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New Record of Coralline Algae from the Holocene Sediments of Agatti Island, Lakshadweep, India

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Abstract: The present paper examines the coralline algal assemblage recovered from the Holocene sediments of Agatti Island, Lakshadweep, India. The assemblage comprises nine species of coralline algae which include *Amphiroa fragilisma, Lithophyllum nitorum, Lithophyllum incrustans*, *Lithoporella melobesioids, Spongites* sp., *Porolithon craspedium, Aethesolithon problematicum*, *Clathromorphum parcum, Melobesoideae* gen. et spec. indet. *Clathromorphum parcum*is an endophytic coralline alga reported for the first time from the Indian subcontinent. Out of these, seven species belong to the family Corallinaceae and the two represent the family Hapalidiaceae of the class Rhodophyceae. Coralline algal association of this area is dominated by Lithophylloideae, Melobesioideae and Mastophoroideae which include encrusting to fragmented growth forms. The associated branching corals are well developed and adapted to shallow, warm water, low turbid, protected lagoonal environment.

Keywords: Coralline algae, Holocene sediments, Agatti Island, Lakshadweep.

INTRODUCTION

The coralline algae as well as the organic buid-ups which these organisms have produced along with other creatures have not been studied properly. This is especially true in the case of Holocene beds of the Lakshadweep Islands, especially the study area. The present paper reports occurrence of the coralline algal taxa not previously known from the area and includes an endophytic form reported for the first time from the Indian sub-continent. The purpose of the paper is to present taxonomic features of the reported coralline algae and to discuss effect of environment on sub-family groups represented in the Agati sediments. The Lakshadweep islands are located between N 8° and 12°latitude and E 72° and 74° longitude, about 120 to 200 nautical miles off the southwest coast of India in the Arabian sea. There are 36 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 sq.km with lagoons occupying an area of about 4200 sq. km. Only 11 of the 36 islands are inhabited and these include Androth, Amini, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kiltan, Minicoy and the headquarters at Kavarati. The Minicoy Island is separated from the rest by a 180 km wide stretch known as the Nine degree channel. Coral-algal reefs are present in Agatti (10°51' N : 72° 11' E).

Agatti is the westernmost island of Lakshadweep. It is club shaped, broad in the north, tapering in the middle and ending in a narrow strip (hardly 95 meters wide) in the south. It is 5.6 km long and 0.57 km broad. It is located on N $10^0$51'30" latitude and E 72^0 11' longitudes with a total area of 2.7 sq km (Fig.1). Kalpitti islet is part of Agatti Island and is located south of Agatti on N 10^0 48'744" latitude and E $72^0$10'170" longitude. It is very small in comparison to Agatti,roughly triangular in shape and composed mainly of branching corals.

The Holocene sediments of Agatti Island have earlier been studied by Mohammed and Nasser (2005); however, the coralline algae, though the important constituents of the Lakshadweep Islands, have remained unstudied. Like corals, coralline algae also play a major role in reef-forming activityand it may be mentioned here that coral reefs support high marine biodiversity and also protect shorelines as they act as natural barriers to waves and currents.

GENERAL GEOLOGY AND STRATIGRAPHY

The Lakshadweep Islands lie on the submerged Lakshadweep ridge which is a southwest-ward extension of the buried Western Ghats along the Aravalli strike of Rajasthan and shows north-south alignment corresponding to the southern part of India. The ridge appears to run for

