



CALCAREOUS ALGAE FROM THE MILIOLITE FORMATION (MIDDLE PLEISTOCENE) OF DIU, SAURASHTRA

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ABSTRACT

The present communication records 06 nongeniculate coralline, 05 geniculate coralline, 01 halimedacean and 01 dasycladalean algal species for the first time from the Miliolite Limestone belonging to the Dhobalia Talav and Adatiana Members of the Miliolite Formation (middle Pleistocene) of Diu and the adjacent areas, southern Saurashtra, Gujarat. The Dhobalia Talav member of the Miliolite Formation shows presence of a dasyclad *Dissocladella* sp., and a geniculate coralline alga *Amphiroa regularis*. The presence of these algal elements indicates that this member was deposited at a depth of 5-6 m below the tide level. The Adatiana Member of the Miliolite Formation shows presence of 11 coralline and 01 halimedacean algal species. These species suggest that this member was deposited at a comparatively more depth, i. e. 25 to 30 m below low-tide level.

Keywords: Calcareous algae, paleoenvironments, middle Pleistocene, miliolites, Diu, Saurashtra

INTRODUCTION

Diu and adjoining areas of Saurashtra fall between longitudes 70° 52' 30" to 71° 22' 30" and latitudes 20° 42' to 20° 52'. Diu island is a part of the union territory of Daman and Diu along the Western coast of India adjacent to Maharashtra and Gujarat states respectively. Diu lies off the southern coast of Saurashtra (Gujarat) and is separated from the mainland by a narrow creek. Diu island exposes miliolitic limestones or miliolites belonging to the Miliolite Formation (Middle Pleistocene). The Miliolite Formation is exposed along the Saurashtra coast covering eastern portion of Dwarka in the north to Diu in the south and further extending to Mahuva in the southeast (Srivastava, 1963). The Miliolite Formation is further subdivided into the Dhobalia Talav Member, characterized by an interbedded sequence of calcarenite/pelletoid limestone and micrites, and the Adatiana Member, characterized by pelletoid calcarenites (Mathur and Verma, 1979; Mathur *et al.*, 1988 and Bhatt, 2003). The Adatiana Member has a maximum thickness of more than 15 m in the Diu Quarry section. The Adatiana Member has two dominant lithologies representing two members, namely Highly Recrystallized Adatiana Member (HRAM) and Friable Adatiana Member (FRAM).

So far, the limestones of the Miliolite Formation have shown presence of biotic constituents such as foraminiferal tests mainly of rotalids, a very small proportion of *Miliolina*, molluscan shell fragments, echinoids, bryozoan, corals, ostracodes, and large number of crustacean fecal pellets (Mathur and Verma, 1979; Chakrabarti and Baskaran, 1989; Bhatt, 2006). Kundal and Mude (2008) have reported 05 ichnospecies namely, *Ophiomorpha borneensis*, *O. irregulare*, *O. nodosa*, *Planolites beverleyensis* and *P. montanus* from the Adatiana Member exposed near the Porbandar area of Saurashtra. Subsequently, Kundal and Mude (2009a, 2009b, 2010) have documented 3 nongeniculate coralline algal species namely *Melobesioideae* gen. et spec. indet., *Sporolithon statillense* and *Lithoporella melobesioides* and 02 geniculate coralline algal species *Amphiroa*

ephedraceae and *Jania sripadaraoi* from the Adatiana Member, Porbandar area of Saurashtra.

No detailed studies on the fossil calcareous algae have been made on the Miliolite Limestone exposed at and around except a meagre presence of calcareous algae. The Miliolite Limestone samples were collected from the study area to investigate the composition of calcareous algae. The sample localities are marked on the location maps of Diu and the adjoining areas (Figs. 1a, b). The studied thin sections reveal the presence of calcareous algae in many samples of the Miliolite Limestone. The aim of the present paper is to record the calcareous algal assemblage and its implications on the depositional environment of the Miliolite Limestones.

The description of the lithosections which have yielded the calcareous algae is given below.

Lithosection south of Sunset Point, Diu (Fig. 2a): The Sunset Point (20° 42' 3" N; 70° 58' 37" E) is at a distance of 2 kms southwest of Diu Point. At sunset point, a 4 m thick section is exposed, consisting of pinkish-red, fine-grained compact limestone belonging to the Adatiana Member. In this section, the upper bed of nearly 2 m thickness shows horizontal bedding with burrows and pipe-like structures, whereas the lower bed is inclined and dipping towards the sea. Some 100 m from this place, a 2.5 m thick section, comprising pinkish red and somewhat friable limestone belonging to the above formation is present. Sample DSPS1 was collected from this section. *Melobesioideae* gen. et spec. indet 1., *Lithophyllum* sp. 1, *Amphiroa regularis*, *A. ishijimai*, *Halimeda* sp. have been recovered from this horizon.

Lithosection south of Una-Samtar Road (Fig. 2b): On Una-Kodinar Road in between Una and Samtar 2 to 3 kms from Una, to the south of Road (20° 46' 43.54"N; 70° 58' 6.2" E), there is an exposure of 2 m thick limestone. The samples USR1 and USR2 were taken from this section. Both the samples are creamish white in colour having fine-grained, well-sorted texture and show presence of broken shell fragments and cross stratification feature, indicating that this limestone belongs to the Adatiana Member. The sample USR1 has yielded *Amphiroa regularis*.

