 2002 (p. 1285, fig. 22). However, *C. reticulum* has very narrow cryptocyst and margin of opesia densely crenulated. In aspects of zooecial morphology the Kachchh taxon resembles the North American early Tertiary species *Conopeum lamellosum* described by Canu and Bassler, 1929 (p. 92, pl. 20, figs. 1-9) but *C. lamellosum* exhibits multilaminar growth habit and has a finely punctate mural rim. The squarish or polygonal zooecial outline, pair of muscle scars on basal wall, sparsely occurring interopesial cavities and numerous septulae of *C. raoei* described by Guha and Nathan (1996, p. 85, pl. 10, figs. 4-5) from the Cretaceous of South India clearly distinguish the Ariyalur species from the Kachchh taxon.

Distribution: 11 colonies from the type locality.

Genus ***Herpetopora*** Lang, 1914

Herpetopora haimei n. sp.

(Pl. 1, figs. 5-6)

Material examined: Holotype - GSI Type No. K60/773, a large colony encrusting saddle-shaped of *Discocyclina*. Paratype - K085/011/002 - 15; 14 colonies.

Dimensions of holotype (in mm): Lz -$\bar{x}$ = 0.755, 0.619 - 0.988; wz - $\bar{x}$ = 0.343, 0.294 - 0.458; ho -$\bar{x}$ = 0.298, 0.217 - 0.429 and wo - $\bar{x}$ = 0.184, 0.139 - 0.265 (N=22).

Type horizon and locality: Argillaceous horizon of the Harudi Formation from the base of cliff, north of Harudi village by the left side of the road from Waior to Narayan Sarovar.

Age: middle Eocene (Lutetian).

Derivation of name: The specific name *'haimei'* is in honor

of Jules Haime who with Viscount Ekienne D'Archiac first noted the occurrence of Bryozoans from the Tertiary sequences of western Kachchh in 1853 (cited in Tewari and Srivastava, 1967).

Diagnosis: Encrusting uniserial colonies with bilateral ramification; autozooecia pyriform with narrow cryptocyst. Gymnocyst smooth, extending to form a long caudal structure proximally whose length increases regularly in successive zooecia of each branch. Lateral walls high, smooth with a single large uniporous septula; opesia entire, elongate-elliptical in outline with smooth opesial rim. Avicularia and ovicells not observed.

Description: Colonies extensive, encrusting; with autozooecia arranged in long uniserial chains with bilateral ramification; budding distal and distolateral. New uniserial branches of zooecia arise as distolateral buds oriented at an angle of 60-90 degrees to the parent branches. Autozooecia elongate, pyriform, highly variable in dimensions. Cryptocyst narrow, indistinct; lateral walls high, smooth; steeply slanting to the encrusting surface with large uniporous septula on either side; basal lamina not calcified. Gymnocyst prominent, smooth, extending proximally to form a long, smooth caudal structure; cauda not developed in few autozooecia; regular increase in zooecial length in successive zooids of a branch. Opesia complete, elliptical in outline, opesial rim smooth; one or two smooth concentric mural rims on the inner periphery of opesium due to regeneration observed at places. Kenozooecia commonly budded at ends of branches, narrower than autozooecia with small opesia. Avicularia and ovicells not observed.

Remarks: The present species resembles the North American early Tertiary species *Pyripora parvicella* Canu and Bassler, 1920 (p. 87, pl. 3, fig. 1) and *Pyripora tuberculum* Londsale, 1845 as illustrated by Canu and Bassler, 1920 (p. 80, pl.19, fig. 4) in autozooecial morphology. However, the Kachchh taxon lacks a prominent cryptocyst and the autozooecia show regular increase in length in successive series in each branch confirming its placement under the genus *Herpetopora* Lang, 1914. The Kachchh species resembles the British Cretaceous species *Herpetopora anglica* Lang, 1914, as illustrated by Taylor (1987, p. 40, pl. 4 fig. 4; pl. 7, fig. 1) in zooecial morphology. In *H. anglica*, Taylor (1987) observed regeneration of zooecia (intramural reparative budding, see Taylor, 1988) with two or more concentric mural rims, degenerated zooecia with closure plates bearing crescentic impression of the operculum, a large uniporous septula on lateral wall and zooecial length sometimes exceeding 5mm. Among 196 colonies examined, the Kachchh taxon has some zooids with two to three concentric mural rims formed by reparative budding, but lacks closure plates and zooecial length rarely exceeds 1mm. Of the five types of branch intersections observed in *Herpetopora* colonies (Taylor, 1988, p. 533, text - fig. 7), the colonies of the present taxon commonly exhibit type 1a (abutment) and type 2 (overgrowth), while in some colonies (Pl. 1, fig. 5) type 4 (lateral collision) (resulting in deformation of the mural rim) is also observed.

Distribution: 185 colonies from the type locality and 11 colonies from the Harudi cliff section of the Harudi Formation.

Suborder **Neocheilostomina** d'Hondt, 1985
Infraorder **Flustrina** Smitt, 1868
Superfamily **Calloporoidea** Norman, 1903
Family **Antroporidae** Vigneaux, 1949
Genus ***Akatopora*** Davis, 1934

Akatopora aidaensis n. sp.
(Pl. I, figs. 7-9)

Material examined: Holotype - GSI Type No. K60/774, unilaminar colony encrusting high-spired gastropod shell. Paratypes - K127/027/002 - 13; 12 colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.273, 0.241-0.363; wz - $\bar{x}$ = 0.201, 0.176 - 0.206; ho - $\bar{x}$ = 0.199, 0.175 - 0.297 and wo - $\bar{x}$ = 0.106, 0.128 - 0.190 (N = 15). Kenozooecia: Lkz - $\bar{x}$ = 0.092, 0.076 - 0.117 and wkz - $\bar{x}$ = 0.060, 0.043 - 0.080 (N = 15).

Type horizon and locality: Argillites of the Khari Nadi Formation exposed over the cliff of the Khari Nadi River, west of the Haripar village.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name "*aidaensis*" is after Aida village near the type locality.

Diagnosis: Unilaminar encrusting colonies with oval to elliptical autozooecial outline; cryptocyst narrow, finely tuberose, descending into opesia; opesia entire; kenozooids numerous, oval to triangular with a well-developed cryptocyst; avicularia similar to the kenozooids, larger without pivots; septulae large, numerous, uniporous; ovicells sparsely occurring, small, endozooecial and of cap-like appearance.

Description: Large mats of unilaminar colonies encrusting high-spired gastropod shells; autozooecial arrangement generally regular, but sometimes small subcolonies grow over the parent colony giving an appearance of multilaminar habit. Autozooecial outline oval to elliptical, trigonal at places; cryptocyst distinct, narrow, finely tuberose, descending into the opesia and slightly wider proximally. Zooidal boundaries distinct; separated by fine grooves; lateral walls medium; septulae large, numerous, uniporous, situated all along the inner margin of the lateral walls. Opesia entire, outline as that of respective autozooid. Numerous kenozooids, often in groups of 3-6, confluent with one another; generally placed distal or slightly distolateral to autozooecia; triangular to oval in outline with finely tuberose cryptocyst; cryptocystal rim rising a little above the surrounding autozooecia. Avicularia similar in shape to kenozooids, but slightly larger in size with complete opesia and lacking pivots. Ovicells very rare, small, endozooecial, cap-like in appearance.