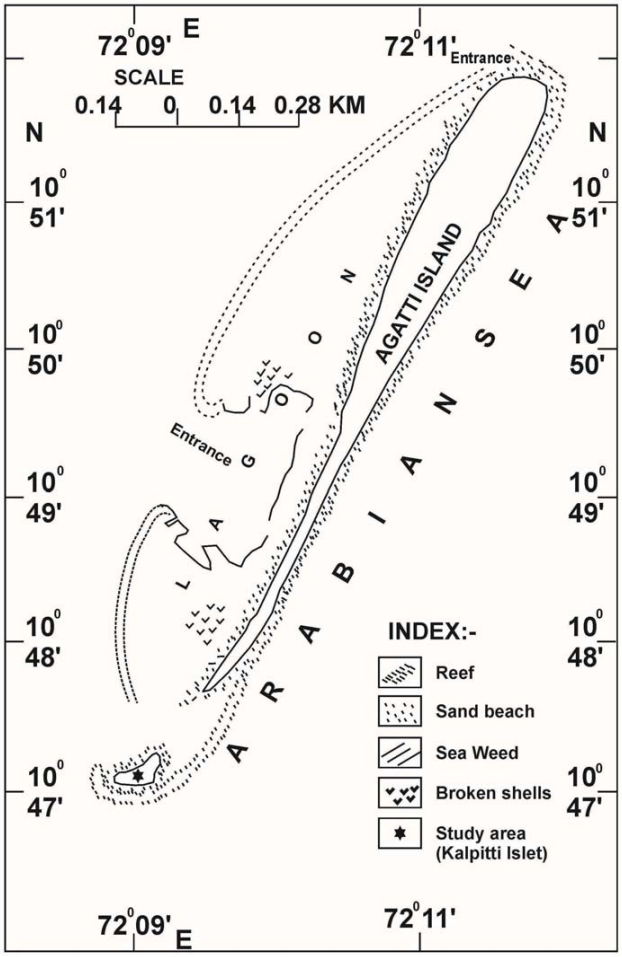

Fig.1. Locality map of the Agatti Island.

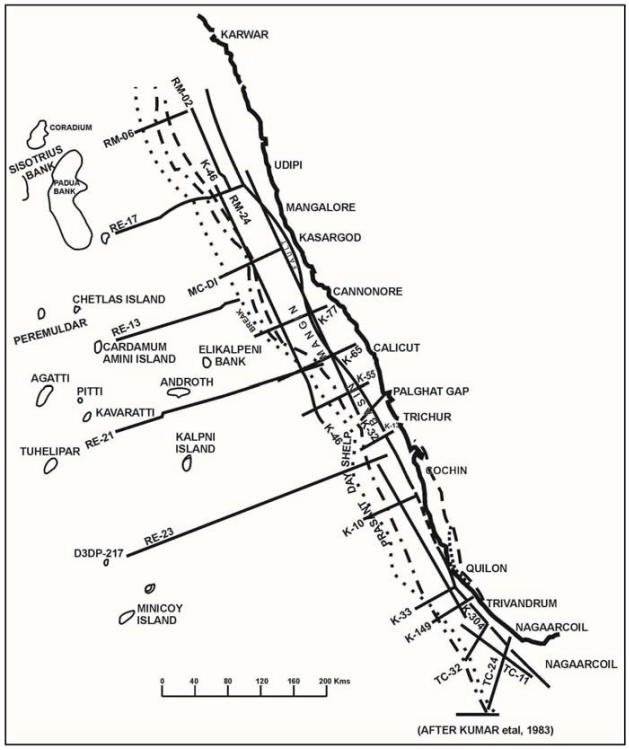

Fig.2. Basin Tectonic map of Kerala-Laccadive (after Mitra et al., 1983).

more than 2000 km from the Laccadive Islands at 14^0 N latitude to Chagos Island at 6^0 S latitude. The Indian ocean expedition and sesmic surveys have revealed that basalts exist on the western flank of the ridge and that 1.5 to 2.0 km thick volcanic rocks lie below the sea floor on the Lakshadweep Ridge which is capped with recent coral reefs. The Deccan traps have been faulted in a north-south direction and downthrown, giving rise to the western scarp of the Western Ghats. To the west of the fault line, the Deccan traps have subsided. Consequently, a great thickness of the trappean beds and associated sediments had been deposited in the Arabian sea between Lakshadweep ridge and the west coast of India.A DSDP cell (DSDP report 1972) which was drilled on the eastern flank of Lakshadweep ridge in a water depth of 1755m, penetrated 411m of sediments and revealed a sequence of beds from late Palaeocene to Recent (Fig. 2). The lowermost horizon is composed of terrigenous clastics dated as late Palaeocene over-lain by a succession of biogenic siliceous and calcareous oozes ranging in age from Eocene to Recent. The presence of clay mineral (montmorillomite) of Deccan trap origin in the Palaeocene sediments indicates location of the site much closer to the Indian mainland. The subsequent separation of the ridge from the mainland occurred during the Eocene due to crustal shortening (Mitra et al.,1983)