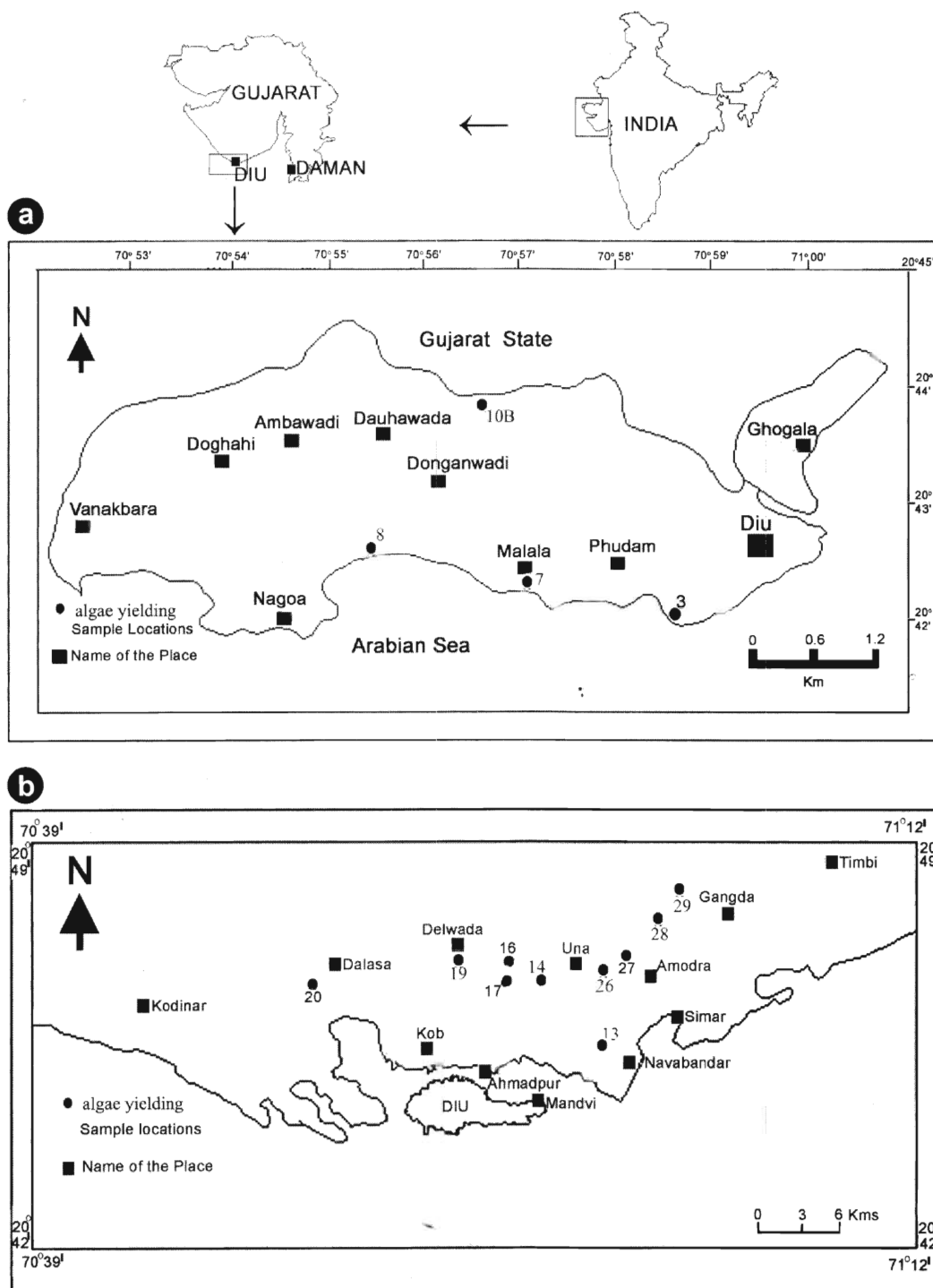
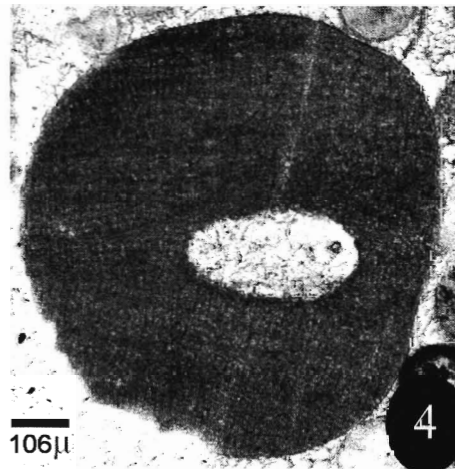
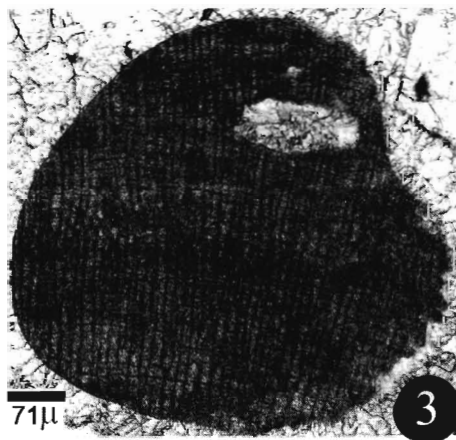
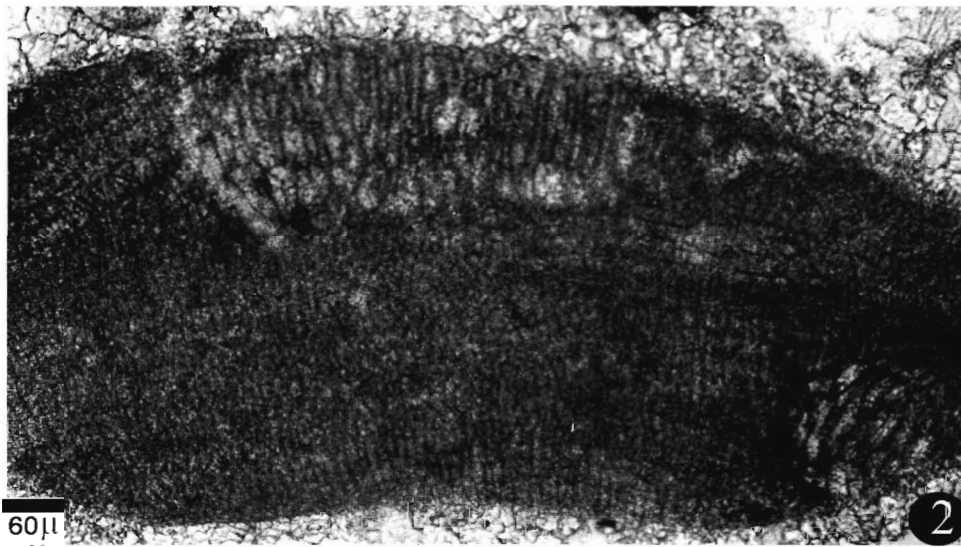
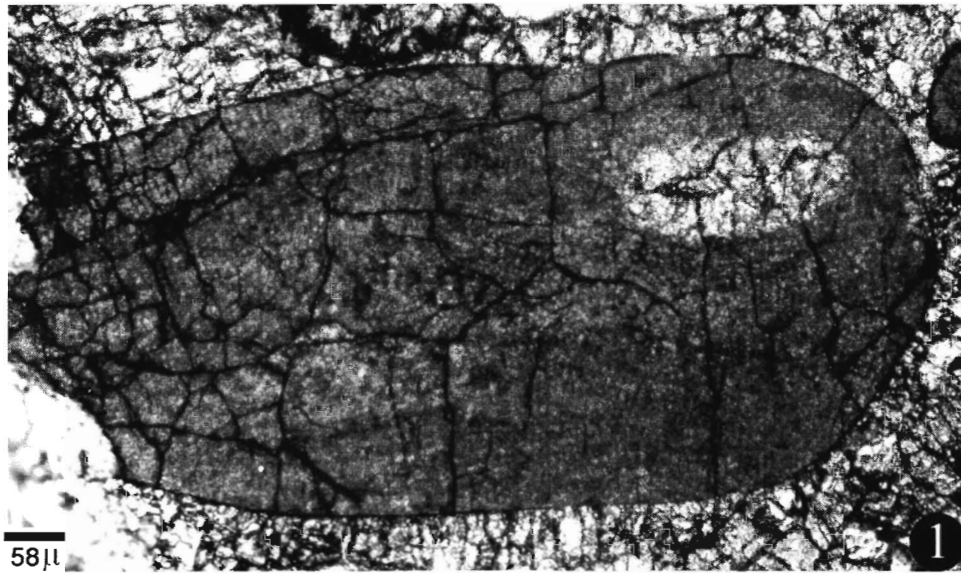


Fig. 1a. Map of Diu Island showing sample locations, 1b. Map showing sample locations adjoining Diu.

EXPLANATION OF PLATE I

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| <p>1. <i>Melobesioideae</i> gen et spec. indet. 1. (PGTDG/MF/SCA/Diu/1): showing mulitporate conceptacle and non-coaxial core.</p> <p>2. <i>Melobesioideae</i> gen et spec. indet. 2 (PGTDG/MF/SCA/Diu/2): showing mulitporate fertile conceptacle and non-coaxial core.</p> | <p>3. <i>Lithophyllum</i> sp. 1 (PGTDG/MF/SCA/Diu/8): showing uniporate conceptacle.</p> <p>4. <i>Melobesioideae</i> gen et spec. indet. 2 (PGTDG/MF/SCA/Diu/7): showing uniporate conceptacle.</p> |
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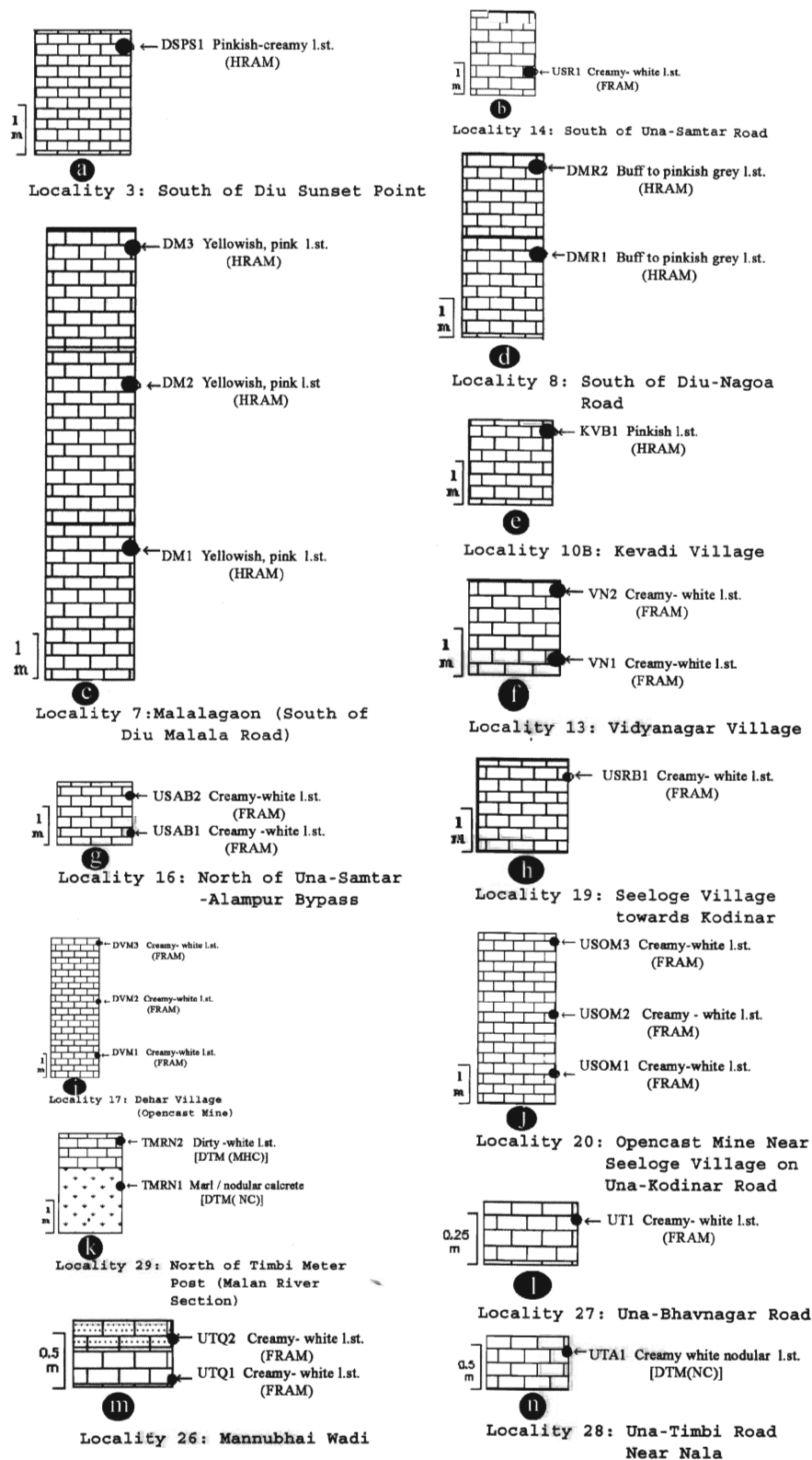


