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GENICULATE CORALLINE ALGAE FROM THE EARLY MIOCENE GODHRA FORMATION OF THE KACHCHH OFFSHORE BASIN, WESTERN INDIA

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ABSTRACT

The Godhra Formation (early Miocene) from the Kachchh Offshore Basin reveals presence of a rich assemblage of calcareous algae along with abundant foraminifera. In the present paper, eight species belonging to five genera of geniculate coralline algae are documented and described. These include *Arthrocardia cretacica* Raineri, *Calliarthron antiquum* Johnson, *Corallina grandis* Rao, *C. hayasaki* Ishijima, *C. raoi* Chatterji and Gururaja, *Jania guamensis* Johnson, *J. sripadaraoi* Kundal and Humane and *Subterraniphyllum thomasii* Elliott for the first time. The present geniculate coralline algal assemblage is associated with the dasycladalean algae and this association points that the limestone of the Godhra Formation was deposited at a depth of 10-25 m in a marine water environment under low-energy conditions.

Keywords: Geniculate coralline algae, early Miocene, Palaeoenvironment, Godhra Formation, Kachchh, Gujarat

INTRODUCTION

The different types of carbonates deposited during the Paleogene, Neogene and Quaternary periods in the shelf environment were suitable for luxuriant growth and accumulation of calcareous algae (Kundal, 2010). As most Cenozoic algal genera range to present–day environment, they are potentially useful for palaeoenvironmental interpretations (Singh *et al*., 2010). The morphology of coralline crusts and their growth forms indicate levels of water energies and depth of deposition (Bosence, 1983; Bassi, 1995; Kishore *et al.*, 2007; Kundal, 2010).

The Kachchh Basin is the westernmost pericratonic rift basin situated at the northern end of the western seaboard of India and this basin represents the earliest rift during the break up of Africa and India (Biswas, 1982) (Fig. 1a). The Kachchh Basin (both onland and offshore) is filled with sediments ranging in age from the Middle Jurassic to Holocene. In the onland part, the Mesozoic sediments are very thicker than the Cenozoic sediments which are present in the outer part of the basin bordering the Mesozoic uplifts and the thickness of the exposed Cenozoic sequence is 700 m while it is 5500 m offshore (Mishra, 2009).

A perusal of Table 1 reveals that a rich assemblage of calcareous algae has been documented from the four formations, Fulra Limestone (35 species) Maniyara Fort (81 species), Khari Nadi (10 species) and Chhasra (28 species) from Onshore sequence of the Kachchh Basin (Kundal and Kundal, 2010). However, no record of calcareous algae exists from the offshore sequence of the Kachchh Basin. The Cenozoic Offshore sequence of the Kachchh Basin is subdivided into ten formations, namely, Nakhtarana Formation (late Paleocene), Jakhau Formation (early Eocene), Fulra Limestone Formation (late middle Eocene), Sir Formation (middle to late Eocene), Tuna Formation (early Oligocene), Narayan Sarovar Formation (early Miocene), Godhra Formation (early Miocene), Mitti Nadi Formation (early Miocene), Chhasra Formation (early middle Miocene) and Kandla Formation (middle Miocene to Recent) (Mishra, 2009) (Fig. 1b).

The Godhra Formation (early Miocene) is 1200 m thick and consists of shale/claystone/limestone alternations and minor sandstone (Mishra, 2009). Nine samples of limestone were obtained from two wells KD-1A (depth 1600-1604m) and GK-17-1 (depth 2320-2322m) from Regional Geosciences Laboratory, Oil and Natural Gas Corporation Ltd., Panvel, Navi Mumbai (Fig. 1c). Petrographically, the limestone is a foram-algal grainstone (Fig. 2a-d) . The well KD-1A shows presence of seven geniculate coralline algal species, namely, *Arthrocardia cretacica* Raineri, *Calliarthron antiquum* Johnson, *Corallina grandis* Rao, *C. hayasaki* Ishijima, *C. raoi* Chatterji and Gururaja, *J. guamensis* Johnson and *J. sripadaraoi* Kundal and Humane, while the well GK-17-1 shows presence of a solitary species *Subterraniphyllum thomasii* Elliott. The geniculate coralline algal species are studied under petrological microscope.

SYSTEMATIC TAXONOMY

The geniculate coralline algal genera are identified based upon distinguishing characteristics given by Wray (1977), Bassi *et al.* (2000), Kundal and Humane (2006b), Kishore *et al.* (2011) and Kundal (2011). The following abbreviations are used to measure the dimensions of various geniculate coralline algal species: SN- Specimen Number; LS- Length of Segment; WS- Width of segment; NT-Number of tiers; TCR- Thickness of Core region; TPR- Thickness of Peripheral region; LCC- Length of Core cell; WCC- Width of Core cell; LPC- Length of Peripheral cell and WPC- Width of Peripheral cell.

Division **Rhodophyta Wittstein 1901**
Class **Florideophyceae Cronquist, 1960**
Subclass **Corallinophycidae Le Gall and Saunders, 2007**
Order **Corallinales Silva and Johansen 1986**
Family **Corallinaceae Lamouroux, 1812**
Subfamily **Corallinoideae Gray, 1821**
Genus ***Arthrocardia*** **Decaisne emend. Areschoug, 1852**

Arthrocardia cretacica Raineri

(Pl. I, fig. 1; Pl. II, fig. 3)

Arthrocardia cretacica Raineri: Johnson, 1969, pp. 17-18, pl. 7, fig. 3. – *Arthrocardia cretacica* Raineri: Kundal and Humane, 2002, pp. 94-95,figs. 7a,b,c,e. – *Arthrocardia cretacica* Raineri: Kundal and Mude, 2009, pp. 268-269, pl. I, fig 7.

