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Newly discovered species of cheilostomatid Bryozoa from the Miocene of western Kachchh, Gujarat, India

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Abstract. Cheilostomatid bryozoans are present in large quantities in Miocene sediments of western Kachchh. A detailed investigation, as presented here, has yielded 11 species. Among them, two species – *Canda ukirensis* sp. nov. and *Antropora ramaniaensis* sp. nov. – are new to science. Five species had already been reported from the same region, while a genus and the remaining three species are left in open nomenclature pending an exhaustive study using better preserved material.

Keywords. Aquitanian, Burdigalian, Cenozoic, Neocheilostomina, new species.

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Introduction

Cenozoic bryozoans from the Indian subcontinent were first reported by Tewari *et al*. (1958) and Tewari & Srivastava (1967). After a large gap, Guha & Gopikrishna (2004a, 2004b; 2005a, 2005b, 2005c, 2005d, 2005e, 2005f, 2007a, 2007b, 2007c, 2007d) and Guha (2013) described the plentiful and diverse bryozoan fauna from the Cenozoic rocks of western the Kachchh region, although the inventory of reported bryozoans from the region is still small. Therefore, we have felt a need to study more bryozoans from Kachchh, Gujarat, India. To do so, our research group has sampled the entire Miocene sequence from Kachchh region. As a result, Sonar & Gaikwad (2013a, 2013b, 2013c) and Sonar & Pawar (2016) have identified poricellariid, steginoporellid, calloporid as well as cyclostomatid bryozoans from the Cenozoic rocks exposed along the shelf zone adjoining the Mesozoic sequences of the western Kachchh (Fig. 1) (Sonar *et al*. 2022).

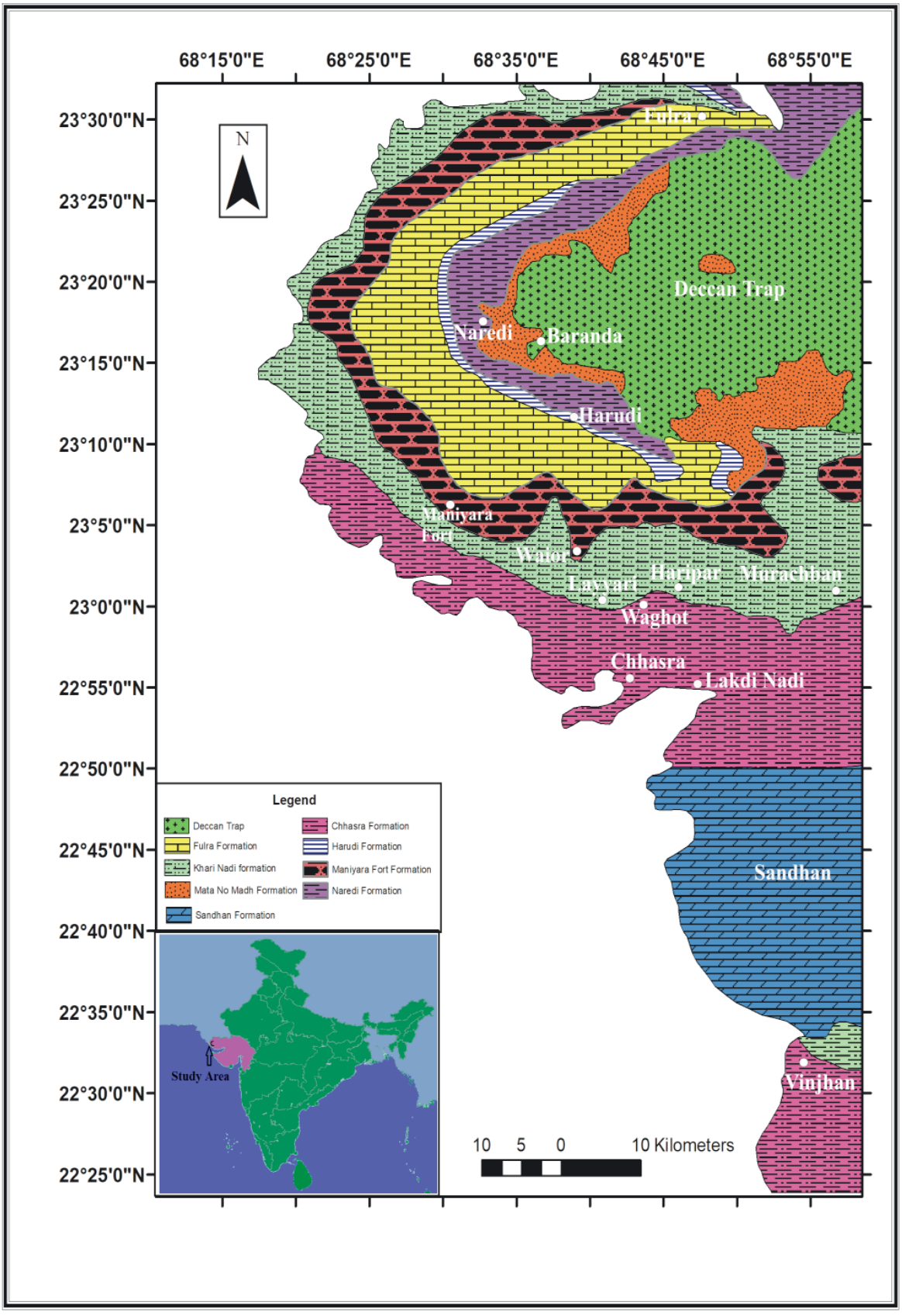

Fig. 1. Geological map of Kachchh (modified after Sonar *et al*. 2022).

In this study, we focus on the cheilostomatid Bryozoa from Kharinadi and Chhasra (early Miocene, Aquitanian–Burdigalian) Formations. We have identified 11 species belonging to the families Candidae d'Orbigny, 1851 (genera *Canda* Lamouroux, 1816 and *Licornia* van Beneden, 1850), Calescharidae Cook & Bock, 2001 (genus ?*Tretosina*), Cellariidae Fleming, 1828 (genus *Cellaria* Ellis & Solander, 1786), Antroporidae Vigneaux, 1949 (genus *Antropora* Norman, 1903), Steginoporellidae Hincks, 1884 (genus *Labioporella* Harmer, 1926), Microporidae Gray, 1848 (genus *Micropora* Gray, 1848), Cupuladriidae Lagaaij, 1952 (genus *Cupuladria* Canu & Bassler, 1919) and Skyloniidae Sandberg, 1963 (genus *Skylonia* Thomas, 1961).

Material and methods

For this study, samples were collected from the Kachchh Basin during Jan.–Feb. 2012. The majority of the bryozoans were recovered using bulk sampling (ca 1 kg each) of crushed limestones, mudstones and siltstone, while some bryozoan colonies were found encrusting bivalve and gastropod shells. 250 g of each sample was soaked in 50% concentrated H_2O_2 for 48–72 hours and then washed over a set of standard sieves with a mesh size of 1.68–0.25 mm. Bryozoan colonies were cleaned by soaking in a dilute H_2O_2 solution and then picked from different fractions for identification. Autozooid orifices and avicularia were cleaned by using a thin metal needle. Colony surfaces were delicately scrubbed in a sodium nitrate solution and water using a 0.2 mm brush. The imaging was done using a Cambridge stereo scanning electron microscope (SEM S120) at the Sophisticated Analytical Instrument Facility (SAIF), Indian Institute of Technology Bombay, Mumbai. The measurements were taken with a 15× ocular micrometer on a Nikon stereoscopic zoom microscope (see Winston & Heimberg 1986).

Institutional abbreviation

GIS/B = Government Institute of Science, Aurangabad, Maharashtra, India

Abbreviations of characters used in the paper

LOp = length of opesia
LOr = length of orifice
LOv = length of ovicell
LZ = length of autozooid
N = number of measurements
SD = standard deviation
WOp = width of opesia
WOr = width of orifice
WOv = width of ovicell
WZ = width of autozooid

Systematic palaeontology follows the classification provided by the World Register of Marine Species (WoRMS 2022).

Results

Taxonomy

Order Cheilostomatida Busk, 1852
Suborder Flustrina Smitt, 1868
Superfamily Buguloidea Gray, 1848
Family Candidae d'Orbigny, 1851
Genus *Canda* Lamouroux, 1816

Canda ukirensis sp. nov.
urn:lsid:zoobank.org:act:1A669348-F122-4A0C-AB7C-185D0E1BA860
Fig. 2; Table 1

Diagnosis

Biserial erect internodes with alternate arrangement, rectangular autozooids; autozooids immediately inclined to the axis, finely granular cryptocyst with large oval opesia; broad, sessile, laterally emplaced avicularia; vibracula with deep setal groove and broad radicular pore placed dorsally. Ooecium not seen.

Etymology

The species is named after its type locality 'Ukir' between Waior and Charopadi in Kachchh.