Remarks: Dr. D. P. Gordon (pers. comm., 2003), on examining the paratype material of this taxon, commented that

the present genus has many smaller kenozooids that is typical of *Conopeum* Norman, 1903 and the larger kenozooids appear to be avicularian in character, even though they lack pivots or crossbars. Regarding the nature of cryptocyst, kenozooids and large uniporous septula, the present taxon is quite similar to the extant *Akatopora circumsaepta* Uttley reported by Gordon (1986, p. 35, pl.7 B-D) from the Western South Island, off New Zealand. However, *A. circumsaepta* has fewer kenozooids, more septulae and common ovicells, while the Kachchh taxon has many kenozooids, often present in groups of 3 to 6, fewer septulae and very rare ovicells. Dr. P. D. Taylor (pers. comm., 2005), while reviewing an earlier version of the manuscript, commented that *Akatopora* is often a hermit crab symbiont. Though large crabs are common in the Khari Nadi Formation, no small crabs were found to occur near the high-spired gastropod shells (about 3-4cm long) on which the colonies of this species were encrusted.

Distribution: 21 colonies from the type locality.

Genus ***Antropora*** Norman, 1903

Antropora gadhavii n. sp.

(Pl. I, fig. 10; Pl. II, fig. 1)

Material examined: Holotype - GSI Type No. K60/775, a large colony encrusting high-spired gastropod shell. Paratypes - K127/008/002 -3; two colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.292, 0.242 - 0.366; wz - $\bar{x}$ = 0.241, 0.209 - 0.297; ho - $\bar{x}$ = 0.201, 0.155 - 0.253 and wo - $\bar{x}$ = 0.145, 0.114 - 0.168 (N = 15). Avicularia: Lav - $\bar{x}$ = 0.114, 0.074 - 0.143 and wav - $\bar{x}$ = 0.085, 0.065 - 0.110 (N = 20).

Type horizon and locality: Argillites of the Khari Nadi Formation exposed over the cliff of the Khari Nadi, west of Haripar village.

Age: early Miocene (Aquitanian).

Derivation of name: After Mr. Mangal Gadhavi of Waior village, who helped as facilitator in the three stints of fieldwork (between 1995-1998) in the difficult terrain of western Kachchh, Gujarat.

Diagnosis: Unilaminar encrusting colonies with thick medium-sized subtrigonal to subrectangular autozooecia having narrowed distal arch and broad proximal margin. Heavily calcified narrow cryptocyst descending into the opesia; opesia subtrigonal to subrectangular. Avicularia interzooecial, oval in outline with complete opesia. Ovicells not observed.

Description: Colonies unilaminar, encrusting high-spired gastropod shells resembling honeycomb structure. Autozooecia thick, medium-sized, subtrigonal to subrectangular in outline, distally narrowed and proximally broader with a truncated margin. Cryptocyst narrow, granular, heavily calcified, descending into the opesia. Gymnocyst indistinct, not well-developed. Basal lamina not calcified; lateral walls medium; zooecial boundary distinct; septulae few, small, rounded, uniporous. Opesia large, subtrigonal to subrectangular in outline, longer than wide, almost entire, extending over much of the frontal. Avicularia small, oval or drop-shaped with acute tips, interzooecial, irregular in disposition and placed at corners between zooecia; opesia of avicularium entire, surrounded by thin narrow cryptocyst; pivot not preserved; rostrum indistinct. Ovicells not observed.

Remarks: In the morphology of zooecia and avicularia the present taxon resembles *Antropora tincta* (Hastings, 1930) and *Antropora typica* (Canu and Bassler, 1928) described and illustrated by Tilbrook (1998, p. 31, figs. 1D-E and p. 36, figs. 1F and 3A). *A. tincta* has a multilaminar growth form with thin crenulated mural rim, inner margins of cryptocyst often denticulate, avicularium opesia with condyles and endozooidal ovicells. *A. typica* has a prominent gymnocyst, sporadically occurring large vicarious avicularia and endozooidal ovicells. The dimensions of zooecia of the above-mentioned species are also higher than the Kachchh taxon. Based on these considerations the present taxon is

EXPLANATION OF PLATE II

(Unless otherwise stated, all figures are SEM images)

1. ***Antropora gadhavii*** n. sp. 1. Details of autozooecia and avicularia.

2-3. ***Nellia quadrangularis*** Tewari and Srivastava, 1967. 2. General aspect of Neotype specimen (GSI Type No. 22172, Oligocene – Rupelian–Chattian). 3. Another specimen (K071/069/001, early Miocene – Aquitanian) showing details of avicularia (black arrow) and large distal septulae (white arrow).

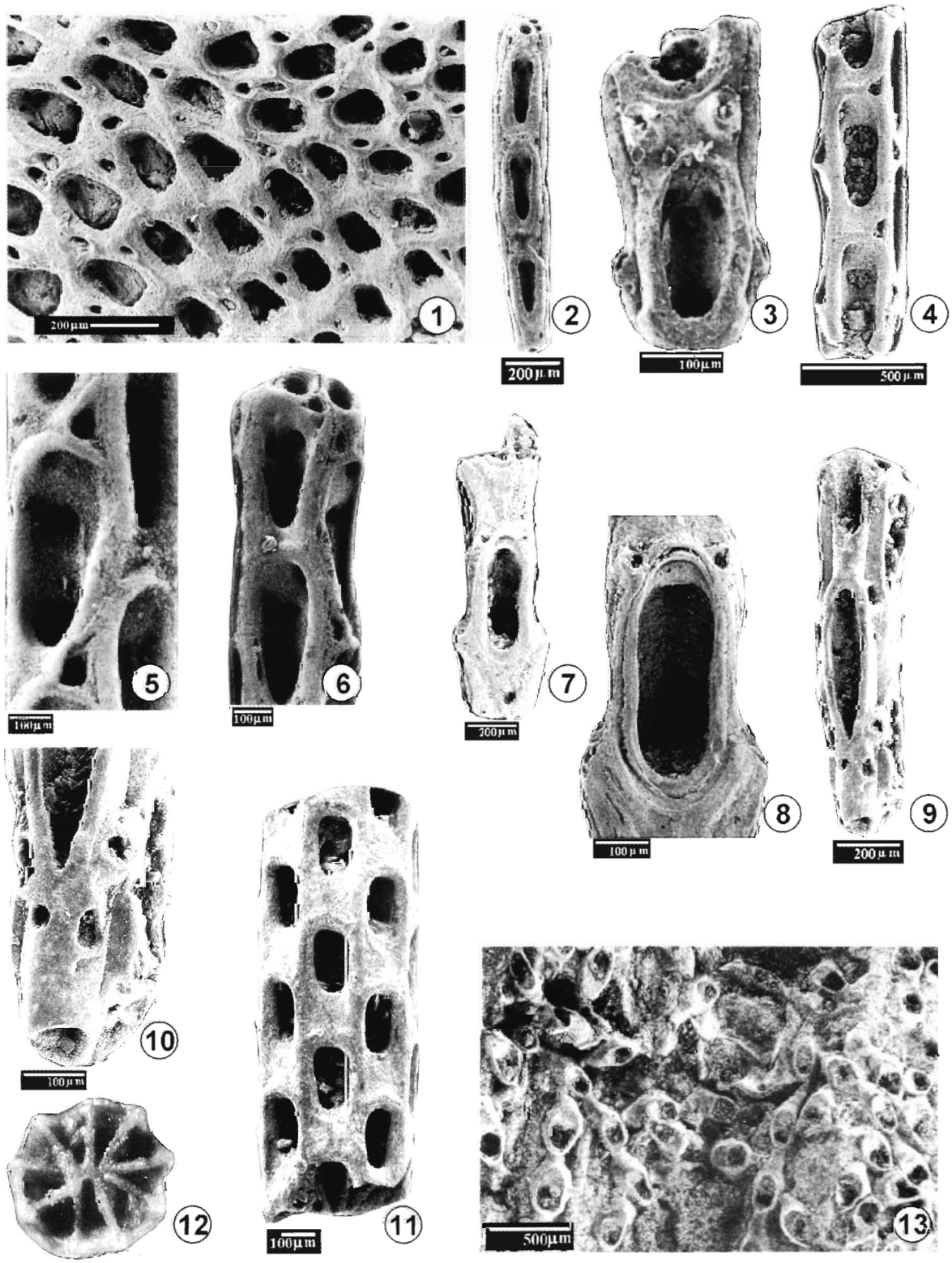
4-6. ***Nellia kutchensis*** Tewari and Srivastava, 1967. 4. General aspect of Neotype specimen (GSI Type No. 22173, Khari Nadi, early Miocene – Aquitanian). 5-6. Another specimen (K003/068/002, Early Miocene – Aquitanian). 5. Details of mural rim and avicularia. 6. View showing three large mural septulae (marked with arrows).