Material: Specimen nos. PGTDG/MF/FCA/649,659.

Dimensions (in µm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
649	656	99-108	5	99-108	-	90-100	5-10	-	-
659	520	170	4	138	16	90-100	4-9	-	-

Description: Intergenicula cylindrical and ovate. Cell rows of core region join regularly and more or less flattened. Cell fusions present. Conceptacle not preserved in the specimens.

Remarks: The present specimens have similar length and width of core cell as that of *Arthrocardia cretacica* Raineri. Therefore the present specimens are described as *Arthrocardia cretacica* Raineri.

Stratigraphical and Geographical distribution: Lower Cretaceous algae from Texas (Johnson, 1969); Maniyara Fort Formation (Oligocene) and Chhasra Formation (early middle Miocene) of Onshore sequence of Kachchh Basin, Gujarat (Kundal and Humane, 2002); Neogene-Quaternary sediments in and around Porbandar, Gujarat, India (Kundal and Mude, 2009).

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Offshore sequence of Kachchh Basin.

Genus ***Calliarthron*** Manza, 1937

Calliarthron antiquum Johnson

(Pl. I, figs. 4-5)

Calliarthron antiquum Johnson: Johnson 1957, p.237, pl.52., figs. 1and 9. – *Calliarthron antiquum* Johnson: Johnson 1964, p. G31.– *Calliarthron antiquum* Johnson: Kundal and Wanjarwadkar 2000, pp. 97-98, pl. 28, figs. 1,2,3,5. – *Calliarthron antiquum* Johnson: Kundal and Humane 2002, p. 97, fig. 8. – *Calliarthron antiquum* Johnson: Kundal and Mude, 2009, p. 269, pl. I, fig 1.

Material: Specimen nos. PGTDG/MF/FCA/651,652.

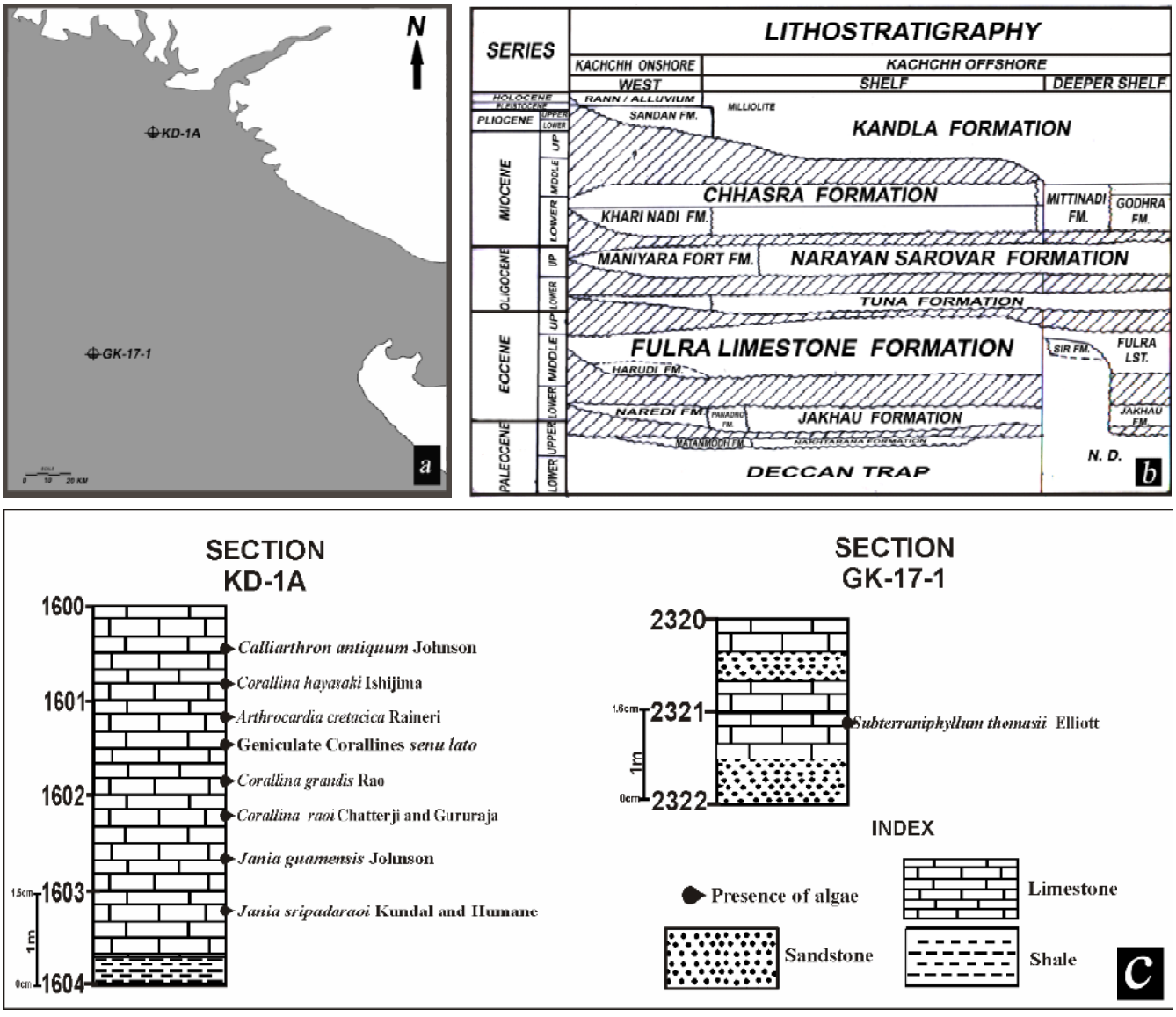

Fig. 1a. Location map of the Kachchh Basin showing position of wells. 1b. Lithostratigraphy of the Kachchh Basin (after Mishra, 2009). 1c. Lithosections showing distribution of geniculate coralline algae.