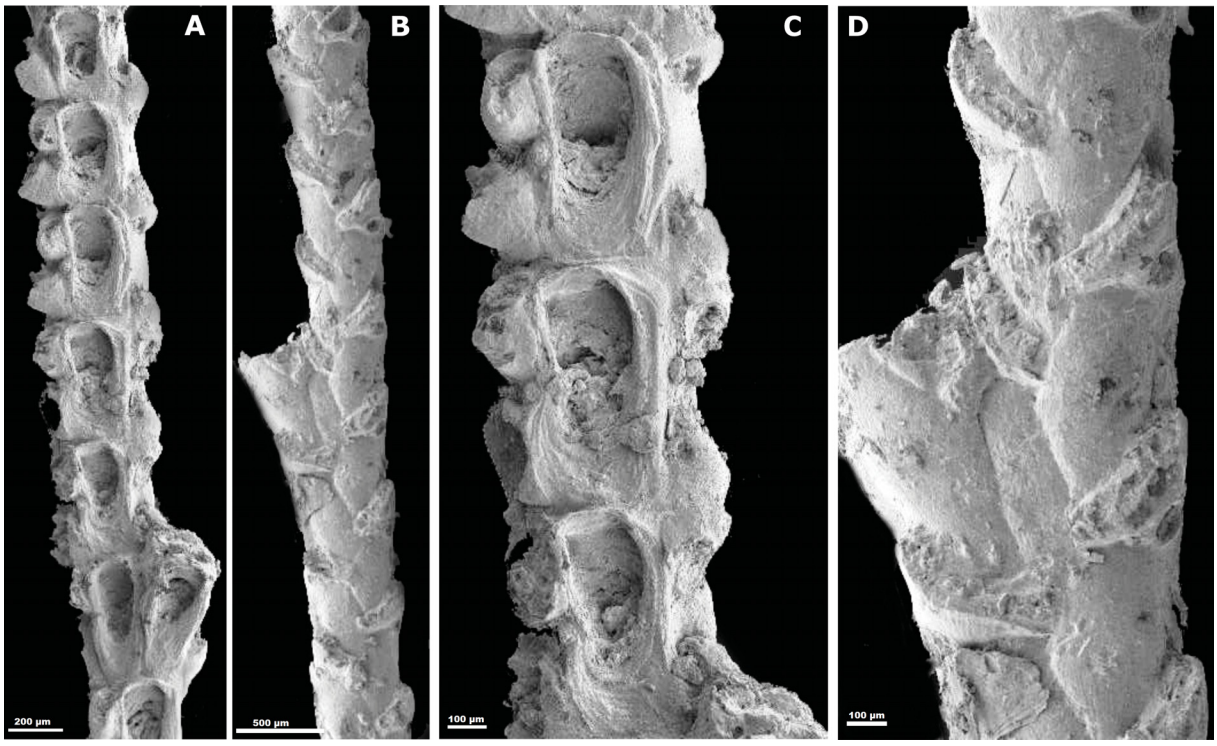

Fig. 2. *Canda ukirensis* sp. nov., holotype (GIS/B 431). **A**. Frontal view of the colony showing different autozooids, avicularia and vibracula. **B**. Dorsal view of the colony showing vibracular pores. **C**. Enlargement of the colony showing autozooids. **D**. Close-up of dorsal view of the colony showing vibracula with setal grooves and vibracular pores.

Table 1. Measurements in mm of *Canda ukirensis* sp. nov., holotype (GIS/B 0431), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.180	0.200	0.192	±0.002	25
WZ	0.060	0.080	0.072	±0.005	25
LOp	0.120	0.130	0.126	±0.002	15
WOp	0.050	0.060	0.054	±0.002	15

Material examined

Holotype

INDIA • fossiliferous limestone of cliff section exposed 1.5 km southeast of Waghot Village in Waior-Charopadi stream; Burdigalian, lower Miocene, Chhasra Formation; 23°23′49″ N, 68°41′35″ E; Jan.–Feb. 2012; Sonar leg.; GIS/B 0431.

Paratypes

INDIA • 7 specs; same collection data as for holotype; 23°25′55″ N, 68°42′40″ E; Jan.–Feb. 2012; Sonar leg; GIS/B 0432 to 0438.

Description

Colonies erect, biserial, with rectilinear or slightly curved, narrow branches, triangular in cross-section. Autozooids distinct, alternating in two rows on either side of median keel, rectangular, slightly asymmetrical, abrupt inclination from median keel, separated by shallow grooves, distal edge slightly raised (Fig. 2A). Gymnocyst absent. Cryptocyst slightly granular, asymmetrically developed, extended more distally on outer side (Fig. 2C, uppermost zooid). Large communication pores visible in distolateral corners, emplaced on broad immersed shelf of each autozooid. Opesia large, oval, tapering proximally. Scutum lacking. Avicularia placed laterally along central axis, sessile, broad and about half as long as zooid, each zooid producing single avicularium occupying its inner distal half, rostrum obliquely positioned with respect to colony surface and long axis (Fig. 2C). The dorsal side occupied by vibracula with long, curved, deep setal groove, oriented distolaterally; shallow crisscross median furrow corresponds to zooidal boundaries. Radicular pore very large (Fig. 2B, D). Ooecium not seen.

Remarks

Canda retiformis (Pourtalès, 1867), the north pacific recent species has resemblance with *C. ukirensis* sp. nov. in broad sessile avicularia but differs in the depressed cryptocyst and presence of scutum. *Canda pecten* Thornely, 1907 (see Tilbrook 2006: 54, pl. 8c) differs from *C. ukirensis* sp. nov. in having triangular opesia and large frontal avicularia above branch bifurcation. Di Martino & Taylor, 2014 studied the Indonesian Cenozoic species *C. federiciae* and *C. giorgioi*, which differ from *C. ukirensis*: the former in the absence of avicularia and the latter in the absence of avicularia, raised distal autozooidal edges and egg-shaped opesia. The Recent species *Canda foliifera* (Harmer, 1926) from Taiwan has some resemblance in general morphology to the Kachchh species but it has a more extensive granular cryptocyst with a straight proximal edge (see Gluhak *et al*. 2007: 403, fig. 7a–d).

Genus *Licornia* van Beneden, 1850

?Licornia sp. 1
Fig. 3; Table 2

Material examined

INDIA • fossiliferous limestone at cliff section of Lakdi Nadi near Tera Village; Burdigalian, lower Miocene, Chhasra Formation; 23°22′19″ N, 68°58′10″ E; Jan.–Feb. 2012; Sonar leg.; GIS/B 0439.

Description

Colony erect biserial, branching. Autozooids club-shaped, arranged in alternate longitudinal rows (Fig. 3A). Cryptocyst barely developed, when present descending into opesia. Gymnocyst extended for ⅓ of frontal surface, occupied by ooecia of the proximal zooid if fertile (Fig. 3B). Opesia rounded to oval. Scutum not preserved. Distal oral spine bases stout, usually two internal, distal spine bases obscured by the ovicells (Fig. 3C). Lateral avicularia large, on outer distolateral corner of each autozooid, laterally directed, with acute rostrum, with somewhat raised tip. A frontal vibracula obliquely placed distolaterally with small rootlet foramen. Ooecia broad, conspicuous, slightly tilted away from axis of branch, ectooecium smooth, perforated by 12–15 unequal sized pseudopores.

Remarks

A single, weathered specimen was available to study, which does not allow to confirm the presence or details of a scutum or oral spine bases, the presence of frontal avicularia or axial vibracula. Hence, the species is left in open nomenclature until better preserved material is available. The present species differs from the Recent Indo-Pacific species *Licornia diadema* (Busk, 1852) in the absence of frontal

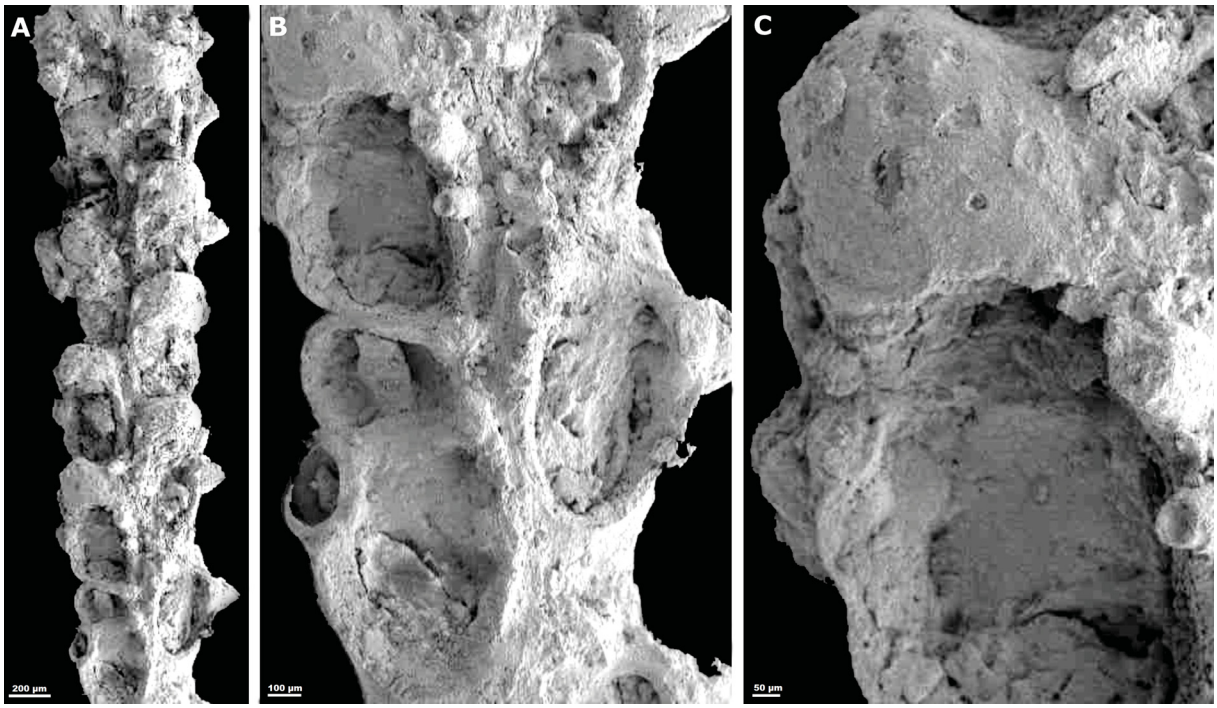

Fig. 3. ?*Licornia* sp. 1 (GIS/B 0539). **A**. Frontal view of the colony autozooids, ooecium and avicularia. **B**. Enlargement of the colony showing autozooids and ooecium. **C**. Close-up of a single autozooid with ooecium having the ectooecium perforated by unequal sized pores.