7-8. ***Nellia narayani*** n. sp. 7. General aspect of the Holotype colony (GSI Type No. K60/776, middle Eocene - Lutetian). 8. Details of gymnocyst, mural rim and avicularium.

9-10. ***Nellia walasaraensis*** n. sp. 9. General aspect of the Holotype colony (GSI Type No. K60/777, Oligocene - Rupelian-Chattian). 10. Tubular gymnocyst and avicularia (marked with arrow).

11-12. ***'Vincularia' ramwaraensis*** n. sp. 11. Details of autozooecia of the Holotype colony (GSI Type No. K60/778, early Miocene - Aquitanian). 12. Cross-sectional view, X 136 (photoautomat image).

13. ***Crepis gurjarensis*** n. sp. 13. View showing branching uniserial zooecia of the Holotype colony (GSI Type No. K60/779, early Miocene - Aquitanian).


1
200 µm
2
200 µm
3
100µm
4
500 µm
5
100µm
6
100µm
7
200µm
8
100 µm
9
200 µm
10
100 µm
11
100µm
12
13
500µm

described as *Antropora gadhavii* n. sp.

Distribution: 14 colonies from the type locality.

Family **Quadricellaridae** Gordon, 1984

Genus ***Nellia*** Busk, 1852

Nellia quadrangularis Tewari and Srivastava, 1967 (Pl. II, figs. 2-3)

Nellia quadrangularis Tewari and Srivastava, 1967, p.22-24, fig. 2, Nos.3 and 3a.

Material examined: Neotype - GSI Type No. 22172, a small fragment with three zooecia in a series (Pl. II, fig. 2). Other well preserved specimens: K071/069/001(Pl. II, fig. 3) K071/069/002 - 22, K141/001- 82, K143/ 001-27, K160/001- 14, K162 / 001 - 12, K182 /001- 10; 167 fragments.

Dimensions (in mm): Holotype (Tewari and Srivastava, 1967, p. 24) Lz - 0.300 - 0.330; wz - 0.130 - 0.150; ho - 0.180 - 0.210 and wo - 0.070 - 0.080. Paratype (Tewari and Srivastava, 1967, p. 24) Lz - 0.310 - 0.340; wz - 0.150 - 0.170; ho - 0.190 - 0.210 and wo: 0.070 - 0.080. The dimensions of avicularia were not given in the original description.

Mean dimensions and ranges of parameters in present collection: Lz - $\bar{x}$ = 0.426, 0.319 - 0.597; wz - $\bar{x}$ = 0.183, 0.148 - 0.224; ho - $\bar{x}$ = 0.307, 0.232 - 0.515 and wo - $\bar{x}$ = 0.113, 0.101- 0.165 (N = 58). Avicularia: Lav - $\bar{x}$ = 0.076, 0.052 - 0.124 and wav - $\bar{x}$ = 0.050, 0.037 - 0.073 (N = 85).

Description: Colonies slender, erect, subsquarish in cross section. Four vertical rows of autozooecia on four sides of colonies separated by shallow fine canal-like longitudinal furrows. Zooecia elongate, arranged in regular, alternate, paired rows, and placed back to back about the central zoarial axis. In many colonies the back to back placed paired rows of zooecia have similar dimensions and differ much from those of the other two zooecial rows (two rows of broad zooecia and two narrower ones). Zooecia slightly elevated; oval in outline with rounded extremities; opesia large, oval, broader distally; opesial rim smooth. Zooecia generally have a large proximal septula and three distal septulae. Avicularia small, paired, one each on the proximolateral corners of the gymnocyst; opesia of avicularium rostrum prominent with well-raised rostral sides. Ovicells not observed.

Remarks: Material belonging to the present collection is much in accordance with the *Nellia quadrangularis* Tewari and Srivastava, 1967 (p.22-24, fig.2, nos. 3 and 3a) reported from the early Miocene ('Upper Gaj' - Burdigalian) beds of western Kachchh. As reported by the Department of Geology, University of Lucknow, the type specimens of this species are permanently misplaced (Prof. M. P. Singh, pers. comm., 2003) and the present description is that of the Neotype, selected here, and associated specimens in our collection. The ranges of zooecial and apertural dimensions of our colonies are much wider than those given by Tewari and Srivastava (1967, p. 24). Though the present taxon resembles the type species *Nellia oculata* Busk, 1852, the presence of prominent gymnocyst and un-identical zoarial faces in *N. quadrangularis* differentiates it from *N. oculata*. This species differs from *N. kutchensis* Tewari and Srivastava, 1967 in having a pair of proximolateral avicularia instead of one distolateral avicularium. *N. walasaraensis* n. sp. of the Maniyara Fort Formation has larger dimensions and a flat broad gymnocyst, while *N. narayani* n. sp. of the Harudi Formation has an elongated tubular gymnocyst. All are distinct from the present taxon. Tewari and Srivastava (1967) reported this species only from the Burdigalian stage (Chhasra Formation), whereas specimens in our collection include some from the Maniyara Fort Formation, thereby extending the lower age limit down to the Rupelian.

Distribution: Of 260 fragments belonging to this species present in the assemblage, 11 come from the Maniyara Fort Formation, 80 from the Khari Nadi formation and 169 from the Chhasra Formation. Thus, this species earlier reported from the ('Upper Gaj' - Burdigalian) beds by Tewari and Srivastava (1967) has now a revised longer range from Oligocene (Rupelian-Chattian) to early Miocene (Burdigalian).

Nellia kutchensis Tewari and Srivastava, 1967 (Pl. II, figs. 4-6)

Nellia kutchensis Tewari and Srivastava, 1967, p.24-26, fig. 2, nos.1 and 1a.