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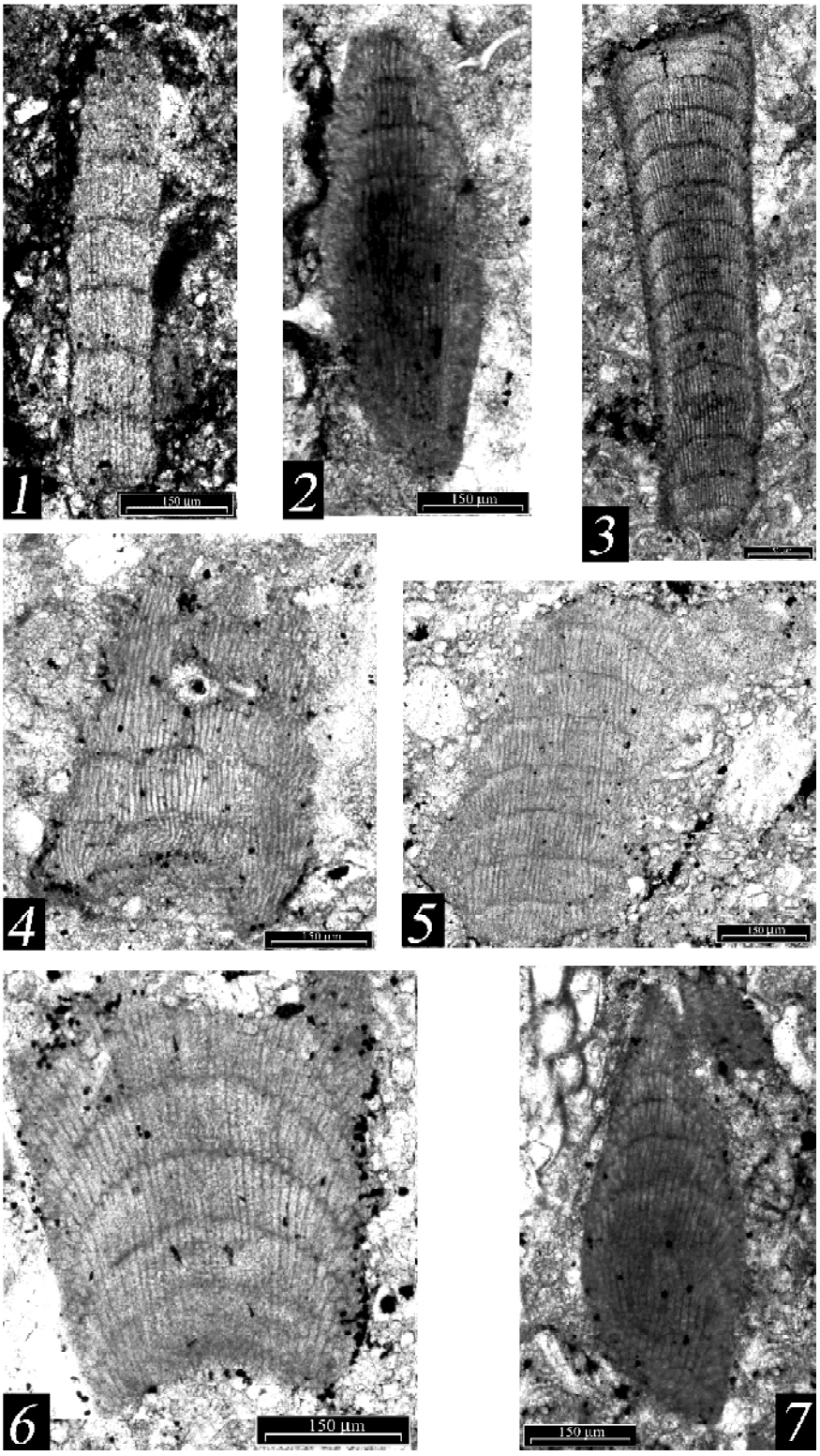
Plate I



KUNDAL AND HUMANE

EXPLANATION OF PLATE I

1. ***Arthrocardia cretacica*** Raineri, Specimen no. PGTDG/MF/FCA/649.
2. ***Corallina grandis*** Rao, Specimen no. PGTDG/MF/FCA/650.
3. ***Corallina raoi*** Chatterji and Gururaja, Specimen no. PGTDG/MF/FCA/655.
4. ***Calliarthron antiquum*** Johnson, Specimen no. PGTDG/MF/FCA/651.
5. ***Calliarthron antiquum*** Johnson, Specimen no. PGTDG/MF/FCA/652.
6. ***Corallina hayasaki*** Ishijima, Specimen no. PGTDG/MF/FCA/654.
7. ***Corallina grandis*** Rao, Specimen no. PGTDG/MF/FCA/653.

Table 1: Calcareous Algae from middle Eocene to early middle Miocene onshore sequence of the Kachchh Basin, western India.