Fig. 2. Lithosections of algae yielding localities in and around Diu, Saurashtra at; a. Locality 3- South of Diu Sunset Point, b. Locality 14- South of Una-samtar Road, c. Locality 7- Malalagaon (south of Diu Malala Road), d. Locality 8- South of Diu- Nagoa Road, e. Locality 10B- Kevadi Village, f. Locality 13- Vidyanagar Village, g. Locality 16- North of Una- Samtar Alampur Bypass, h. Locality 19- Seeloge, Village towards Kodinar, i. Locality 17- Dehar Village (Opencast Mine), j. Locality 20- Opencast Mine Near seeloge Village on Una-Kodinar Road, k. Locality 29- North of Timbi Meter Post (Malan River Section), l. Locality 27- Una-Bhavnagar Road, m. Locality 26- Mannubhai Wadi and n. Locality 28- Una-Timbi Road Near Nala.

{FRAM: Friable Adatiana Member; HRAM: Highly recrystallized Adatiana Member; DTM (NC): Dhobalia Talav Member (Nodular Calcrete)}

Lithosection at Malalagaon, South of Diu-Malala Road (Fig. 2c): At Malalagaon (20° 42' 18.4"N; 70° 57' 9.2" E) which is 4 kms south, on Diu-Malala Road, an exposure of nearly 10 to 10.5 m thickness is present. The samples DM1, DM2 and DM3 were collected from here at an interval of 3 m from bottom to top, respectively. All the three samples belong to same rock type, which is yellowish pink in colour with fine-grained, well-sorted texture and is hard and compact. The characters suggest that this limestone represents pelletic calcarenite belonging to the Adatiana Member. The sample DM3 has yielded *Amphiroa regularis*.

Lithosection at south of Diu-Nagoa Road (Fig. 2d): The sample location, i.e. the locality 8 (20° 42' 36.9"N; 70° 55' 30" E) is 6.7 kms by road from Diu Point and is south of Diu-Nagoa Road. At this place, a 4 m thick outcrop is present, from where the samples DMR1 and DMR2 were collected at an interval of 2m. The limestone has buff to pinkish grey colour and medium-grained, well-sorted texture. It is friable, porous and contains large number of broken shell fragments. Thus, the limestone represents an ancient beach ridge comprising porous seaward dipping younger shell limestone, i.e. pelletic calcarenite of the Adatiana Member. The sample DMR1 has yielded *Lithophyllum* sp. 2.

Lithosection at Kevadi Village (Fig. 2e): The Kevadi Village (20° 43' 50.6"N; 70° 56' 32.2" E) is located 5 kms northwest of Diu Point. Here, a 2 m thick section is seen, consisting of creamy pink coloured, fine-grained and porous limestone. The sample KVB1 was collected from here. Its colour and porosity indicates that it might belong to the transition zone between old pinkish recrystallised miliolite limestone unit and younger dirty white porous, cross-stratified unit belonging to the Miliolite Formation. But other petrographic characters suggest that it belongs to the Adatiana Member. This locality has yielded *Amphiroa regularis* and *Melobesioideae* gen et spec. indet. 2.

Lithosection at Vidyanagar Village (Fig. 2f): The Vidyanagar Village (20° 45' 33.06"N; 71° 00' 29" E) is 8 kms from Diu point on Diu-Una Road. On the eastern side of the road in front of Shri Lohada Kanya Chatralaya, Una, there is a natural drain (nala) of nearly 2 m depth. On the western bank of this drain, a section of 2m thickness is observed, from where the samples VN1 and VN2 were collected. Both the samples are creamish white in colour having fine-grained, well-sorted texture showing presence of broken shell fragments. The miliolite limestone of Vidyanagar village belongs to the Adatiana Member. The samples VN1 and VN2 have yielded *Amphiroa anchivericossa* and *A. regularis* respectively.

Lithosection north of Una-Samtar-Alampur Bypass (Fig. 2g): Towards north of Una-Kodinar Road 5 kms from Una near Alampur Bypass (20° 47' 7.04"N; 70° 56' 54.8" E), there is an exposure of limestone, which is roughly 1.5 m thick. This exposure is composed of white, friable miliolite limestone belonging to the Adatiana Member that is traversed by two prominent sets of joints trending NW-SE and NE-SW. The samples USAB1 and USAB2 were collected from this section. *Jania occidentalis* is recovered from the sample USAB1 while the sample USAB2 has yielded *Amphiroa regularis*.

Lithosection at Dehar Village opencast mine (Fig. 2i): The Dehar village opencast mine (20° 46' 43.54"N; 70° 56' 44.6" E) is located 1 km southwards from Una-Kodinar Road at a distance of 5 kms from Una. Dehar opencast mine is an abandoned mine, the working of which has left a face of 6 to 8 m thickness exposed. The samples DVM1, DVM2 and DVM3

were collected from this section from the bottom to top respectively. All the three samples are of creamy white, friable miliolite limestone belonging to the Adatiana Member. The section exhibits beautiful cross-bedding. The sample DVM1 shows presence of *Lithoporella melobesioide* and the sample DVM3 has yielded *Melobesioideae* gen et spec. indet. 2, *Amphiroa regularis* and *Sporolithon* sp.

Lithosection on Una-Siloge Road (Fig. 2h): The exposure (20° 47' 11.74"N; 70° 55' 12.8" E) is to the north of Una-Kodinar Road, 9 kms from Una and 2 kms forwards from Siloge Village towards Kodinar. This exposure is 2 m in thickness and the sample USB1 was collected from here. The section is composed of creamy white, fine to medium-grained, well-sorted, friable miliolite limestone belonging to the Adatiana Member. *Amphiroa regularis* has been recovered from this locality.

Lithosection at Siloge opencast mine, Una (Fig. 2j): An abandoned opencast limestone mine (20° 46' 39.25"N; 70° 49' 36.2" E) is present next to Siloge Village and to the south of Una-Kodinar Road at a distance of 20 kms from Una. The mine working has left 4 m to 5 m face exposed, from where the samples USOM1, USOM2 and USOM3 were collected from bottom to top respectively. The exposed face shows a prominent cross-stratification, a feature characteristic of aeolian or dune deposits. The samples are of creamy white, friable miliolite limestone representing the Adatiana Member. The sample USOM1 shows presence of *Corallina* sp. and sample USOM2 shows *Amphiroa ishijimai*.