Material examined: Neotype - GSI Type No. 22173, a small fragment with two and half zooecia in a series (Pl. II, fig. 4). Other well preserved specimens: K003/068/002 (Pl. II, figs. 5 & 6), K003/068/003 - 5, K004/001-3, K028/001 - 3, K030/003 - 32, K036/001 - 11, K038/001- 19, K071/001 - 26, K081/001 - 20, K105/001 - 9, K121/001, K150/001 - 2, K162/001 - 5; 136 fragments.

Dimensions (in mm): Holotype (Tewari and Srivastava, 1967, p.24) Lz - 0.710-0.740; wz - 0.440-0.460; ho - 0.560 - 0.580 and wo - 0.230 - 0.250. Paratype (Tewari and Srivastava, 1967, p.24) Lz - 0.710 - 0.730; wz - 0.430 - 0.460; ho - 0.560 - 0.580 and wo - 0.250 - 0.260. The dimensions of avicularia were not given in the original description.

Ranges and mean dimensions of parameters in present collection: Lz - $\bar{x}$ = 0.656, 0.439 - 0.853; wz - $\bar{x}$ = 0.347, 0.250 - 0.509; ho - $\bar{x}$ = 0.430, 0.265 - 0.636 and wo - $\bar{x}$ = 0.231, 0.149 - 0.355 (78 zooecia measured in 12 colonies). Avicularia Lav - $\bar{x}$ = 0.154, 0.096 - 0.234 and wav - $\bar{x}$ = 0.087, 0.060 - 0.128 (64 avicularia measured in 12 colonies).

Description: Colonies slender, erect, rhombic to subsquarish in cross section. Four vertical rows of autozooecia on four sides of colonies separated by two rows of avicularia on acute edges. Autozooecia elongate; arranged in regular, alternate, paired rows and placed back to back about the central zoarial axis. In many of the colonies measured, the back to back placed paired rows of zooids have similar dimensions and differ much from those of the

other paired rows (two rows of broad zooids and two narrower ones). Autozooecia of average depth, proximally more depressed with oblique opening, subrectangular to elongate oval in outline with thick lateral walls; lateral sides straight, extremities rounded and confluent with autozooecia of adjacent rows. Opesia elongate oval to elliptical, obliquely placed; distal margin of the opesia wider than the proximal; opesial rim smooth. Most colonies with a large proximal septula and three distal septulae; few with single distal septula. Avicularia placed along acute edges of the rhombic segment; each zooecium having one avicularium on either right or left distolateral corner; trigonal in outline, slightly raised distally and proximally flush with the surface; opesia of avicularium undivided; oval to trigonal in outline with indistinct rostrum. Ovicells not observed.

Remarks: Material belonging to the present collection is much in accordance with the *Nellia kutchensis* Tewari and Srivastava, 1967 (p.24-26, fig.2, nos. 1 and 1a) reported from the Early Miocene ('Upper Gaj' - Burdigalian) beds of western Kachchh. As reported by the Department of Geology, University of Lucknow, the type specimens of this species are permanently misplaced (Prof. M. P. Singh, pers. comm., 2003) and the present description is that of the Neotype, chosen here, and associated specimens in our collection. The avicularia in the original type material were described as occurring only on the right proximolateral corners of gymnocyst. However, specimens belonging to the present collection have their avicularia placed along acute edges of the rhombic segment, each zooecium having one avicularium on either right or left distolateral corner. Further, the zooecial and apertural dimensions of the specimens belonging to the present collection have much wider ranges when compared with those given by Tewari and Srivastava (1967, p. 24). *N. quadrangularis* Tewari and Srivastava, 1967, also recognised in the present assemblage, has two avicularia on the proximolateral corners of the gymnocyst. *N. walasaraensis* n. sp., described from the Maniyara Fort Formation has large zooecia and an elongated tubular gymnocyst. *N. narayani* n. sp. from the Harudi Formation has a flat broad gymnocyst with a pair of avicularia on the proximolateral corners. Tewari and Srivastava (1967, p. 26) reported *N. kutchensis* from the Chhasra Formation (Burdigalian) only, whereas the present collection includes material from the Fulra, Maniyara Fort and Khari Nadi Formations, thereby extending the lower age limit of the taxon to Middle Eocene (Lutetian).

Distribution: Of the 410 fragments of this species in the present collection 57 zoarial fragments are from the Fulra Formation, 121 from the Maniyara Fort Formation, 64 from the Khari Nadi Formation and 168 from the Chhasra Formation. Thus this species, earlier reported from the ('Upper Gaj' - Burdigalian) beds by Tewari and Srivastava (1967) now has a revised longer range from Middle Eocene (Lutetian) to Early Miocene (Burdigalian). It may be further noted that for both the species of Tewari and Srivastava (1967), i. e. *N. quadrangularis* and *N. kutchensis*, the density increases in the Chhasra Formation (Burdigalian).

Nellia narayani n. sp.

(Pl. II, figs. 7-8)

Material examined: Holotype - GSI Type No. K60/776, a small erect vinculariiform colony with few zooecia. Paratypes - K085/100/002 - 6; five colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.777, 0.725 - 0.840; wz - $\bar{x}$ = 0.500, 0.473 - 0.514; ho - $\bar{x}$ = 0.547, 0.525 - 0.575 and wo - $\bar{x}$ = 0.189, 0.183 - 0.199 (N = 4). Avicularia: Lav - $\bar{x}$ = 0.129, 0.121 - 0.139 and wav - $\bar{x}$ = 0.101, 0.095 - 0.111 (N = 6).

Type horizon and locality: The argillaceous sediments of the Harudi Formation from the cliff, N of Harudi village by the side of the road from Waior to Narayan Sarovar.

Age: middle Eocene (Lutetian).

Derivation of name: The specific name is after Lord "Narayan", the deity of the famous Lakshminarayan temple of Narayan Sarovar, one of the most sacred pilgrimage sites of Hindus.

Diagnosis: Colonies slender, jointed, fairly stout, squarish in cross-section; four longitudinal rows of elliptical autozooecia alternating with each other. Gymnocyst well developed with a broader distal and narrowed proximal ends; opesia large, elliptical with smooth opesial rim. Avicularia paired, one each on the distolateral corners of the zooecia; trigonal in outline with complete opesia and indistinct rostrum.

Description: Colonies slender, erect, articulated, radicellate; subsquarish in cross-section. Four similarly sized rows of zooecia alternating with each other. Autozooecia elongate oval in outline with thick lateral walls; lateral sides straight; extremities rounded and confluent with zooecia of adjacent rows. Gymnocyst well developed, flat, faintly ridged with a broader distal and narrowed proximal. Opesia anterior, large, elliptical in outline with a thin distal marginal rim; width of opesia constant over the entire length; mural rim thick, smooth and slightly raised. Avicularia small, trigonal in outline, paired, one each on the distolateral corners of zooecia and confluent with opesial rim of the preceding zooid; opesia of avicularium complete; rostrum indistinct. Ovicells not observed.

Remarks: The present taxon is characterised by large dimensions of autozooecia and well-developed gymnocyst that is wider distally and narrowed proximally. The avicularia are paired and attached to distolateral margins of the opesium. This taxon resembles the North American early Tertiary species *Nellia midwayanica* Canu and Bassler 1920 (p. 197, pl. 4, figs. 20-21) in zooecial and avicularial aspects. However, the American species has much smaller zooidal dimensions and has radicular pore at the base of certain opesia. The radicellate

autozooecial aspect, shape of opesia and well-developed gymnocyst with avicularia on distolateral corners distinguish the present taxon from other species of *Nellia* belonging to this assemblage. Though there are only a few fragments in the present collection with few zooecia, for which dimensions can be measured, the characters of zooecia and avicularia are prominent and well-preserved, hence this taxon is described as *Nellia narayani* n. sp.