Name of the Formation	Authors	Algal assemblage
Sandhan Formation		**Absent**
Chhasra Formation (early middle Miocene)	Kundal and Humane (2002, 2003, 2006a, 2007b); Humane and Kundal (2005, 2010); Humane, Kundal and Naitam (2006)	**Cyanophycean algae:** *Rivularia lissaviensis* (Bornemann) Dragastan, *R. dianae* (Dragastan and Bucur) and *Rivularia* sp. **Coralline algae:** *Amphiroa anchiverricosa* Johnson and Ferris, *Arthrocardia cretacica* Raineri and *Calliarthron antiquum* Johnson, *Corallina elliptica* Ishijima, *C. hayasaki* Ishijima, *C. kachchhensis* Kundal and Humane, *C. marshallensis* Johnson, *C. matansa* Johnson, *C. prisca* Johnson, *C. raoi* Chatterji and Gururaja, *C. typica* Ishijima, *Lithophyllum* sp., *Lithoporella melobesioides* (Foslie) Foslie, *Lithothamnion cardinellense* Fravega, Piazza and Vannucci, *Metagoniolithon* sp., and *Sporolithon affine* Howe **Dasyclads:** *Acroporella* sp., *Broeckella* sp., *Clypeina* sp., *Neomeris plagnensis* Deloffre, *N. ramwadaensis* Kundal and Humane and *Orioporella* sp. **Halimedacean alga:** *Halimeda cylindracea* Decaisne **Udoteacean algae:** *Ovulites margaritula* Lamarck and *O. pyriformis* Schwager
Khari Nadi Formation (early Miocene age)	Pal and Ghosh (1974); Kundal and Humane (2002, 2006b); Humane and Kundal (2010)	**Coralline algae:** *Aethesolithon cutchensis* Pal and Ghosh, *A. problematicum* Johnson, *Amphiroa anchiverricosa* Johnson and Ferris, *Archaeporolithon miocenicum* Pal and Ghosh, *Calliarthron antiquum* Johnson, *Jania badvei* Kundal and Humane, *Lithophyllum* aff. *L. kladosum* Johnson, *Lithothamnion florea-brassica* (Millet) Lemoine, *Mesophyllum commune* Lemoine and *Sporolithon eniwetokensis* Johnson
Maniyara Fort Formation (Oligocene)	Tandon, Gupta and Saxena (1978); Singh and Kishore (2001); Misra, Jauhri, Singh, Kishore and Chowdhury (2001); Kundal and Humane (2002, 2003,2006b, 2007a, 2007b); Ghosh (2002): Singh, Kishore,Misra, and Jauhri (2002) Humane and Kundal (2005, 2010); Singh, Kishore, Singh, Misra and Jauhri (2009); Singh, Kishore, Jauhri and Misra (2011).	**Coralline algae:** *Amphiroa anchiverricosa* Johnson and Ferris, *Amphiroa* sp., *Arthrocardia cretacica* Raineri, *A. indica* Kundal and Humane, *A. konitaensis* Ishijima, *Arthrocardia* sp.1, *Corallina delicatula* Johnson and Ferris, *C. elliptica* Ishijima, *C. grandis* Rao, *C. kachchhensis* Kundal and Humane, *C. marshallensis* Johnson, *C. matansa* Johnson, *C. otsukiensis* Ishijima, *Corallina* sp.1, *Corallina* sp. 2, *Jania badvei* Kundal and Humane, *J. guamensis* Johnson, *J. indica* Kundal and Wanjarwadkar, *J. mayei* Johnson, *J. sripadaraoi* Kundal and Humane, *J. vetus* Johnson, *Lithophyllum bermotiensis* Tandon, Gupta and Saxena, *Lithophyllum* sp. A, *Lithophyllum* sp. B, *Lithophyllum* sp. C, *Lithoporella melobesioides* (Foslie) Foslie, *L. minus* Johnson, *Lithoporella* sp., *Lithothamnion cardinellense* Fravega, Piazza and Vannucci, *L. giammarinoi* Fravega, Piazza and Vannucci, *Lithothamnion iorii* Maslov, *L. manni* Johnson and Stewart, *L. nanosporum* Johnson and Ferris, *L. tectifons* Mastrorilli, *L. florea-brassica* (Millet) Lemoine, *Lithothamnion* sp.1, *Lithothamnion* sp. 2, *Lithothamnion* sp.3, *Lithothamnion* sp., *Melobesioideae* gen. et spec. indet. 1, *Melobesioideae* gen. et spec. indet. 2, *Melobesioideae* gen. et spec. indet. 3, *Mesophyllum commune* Lemoine, *M. curtum* Aguirre and Braga, *M. koritzae* Lemoine, *M. roveretoi* Contii, *Mesophyllum* sp. A, *Mesophyllum* sp. B, *Mesophyllum* sp.1, *Mesophyllum* sp.2, *Mesophyllum* sp., *Neogoniolithon* sp. 1 Bassi and Nebelsick, *Neogoniolithon* sp. 2 Hassan and Ghosh, *Neogoniolithon* sp. 2 *Neogoniolithon* sp., *Spongites* sp., *Sporolithon brevium* (Lemoine) Aguirre and Braga, *Sporolithon taiwanensis* Ishijima, *Sporolithon* sp. 1 Bassi and Nebelsick and *Sporolithon* sp. **Dasyclads:** *Acicularia* sp., *Goniolina* sp., *Cymopolia* sp., *Neomeris* sp. and *Salpingoporella* sp. **Halimedacean algae:** *Halimeda fragilis* Taylor, *H. incrassata* (Ellis) Lamouroux, *H. opuntia* (Linneaus) Lamouroux, *H. tuna* (Ellis and Solander) Lamouroux and *Halimeda* sp. **Udoteacean algae:** *Ovulites margaritula* Lamarck and *O. pyriformis* Schwager
Fulra Limestone Formation (middle Eocene)	Kar (1979); Singh and Kishore (2001); Kundal and Humane (2002, 2003, 2005, 2006b, 2007a); Humane and Kundal (2005, 2006, 2010); Misra, Jauhri, Singh and Kishore (2006); Singh, Kishore, Misra, Jauhri and Gupta (2010)	**Coralline algae:** *Arthrocardia indica* Kundal and Humane, *Arthrocardia* sp., *Calliarthron antiquum* Johnson, *Corallina crossmanni* Lemoine, *C. marshallensis* Johnson, *Jania guamensis* Johnson, *J. mayei* Johnson, *J. sripadaraoi* Kundal and Humane, *J. vetus* Johnson, *Lithophyllum* sp. *Lithoporella melobesioides* (Foslie) Foslie, *Lithoporella minus* Johnson, *Lithothamnion* sp. cf. *L. bofilli* Lemoine, *Lithothamnion ishigakiensis* Johnson, *Lithothamnion roveretoi* Airoldi, *Lithothamnion* sp. cf. *L. validum* Foslie, *Melobesioideae* gen. et spec. indet. 1, *Melobesioideae* gen. et spec. indet. 2, *Mesophyllum contii* Ishijima, *Mesophyllum* sp., *Neogoniolithon* sp. 1, *Phymatolithon* sp., *Spongites* sp., *Sporolithon keenani* Johnson, *Sporolithon* sp. 1 and *Subterraniphyllum thomasii* Elliott **Dasyclads:** *Cymopolia* sp., *Dissocladella longijangensis* Mu and Wang and *Morelletpora* sp. **Halimedacean algae:** *Halimeda cylindracea* Decaisne and *H. opuntia* (Linneaus) Lamouroux **Udoteacean algae:** *Ovulites arabica* (Pfender) Massieux, *O. elongata* Lamarck, *O. margaritula* Lamarck and *O. pyriformis* Schwager
Harudi Formation		**Absent**
Naredi Formation		**Absent**
Matanomadh Formation		**Absent**