Table 2. Measurements in mm of ?*Licornia* sp. 1 (GIS/B 0439), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	**Maximum**	**Mean**	SD	**N**
LZ	0.370	0.400	0.390	±0.005	15
WZ	0.200	0.230	0.212	±0.006	15
LOp	0.160	0.200	0.178	±0.010	10
WOp	0.120	0.156	0.133	±0.006	10
LOv	0.110	0.160	0.134	±0.020	3
WOv	0.180	0.210	0.196	±0.012	3

avicularia, comparatively large lateral avicularia and the absence of a raised ooecial rim (see Vieira *et al.* 2013: 1914–1915, fig. 3e–f). The Recent south Pacific Australian species *Licornia prolata* Tilbrook & Vieira, 2012 differs in the presence of frontal avicularia, small lateral avicularia and the number of frontal pores on the ooecia.

Superfamily Calloporoidea Norman, 1903
Family Antroporidae Vigneaux, 1948
Genus *Antropora* Norman, 1903

Antropora ramaniaensis sp. nov.
urn:lsid:zoobank.org:act:24CED4FE-BFAA-4443-A52B-9A2A97D58DB7
Fig. 4; Table 3

Diagnosis

Unilaminar encrusting colonies with rhomboidal to oval autozooids; opesia oval to subtriangular, extensive finely granular cryptocyst, small elongate avicularia placed on raised cystid randomly located in the narrow interzooecial space. Ovicells endozooecial, cap like.

Etymology

The species is named after the locality 'Ramania' in Kachchh, Gujarat.

Material examined

Holotype

INDIA • fossiliferous limestone of cliff section exposed 1.5 km southeast of Waghot Village in Waior-Charopadi stream; Burdigalian, lower Miocene, Chhasra Formation; 23°25′49″ N, 68°42′35″ E; Jan.–Feb. 2012; Sonar leg.; GIS/B 0440.

Paratypes

INDIA • 20 specs; same collection data as for holotype; GIS/B 0441 to 0460.

Description

Colony unilaminar, encrusting. Autozooids oval to lozenge-shaped, separated by shallow, thin grooves (Fig. 4A). Gymnocyst vestigial; cryptocyst extensive, finely granular, gently sloping into opesia. Opesia roughly oval to bell shaped given the later constrictions, narrowing distally, occupying ½ of frontal area (Fig. 4B–C). Distal zooidal margins arched, raised. Small interzooecial avicularia elongate, with rounded

Table 3. Measurements in mm of *Antropora ramaniaensis* sp. nov., holotype (GIS/B 0440), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.250	0.320	0.289	±0.022	10
WZ	0.210	0.290	0.259	±0.015	10
LOp	0.025	0.079	0.046	±0.003	10
WOp	0.130	0.170	0.145	±0.008	10

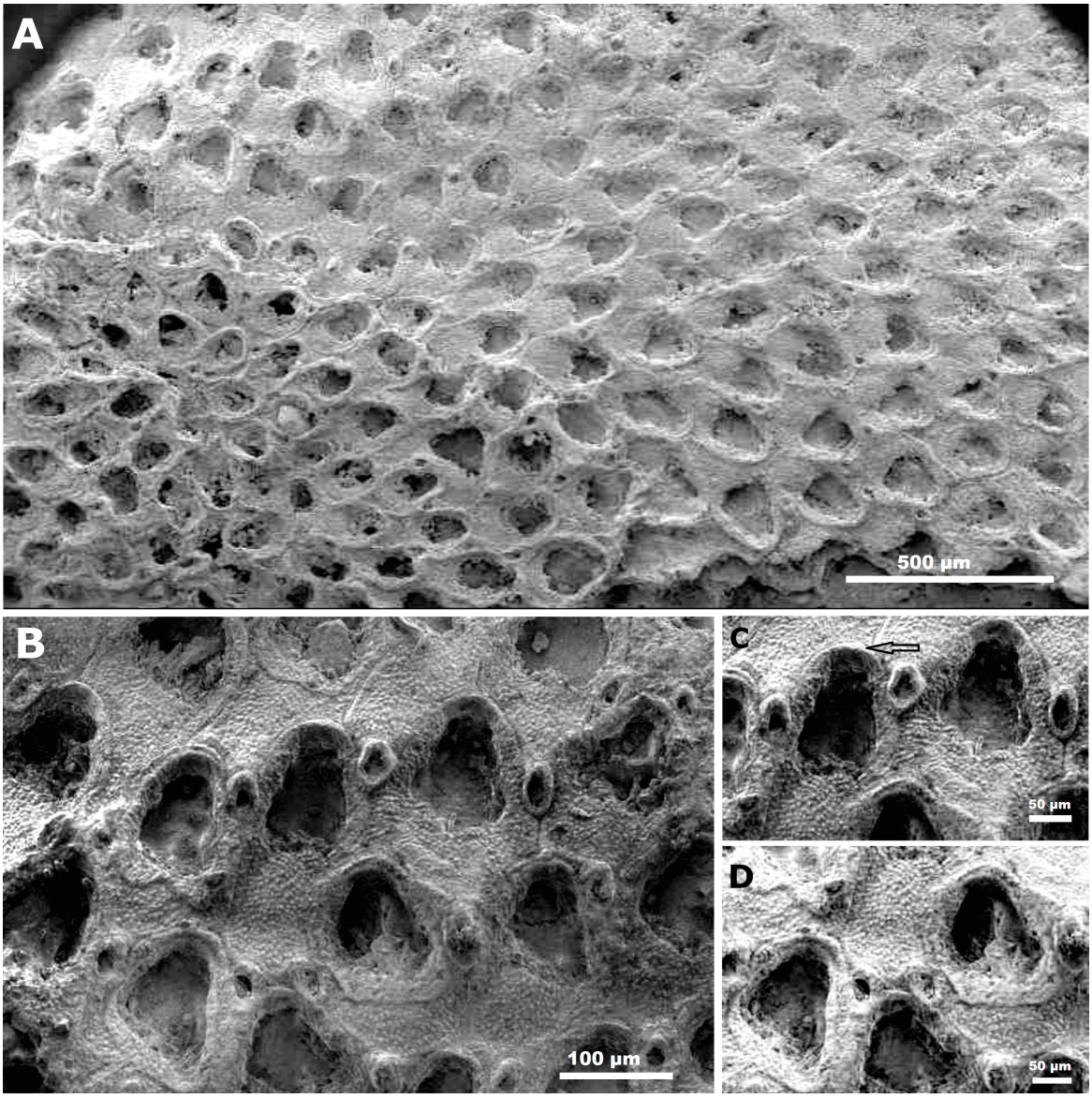

Fig. 4. *Antropora ramaniaensis* sp. nov., holotype (GIS/B 0440). **A**. General view of the colony showing rhomboidal to oval autozooids. **B**. Enlargement of the colony showing autozooids with extensive cryptocyst and interzooecial avicularia. **C**. Close-up of autozooids with cap like, endozooecial ovicells (arrow) and interzooecial avicularia. **D**. Close-up of autozooids with the endozooecial ovicells.

rostrum, mostly distally directed, without crossbar, avicularium raised on small cystid seated randomly in narrow interzooidal space. Ovicells endozooecial, cap like, observed in fertile zooids (Fig. 4C–D).

Remarks

The circum-tropical Recent species *Antropora minor* (Hincks, 1880) is similar to the Kachchh species in the shape of autozooids and opesia but differs in having a coarsely granular cryptocyst, the presence of small kenozooidal papillae at the proximal end of the autozooid and the occurrence of large vicarious avicularia (see Tilbrook 1998: 34, fig 2a–f). *Antropora typica* Canu & Bassler, 1928 has a superficial resemblance with the Kachchh species in its general morphology; however, the former species is characterized by smoothly calcified gymnocysts, interzooecial avicularia with an acutely triangular rostrum, and sporadic large vicarious avicularia (see Tilbrook 1998: 37, figs 1f, 3a). *Antropora leucocypha* Marcus, 1937 also resembles the new Kachchh species in the shape of the autozooid (see Winston 1982: 123, figs 36–37). However, the former has a beaded and crenulated cryptocyst and autozooids surrounded by numerous kenozooids. The Recent cosmopolitan warm-water species *A. granulifera* Hincks, 1880 differs in the crenulated, raised mural rim and shows a similarity in the shape of the autozooids. The Indonesian late Burdigalian species *A.* cf. *subvespertilio* (Canu & Bassler, 1929) differs in having a trifoliate opesia and differently shaped autozooids (see Di Martino & Taylor 2014: 43, pl. 15, fig. 2a–e). *Antropora gadhavii* Guha & Gopikrishna, 2005 differs from *A. ramaniaensis* sp. nov. in having a much less developed cryptocyst steeply sloping into the opesia, distal zooidal margins broad and subrectangular, indistinct autozooidal boundaries and oval avicularia with an acute rostrum.