Distribution: Six colonies from the type locality.

Nellia walasaraensis n. sp.

(Pl. II, figs. 9-10)

Material examined: Holotype - GSI Type No. K60/777, a small erect vinculariiform colony. Paratypes - K150/099/002 - 4; three colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.883, 0.819 - 0.944; wz - $\bar{x}$ = 0.212, 0.209 - 0.216; ho - $\bar{x}$ = 0.563, 0.549 - 0.585 and wo - $\bar{x}$ = 0.151, 0.143 - 0.163 (N = 5). Avicularia: Lav - $\bar{x}$ = 0.159, 0.150 - 0.163 and wav - $\bar{x}$ = 0.081, 0.075 - 0.085 (N = 5).

Type horizon and locality: Foraminiferal limestones of the Maniyara Fort Formation of the Walasara waterfall section near the Ramania village.

Age: Oligocene (Rupelian-Chattian).

Derivation of name: The specific name "*walasaraensis*" is after Walasara village near the type locality.

Diagnosis: Colonies slender, jointed, rhombic in cross-section; four longitudinal rows of elongate-oval autozooecia alternating with each other; each row separated by a prominent longitudinal furrow; two opposite rows of broad zooids and two narrower ones. Gymnocyst smooth, elongate and tubular; opesia elongate with narrowed proximal region; a single avicularia either on proximolateral or distolateral corner of zooecial margin situated in between zooecial rows. Ovicells not observed.

Description: Colonies slender, erect, rhombic in cross section. Four vertical rows of autozooecia demarcated by shallow longitudinal furrows. Autozooecia arranged in regular, alternate, paired rows with two opposite rows of broader zooids and two narrower ones. Autozooecia elevated; elongate-oval to fusiform with smoothly curved zooidal margins. Gymnocyst tubular narrowed down proximally, thick and stout; surface smooth. Opesia large, elongate with much narrowed proximal; opesial rim thick, smooth and raised; the proximal and distal margins of opesia having one septula each on the inner walls of opesia. Avicularia placed in the marginal furrow separating adjacent zooecial rows; avicularia small, oval, confluent with either proximolateral or distolateral corners of the zooecia; opesia of avicularium small and oval. Ovicells not observed.

Remarks: This species is characterised by large dimensions of the autozooecia and a prominent tubular gymnocyst. It resembles the North American early Tertiary species *Nellia concatenata* Canu, 1907 (Canu and Bassler, 1920, p. 197, pl. 32, figs. 20-21) in zoarial and autozooecial aspects. However, the presence of avicularia distinguishes the Kachchh taxon from the American species. The much larger dimensions of zooecia, aperture and tubular gymnocyst separates this taxon from all other species of Nellia belonging to the Kachchh assemblage. Though there are only four fragments in the present collection with very few zooecia, the characters of autozooecia and avicularia are prominent and well preserved. Accordingly the taxon is described as *Nellia walasaraensis* n. sp.

Distribution: Four colonies from the type locality.

Family **Vinculariidae** Busk, 1854

Genus ***Vincularia*** Defrance, 1829

'Vincularia' ramwaraensis n. sp.

(Pl. II, figs. 11-12)

Material examined: Holotype - GSI Type No. K60/778, an erect vinculariiform colony. Paratypes - K071/006/002-20; K121 /001, K 036 /001-3, K 124/ 006/001-004; 27 colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.399, 0.377 - 0.419; wz - $\bar{x}$ = 0.222, 0.212 - 0.238; ho - $\bar{x}$ = 0.220, 0.212 - 0.234 and wa - $\bar{x}$ = 0.128, 0.118 - 0.136 (N = 15).

Type horizon and locality: The Khari Nadi Formation, 100 m NW along the road to Naniber village arising out of the Waior - Ramwara road.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name "*ramwaraensis*" is after Ramwara village near the type locality.

Diagnosis: Erect, long, slender, articulated (inferred) columnar stems with subrectangular autozooecia arched

EXPLANATION OF PLATE III

(All figures are SEM images)

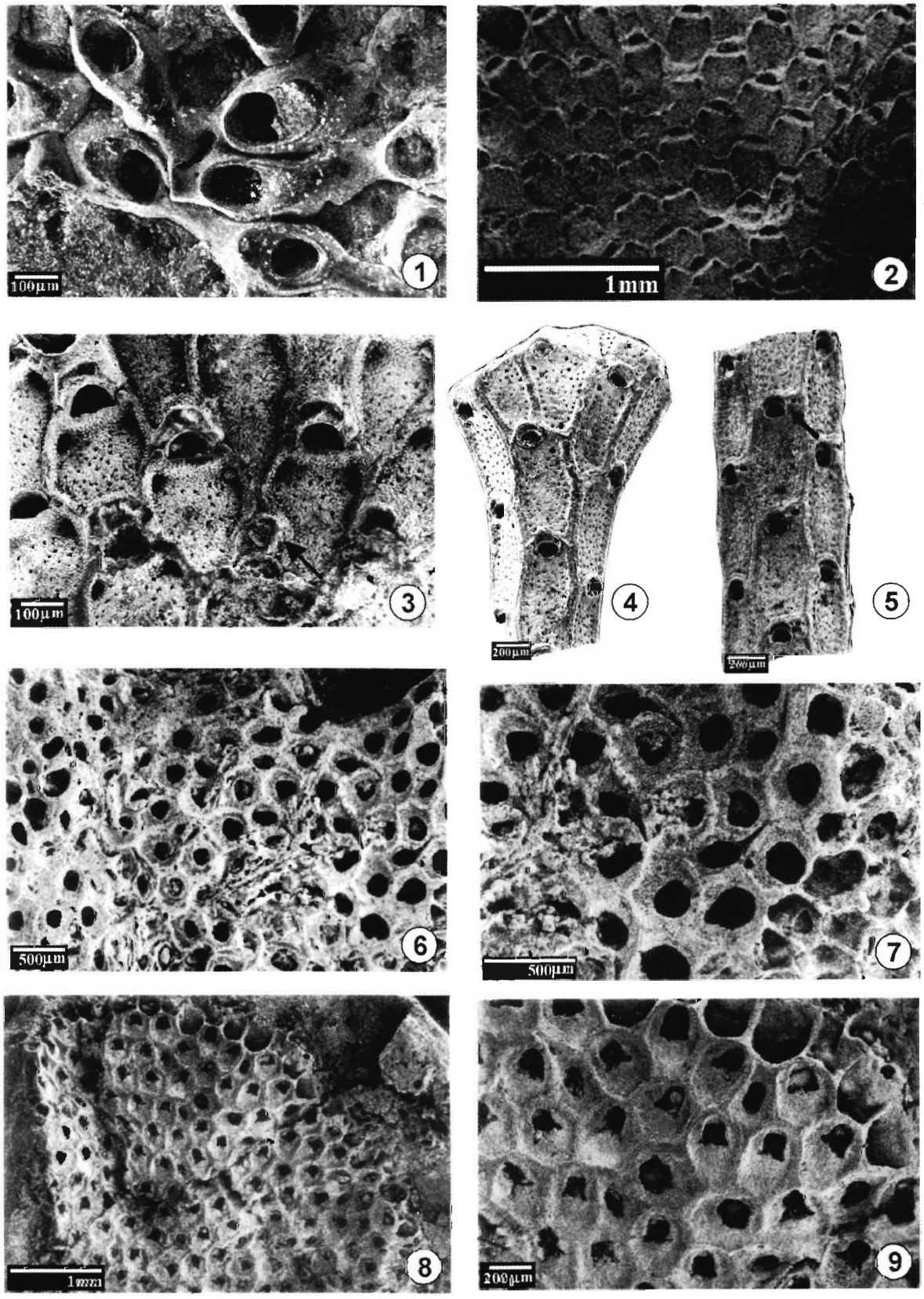
1. ***Crepis gurjarensis*** n. sp. 1. View of a part of the Holotype colony showing cryptocyst and caudae.