Dimensions (in μm):

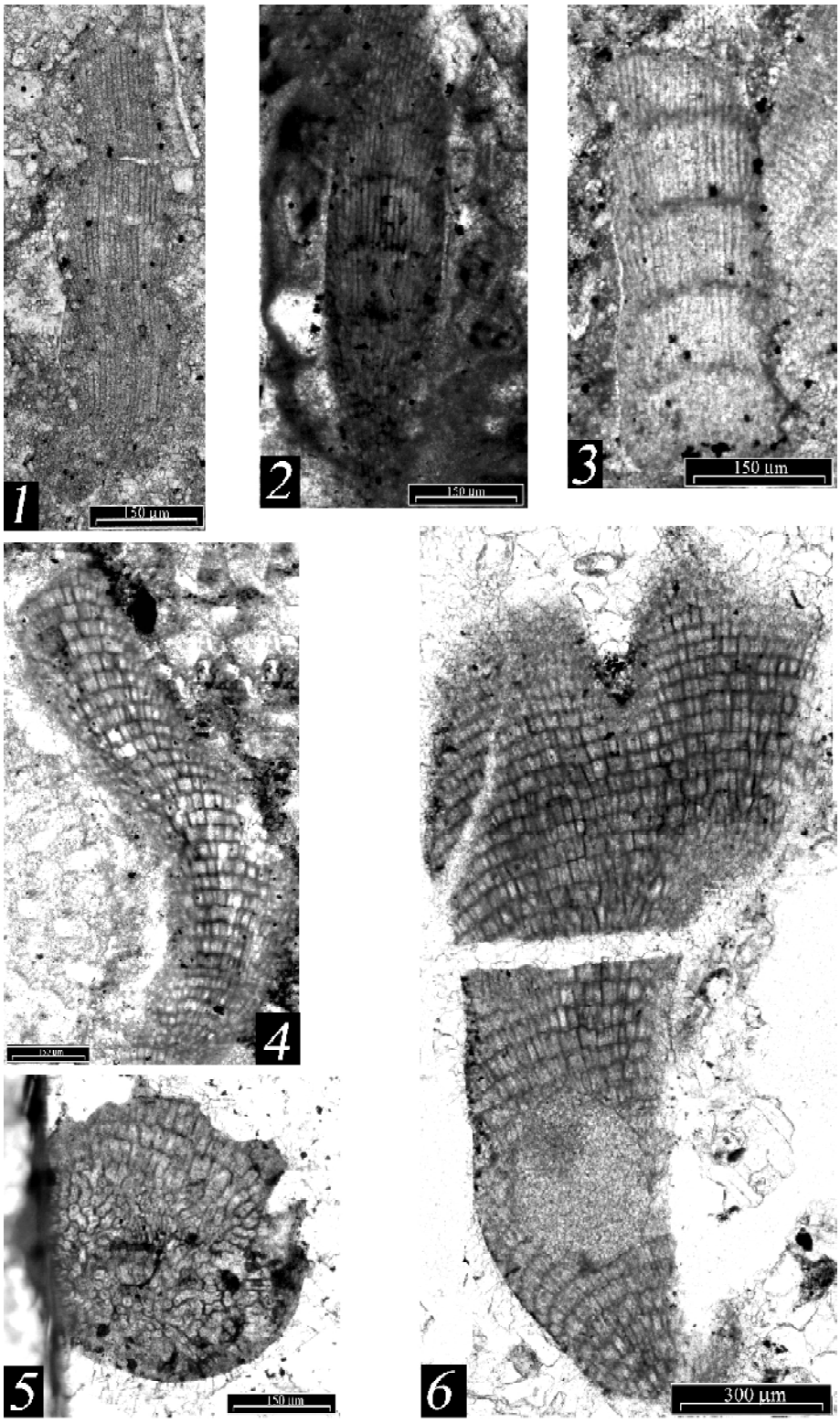
SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
651	470	296-418	4	280-402	8	84-110	8-11	-	-
652	610	300-350	7	274-324	26	70-80	8-10	-	-

Description: Intergenicula subcylindrical. Cell rows of core region join regularly and core filaments sinuous, and interlacing. Peripheral region thin and having sparse cells. Cell fusions present. Conceptacle not preserved.