Lithosection at Mannubhai Wadi (Fig. 2m): The Mannubhai Wadi (20° 46' 58.4"N; 71° 00' 29" E), a working limestone mine south of Una-Bhavnagar Road, is hardly 2 kms from Una. Since the mining has recently started, the total thickness of the deposit cannot be ascertained but an exposure of 0.5 m was seen, from where the samples UTQ1 and UTQ2 were collected. The sample UTQ1 is creamy white, fine grained, well sorted, fossiliferous and friable, belonging to the Adatiana Member. The sample UTQ2 is dirty creamy white in colour having fine-grained, well-sorted texture. It is also a friable and fossiliferous limestone belonging to the Adatiana Member. The dirty colour of the sample is due to weathering. This sample has yielded *Amphiroa anchivericossa*.

Lithosection at Una-Bhavnagar Road (Fig. 2l): An exposure (20° 47' 12.14"N; 71° 00' 18.2" E) of 0.25 m thickness was seen south of Una-Timbi road, i.e. on Una-Bhavnagar Highway, 3 kms from Una. The exposure is of creamy white, fine-grained, well-sorted, fossiliferous and friable miliolite limestone belonging to the Adatiana Member. The sample UT1 was collected from here and it shows presence of *Lithoporella melobesioides*.

Lithosection at Una-Timbi Road near nala (Fig. 2n): On Una-Timbi Road 6-7 kms from Una, there is a small drain (20° 47' 50.23"N; 71° 01' 30" E) crossing the road. In this drain, a 0.5 m thick exposure is observed, from where the sample UTA1 was collected. The sample is of creamy white fine-grained, well-sorted, fossiliferous and friable miliolite limestone representing the nodular calcrete belonging to the Dhovalia Talav Member of the Miliolite Formation. This shows presence of *Dissocladella* sp.

Lithosection at north of Timbi Meter Post, i.e. Malan River Section (Fig. 2k): At the Malan River Section (20° 47' 31.13"N; 71° 02' 41" E), the 1.75 m thick brown colored marl is exposed. It is overlain by 0.75 m thick dirty white, fine-grained well-sorted massive hardpan calcrete belonging to the Dhovalia

Talav Member. The sample TMRN1 is of marl/nodular calcrete belonging to the Dhobalia Talav Member of the Miliolite Formation, whereas sample TMRN2 belongs to the massive hardpan calcrete of the Dhobalia Talav Member. It contains *Amphiroa regularis*.

SYSTEMATIC DESCRIPTION

The present paper describes 04 nongeniculate coralline algal species (*Lithophyllum* sp. 1, *L.* sp. 2, *Lithoporella melobesioides* Foslie and *Sporolithon* sp. and 02 nongeniculate algal forms identified up to subfamily level as *Melobesiodeae* gen. et spec. indet. 1 and 2); 05 geniculate coralline algal species (*Amphiroa anchiverricosa* Johnson and Ferris, *A. ishijimai* Kundal and Dharashivkar and *A. regularis* Johnson and Ferris, *Corallina* sp. and *Jania* sp); 01 species of *Halimeda* and 01 species of *Dissocladella* from the limestones of the Miliolite Limestone Formation.

Division Rhodophyta Wettstein, 1901

Class Rhodophyceae Rabenhorst, 1863

Order Corallinales Silva and Johansen, 1986

Family Corallinaceae Lamouroux, 1812

Subfamily Melobesiodeae Bizzozero, 1885

Melobesiodeae gen. et spec. indet. 1

(Pl. I, fig. 1)

Material: PGTDG/MF/SCA/ Diu/1

Vegetative Anatomy: Growth form encrusting with the monomerous thallus organization. Core region not preserved. Peripheral region 250-255 μ thick. Cells of peripheral region rectangular ranging from 18 to 19 μ in length and 5 to 16 μ in width. Asexual multiporate conceptacle present in the peripheral region ranging from 230 to 235 μ in diameter and 105 to 110 μ in height.

Remarks: The present solitary algal specimen is incompletely preserved. Hence, it is kept in open nomenclature as *Melobesiodeae* gen. et spec. indet. 1.

Horizon and Locality: The Miliolite Limestone of Sunset Point, Diu belonging to the Adatiana Member of the Miliolite Formation.

Melobesiodeae gen. et spec. indet. 2

(Pl. I, figs. 2, 4)

Material: PGTDG/MF/SCA/ Diu/2, 7

Vegetative Anatomy: Thallus organization monomerous with encrusting growth form. Core region not preserved. Peripheral region 330-340 μ thick. Cells of peripheral region rectangular, ranging from 16 to 17 μ in length and 9 to 10 μ in width. Cell fusions present. Tetra/bisporangial multiporate conceptacles present in the peripheral, ranging from 445 to 454 μ in diameter and 150 to 152 μ in height.

Remarks: The present solitary algal specimen is incompletely

preserved. Hence, it is kept in the open nomenclature as *Melobesiodeae* gen. et spec. indet. 2.

Horizon and Locality: Creamy-pink coloured hard, compact recrystallized miliolite limestone belonging to the Adatiana Member of the Miliolite Formation of Kevadi Village, Diu and the creamy-white, friable miliolite limestone belonging to the Adatiana Member, Miliolite Formation of the Dehar village opencast mine, Una.

Subfamily Lithophylloideae (Setchell) Bailey, 1999

Genus Lithophyllum Philippi, 1837

Lithophyllum sp. 1

(Pl. I, fig. 3)

Material: PGTDG/MF/SCA/ Diu/8

Vegetative Anatomy: Thallus dimerous with encrusting growth form. Primigenous region thick and made up of comparatively larger cells. Thickness of primigenous region from 84 to 86 μ . Cell fusions absent but secondary pit-connections present. Cells in the primigenous region rectangular, 14-15 μ in length and 8-9 μ in width. Postigenous region is 180-185 μ thick. Cells of postigenous region rectangular, 10-11 μ in length and 7-8 μ in width. Conceptacle present in the peripheral region, 150-151 μ in diameter and 135-136 μ in height with indistinct pore.

Remarks: The thallus organization, cell size of primigenous and postigenous regions, conceptacles and presence of pit-connections of the specimen indicate its broad similarity with *Lithophyllum alifanense* Johnson (1964) reported from the Guam. However, the height of the studied specimen is less than *L. alifanense*.

Horizon and Locality: Pinkish, red, hard and recrystallized miliolite limestone belonging to the Adatiana Member of the Miliolite Formation, Sunset Point, Diu.; the creamy-white, friable miliolite limestone belonging to the Adatiana Member, Miliolite Formation of the Dehar village opencast mine, Una.

Lithophyllum sp. 2

(Pl. III, fig. 1)