CORALLINE ALGAE

Coralline algae are sensitive to light intensity, temperature, water energy, depth, etc and show changes in distribution in relation to changing conditions of these factors. The well-developed algal build-ups of the Holocene sediments of Kalpitti islet, close to Agatti, provide an opportunity to study the algal flora. The present study examines the coralline algal assemblage to determine their taxonomic composition, growth forms and significance in terms of environment. Using the taxonomic criteria developed by Harvey et al. (2003), Bassi et al. (2007) and Iryu et al.(2009), the present study has recognized nine taxa of the coralline algae. The material for the present work has been collected from Kalpitti islet, south of Agatti island of Lakshadweep. The radiocarbon dating of the sample (BS# 3633, Limestone=Kal-12/2) of this islet suggests 460±90 Yr AD. The study of the samples from this islet shows presence of rich algal material in which the corallines occur abundantly.

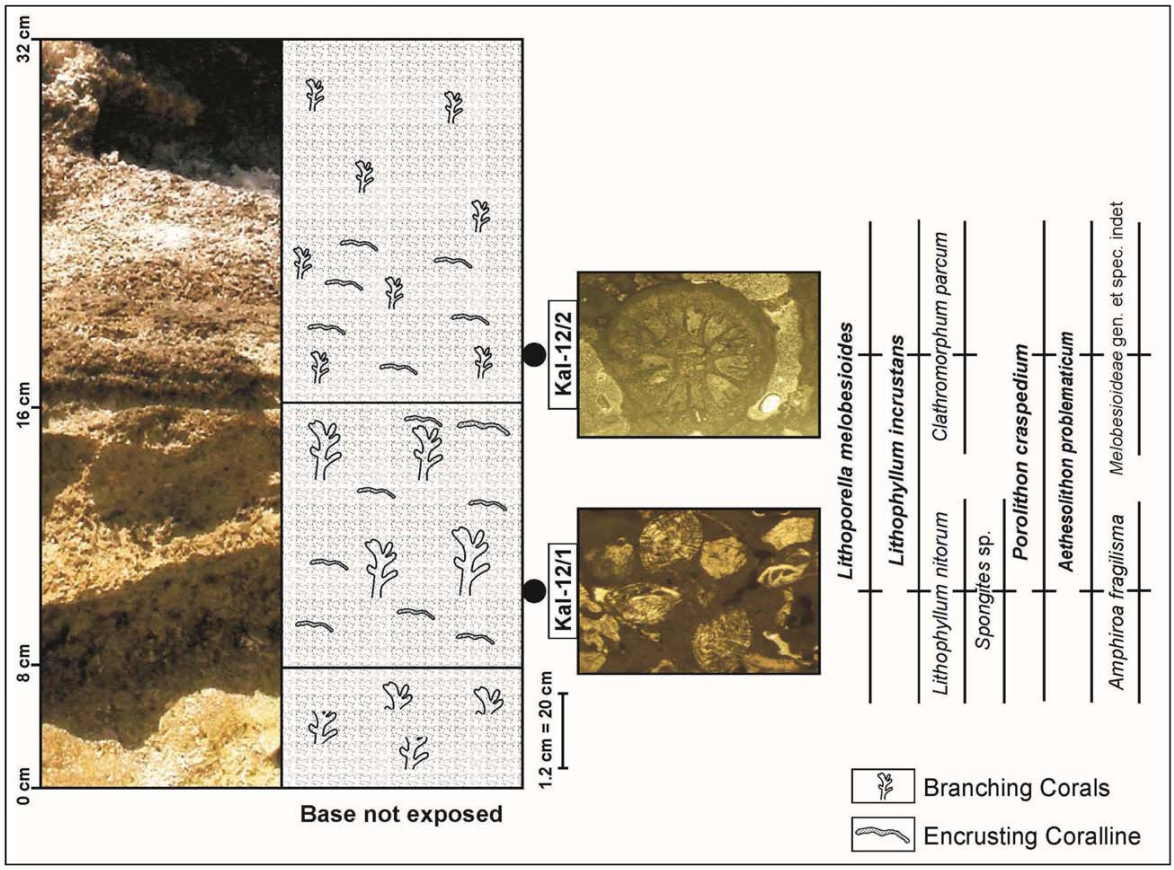

Fig.3. Lithocolumn showing representation of corals and coralline algae in the Holocene beds of Kalpitti Islet: corals are abundant throughout the succession though they become smaller in the upper part. Though absent in the lower part, corallines are less frequent in comparison to corals.

SYSTEMATIC DESCRIPTION

Division: Rhodophyta Wettstein, 1901
Class: Florideophyceae Cronquist, 1960
Subclass: Corallinophycidae Le Gall and Saunders, 2007
Order: Corallinales Silva and Johansen, 1986
Family: Corallinaceae Lamouroux, 1812
Subfaimly: Lithophylloideae (Setchell) Bailey, 1999

Genus: *Amphiroa* Lamouroux, 1812
Amphiroa fragilissima (Linnaeus) Lamouroux