Remarks: The present specimens closely resemble *Calliarthron antiquum* Johnson.

Stratigraphical and Geographical distribution: Early Miocene of Saipan, Mariana Islands (Johnson, 1957); early Miocene of Guam (Johnson, 1964); late Paleocene of Middle Andaman Island, Andaman (Wanjarwadkar, 2000); middle Eocene to early Miocene of Onshore sequence of Kachchh Basin, Gujarat (Kundal and Humane 2002); Neogene-

Plate II



EXPLANATION OF PLATE II

1. **Geniculate Corallines** *sensu lato*, Specimen no. PGTDG/MF/FCA/662.
2. ***Jania sripadaraoi*** Kundal and Humane, Specimen no. PGTDG/MF/FCA/658.
3. ***Arthrocardia cretacica*** Raineri, Specimen no. PGTDG/MF/FCA/659.
4. ***Jania guamensis*** Johnson, Specimen no. PGTDG/MF/FCA/657.
5. ***Subterraniphyllum thomasii*** Elliott Specimen no. PGTDG/MF/FCA/661.
6. ***Subterraniphyllum thomasii*** Elliott Specimen no. PGTDG/MF/FCA/660.

Quaternary sediments in and around Porbandar, Gujarat, India (Kundal and Mude, 2009).

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Offshore sequence of Kachchh Basin, Gujarat.

Genus ***Corallina*** Linnaeus, 1758

Corallina grandis Rao

(Pl. I, fig. 7)

Corallina grandis Rao: Rao, 1943, pp. 286-287, pl. 2, figs. 16,17,18, text figs. 27-30. - *Corallina grandis* Rao: Kundal and Humane, 2003, pp. 264-265, pl. 5, fig. 1. - *Corallina grandis* Rao: Mude and Kundal, 2012, pp. 73-75, pl. 2, fig c.

Material: Specimen nos. PGTDG/MF/FCA/650,653.

Dimensions (in μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
650	628	150-238	3	100-142	48	83	9-13	-	-
653	506	108-285	2	58-235	25	42-58	8-15	-	-

Description: Intergenicula conical in shape. Core region shows regular rows of cells. Peripheral region thin. Conceptacle absent.

Remarks: The present specimens have conical intergenicula and similar length and width of core cells like *Corallina grandis* Rao.

Stratigraphical and Geographical distribution: Sylhet Limestone Formation (Eocene), Khasi Hills, Assam (Rao, 1943). Maniyara Fort Formation (Oligocene) at Maniyara Dam, Onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2003) and late Miocene to late Holocene sediments of Porbandar Group, Gujarat (Mude and Kundal, 2012).

Horizon and Locality: Godhra Formation(early Miocene) of well KD-1A of Offshore sequence of Kachchh Basin.

Corallina hayasaki Ishijima

(Pl. I, fig. 6)

Corallina hayasaki Ishijima: Ishijima 1954, pp. 72, p. 40. 3,5,7,8; pl.41 fig. 12.– *Corallina hayasaki* Ishijima: Kundal and Humane, 2003, pp. 265-266, pl.3, fig.1.– *Corallina hayasaki* Ishijima: Kundal and Mude, 2009, p. 271, pl. I, fig 5.

Material: Specimen no. PGTDG/MF/FCA/654.

Dimensions in (μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
654	413	295-400	4	271-376	12	85-95	3-10	-	-

Description: Intergeniculum rectangular. Cells rows of core region join regularly. Peripheral region is thin. Conceptacle absent.

Remarks: The present specimen is similar to *Corallina hayasaki* Ishijima in length and width of core cells as well as the shape of intergeniculum.

Stratigraphical and Geographical distribution: Miocene limestone of Binangonan, Rizal state, Ruzon Island, Philippine, Western Pacific (Ishijima, 1954), early middle Miocene Chhasra Formation, Onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2003) and Neogene-Quaternary sediments in and around Porbandar, Gujarat, India (Kundal and Mude, 2009).

Horizon and Locality: Godhra Formation of well KD-1A of Offshore sequence of Kachchh Basin.

Corallina raoi Chatterji and Gururaja

(Pl. I, fig. 3)

Corallina raoi Chatterji and Gururaja: Chatterji and Gururaja,1972, pp.141, Pl.39, fig.5.– *Corallina raoi* Chatterji and Gururaja: Kundal and Humane, 2003, pp.271-272, pl.3, fig.4.

Material: Specimen no. PGTDG/MF/FCA/655.