Antropora gadhavii Guha & Gopikrishna, 2005
Fig. 5; Table 4

Antropora gadhavii Guha & Gopikrishna, 2005d: 140, pl. I fig. 10, pl. II fig 1.

Material examined

INDIA • 4 specs; yellowish limestone west of Haripar, Aquitanian, lower Miocene, Kharinadi Formation; 23° 21′12″ N, 68°49′13″ E; Sonar leg.; GIS/B 0461 to 0464 • 6 specs; yellow limestones of the Waghot in Waior-Charopadi stream cliff section and Lakdi Nadi cliff section; Burdigalian, lower Miocene, Chhasra Formation; 23°22′25″ N, 68°58′35″ E; Sonar leg; GIS/B 0465 to 0470.

Description

Colony unilaminar encrusting. Autozooids subtrigonal to subrectangular, indistinct zooidal boundaries (Fig. 5A). Gymnocyst indistinguishable; cryptocyst narrow, thickly calcified, descending into opesia. Opesia subrectangular to subtriangular in shape, elongate, occupying almost entire frontal area. Distal zooidal margins broad, subrectangular (Fig. 5B–C). Avicularia small, interzooecial, oval with acute rostrum, randomly placed at corners between autozooids, without crossbar (Fig. 5C–D). Ovicells not observed.

Remarks

The present species agrees with all the essential characters of *Antropora gadhavii* Guha & Gopikrishna, 2005.

Table 4. Measurements in mm of *Antropora Gadhavii* Guha & Gopikrishna, 2005 (GIS/B 0461 to 0470), Aquitanian, lower Miocene, Kharinadi Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.240	0.360	0.296	±0.022	10
WZ	0.200	0.290	0.240	±0.013	10
LOp	0.081	0.100	0.092	±0.007	10
WOp	0.120	0.160	0.143	±0.004	10

Family Cupuladriidae Lagaaij, 1952
Genus *Cupuladria* Canu & Bassler, 1919

Cupuladria sp.
Fig. 6; Table 5

Material examined

INDIA • 22 specs; South of Walaram Tirth Dham at Murachbann, Aquitanian, lower Miocene, Kharinadi Formation; 23°39′15″ N, 68°58′02″ E; Jan.–Feb. 2012; Sonar leg.; GIS/B 0471 to 0492 • 11 specs;

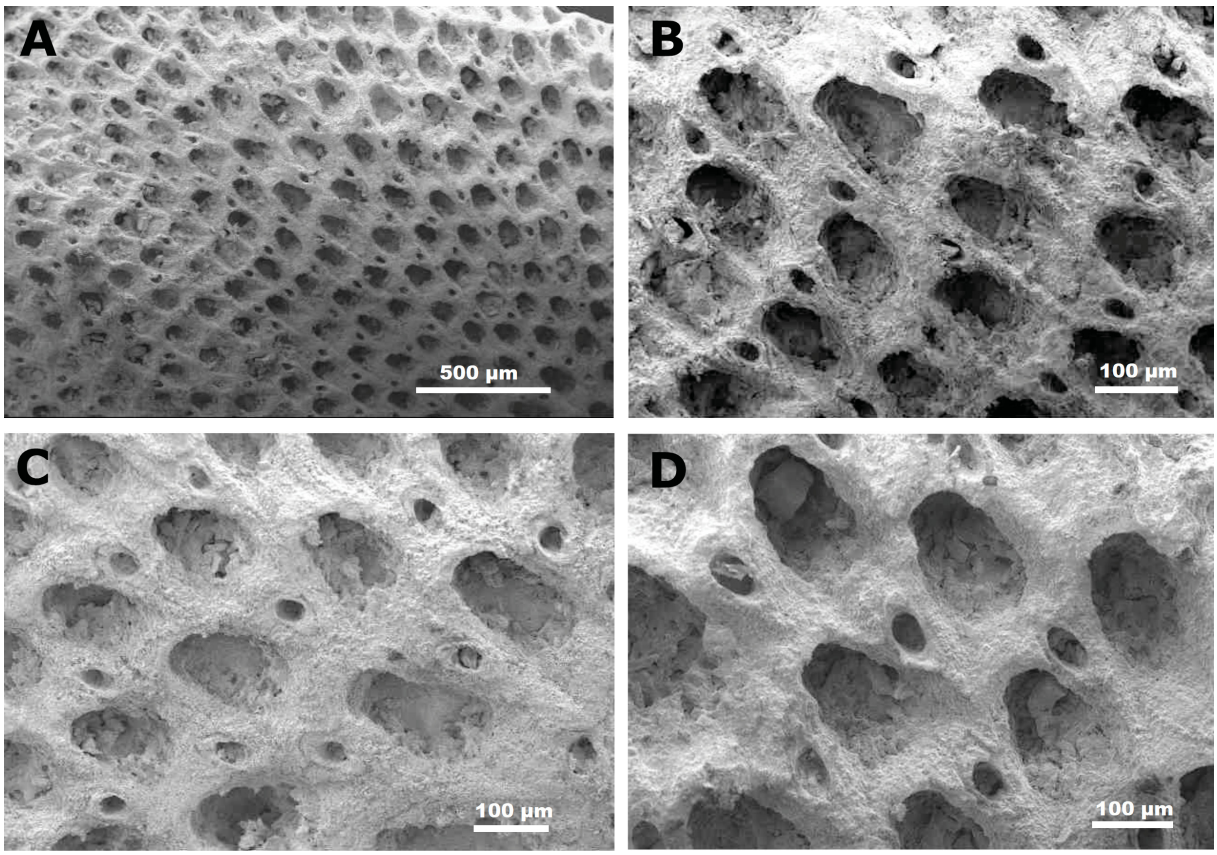

Fig. 5. *Antropora gadhavii* Guha & Gopikrishna, 2005 (GIS/B 0461). **A**. General view of the colony showing autozooids. **B–C**. Enlargement of the colony showing autozooid and interzooecial avicularia. **D**. Close-up of the colony showing autozooids with cryptocyst and interzooecial avicularia.

Table 5. Measurements in mm of *Cupuladria* sp. (GIS/B 0471 to 0503), Aquitanian, lower Miocene, Kharinadi Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.140	0.160	0.152	±0.005	10
WZ	0.100	0.110	0.104	±0.001	10
LOp	0.070	0.090	0.081	±0.004	10
WOp	0.050	0.070	0.060	±0.004	10