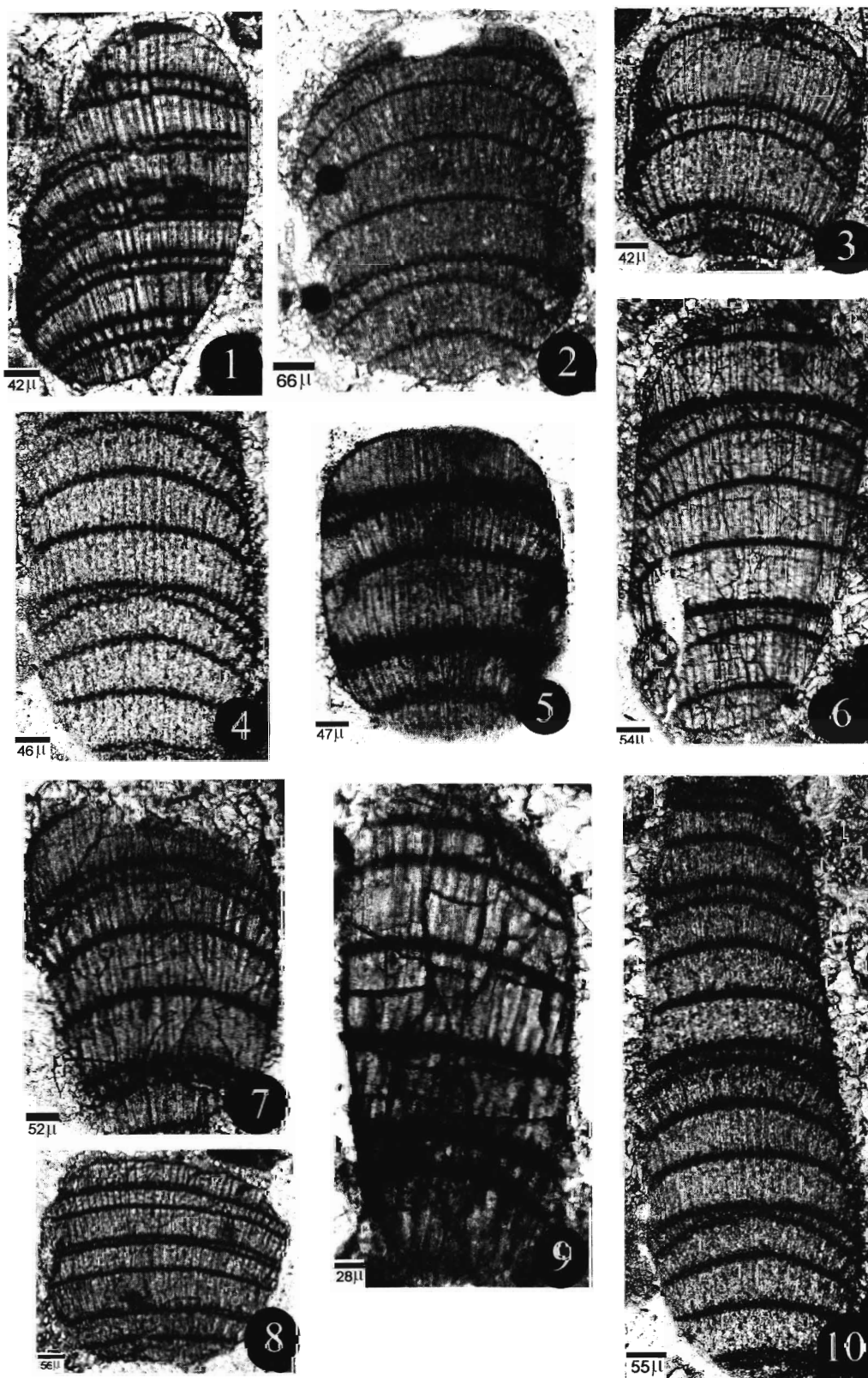
Material: PGTDG/MF/SCA/ Diu/11

Vegetative Anatomy: Thallus dimerous, with encrusting growth form. Primigenous region thick, made up of comparatively larger cells. Thickness of primigenous region varies from 110 to 113 μ . Cell fusions absent but secondary pit-connections present. Cells in the primigenous region rectangular, 15-17 μ in length and 8-9 μ in width. Postigenous region 110-115 μ thick. Cells of postigenous region squarish to rectangular, 6-7 μ in length and 5-6 μ in width. Uniporate conceptacles present in the peripheral region, ranging from 70 to 74 μ in diameter and 55 to 57 μ in height. Height of pore canal is 16-17 μ .

Remarks: The nature of primigenous and postigenous region and uniporate conceptacles point that this specimen

EXPLANATION OF PLATE II

- Amphiroa anchiverricosa* (PGTDG/MF/SCA/Diu/17): showing alternation formula of 1S- 1L in intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/29): showing alternation formula of 1S-3L in the intergenicula and the multiporate conceptacle in the axial position of the thallus.
- Amphiroa anchiverricosa* (PGTDG/MF/SCA/Diu/18): showing alternation formula of 1S-1L in the intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/25): showing alternation formula of 1S-3L in the Intergenicula of the thallus.
- Amphiroa anchiverricosa* (PGTDG/MF/SCA/Diu/19): showing alternation formula of 1S-1L in the intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/20): showing alternation formula of 1S-3L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/24): showing alternation formula of 1S-3L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/33): showing alternation formula of 1S-2L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/22): showing alternation formula of 1S-3L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/23): showing alternation formula of 1S-3L in the Intergenicula of the thallus.



broadly resembles *Lithophyllum*. The present specimen is not comparable with any known species of the genus *Lithophyllum*.

Horizon and Locality: Buff to pinkish grey, friable shell limestone belonging to the Adatiana Member, Miliolite Formation exposed along the Diu-Nagoa Road.

Genus *Amphiroa* Lamouroux, 1812

Amphiroa anchiverricosa Johnson and Ferris, 1950

(Pl. II, figs. 1,3, 5)

Amphiroa anchiverricosa Johnson and Ferris, 1950; p. 19, pl. 7, fig. e.- Ishijima, 1954, pp.61-62, pl.39, figs. 1- 3.- Johnson, 1964, p.G-32, pl. 11, figs. 9-10.- Kundal and Humane, 2002, pp. 89-101.- Kundal and Dharashivkar, 2003, p. 248, p.1, figs. 4, 5.- Kundal and Mude, 2010

Material: Specimen Nos. PGTDG/MF/SCA/ Diu/ 17-19

Dimensions (ì):

SN	LS	WS	NT	TCR	TPR	LCCS	LCCL	WPC	LPC	WPC	AF
17	399-400	313	9	399-400	-	10-11	60-62	10-11	-	-	1-L 1-S
18	270	259	6	194	21-22	30-32	84-86	9-10	11-12	6-7	1-L 1-S
19	410	237-238	13	237-238	-	14-15	40	9-10	-	-	1-L 1-S

Description: Intergenicula elliptical to subcylindrical. The core region thick, showing alternation of single row of long cells and single row of short cells. Thickness of the core region ranging between 194 and 399ì. Peripheral region thin. Short and long cells in the core region are rectangular, with 9-11ì and 11 and 32ì in width and 40-86ì in length respectively. Length of cells in the peripheral region ranges between 11 and 12ì. Width of cells in the peripheral region 6-7ì. The conceptacles not present in the studied specimens.

Remarks: The present specimens are placed under *Amphiroa anchiverricosa* Johnson and Ferris owing to their similarity in both alternation formulae and length and width of cells of the core region.

Stratigraphic and Geographical Distribution: Pleistocene Ryuku limestone, Jinkoshi, Koshun-gun, Takao-shu, Formosa, Western Pacific (Ishijima, 1954) and the Maniyara Fort Formation (Oligocene), the Chhasra Formation (Lower Miocene) and the Khari Nadi Formation (Lower Miocene) of Kachchh, Gujarat (Kundal and Humane, 2002) and Middle Miocene Coralline Limestone belonging to Positra Limestone Member of the Dwarka Formation exposed at Samlasar and Lower Pliocene bioclastic limestone of Kalyanpur Limestone Member of the Dwarka Formation at Gadhechi Hill Section (Kundal and Dharashivkar, 2003) and the Dwarka Formation (early middle Miocene) of Bhavapura Village of Porbandar.

Horizon and Locality: Creamy-white, fine-grained, friable shell limestone belonging to the Adatiana Member of the

Miliolite Formation exposed at Vidyanagar Village on Diu-Una Road; Mannubhai wadi - opencast mine on Una-Timbi Road.

Amphiroa regularis Johnson and Ferris, 1950

(Pl. II, figs. 2,4,6,7, 8, 9,10; Pl. III, figs. 2-7)

Amphiroa regularis Johnson and Ferris: Johnson and Ferris, 1950, p. 20, pls. 5, E: 8 E.- Ishijima, 1954, 87 R, P. 56-57, pl. XLI, figs. 6, 10,11

Material: Specimen Nos. PGTDG/MF/SCA/Diu/20-25, 28-34, 37

Dimensions (ì):

SN	LS	WS	NT	TCR	TPR	LCCS	LCCL	WCC	LPC	WPC	AF
20	929	302-230	17	238-302	-	23-24	70	16	-	-	3-L 1-S
21	648	313	9	313	-	35	94-95	13-14	-	-	3-L 1-S 3-L 1-S
22	864	280	16	280	-	29	70	10-11	-	-	3-L 1-S 1-S
23	518	453-454	8	453-454	-	32	91-92	10-11	-	-	3-L 1-S 1-S
24	453-454	302	6	302	-	25-26	86	8	-	-	3-L 1-S
25	432	173	7	173	-	22-24	70	11	-	-	3-L 1-S
28	669	300-313	11	291	21.6	27	81	13-14	10-11	5-6	2-L 1-S
29	756	280	10	259	21.6	32	75-76	10-11	-	-	2-L 1-S 1-S
30	388-389	225-226	7	226-8	-	19	81	9-10	-	-	2-L 1-S
31	540	320-345.8	8	320-345	-	32	97	16	-	-	2-L 1-S 1-S
32	270	194	6	184	-	19	54	19	-	-	2-L 1-S
33	410	346-497	9	346-497	-	11	13	16-22	-	-	2-L 1-S
34	1252	310-345	16	310-345	-	10-11	32	8	-	-	2-L 1-S
37	594	216-324	10	291	25-32	24	75-76	10-11	-	-	2-L 1-S 3-L