Dimensions in (μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
655	1287	241-373	13	187-319	42	67-83	8-12	24	16

Description: Intergeniculum subcylindrical and long. Core region consists of thirteen to fourteen cell rows which join

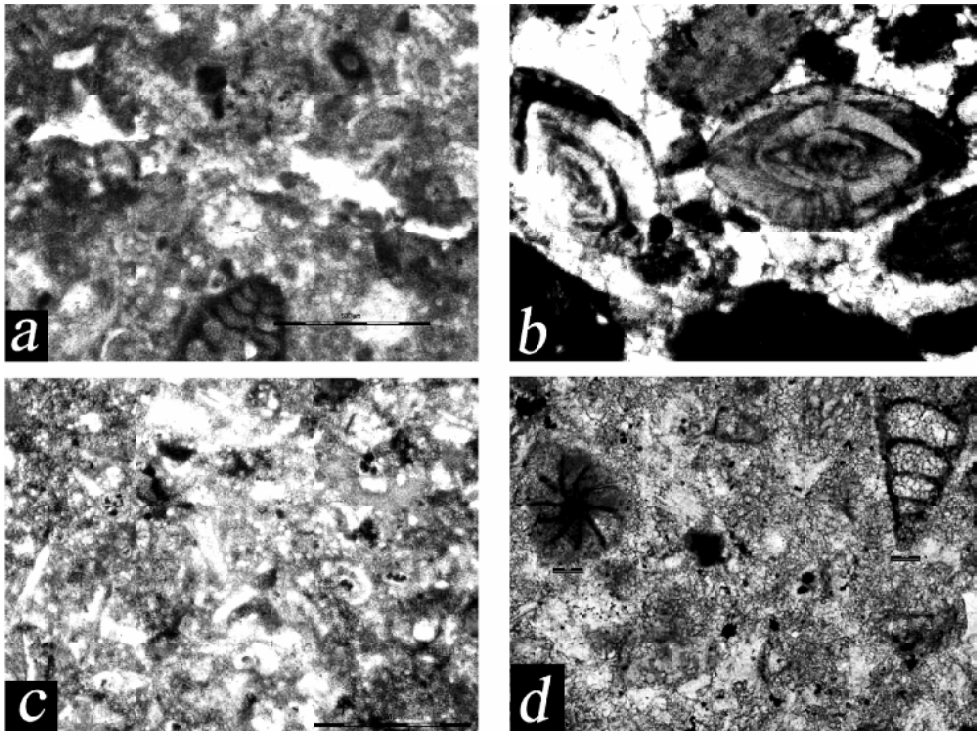


Fig. 2a-d. Microphotographs showing foram-algal grainstone.

regularly. Peripheral region thin. Conceptacle absent.

Remarks: On the basis of dimension of core cells and peripheral cells the present specimen is described as *Corallina raoi* Chatterji and Gururaja.

Stratigraphical and Geographical distribution: Early Miocene (Aquitanian) of Archipelago Series, Western Coast, Wilson Island, Andaman (Chatterji and Gururaja, 1972), Chhasra Formation (early middle Miocene) and Onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2003).

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Offshore sequence of Kachchh Basin.

Genus ***Jania*** Lamouroux, 1812

Jania guamensis Johnson

(Pl. II, fig. 4)

Jania guamensis Johnson: Johnson, 1964, p.G-36, pl.12, figs. 1-3.– *Jania guamensis* Johnson: Kundal and Wanjarwadkar, 2000, p.231, pl. 1, fig. 2, pl. 3, fig. 2.– *Jania guamensis* Johnson: Kundal and Humane, 2006b, p. 633, pl.2, figs. 2-3.– *Jania guamensis* Johnson: Mude and Kundal, 2012, p. 75, pl. 2, fig b.

Material: Specimen no. PGTDG/MF/FCA/657.

Dimensions (in μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
657	1107	186-229	-	150-193	18	26-39	13-26	-	-

Description: Intergeniculum sinuous. Cell rows of core region join irregularly and core cells are wedge shaped. Cell fusions clearly visible. Peripheral region poorly preserved. Conceptacle lacking.

Remarks: The dimension of core cells in the present specimen is similar to *Jania guamensis* Johnson. Therefore the present specimen is kept under *Jania guamensis* Johnson.

Stratigraphical and Geographical distribution: Early Micoene of Guam, Mariana Island (Johnson, 1964); late Paleocene of Middle Andaman, India (Kundal and Wanjarwadkar, 2000); middle Eocene to early Miocene Onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2006b) and late Miocene to late Holocene sediments of the Porbandar Group, Gujarat (Mude and Kundal, 2012).

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Offshore sequence of Kachchh Basin.

Jania sripadaraoi Kundal and Humane

(Pl. II, figs. 2)

Jania sripadaraoi Kundal and Humane: Kundal and Humane, 2006b, p. 634, pl.1, figs.1,2. *Jania sripadaraoi* Kundal and Humane: Kundal and Mude, 2009, p.272, pl. I, fig 9,12.

Material: Specimen no. PGTDG/MF/FCA/658.

Dimensions (in μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
658	780	110-180	3	66-136	22	99-109	4-12	-	-

Description: Intergeniculum cylindrical to subcylindrical. Core cell rows join irregularly. Core cells wedge shaped. Peripheral region thin. Conceptacle not preserved.

Remarks: The dimension of core cells are similar to *Jania sripadaraoi* Kundal and Humane. Therefore, the present specimen is identified as *Jania sripadaraoi* Kundal and Humane.

Stratigraphical and Geographical distribution: Middle Eocene to early Miocene Onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2006b) and Neogene-Quaternary sediments in and around Porbandar, Gujarat, India (Kundal and Mude, 2009).

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Kachchh Offshore Basin of Offshore sequence of Kachchh Basin.