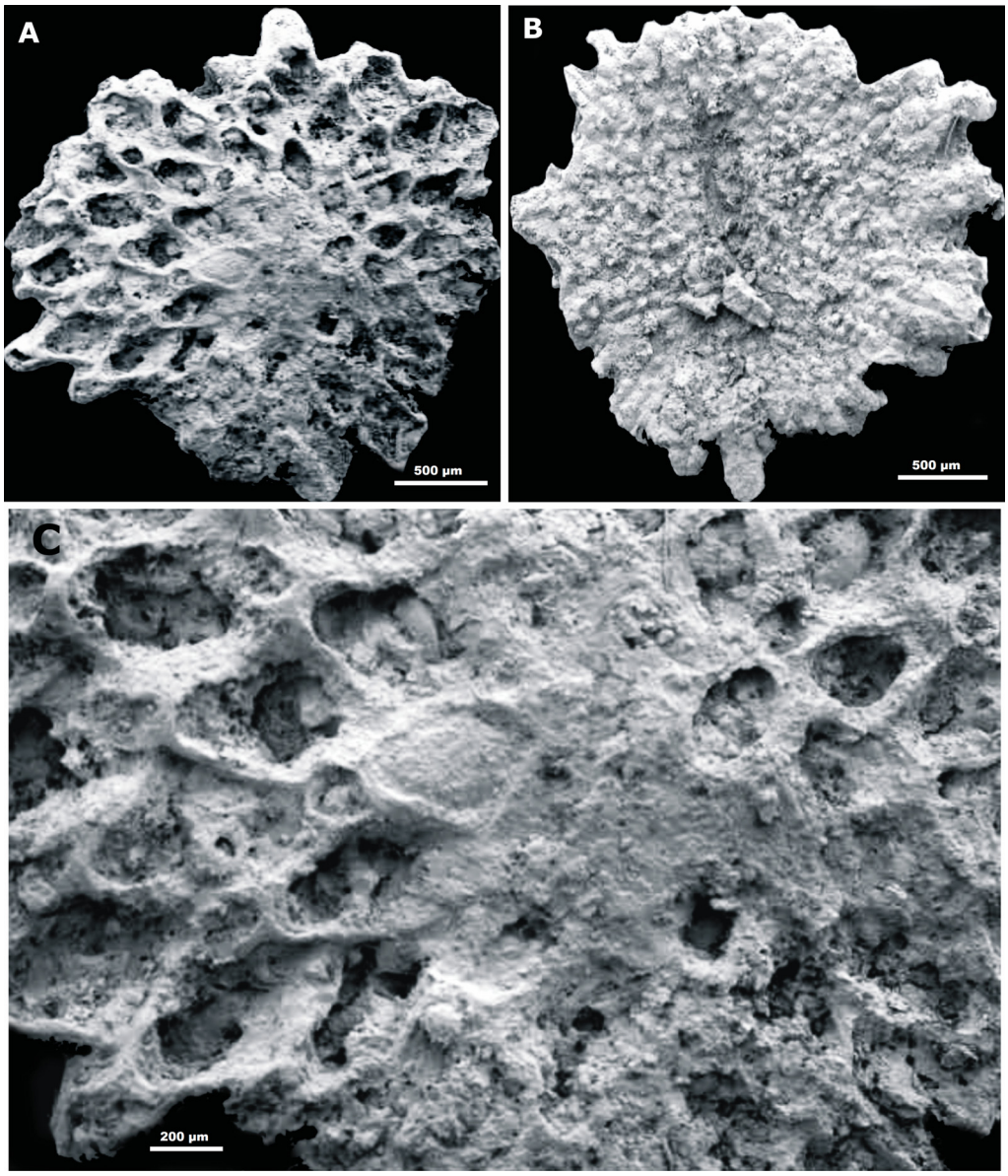

Fig. 6. *Cupuladria* sp. (GIS/B 0471). **A**. General view of the colony showing autozooids and vibracula on the distal periphery. **B**. Basal view of the colony showing more or less irregular inconspicuous tangential grooves with basal kenozooidal pores in the form tubercles. **C**. Close-up of the colony showing autozooids and vibracula.

yellowish siltstone Waghot cliff section and claystone section in Kankawati River south of Vinjhan Village, Burdigalian, lower Miocene, Chhasra Formation; 23°03′10″ N, 69°00′23″ E, Jan.–Feb. 2012; Sonar leg.; GIS/B 0493 to 0503.

Description

Colony unilaminar, discoidal. Autozooids radially arranged, more or less hexagonal, radiating from near the center (Fig. 6A). Ancestrula placed centrally, filled with sediment. Opesia almost longitudinally ovoidal, bordered by a steeply descending, tuberculate cryptocyst. Vibraculum placed at distal periphery of each autozooid, broad, with lateral elevation (Fig. 6C). Basal surface concave, coarsely tuberculated (Fig. 6B).

Remarks

The present Kachchh material is too poorly preserved to be meaningfully compared with other known species. Therefore, until we get better preserved material clearly showing the basal kenozooids and frontal surface, the species is left in open nomenclature.

Family Cymuloporidae Winston & Vieira, 2013
Genus *Crepis* Jullien, 1882

Crepis gurjarensis Guha & Gopikrishna, 2005
Fig. 7; Table 6

Crepis gurjarensis Guha & Gopikrishna, 2005d: 146, pl. II fig. 13, pl. III fig 1.

Material examined

INDIA • 11 specs; yellow limestone of the section south of Walaram Tirth Dham near Murachbann, Aquitanian, lower Miocene, Kharinadi Formation; 23°39′15″ N, 68°58′02″ E; Jan.–Feb. 2012; Sonar leg.; GIS/B 0504 to 0514.

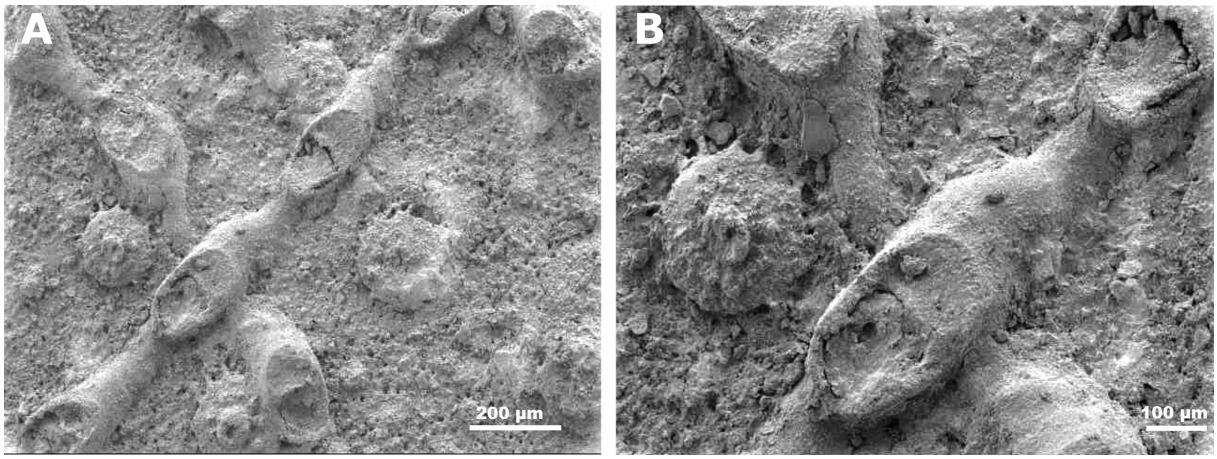

Fig. 7. *Crepis gurjarensis* Guha & Gopikrishna, 2005 (GIS/B 0504). **A**. General view of the colony encrusting an echinoid test showing uniserial chains with branching on both sides. **B**. Close-up of an autozooid showing oval opesia, cryptocyst and well-developed gymnocyst.

Table 6. Measurements in mm of *Crepis gurjarensis* Guha & Gopikrishna, 2005 (GIS/B 0504 to 0514), Aquitanian, lower Miocene, Kharinadi Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.400	0.540	0.484	±0.044	10
WZ	0.190	0.362	0.284	±0.054	10
LOp	0.130	0.200	0.161	±0.022	10
WOp	0.120	0.170	0.143	±0.015	10

Description

Colony adnate, delicate, encrusting echinoid test. Autozooids arranged in uniserial chains with branching on both sides. New uniserial branches of autozooids starting from distolateral buds oriented at angle of 90° to the parent branch (Fig. 7A). Autozooids elongate, pyriform. Opesia semioval with concave proximal edge, occupying roughly ⅓ of the frontal area. Cryptocyst well developed, smooth, descending into opesia. Marginal rim smooth, indistinct. Lateral walls smooth, irregular in basal contact. Gymnocyst smooth, tapering proximally, shrinks in proximal cauda (Fig. 7B). Ancestrula and ooecium not seen.

Remarks

The present species agrees with all the essential characters of *Crepis gurjarensis* Guha & Gopikrishna, 2005.

Superfamily Cellarioidea Fleming, 1828
Family Cellariidae Fleming, 1828
Genus *Cellaria* Ellis & Solander, 1786

Cellaria sp.
Fig. 8; Table 7

Material examined

INDIA • 1 spec.; fossiliferous limestone of Lakdi Nadi near Tera Village, Burdigalian, lower Miocene, Chhasra Formation; 23°22′19″ N, 68°58′10″ E; Sonar leg.; Jan.–Feb. 2012; GIS/B 0515.

Description

Internode cylindrical, slender, straight, or slightly curved. Autozooids diamond shaped, longer than wide, arranged in 5–6 alternating rows, distinctly separated by raised margins (Fig. 8A). Orifice semicircular, proximal lip straight, laterally flanked by pair of robust denticles. Frontal cryptocyst depressed, smooth, surrounded by elongate cryptocystal rim converging on both sides, becoming acute proximally or running parallel (Fig. 8B). Avicularia not observed. Ovicell endozooidal, placed at distal extremities of maternal zooids.

Remarks

A single internode is available in the material which lacks avicularia and is therefore difficult to assign to a species, so it is left in open nomenclature until better preserved specimens are found.