(Pl.1, fig. 1)

Amphiroa fragilissima Lamouroux: Johnson and Ferris, 1950, p.19.
Amphiroa prefragilissima Lemoine: Khalifa, 1984, p. 194.
Amphiroa fragilissima Lamouroux:Kundal and Dharashivkar, 2003, p.238.
Amphiroa fragilissima Lamouroux:Kundal and Mude, 2010, p.42.
Amphiroa fragilissima Lamouroux: Kishore et al., (2012a), p.155.

Description: Plant fragment, thallus about 1.0 mm long and up to 0.15 mm broad, medullary filaments in alternate of rows of long and short cells with following formula 4L, 1S to 5L, 1S. Long cells 40-60 ìm in length and 8-10 ìm in width, short cells 15-30 ìm long and 6-10 ìm broad, peripheral filaments about 20-25ìm in diameter and cells 4-6 ìm in length and 5-8 ìm in width.

Sample No.: Kal 12/1
Slide No.: Kp/17/6
Locality: Kalpitti islet

Remarks: The present specimen is identified as *Amphiroa fragilissima* on the basis of the characteristic feature of alternate arrangement of 4-8 long cells with a single row of short cells in thallus as suggested by Johnson and Ferris (1950). It commonly occurs in the sediments ranging from Miocene to Holocene (Miocene, Fiji, Johnson and Ferris (1950); Pliocene, Egypt, Khalifa (1984); Pliocene, Saurashtra, India, Kundal and Dharashivkar (2003); Pleistocene-Holocene, Saurashtra, India, Kundal and Mude (2010) and Kishore et al. (2010).

Family Corallinaceae Lamouroux, 1812
Subfamily Lithophylloideae Setchell, 1943

Lithophyllum nitorum Adey and Adey, 1973
(Pl. 1, fig.2,3)

Lithophyllum nitorum Adey and Adey, 1973, p. 386.
Lithophyllum nitorum Adey and Adey: Braga and Aguirre, 1995, p. 277, pl. 2, figs. 5-6.
Lithophyllum nitorum Adey and Adey: Kishore *et al*., (2012b) p. 219, pl. 2, figs. 12.