Genus ***Subterraniphyllum*** Elliott, 1957

Subterraniphyllum thomasii Elliott

(Pl. II, figs. 5-6)

Subterraniphyllum thomasii Elliott: Elliott , 1957, pp.73-75, pl.13.– *Subterraniphyllum thomasii* Elliott: Beckmann and Beckmann, 1966, pp.1-45, pl.8, fig.112.– *Subterraniphyllum thomasii* Elliott: Mastrorilli, 1968, pp.1275-1284, pls.1-4.– *Subterraniphyllum thomasii* Elliott: Vannucci, Basso and Fravega, 2000, pp.237-246, pl.1-4.– *Subterraniphyllum thomasii* Elliott: Bassi, Woelkerling and Nebelsick, 2000, pp.405-425, pl.1,2,3.– *Subterraniphyllum thomasii* Elliott: Kundal and Humane, 2005, figs 2a,b,c.d, fig 3a,b,c,d. *Subterraniphyllum thomasii* Elliott: Mude and Kundal, 2011, pp 51-55, pl. 1.

Material: Specimen no. PGTDG/MF/FCA/660-661.

Dimensions (in μm):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
660	1743	411-744	-	411-744	-	33-44	11-22	-	-
661	Circular in shape diameter is 444μm		-	-	-	48-31	13-19	-	-

Description: Intergenicula subcylindrical and circular. Intergeniculum exhibits bifurcation. Intergeniculum composed of core region, peripheral region and epithallium. Cells in the core region rectangular to polygonal having thick cell wall. Peripheral region in 2-4 rows. Cells in the peripheral region rectangular to polygonal having thick cell wall. Cells in both core region and peripheral region show cell fusions. Epithallial cells in one row but sparsely preserved and present only top right side of segment. Epithallial cells rectangular but smaller than cells in the core and peripheral region. A pear-shaped uniporate conceptacle having lining cells present. The conceptacle having width 286μm and height 360μm.

Remarks: The dimension of cells in both core and peripheral region are as like that of *Subterraniphyllum thomasii* Elliott. The present material has presence of conceptacle having lining cells like *Subterraniphyllum thomasii* Elliott documented by Vannucci *et al.* (2000) from late Eocene to Oligocene, Molare Formation, Italy. Therefore the present specimens are described as *Subterraniphyllum thomasii* Elliott.

Stratigraphical and Geographical distribution: Tertiary calcareous algae (Elliott, 1957), Oligocene Formation lying northeast to Ponzne (Piedmont) (Mastrorilli, 1968), late Eocene to Oligocene, Molare Formation outcropping close to Alessandria NW Italy (Vannucci, Basso and Fravega, 2000), Oligocene rocks from northen Slovenia north east Italy (Bassi, Woelkerling and Nebelsick, 2000), Fulra Limestone Formation (late middle Eocene) onshore sequence of Kachchh Basin, Gujarat, India (Kundal and Humane, 2005) and lower to middle Miocene Dwarka Formation, Porbandar, Saurashtra, Gujarat, India (Mude and Kundal, 2011).

Horizon and Locality: Godhra Formation (early Miocene) of well GK-17-1 of Offshore sequence of Kachchh Basin.

Geniculate Corallines *sensu lato*

(Pl. II, fig.1)

Geniculate Corallines *sensu lato*: Bassi and Nebelsick, 2000, p.115, pl.5, fig.4-6

Material: Specimen no. PGTDG/MF/FCA/662

Description: Intergeniculum does not contain rows. Cells

are not clearly differentiated into core and peripheral regions. Conceptacle absent.

Remarks: Following the scheme of Bassi and Nebelsick (2000), the present specimen is identified as Geniculate Corallines *sensu lato* Bassi and Nebelsick.

Horizon and Locality: Godhra Formation (early Miocene) of well KD-1A of Kachchh Offshore Basin of Offshore sequence of the Kachchh Basin.

DISCUSSION

The present geniculate coralline algal assemblage comprises eight species belonging to five genera, namely *Arthrocardia cretacica* Raineri, *Calliarthron antiquum* Johnson, *Corallina grandis* Rao, *C. hayasaki* Ishijima, *C. raoi* Chatterji and Gururaja, *Jania guamensis* Johnson, *J. sripadaraoi* Kundal and Humane and *Subterraniphyllum thomasii* Elliott. Present geniculate coralline algal assemblage is associated with the dasycladalean algae (not described here).

Without indicating precise depth of deposition, Mishra (2009) surmised that the Godhra Formation was deposited in the inner-shelf environment. As corallines occupy a large depth range from 0 to 270 m (Littler *et al.,* 1986), the present geniculate algal assemblage is not indicative of precise depth of deposition. However, the present assemblage is useful to denote energy conditions prevailing during the deposition of the Godhra Formation. Bosence (1991) noted that coralline algae growing in high-energy conditions have robust, fused framework with thick crusts, branches and columns, while those growing in low-energy conditions have delicate framework with thin branches and crusts. Nearly all the present coralline algal species have thin crusts with no branches except *Subterraniphyllum thomasii* Elliott (Pl. II, fig. 6). They thus indicate low-energy conditions.

The living dasycladales generally occur at depths of 10-12 m below low-tide level in marine conditions (Johnson, 1961), but rarely at depths of 25 m (Valet, 1979). Wray (1977) and Genot (1991) concluded that dasycladales are always known from marine environment and restricted to tropical warm water. Dragastan *et al*. (2005) surmised that dasycladaleans are restricted to open lagoon environment having low-energy conditions. Hence, the association of geniculate coralline algal assemblage with dasycladalean points out that the limestone of the Godhra Formation was deposited at a depth of 10-25 m in marine environment under low-energy conditions.

REPOSITORY

The specimens studied are kept in the Micropaleontology Laboratory of the Postgraduate Department of Geology, RTM Nagpur University, Nagpur.

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