Table 7. Measurements in mm of *Cellaria* sp. (GIS/B 0515), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.223	0.241	0.233	±0.007	10
WZ	0.090	0.109	0.102	±0.006	10
LOr	0.043	0.051	0.048	±0.002	05
WOr	0.020	0.032	0.028	±0.003	05

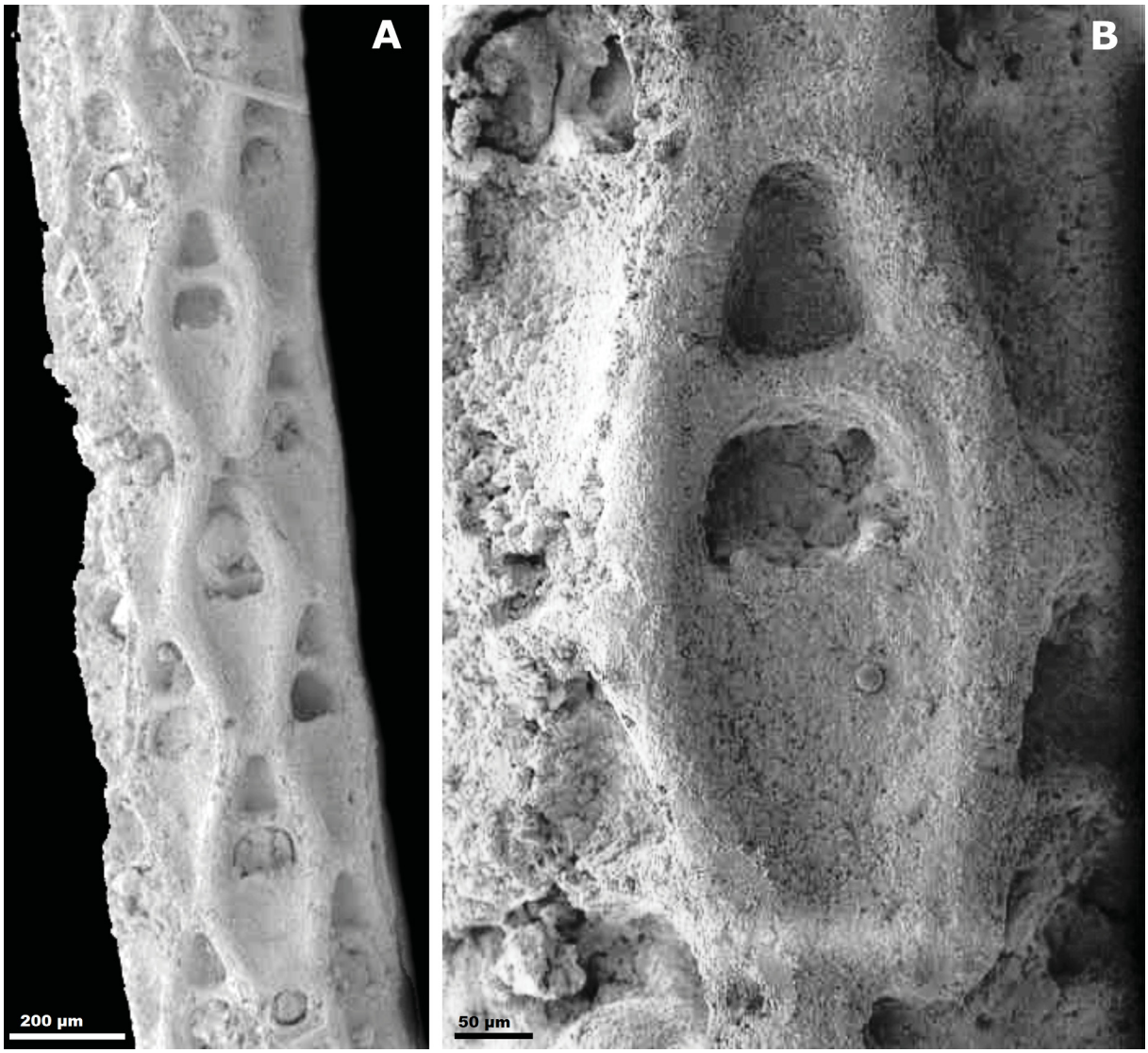

Fig. 8. *Cellaria* sp. (GIS/B 0515). **A**. General view of the colony showing hexagonal autozooids. **B**. Close-up of a single autozooid showing semicircular orifice with a pair of strong denticles, depressed proximal cryptocyst and distally placed ooecial cavity.

Superfamily Microporoidea Gray, 1848
Family Microporidae Gray, 1848
Genus *Micropora* Gray, 1848

Micropora vredenburgi Guha & Gopikrishna, 2005
Fig. 9; Table 8

Micropora vredenburgi Guha & Gopikrishna, 2005d: 147, pl. III figs 2–3.

Material examined

INDIA • 6 specs; yellowish limestone at cliff section of Waior-Charopadi stream near Waghot, Burdigalian, lower Miocene, Chhasra Formation; 23°25′55″ N, 68°42′40″ E; Jan.–Feb. 2012; Pawar leg.; GIS/B 0516 to 0521.

Description

Colony encrusting, unilaminar. Autozooecia vase shaped or subhexagonal, arranged quincuncially (Fig. 9A). Cryptocyst extensive, flat, surface coarsely granular and with fine pseudopores, slightly bulging in middle, sinking distally and near opesiules, bordered by thick, raised mural rim. Opesiules small, slit like, placed at proximolateral corners of orifice near lateral margins. Orifice semielliptical, wider than long, arched distally, proximal edge concave. Ooecia small, semi-immersed, smooth, with semicircular frontal surface (Fig. 9B). Avicularia not observed.

Remarks

All the essential characters agree with *Micropora vredenburgi* Guha & Gopikrishna, 2005. However, the interzooecial avicularia observed by Guha & Gopikrishna (2005) were not noticed in the present specimens.

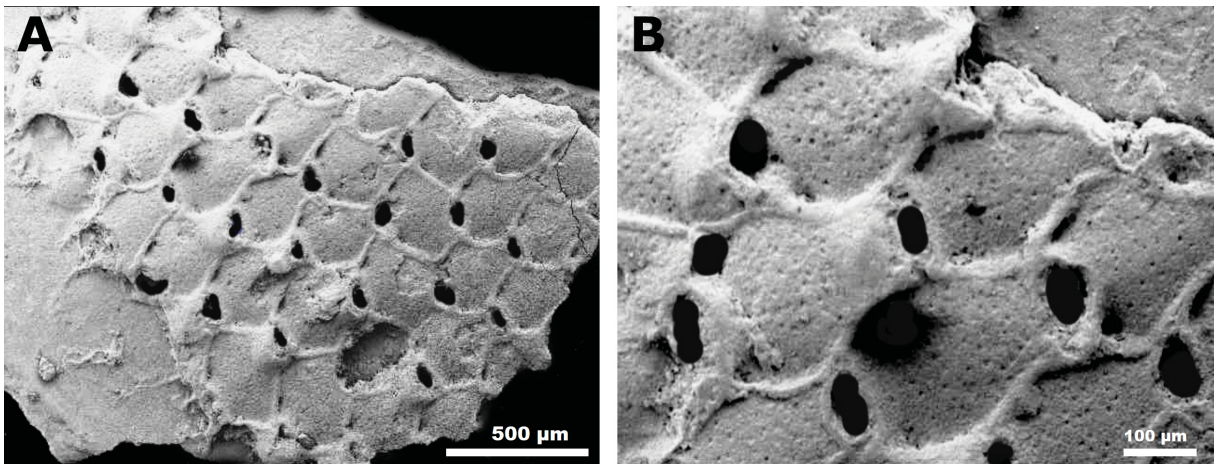

Fig. 9. *Micropora vredenburgi* Guha & Gopikrishna, 2005 (GIS/B 0516). **A**. General view of the colony showing subhexagonal autozooid. **B**. Close-up of an autozooids showing orifices opesia, opesiules, thick mural rims and ooecia.

Table 8. Measurements in mm of *Micropora vredenburgi* Guha & Gopikrishna, 2005 (GIS/B 0516 to 0521), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.340	0.420	0.389	±0.034	20
WZ	0.292	0.350	0.317	±0.020	20
LOr	0.062	0.085	0.073	±0.007	10
WOr	0.082	0.106	0.096	±0.008	10

Family Calescharidae Cook & Bock, 2001

?Tretosina gen. et sp. indet.
Fig. 10; Table 9

Material examined

INDIA • 11 specs; yellow limestone of the south of Walaram Tirth Dham near Murachbann, Aquitanian, lower Miocene, Kharinadi Formation; 23°39′15″ N, 68°58′02″ E; Jan.–Feb. 2012; Pawar leg.; GIS/B 0522 to 0532.

Description

Colony erect with six zooidal series. Zooids hexagonal, arranged quincuncially in alternating longitudinal rows, bordered by thin raised, smooth mural rim (Fig. 10A). Opesia oval, less than ½ length of the zooid. Cryptocyst tuberculated, descending into the opesia narrowing proximally. Distal arch smooth, thin and raised (Fig. 10B). Spines, avicularia and ooecia not observed.

Remarks

In these Kachchh specimens, the median cryptocystal process and ooecium typical of *Tretosina* were not observed making even genus-level attribution difficult. So, the genus is left in open nomenclature until better preserved material is available.

Suborder Thalamoporellina Ostrovsky, 2013
Superfamily Thalamoporelloidea Levinsen, 1902
Family Steginoporellidae Hincks, 1884
Genus *Labioporella* Harmer, 1926

Labioporella hariparensis Guha & Gopikrishna, 2007
Fig. 11; Table 10

Labioporella hariparensis Guha & Gopikrishna 2007b: 805, pl. I figs 4–6.

Material examined

INDIA • 16 specs; argillaceous limestone in Waior-Charopadi stream near Waghot, Burdigalian, lower Miocene, Chhasra Formation; 23°25′55″ N, 68°42′40″ E; Jan.–Feb. 2012; Pawar leg.; GIS/B 0533 to 0548.