2-3. ***Micropora vredenburgi*** n. sp. 2. General aspect of the Holotype colony (GSI Type No. K60/780, early Miocene - Aquitanian). 3. Details of ovicell and avicularium (marked with arrow)

4-5. ***Microporina biswasi*** n. sp. 4. General aspect of the Holotype colony (GSI Type No. K60/781, middle Eocene - Lutetian). 5. Paratype specimen showing transversely disposed avicularia with median pivot (marked with arrow)

6-7. ***Onychocella torquata*** n. sp. 6. General aspect of the Holotype colony (GSI Type No. K60/782, middle Eocene - Lutetian-Bartonian). 7. Details of strongly torqued avicularium.

8-9. ***Floridina pentagonus*** n. sp. 8. General aspect of the Holotype colony (GSI Type No. K60/783, early Miocene - Aquitanian). 9. Details of trifoliate opesia and pentagonal avicularium.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9

distally and proximally arranged in 8 or 10 alternating vertical rows separated by moderately thick raised common rim. Frontal a smooth depressed cryptocyst, opesia subrectangular to elongate-oval in outline. Avicularia and ovicells not observed.

Description: Long, erect, slender, articulated columnar stems with eight or ten (rarely nine, as in the Holotype specimen) vertical alternating rows of autozooecia; cross-section octagonal or decagonal, diameter of the colonies remaining almost constant. Some paratype specimens have poorly preserved proximal tapering ends representing the primary region with terminal openings of four rows of zooecia, the other rows arising alternately with those of primary ones. Autozooecia near the tapering end similar to that of mature zooecia but with a comparatively longer cryptocystal region. Autozooecia subrectangular in outline, slightly arched distally, zooidal boundaries of adjacent series merged with each other to form a fairly thick and raised common rim. Cryptocyst proximally developed, depressed smooth, gently descending into the opesium. Opesia distal, moderately depressed, subrectangular to elongate-oval in outline, higher than wide, occupying about half of the zooecial frontal; rim of opesia smooth. Avicularia and ovicells not observed.

Remarks: Dr. D. P. Gordon (pers. comm., 2002), on examining the paratype material of this taxon, commented that "though the Kachchh taxon lacks the occlusor muscle scars, it is a reminiscent of *Bryopastor* Gordon, 1982". However, the description and illustrations of species of *Bryopastor* by Gordon (1986), d'Hondt and Gordon (1999) show the presence of occlusor ridges defined by conspicuous muscle lacunae and multiporous mural septula as the distinctive features of the genus. The zoarial and zooecial aspects of the present taxon resemble many Cretaceous species of Vincularia, Defrance, 1829 viz, *Vincularia fragilis* Defrance, 1829 (p. 214, and website: http// www.civgeo.rmit.edu.au /bryozoa/ cheilostomata/vinculariidae/*vincularia*.html), *Vincularia excavata d'* Orbigny, 1851 (p.69, pl.654, figs.17-19) from the Senonian of France, *Vincularia prismatica* (Hagenow, 1839) described by Berthelsen (1962, p.67, pl.4, fig.5) from the Danian of East Denmark and *'Vincularia' lauta* (Stoliczka, 1873) described by (Guha and Nathan, 1996; p.187, pl.14, figs. 3-6) from the Upper Cretaceous of South India.

The present taxon has slender, erect, columnar stems with octagonal or decagonal cross-section, subrectangular zooecia with arched distal margin and prominent proximal cryptocyst. *V. fragilis* has quadriserial rows of zooecia, very narrow cryptocyst and strongly torted autozooids (Cheetham, 1973, pp. 390-391, pl. 1, figs. 1 & 2). *V. excavata* lacks an elongate-oval to subrectangular opesia. *V. prismatica* has a much depressed cryptocyst, well raised zooecial rim, groove-like median section of proximal cryptocyst and ovicells. *'V.' lauta* has elongate-subhexagonal (ogival) with narrowed proximal end. Cheetham (1973, p. 403), while studying the cheilostome polymorphism, noted that "Miocene specimens of *Vincularia* have been reported by Tewari and Srivastava, 1967, as *Nellia,* and by Lagaaij, 1968, but none were available for this analysis". While reviewing an earlier version of the manuscript, Dr. P. D. Taylor (pers. comm., 2005), remarked, "such *'Vincularia'* species are very difficult to place generically". Based on these comments, this new taxon is placed under *'Vincularia'*.

Distribution: 37 colonies from the Khari Nadi Formation; 21 from the type locality; 3 from the Barkhan River section, 5 from the Rakhadi River section and 7 colonies from near the Gohela village.

Family **Chlidoniidae** Busk, 1884

Genus ***Crepis*** Jullien, 1882

Crepis gurjarensis n. sp.

(Pl. II, fig. 13; Pl. III, fig. 1)

Material examined: Holotype - GSI Type No. K60/779, a large colony encrusting high-spired gastropod shell. Paratypes - K127/010/002 - 5, K121/010/001, K156/010/001- 2; seven colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.510, 0.410 - 0.585; wz - $\bar{x}$ = 0.266, 0.199 - 0.399; ho - $\bar{x}$ = 0.166, 0.131 - 0.195 and wo - $\bar{x}$ = 0.150, 0.117 - 0.180 (N = 22).

Type horizon and locality: Argillites of the Khari Nadi Formation exposed over the cliff of the Khari Nadi, west of the Haripar village.

Age: Early Miocene (Aquitanian-Burdigalian).

Derivation of name: The specific name "*gurjarensis*" is after the land of Gurjars, the original inhabitants of the land part of which later came to be known as Gujarat.

Diagnosis: Encrusting uniserial colonies with bilateral ramification; autozooecia pyriform with a prominent flat cryptocyst covering half of the zooidal frontal. Gymnocyst extended proximally to form a thick short caudal structure; opesia semielliptical to oval. Avicularia and ovicells not observed.

Description: Colonies encrusting either high-spired gastropod shells or bilaminar fronds of *Thalamoporella kachchhensis* Guha and Gopikrishna, 2004. Autozooecia medium-sized, pyriform; arranged uniserially in long chains with bilateral ramification. Budding distal to distolateral; new branches of uniserial autozooecia arising as distolateral buds oriented at an angle of 60 to 90 degrees to the parent branches. Cryptocyst thick, prominent, flat, smooth but slightly depressed, covering half of the zooecial frontal. Gymnocyst smooth, thick extended proximally to form a thick, stout caudal structure that coalesces with the distal margin of the proximal zooid. Lateral walls smooth, high and steeply slanting to the encrusting surface with a large single uniporous septula; basal lamina weekly calcified. Opesia semielliptical to oval, distal, higher than wide; opesial rim smooth, some times with a thin calcified rim along the internal periphery. Avicularia and ovicells not observed.