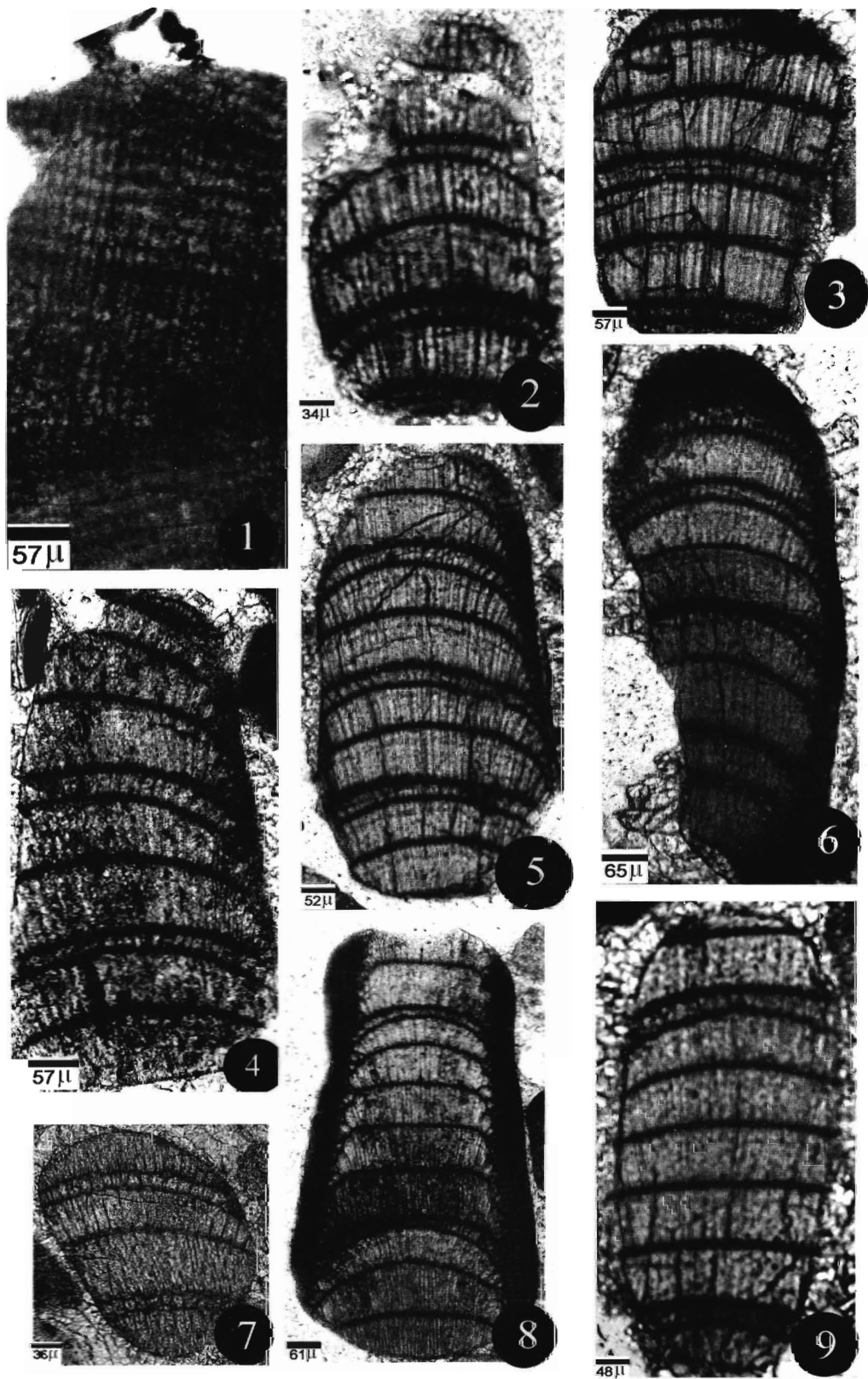
Description: Intergenicula elliptical to subcylindrical. Core region displaying alternation of three rows (sometimes two rows) of long cells followed by single row of short cells. Core cell rows uparched. Peripheral region very thin and ill preserved in some material. One of the specimens with multiporate conceptacle in the axial position, with the diameter ranging from 148 to 150ì and height from 56 to 57ì.

Remarks: Present species exhibits the alternation of long and short cells formulae: 2L, 1S; 3L, 1S (rarely 4L, 1S) like *Amphiroa regularis*. Moreover, the present specimens show similarity in the shape and size of the core cells (cells of medullary region) with *A. regularis*. Hence, the present specimens are described as *A. regularis*.

Stratigraphic and Geographical Distribution: Pleistocene

EXPLANATION OF PLATE III

- Lithophyllum* sp. 2 (PGTDG/MF/SCA/Diu/11): showing uniporate conceptacle in the postigenous region
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/30): showing alternation formula of 1S-2L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/31): showing alternation formula of 1S-2L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/37): showing alternation formula of 1S-2L-3L in the Intergenicula of the thallus.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/28): showing alternation formula of 1S-2L in the Intergenicula of the thallus with the thin cortex.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/29): showing alternation formula of 1S-2L in the Intergenicula of the thallus with the thin cortex.
- Amphiroa regularis* (PGTDG/MF/SCA/Diu/32): showing alternation formula of 1S-2L in the Intergenicula of the thallus.
- Amphiroa ishijimai* Kundal and Dharashivkar (PGTDG/MF/SCA/Diu/26): showing alternation formula of 1S- 5L in the intergenicula of the thallus with the thick cortex.
- Amphiroa ishijimai* Kundal and Dharashivkar (PGTDG/MF/SCA/Diu/27): showing alternation formula of 1S-5L in the intergenicula of the thallus.



KUNDAL, HUMANE AND HUMANE

Ryuku Limestone of Daihanroku, Koshun-sho, Koshun-gun, Takao-shu, Formosa.

Horizon and Locality: Creamy-white, fine grained, friable shell limestone belonging to the Adatiana Member of the Miliolite Formation exposed at Vidyanagar Village on Diu-Una Road; Dirty-white, fine grained massive hardpan calcrete belonging to Dhobalia Talav Member of the Miliolite Formation, Malan River section on Una-Timbi Road, Una; Creamy-white, fine grained, friable shell limestone belonging to the Adatiana Member of the Miliolite Formation, in the north of Una-Kodinar Road near Siloge village and at south of Una-Samtar Road, Una.; Creamy-pink coloured hard, compact recrystallized miliolite limestone belonging to the Adatiana Member of the Miliolite Formation, Kevadi Village area, Diu; Pinkish-red fine grained, hard and compact miliolite Limestone of Sunset Point, Diu belonging to the Adatiana Member of the Miliolite Formation. Creamy-white friable miliolite limestone belonging to the Adatiana Member, Miliolite Formation, exposed at Dehar Village opencast mine; Creamy-white, fine grained, friable shell limestone belonging to the Adatiana Member, Miliolite Formation, on north of Una-Kodinar Road near Siloge village; Yellowish-pink, fine grained, hard and compact recrystallised miliolite limestone belonging to the Adatiana Member, Miliolite Formation, at Malalagaon south of Diu-Malala Road and Creamy-white friable miliolite limestone of the Adatiana Miliolite Formation, north of Una-Samtar Alampur bypass.

Amphiroa ishijimai Kundal and Dharashivkar, 2010

(Pl. III, figs. 8, 9)

Amphiroa ishijimai Kundal & Dharashivkar: Kundal and Dharashivkar, 2010.

Material: Specimen Nos. PGTDG/MF/SCA/Diu/ 26-27

Dimensions (μ):

SN	LS	WS	NT	TCR	TPR	LCCS	LCCL	WCC	LPC	WPC	AF
26	778	324-432	12	216-302	43-65	16	76	11	16	8	5-L 1-S
27	648	248	10	248	-	21-22	86	10-11	-	-	5-L 1-S

Description: Intergenicula elliptical to subcylindrical. Core region showing alternation of five rows of long cells and single row of short cells. Core-cell rows uparched. Peripheral prominently observed in one of the specimens. Conceptacles not present.