Table 9. Measurements in mm of ?*Tretosina* gen. et sp. indet. (GIS/B 0522 to 0532), Aquitanian, lower Miocene, Kharinadi Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.122	0.144	0.135	±0.004	10
WZ	0.050	0.060	0.056	±0.002	10
LOp	0.040	0.055	0.048	±0.004	10
WOp	0.033	0.041	0.036	±0.002	10

Description

Colony unilaminar, encrusting. Autozooids hexagonal, rounded distally (Fig. 11A). Lateral margins

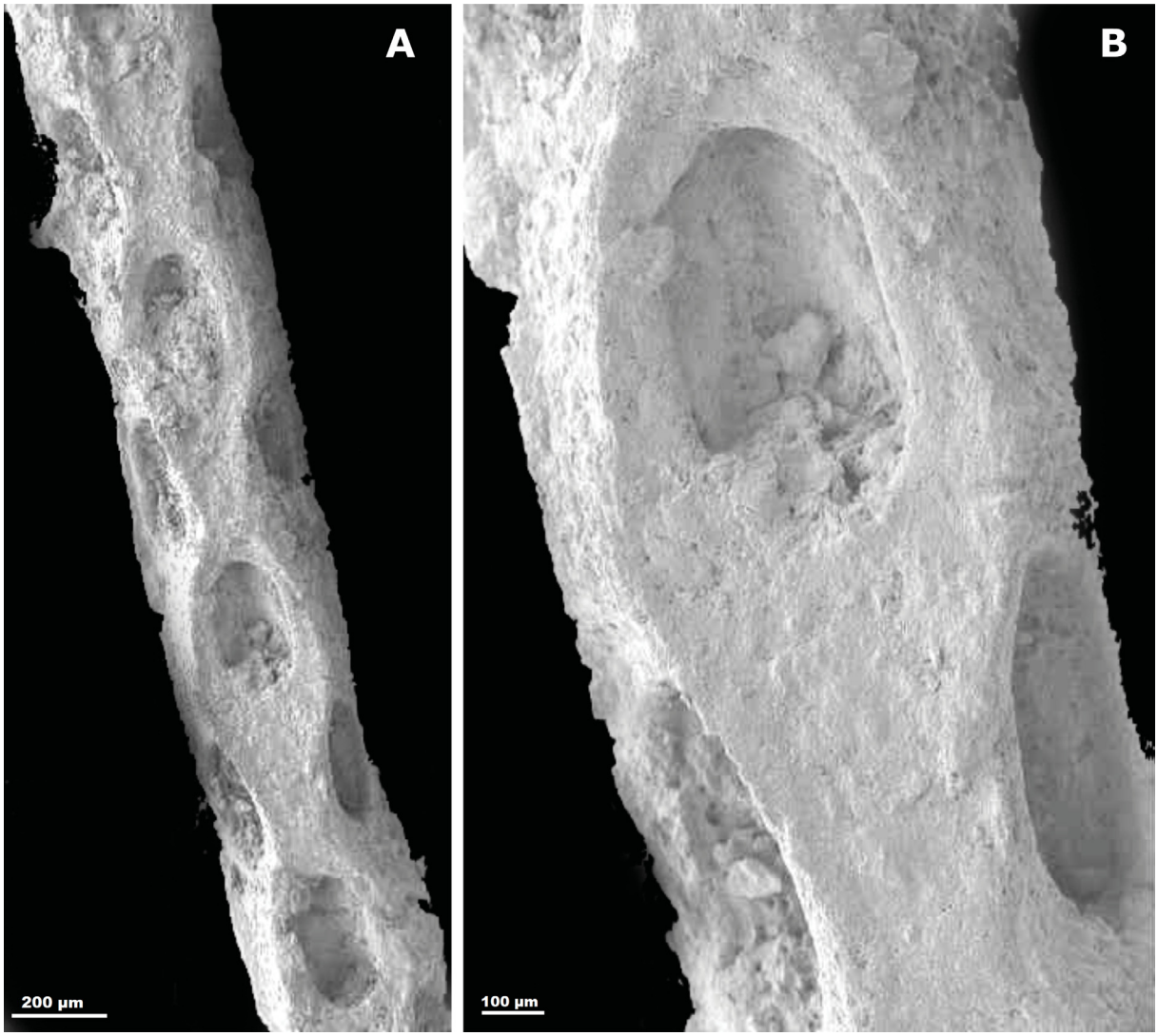

Fig. 10. ?*Tretosina* gen. et sp. indet. (GIS/B 0522). **A**. General view of the colony showing hexagonal autozooid arranged in longitudinal rows. **B**. Close-up of a single autozooid showing oval opesia and tuberculated cryptocysts.

Table 10. Measurements in mm of *Labioporella hariparensis* Guha & Gopikrishna, 2007, Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India (GIS/B 0533 to 0548). Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.360	0.570	0.472	±0.041	20
WZ	0.220	0.320	0.273	±0.015	20
LOr	0.110	0.190	0.155	±0.019	10
WOr	0.140	0.220	0.178	±0.020	10

beaded, thickly calcified, raised in relation to autozooidal frontal shield; autozooidal boundaries also marked by thin grooves. Cryptocyst coarsely granular, occupying nearly ⅔ of autozooidal frontal surface and descending smoothly into the orifice; polypide tube slender, opening into the orifice with medium-sized lateral indentations (Fig. 11B). Two conspicuous tubercles at distolateral corners of each autozooid (Fig. 11C). Opesia rounded quadrangular, wider than long with smooth curved distally. Avicularia small, interzooecial, oval; cryptocyst narrow; opesia large, oval with broader proximal; rostrum thick, prominent, next distal zooid arise from rostral margin of avicularia (Fig. 11D).

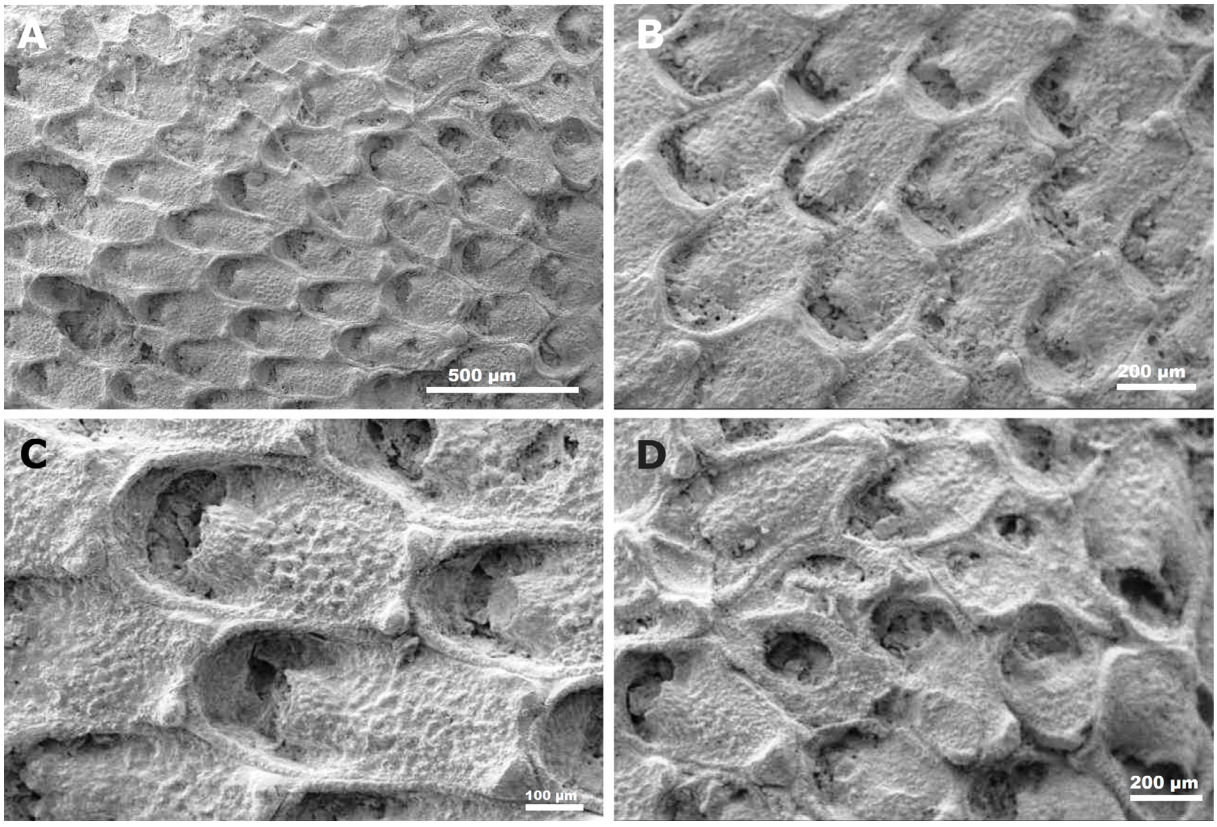

Fig. 11. *Labioporella hariparensis* Guha & Gopikrishna, 2007 (GIS/B 0533). **A**. General view of the colony showing autozooids. **B**. Enlargement of an autozooid showing cryptocyst and polypide tube. **C**. Close-up of the colony showing autozooid with proximal tubercles. **D**. Enlargement of the colony showing ancestrula and interzooecial avicularia.

Remarks

The present species shows a superficial resemblance to *Labioporella filiparietis* Canu & Bassler, 1935 in the shape of the autozooids and the polypide tube but differs in having a granular cryptocyst, and the presence of avicularia and tubercles. The Aquitanian species *Labioporella bassleri* Guha & Gopikrishna 2007 from Kharinadi Formation differs in not having avicularia or tubercles. The Gran Canarian Pliocene *Labioporella* sp. Sendino & Taylor, 2014 differs from the present species in the absence of avicularia, a stout polypide tube and the distal margin of the opesia is higher than wide.