Remarks: Dr. D. P. Gordon (pers. comm., 2002), on examining the paratype material of this taxon, remarked that 'the species, a reminiscent of *Crepis* Jullien, 1882, is puzzling in having too large opesia which is unusual for species under this genus, and when compared with species of d'Orbigny's Cretaceous genus *Pyriflustrina* (from his personal collection), it differs from the Kachchh taxon in having less raised distal rim and ovicells'. Based on Gordon's comments along with the presence of large distinct cryptocyst and semielliptical to oval opesia, the present taxon is placed under the genus *Crepis* Jullien, 1882. The cryptocyst is slightly depressed and occupies nearly half of the zooecial frontal and the remaining half by opesia, a unique feature that distinguishes the present taxon from all the known species of *Crepis* described so far.

Distribution: 211 colonies from the Khari Nadi Formation; of which 163 are from the type locality and 48 from the argillites near the Waior village. 15 colonies from the Kankawati river section of the Chhasra Formation near the Vinjhan village.

Superfamily **Microporoidea** Gray, 1848

Family **Microporidae** Gray, 1848

Genus ***Micropora*** Gray, 1848

Micropora vredenburgi n. sp.

(Pl. III, figs. 2-3)

Material examined: Holotype - GSI Type No. K60/780, a small unilaminar colony encrusting oyster shell. Paratypes - K180/077/001, K001/001; two colonies.

Dimensions of holotype (in mm): Autozooecia: Lz - $\bar{x}$ = 0.352, 0.323 - 0.402; wz - $\bar{x}$ = 0.319, 0.287 - 0.367; ha - $\bar{x}$ = 0.075, 0.066 - 0.083 and wa - $\bar{x}$ = 0.127, 0.118 - 0.136 (N = 12). Ovicellate zooecia: Lz - $\bar{x}$ = 0.479, 0.465 - 0.525; wz - $\bar{x}$ = 0.307, 0.278 - 0.375; ha - $\bar{x}$ = 0.072, 0.070 - 0.73; wa - $\bar{x}$ = 0.131, 0.125 - 0.139; hov - $\bar{x}$ = 0.094, 0.089 - 0.099 and wov - $\bar{x}$ = 0.167, 0.155 - 0.191 (N = 6).

Type horizon and locality: Specimen from the shell bank within the buff-colored siltstone horizon of the Khari Nadi Formation, near the horseshoe bend of the Waior stream, 1 km NE of the Chedopadi village.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name is in honour of Mr. E. W. Vredenburg for his significant work on post-Eocene molluscs of Kachchh.

Diagnosis: Encrusting unilaminar colonies with autozooecia having subhexagonal or vase-shaped outline; cryptocyst coarsely granular, finely porous. Aperture semicircular; wider than high, with small tubercles on the proximolateral corners and opesiules beneath the proximal apertural rim. Avicularia small, interzooecial, oval in outline; ovicells small, hyperstomial; smooth frontal triangular area; ooecial rim smooth or finely granular.

Description: Encrusting unilaminar colonies with subhexagonal to vase-shaped autozooecial outline; zooids arranged in quincunx; budding distal or distolateral; maximum width of zooecia distal from middle. Cryptocyst extensive, flat, coarsely granular with minute pores; slightly convex at or near the middle; descending distally and distolaterally near opesiules. Lateral walls thick, finely beaded, fused with those of adjacent autozooecia; basal lamina not calcified; septulae indistinct. Aperture semicircular, wider than high, broadly arched distally and truncated proximally; often bearing tubercles on the proximolateral corners. Two small opesiules below the aperture; oval in outline, shallow, nearly equal in size. Avicularia rarely occurring, interzooecial, oval in outline. Ovicells small, hyperstomial, with a smooth frontal triangular area; ooecial rim smooth or finely granular, often with an apical umbo; ovicell opening into aperture.

Remarks: In the morphology of the autozooecial frontal the present taxon resembles *Micropora santacruzana* Soule, Soule and Chaney (1995, p.46-48, p.7). However, the Recent Pacific species has avicularia with distinct ovoid rostra and large porous, subglobular, hyperstomial ovicells. *Micropora mortenseni* Livingstone described and illustrated by Gordon (1984, p.53, pl.15 C-D) from the Kermadec Ridge off New Zealand also has ovicells with smooth triangular area frontally, but has crescentic opesiules and avicularia with prominent sloping rostra directed obliquely distal.

Distribution: Four colonies from the type locality and 3 colonies from the bioturbated ochreous claystone horizon of the Waior stream section near the Waior village.

Genus ***Microporina*** Levinsen, 1909

Microporina biswasi n. sp.

(Pl. III, figs. 4-5)

Material examined: Holotype - GSI Type No. K60/781, an erect vinculariform colony. Paratypes - K085/084/002 - 18; 17 colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.668, 0.656 - 0.710; wz - $\bar{x}$ = 0.341, 0.323 - 0.363; ha - $\bar{x}$ = 0.149, 0.136 - 0.165; wa - $\bar{x}$ = 0.147, 0.133 - 0.165; Lav - $\bar{x}$ = 0.103, 0.085 - 0.117 and wav - $\bar{x}$ = 0.079, 0.055 - 0.099 (N = 12).

Type horizon and locality: The argillaceous sediments of the Harudi Formation from the cliff, N of the Harudi village by the side of the road from Waior to Narayan Sarovar.

Age: middle Eocene (Lutetian).

Derivation of name: The specific name "*biswasi*" is after Dr. S. K. Biswas for his contribution to the Tertiary stratigraphy of western Kachchh, Gujarat.

Diagnosis: Dichotomously branching, erect colonies composed of subhexagonal autozooecia arranged in six or eight alternating vertical rows. Frontal wall cryptocystal with minute pores in the central region and a row of larger pores along the inner margin of the lateral wall; aperture elliptical in outline with a narrow crescentic distal rim; two small distolateral opesiules. Avicularia small, nodal, drop-shaped, transverse to the long axis of zooecia and confluent with the distolateral margin of the aperture. Opesia of avicularium entire, divided

into subequal halves by thin pivot; mandibles acute, directed towards the aperture; ovicells not observed.

Description: Dichotomously branching, erect-rigid vinculariiform colonies composed of 6 or 8 (rarely nine) vertical rows of autozooecia alternating with each other; transverse section hexagonal or octagonal with lateral walls of zooecial series directed towards the center. Autozooecia subhexagonal in outline bordered by a thick well raised corrugated lateral wall delineating zooidal boundaries; adjacent vertical rows of autozooecia separated by fine sutures. Frontal wall cryptocystal, flat, slightly depressed with few regular minute pores in the central part; a row of larger pores along the inner margins of lateral walls; single pair of opesiules larger than pores, placed at the distolateral corners of autozooecia, below the proximal apertural rim. Aperture elliptical in outline with a narrow crescent shaped distal rim and shallow proximal lip. Avicularia small, drop-shaped, transverse to the long axis of zooecia and confluent with the distolateral margin of the aperture. Opesia of avicularium entire, divided into subequal halves by a slender pivot, rostrum acute, directed towards the aperture. Ovicells not observed.