Remarks: The present specimens are placed under *Amphiroa ishijimai* Kundal and Dharashivkar (2010) owing to their similarity in both alternation and length and width of cells of medullary region.

Stratigraphic and Geographical Distribution: The Lower Pliocene bioclastic limestone belonging to the Kalyanpur Limestone Member of the Dwarka Formation and Pleistocene to Holocene bioclastic shell limestone of the Okha Shell Limestone Member belonging to the Chaya Formation (Kundal

and Dharshivkar, 2010).

Horizon and Locality: Creamy-white, friable miliolite limestone belonging to the Adatiana Member of the Miliolite Formation at opencast mine near Siloge village along Una-Kodinar Road, Una; Pinkish-red fine grained, hard and compact Miliolite Limestone of Sunset Point, Diu belonging to the Adatiana Member of the Miliolite Formation.

Subfamily Mastophoroideae Setchell, 1943

Genus Lithoporella Foslíe, 1909

Lithoporella melobesioides Foslíe, 1909

(Pl. IV, Figs. 1, 5)

Lithoporella melobesioides Foslíe: Ishijima, 1954, pp. 47-48, pl. XLV, figs. 1-6; pl. XLVI, fig.1.- Johnson, 1957, p. 234, Pl. 37, fig. 5; pl. 43, figs. 1.2; pl. 49, fig. 4; pl. 56, fig. 6.- Johnson, 1961, p. 936.- Johnson, 1964 (a), p. C10. Johnson, 1964 (b), p. G28-29.- Johnson and Kaska, 1965, pp. 50-51, pl. 44, fig. 3.- Vannucci, 1970, p. 472, pl. 9, figs. 1-2.- Fravega and Vannucci, 1980, pp. 113.- Fravega *et al.*, 1988, pp. 213.- Bosence, 1983, pp. 165-166, pl. 18, fig. 2, text. fig. 11. Bassi, 1995, p. 90, pl. 1, fig. 8.- Bassi and Nebelsick, 2000, p. 104, pl. 2, fig. 1.

Material: PGTDG/MF/SCA/ Diu/12-15

Vegetative Anatomy: Thalli dimerous, with encrusting growth form. Multi-stratose primigenous region formed by growth of several filaments one above other. Thickness of the primigenous region 35-410μ in various fragments. Cells in primigenous region 17-42μ in length and 9-18μ in width. Postigenous region 65-70μ in thickness. Cells in the postigenous region 13-14μ in length and 7.5-10μ in width. Cell fusions present but the secondary pit-connections absent. A uniporate conceptacle 220-226μ in diameter and 80-84μ in height.

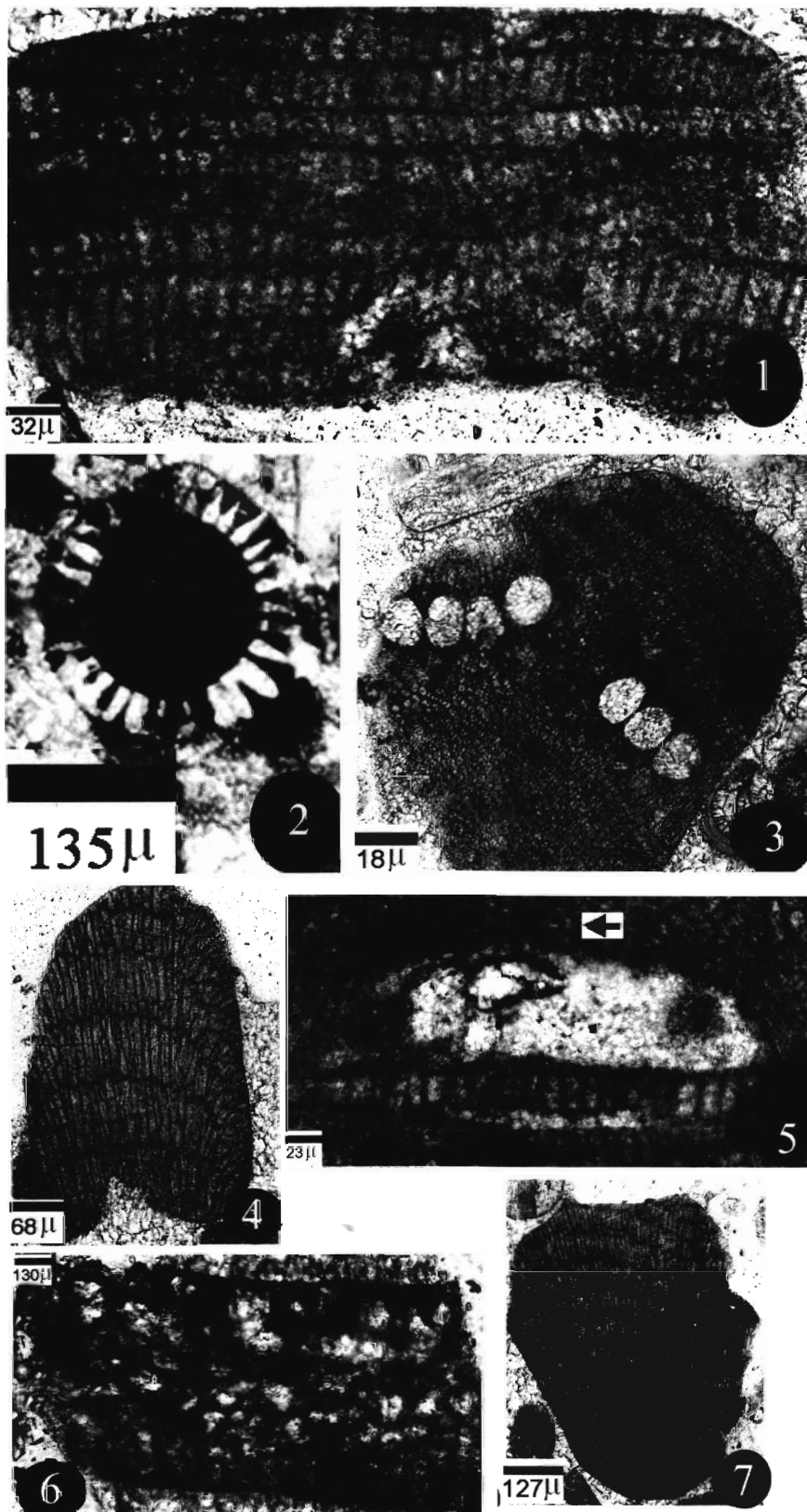
Remarks: Bassi (1998) described that *Lithoporella melobesioides* Foslíe possesses larger cells in primigenous filaments as compared to *Lithoporella minus* Johnson which has smaller cells. The present specimens have larger cells in the primigenous region and hence, they are assigned to *Lithoporella melobesioides* Foslíe.

Stratigraphic and Geographical Distribution: Cenozoic calcareous algae from Western Pacific (Ishijima, 1954); Eocene to Pleistocene rocks from Faunafuti, Kiata Diato-Jima and Eniwetok (Johnson, 1961); Eocene rocks of Ishigakishima and Eniwetok (Johnson, 1964a); Eocene to Recent rocks of Guam (Johnson, 1964 b); Miocene rocks of Guatemala (Johnson and Kaska, 1965); Oligocene rocks of Nullipore Formation (Vannucci, 1970); Lower Oligocene rocks of Ranzano Formation (Fravega and Vannucci, 1980); Miocene- Eocene rocks of Colli Berici of Northern Italy (Bassi, 1995) and Lower Oligocene rocks of Gornji Grad beds, Northern Slovenia (Bassi and Nebelsick, 2000).

Horizon and Locality: Creamy-white friable miliolite limestone belonging to the Adatiana Member, Miliolite Formation exposed at the Dehar Village Opencast Mine, Una; the Una-Bhavnagar road section near Vidyanagar village, Una.

EXPLANATION OF PLATE IV

- Lithoporella melobesioides* Foslíe (PGTDG/MF/SCA/Diu/12): showing multistratose thallus.
- Disocladella* sp. (PGTDG/MF/SCA/Diu/44): showing central stem, primary braches with sporangia and secondary branches.
- Sporolithon* sp. (PGTDG/MF/SCA/Diu/16): showing sporangial sorii in a row on the thallus.
- Jania occidentalis* Johnson & Kaska, 1965 (PGTDG/MF/SCA/Diu/38): showing intergenicula of the thallus.
- Lithoporella melobesioides* Foslíe, (PGTDG/MF/SCA/Diu/13): showing uniporate conceptacle (arrow).
- Halimeda* sp. (PGTDG/MF/SCA/Diu/43): showing medullary filaments emerging into the the cortical branches of the thallus.
- Corallina* sp. (PGTDG/MF/SCA/Diu/41): showing intergenicula of the thallus.