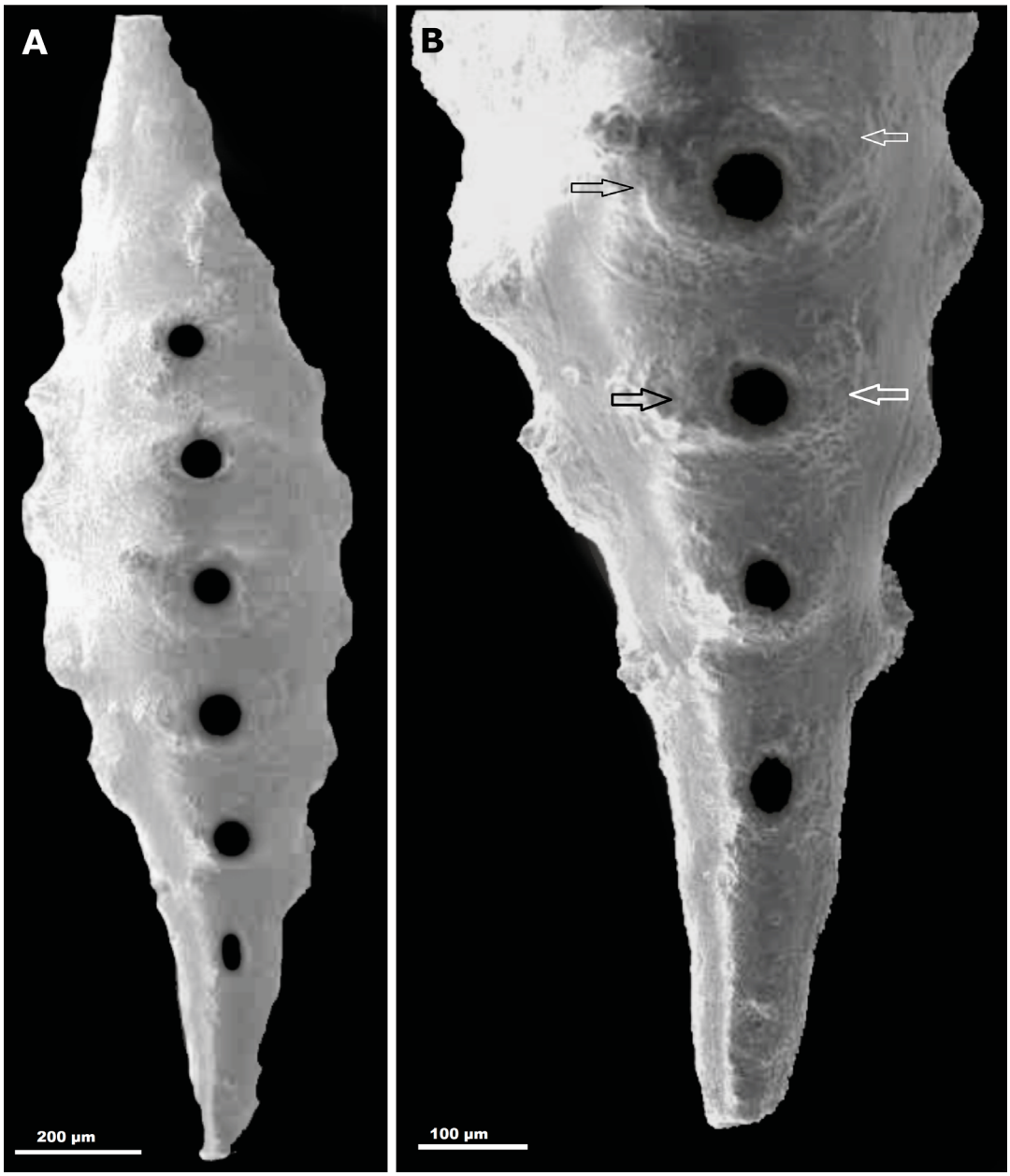

Fig. 12. *Skylonia sandbergi* Sandberg, 1962 (GIS/B 0549). **A**. General view of the colony showing autozooids and well-developed knobs bordering the aperture. **B**. Close-up of the colony showing autozooids and well-developed knobs (arrows).

Table 11. Measurements in mm of *Skylonia sandbergi* Sandberg, 1962 (GIS/B 0549 to 0569), Burdigalian, lower Miocene, Chhasra Formation, western Kachchh, Gujarat, India. Abbreviations: see Material and methods.

	Minimum	Maximum	Mean	SD	N
LZ	0.070	0.090	0.082	±0.002	10
WZ	0.050	0.065	0.056	±0.002	10
LOr	0.021	0.033	0.026	±0.001	05
WOr	0.040	0.051	0.045	±0.002	05

Family Skyloniidae Sandberg, 1963
Genus *Skylonia* Thomas, 1961

Skylonia sandbergi Sandberg, 1962
Fig. 12; Table 11

Material examined

INDIA • 21 specs; Yellow limestone of Waghot section, Burdigalian, lower Miocene, Chhasra Formation; 23°25′35″ N, 68°42′20″ E; Jan.–Feb. 2012; Pawar leg.; GIS/B 0549 to 0569.

Description

Colony spindle-shaped having six to nine zooids, more or less rectangular in each longitudinal row (Fig. 12A). Length and width of a few complete spindles vary between 0.8 mm and 0.3 mm, respectively. Spindles have maximum diameter at or just below central point. Width/length ratio of median zooids varies between 0.3 mm to 0.8 mm. Width of apertures ranges from 0.05 mm to 0.07 mm. Apertures above greatest diameter of spindles open obliquely upwards. End of frontal cover depressed, forming shallow groove. Usually very well-developed knobs bordering aperture (Fig. 12B).

Remarks

The present Kachchh species differs from *Skylonia mirabilis* Thomas, 1961 in the shape of the autozooids and orifice (see Keij 1973: 224, pl. 3 figs 10–13). Compared to the present species, *S. dohmi* (Sandberg, 1962) and *S. thomasi* Keij, 1973 have fewer autozooids in each longitudinal row, knobs adjoining the orifice, and a raised border around the orifice. *Skylonia malabarica* Sonar & Badve, 2019 differs in the number of zooids and the nature of the knobs around the orifice.

Discussion

In the Kharinadi Formation, erect flexible articulated branching cheilostomes are abundant in the Laiyari, Haripar and Murachbann sections, indicating moderate to high energy level and moderate to high sedimentation rate (Amini *et al*. 2004: 13). Free lunulitiform (*Cupuladria* sp.) and erect rigid delicate cheilostomes (?*Tretosina* sp.) are more abundant in the Murachbann and Lakdi River sections. Cupuladriids indicate a stabile sea floor and a very low energy environment (McKinney & Jackson 1989); Zágoršek *et al*. 2012: 215). However, erect rigid delicate forms indicate decreasing water energy and low a sedimentation rate (Amini *et al*. 2004: 13). These zoarial forms are generally cemented to hard substrates at depths of 20–80 m (Moissette *et al*. 2007). Unilaminar encrusting forms viz. *Antropora gadhavii* were found at Haripar in large quantities, where they have *Ostrea*, echinoids and *Turritella* as a hard substrate for their growth. Foraminifera like *Miogypsina*, *Nephrolepidina*, *Austotrillina* and *Spaerogypsina*, *Turritella*, *Ostrea* as well as echinoids – plant fossils are the associated fauna with the

bryozoans indicating that the deposition in Kharinadi Formation took place in a tidal flat, littoral, to shallow inner-shelf environment with a slowly transgressive sea over a stable shelf (Biswas 1992).

In the Chhasra Formation, four localities show an abundance of bryozoans viz. Chhasra, Waghot, Lakdi River and Vinjhan. Erect flexible articulated branching cheilostomes such as *Canda ukirensis* sp. nov., ?*Licornia* sp. 1, *Cellaria* sp. and *Skylonia sandbergi* colonies are most abundant here. These shallow water colonies attached to indurated sediments survive in moderate to high energy waters and occur in littoral environments (Keij 1972; Moissette *et al*. 2007). Free-living lunulitiform viz. *Cupuladria* sp. cheilostomes are also present at Vinjhan. These zoarial growth forms are observed at depths of 20–70 m mainly, but not exclusively on continental shelves (McKinney & Jackson 1989). Unilaminar encrusting growth forms are the next most abundant growth form in the Chhasra Formation. These morphotypes are represented by *Antropora ramaniaensis* sp. nov., *A. gadhavii*, *Micropora vredenbergi* and *Labioporella hariparensis*, which need a hard substrate for encrustation and typically occur at shallow depths with moderate to high water energy and fairly slow sedimentation rate (Moissette *et al*. 2007). The associated fauna includes gastropods like *Turritella*, *Physa*, *Conus*, and others; bivalves like *Ostrea*, *Pecten*, *Arca*, *Venus*, etc. echinoids like *Cidaris*, *Clypeaster* and *Scutella* on which bryozoan encrustations occur. Furthermore, larger foraminifers, especially *Miogypsina*, also show bryozoan encrustations. They occur in both lagoon and shallow subtidal environments. This fauna indicates deposition in the sublittoral environment during maximum sea-level. Foraminifers show a fluctuating marginal marine to a shallow inner-shelf environment of deposition (Biswas 1992).

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