Remarks: Transverse disposition of avicularia with respect to the long axis of autozooecia and mandibles pointing towards the aperture are the distinctive characters of the present species. In the morphology of zooecial frontal and avicularia the Kachchh taxon shows similarities with the Recent Atlantic species *Microporina elongata* (Hincks, 1880; from Bassler, 1953, p. G171, Fig. 131,5). However, *M. elongata* has vase-shaped zooecia, larger opesiules attached to the lateral walls and the avicularium has a prominent rostrum with distal tips/ mandibles directed oblique distally. The disposition of avicularia (transverse to the long axis of zooecia) is distinctive for the Kachchh taxon and separates it from all other known species under this genus.

Distribution: 23 colonies from the type locality.

Family **Onychocellidae** Jullien, 1882

Genus ***Onychocella*** Jullien, 1882

Onychocella torquata n. sp.

(Pl. III, figs. 6-7)

Material examined: Holotype - GSI Type No. K60/782; encrusting unilaminar colony. Paratypes - K001/031/001-5, K005/002, K028/ 002-4; nine colonies.

Dimensions of holotype (in mm): Lz - $\bar{x}$ = 0.408, 0.363 - 0.475; wz - $\bar{x}$ = 0.407, 0.355 - 0.487; ho - $\bar{x}$ = 0.218, 0.184 - 0.263; wo - $\bar{x}$ = 0.216, 0.177 - 0.286 (N = 17). Avicularia: Lav - $\bar{x}$ = 0.545, 0.424 - 0.633 and wav- $\bar{x}$ = 0.281, 0.234 - 0.322 (N = 13).

Type horizon and locality: Foraminiferal limestone bed of the Fulra Formation near Jadva village; 2.5 km NE from Bermoti village.

Age: middle Eocene (Lutetian-Bartonian) and Early Miocene (Aquitanian).

Derivation of name: The specific name "*torquata*" is for the strongly torqued acute distal tip of avicularia.

Diagnosis: Colonies encrusting, unilaminar; autozooecia subhexagonal in outline; cryptocyst finely granular, extending around the semicircular opesia. Avicularia longer than autozooecia, falciform or pentagonal with strongly torqued acute distal tip and proximally narrowed opesia.

Description: Thin unilaminar encrusting colonies having subhexagonal autozooecia with a gently arched or subrounded distal portion forming a honeycomb appearance; average length of zooids equalling average width in most colonies. Frontal wall a finely granular cryptocyst, prominent proximally and extending around the opesia; cryptocyst gently slanting into the opesia from all sides. Lateral walls raised above the autozooecial surface, high on the proximal and lateral regions and becoming low distally, often coalescing with the proximal wall of adjacent distal zooid. Opesia distally placed, semicircular in outline. Avicularia longer than autozooecia; falciform, often pentagonal, broader in the middle and narrowed distally to form a sharp acute strongly torqued tip around adjacent autozooecia. Opesia of avicularia small, oval, narrowed proximally and surrounded by a prominently rugose cryptocyst.

Remarks: In the morphology of autozooecia and avicularia, the present species shows similarities with North American early Tertiary species *Onychocella angulosa* Reuss, 1847 (Canu and Bassler 1920, p. 205, pl.32, figs. 31-32), *Onychocella laciniosa* Canu and Bassler, 1920 (p. 207, pl.32, figs. 26-27) and *Onychocella dupliciter* Canu and Bassler, 1920 (p. 208, pl.32, figs. 28-30). The zooidal dimensions of the Kachchh species are lower than *O. angulosa* and higher than *O. laciniosa* and *O. dupliciter*. Moissette (1988) described *O. angulosa* from the Messinian of Algeria (p.91, pl.14, fig.5) with autozooecia and avicularia of almost equal length. The Kachchh taxon has length of avicularia much larger than the autozooecia. Further, the strongly torqued nature of distal tips of avicularia distinguishes the present taxon from *O. angulosa*.

Distribution: Four colonies from the type horizon and locality, six from the bioturbated ochreous marlite horizon of the Khari Nadi Formation of the Waior stream section near the Waior village and eight from the same horizon near the Chedopadi village.

Genus ***Floridina*** Jullien, 1881

Floridina pentagonus n. sp.

(Pl. III, figs. 8-9)

Material examined: Holotype - GSI Type No. K60/783; encrusting unilaminar colony. Paratypes - K001/039/002 - 3, K005/001- 4, K001/001-2; eight colonies.

Dimensions of holotype (in mm): Lz - 0.319 - 0.443, $\bar{x}$ = 0.385; wz - 0.263 - 0.373, $\bar{x}$ = 0.315; ho - 0.139 - 0.194, $\bar{x}$ = 0.161; wo - 0.117 - 0.184; $\bar{x}$ = 0.147 (N = 21). Avicularia: Lav - 0.351-0.483, $\bar{x}$ = 0.420 and wav - 0.191-0.297, $\bar{x}$ = 0.241 (N = 15).

Type horizon and locality: The impure fossiliferous limestone horizon of the Khari Nadi Formation on the eastern scarp of the Waior stream towards Chedopadi village.

Age: early Miocene (Aquitanian).

Derivation of name: The specific name "*pentagonus*" is for the pentagonal outline of the avicularia.

Diagnosis: Colonies encrusting, unilaminar; autozooecial outline subhexagonal; cryptocyst finely granular, extending around the opesia. Opesia trifoliate with proximolateral opesiular indentations. Avicularia longer than autozooecia; pentagonal in outline with elongate-oval opesia.

Description: Colonies thin, unilaminar, encrusting extensively on bivalve shells and other hard shelly substrates forming a honeycomb structure. Autozooecia distinct, subhexagonal in outline with a gently arched or subrounded distal. Cryptocyst shallow, finely granular, extending around the opesia and gently sloping into it. Lateral walls slightly raised above the autozooecial surface, high on the proximal and lateral regions and becoming somewhat low distally, often coalescing with the proximal wall of adjacent distal zooid. Opesia distally placed; trifoliate, distally arched and having two narrow proximolateral opesiular indentations formed by the projection of cryptocyst from the sides bordering the opesia; making the aperture proximally broader. The two lateral processes thus formed serve as upper limits to two incomplete and asymmetrical opesiules imparting a bell-shaped appearance to the opesium. Avicularia longer than autozooecia, elongate-pentagonal in outline, with its long axis parallel to the zooidal length; avicularia broader in the middle and narrowed distally into sharp acute tips placed between adjacent autozooecia. Opesia of avicularia small, oval, proximally narrowed, medially placed and surrounded by a prominent rugose cryptocyst.

Remarks: In aspects of autozooecial morphology and asymmetric opesiular indentations, the present species shows similarities with North American early Tertiary species *Floridina asymmetrica* Canu and Bassler, 1920 (p. 224, pl.35, figs. 6-8). The much smaller dimensions of autozooecia and avicularia and typical pentagonal shape of avicularia distinguish the Kachchh taxon from the American species. The opesia of avicularia of the present species is generally oval, often with a narrowed proximal end, whereas *F. asymmetrica* has trigonal avicularian opesia.

Distribution: Seven colonies from the bioturbated ochreous marlite horizon of the Khari Nadi Formation of the Waior stream section near the Waior village and four from the same horizon near the Waghot village.

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