Family **Sporolithaceae** Verheij, 1993
 Subfamily **Sporolithoideae** Setchell, 1943
 Genus **Sporolithon** Heydrich, 1897
Sporolithon sp.
 (Pl. IV, fig. 3)

Material: PGTDG/MF/SCA/ Diu/16

Vegetative Anatomy: Thallus monomerous, with obscure core region. Thickness of core region 170-172 μ . Cells of core region oblique (10-11 μ long and 9-10 μ wide). Peripheral region moderately thick, ranging from 345 to 346 μ . Cells in the peripheral region 13-14 μ in length and 10-11 μ in width. Peripheral region demarcated by a row of sporangial sori. Cell fusions present. A clear single row of 7 sporangial sori present in the peripheral region. Sori rounded to sub-rounded in oblique section. Diameter of sori 30-50 μ and height 60-65 μ . Top of the sori marked by small opening.

Remarks: The present specimen broadly resembles *Sporolithon eniwetokensis* Johnson (1961) in length and width of cells of peripheral region and in diameter of sporangial sori. However, height of sporangial sori of the studied genus *Sporolithon* is more than that of *S. eniwetokensis* Johnson, 1961.

Horizon and Locality: Creamy-white friable miliolite limestone belonging to the Adatiana Member of the Miliolite Formation exposed at Dehar Village Opencast Mine.

Subfamily **Corallinoideae** Gray, 1821

Genus **Jania** Lamouroux, 1812

Jania occidentalis Johnson and Kaska, 1965
 (Pl. IV, fig. 4)

Jania occidentalis Johnson and Kaska: Johnson and Kaska, 1965, pp.56-57, pl. 26, figs. 1-3; pl. 30, fig. 2.- Pal and Dutta, 1979, p. 149, pl. 2, fig. 16.- Kundal and Wanjarwadkar, 2000, pp.227-237, pl. 1, fig. 5; pl. 2, fig. 5.

Material: PGTDG/MF/SCA/Diu/38

Dimensions (i):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
38	443	270-281	6	243	32	86.4	8.1	19	9.45

Description: Intergenicula cylindrical, sinuous and elongated. Cell rows of core region joins irregularly forming wedge-shaped medullary cells. The peripheral region and conceptacles absent.

Remarks: The present specimen of *Jania* is comparable with the other species of *Jania occidentalis* Johnson and Kaska in cell size and nature of thallus. Hence, it is described as *J. occidentalis* Johnson and Kaska, 1965.

Stratigraphic and Geographical Distribution: Palaeocene of Guatemala (Johnson and Kaska, 1965); Upper Palaeocene (Landenian) of Khasi hills of Meghalaya (Pal and Dutta, 1979); Palaeocene limestone of Middle Andaman Island, Andaman (Kundal and Wanjarwadkar, 2000); the Palaeocene Lakadong Formation, Khasi Hills, Meghalaya (Misra *et al.*, 2002) and the Eocene Jaintia Hills, Meghalaya (Kishore *et al.*, 2009).

Horizon and Type Locality: Creamy-white friable miliolite limestone of the Adatiana Member, Miliolite Formation, north of Una-Samtar Alampur bypass.

Corallina sp.

(Pl. IV, fig. 7)

Material: PGTDG/MF/SCA/Diu/ 40

Dimensions (i):

SN	LS	WS	NT	TCR	TPR	LCC	WCC	LPC	WPC
40	626	280-496	10	280-496	-	59.4	9.45	-	-

Description: Intergenicula elliptical. Core region showing four to five regular rows of elongated cells. Peripheral region and conceptacle absent.

Remarks: The present specimens have length of medullary cells similar to that of *Corallina elliptica* Ishijima. But due to insufficient material, the present specimen is kept in the open system of nomenclature and described as *Corallina* sp. 1.

Horizon and Locality: Creamy-white, friable miliolite limestone belonging to the Adatiana Member, Miliolite Formation at Opencast Mine near Siloge village on Una-Kodinar Road, Una.

Division **Chlorophyta**, Papenfuss, 1946

Class **Bryopsidophyceae** Round, 1963

Order **Bryopsidales** Schaffner, 1922

Sub-order **Halimedineae** Hillis-Colinvaux, 1984

Family **Halimedaceae** Link, 1832

Genus **Halimeda** Lamouroux, 1812

Halimeda sp.

(Pl. IV, fig. 6)

Material: PGTDG/MF/SCA/ Diu/43

Description: Thallus cylindrical. Thickness of medullary region 390 μ . Diameter of medullary siphons 26 μ and 5 to 6 in number. Thickness of cortical region 140 μ , consisting of 1 to 2 utricles. Primary utricles long and tubular. Diameter of primary utricles in cortex 52 μ and length of primary utricles 104 μ . Secondary utricles short. Length of secondary utricles 26 μ . Whereas diameter of secondary utricles 20 μ .

Remarks: The present specimen of *Halimeda* is comparable with the *Halimeda tuna* (Ellis and Solander) Lamouroux, 1812 in appearance, similarity of dimensions of medullary siphons and utricles in cortex to some extent. Moreover, the number of specimens are limited in number. Hence, the present material is described as *Halimeda* sp.

Horizon and Locality: Pinkish-red fine grained, hard and compact but somewhat friable miliolite Limestone of Sunset Point, Diu belonging to the Adatiana Member of the Miliolite Formation.

Class **Chlorophyceae** Kützing, 1843

Order **Dasycladales** Pascher, 1931

Family **Dasycladaceae** Kützing, 1843

Dissocladella Pia, 1936,

Dissocladella sp.

(Pl. IV, fig. 2)

Material: PGTDG/MF/SCA/ Diu/44

Thallus circular in transverse section. Central stem thick with 150 μ diameter. Primary branches short, with two secondary branches. Primary branches 20 μ in length and 10 - 15 μ in width. Secondary branches 8-10 μ in length and 4-6 μ in width.

Remarks: Only one fragment is available and hence it is described as *Dissocladella* sp.

Horizon and Locality: The sample is from the creamy white fine-grained well-sorted, fossiliferous and friable miliolite limestone representing nodular calcrete belonging to the Dhobalia Talav Member of the Miliolite Formation.

DISCUSSION

The present algal assemblage comprises 11 coralline algal species, 01 halimedacean and 01 dasycladalean species. The

stratigraphic distribution of algal species in the Dhobalia Talav Member and the Adatiana Member of the Miliolite Formation is as under:

Name of the Member	Name of the species
Dhobalia Talav Member, Miliolite Formation	<i>Dissocladella</i> sp., <i>Amphiroa regularis</i>
Adatiana Member, Miliolite Formation	<i>Lithophyllum</i> sp. 1, <i>Lithophyllum</i> sp. 2, <i>Amphiroa anchivericossa</i> , <i>A. regularis</i> , <i>A. ishijimai</i> , <i>Lithoporella melobesioides</i> , <i>Sporolithon</i> sp., <i>Corallina</i> sp., <i>Jania</i> <i>occidentalis</i> , Melobesioideae gen. et spec. indet 1, 2 and <i>Halimeda</i> sp.

Littler *et al.* (1986) mentioned that the overall range of coralline algae is from 0 to 270m. The coralline algae occur usually from low-tide level down to depth of 25 to 30m (Johnson, 1961). Dasycladalean algae generally occur at a depth of 5-6 m below tide level down to 5 to 6m and can extend down to 10-12m (Johnson, 1961; Wray, 1977; Humane *et al.* 2010; Kundal, 2010). The halimedacean algae are generally abundant from depth below low-tide level to a depth of 10-12m (Hillis-Colinvaux; 1980, Humane and Kundal, 2005).

The Dhobalia Talav Member of the Miliolite Formation shows presence of a dasycladalean alga *Dissocladella* sp. and a geniculate coralline alga *Amphiroa regularis*. The presence of these algal elements indicates that this member was deposited at a depth of 5-6 m below tide level. The Adatiana Member of the Miliolite Formation has presence of 11 coralline and 01 halimedacean algal species. These species suggest that this member was deposited at a comparatively higher depth, i.e. 25 to 30m below low tide level.

REPOSITORY

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

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