Description: Growth form encrusting. Thallus dimerous. Primigenous filaments formed by rectangular cells, which are usually 10-15 μm in length and 12-18 μm in diameter. Postigenous filaments well developed. There is clear lateral alignment of cells of adjacent filaments, thallus with a net-like appearance. Cells of the postigenous filaments 10-20 μm in length and 8-20 μm in diameter. Cell fusions absent. Epithallial cells not seen. Tetra/bisporangial conceptacles are uniporate; pore canals, tapering to the conceptacle roof; some with a raised floor which can be interpreted as the remnants of a columella. They measure 200-300 μm in diameter and 75-150 μm in height.

Sample No.: Kal 12/1
Slide No.: Kp/14/18
Locality: Kalpitti islet
*Remarks***:** The present specimen seems to berepresentative of *Lithophyllum nitorum* Braga and Aguirre and shares characters such as shape, size of primigenous, postigenous filaments and shape and size of Tetra/bisporangial conceptacles. It is known from the Neogene of southern Spain (Braga and Aguirre, 1995) and the Pleistocene of Dwarka, Gujarat, India (Kishore et. al., 2012a).

Lithophyllum incrustans Philippi, 1837
(Pl. 1, fig. 4, 5)

Lithophyllum incrustans Philippi, 1837, p. 388.
Lithophyllum incrustans Philippi: Braga and Aguirre, 1995, p. 273, pl. 1, fig. 6.
Lithophyllum incrustans Philippi: Kishore et al., (2012b) p. 219, pl. 1, figs. 4-6.

Description: Growth form encrusting. Thallus organization dimerous. Cells of primigenous filaments not measurable due to poor preservation. Cells of postigenous filaments 10-14 μm in length and 8-10 μm in width. Cell fusions not observed due to bad preservation of thallus. The conceptacle oval in shape, 100-250 μm wide, 50-70 μm high. The present specimen is identified as genus *Lithophyllum* on the basis of uniporate nature of conceptacles

Sample No.: Kal 12/2
Slide No.: Kp/14/18
Locality . : Kalpitti islet
*Remarks***:** The present specimen resembles *Litho-phyllumin crustans* in the cells of primigenous, postigenous filaments and size of Tetra/bisporangial conceptacles. It is known fromthe Neogene of southern Spain, Braga and Aguirre (1995) and the Pleistocene of Dwarka, Gujarat, India (Kishore et. al.,2012 a).

Subfamily Mastophoroideae Setchell, 1943
Genus *Lithoporella* (Foslie) Foslie, 1909

Lithoporella melobesioides (Foslie) Foslie, 1909
(Pl. 1; fig. 6)

Lithoporella melobesioides Foslie: Johnson and Ferris, 1950,p. 18-19, pl. 8. fig. A.
Lithoporella melobesioides Foslie: Bosence, 1983, p. 165-166, pl. 18, fig. 2.
Lithoporella melobesioides Foslie: Kishore et al., (2012b) p. 222, pl. 3, figs. 3.
Description: Growth form encrusting, thallus showing multiple growth, often encrusting on other coralline algae and skeletal material. Thallus dimerous. Primigenous filaments show cell fusions. Cell length 40-60 μm, cell diameter 18-20 μm. Postigenous filaments not preserved. Tetra/biosporangial conceptacles not preserved.

Sample No.: Kal 12/1
Slide No.: Kp/15
Locality: Kalpitti islet
*Remarks***:** The present specimen is identified on the basis of its

primigenous filaments. *Lithoporella melobesioides* (Foslie) Foslie reported by Rasser and Piller (1999) from the late Eocene of Austrian Molasse zone. It is widely distributed in the Indian subcontinent (Eocene of Meghalaya Kishore et al. (2007); Oligocene of Kachchh Singh et al. (2009); Pleistocene of the Dwarka, Gujarat, Kishore et.al. (2012b).

Genus *Spongites* Kützing, 1841
Spongites sp.
(Pl. 1, fig. 7)

Description: Growth form encrusting. Thallus monomerous with poorly preserved core filaments. Postigenous filaments, poorly visible, hence cell fusions are not observed. Cells are 20-22mm in length and 14-16mm in

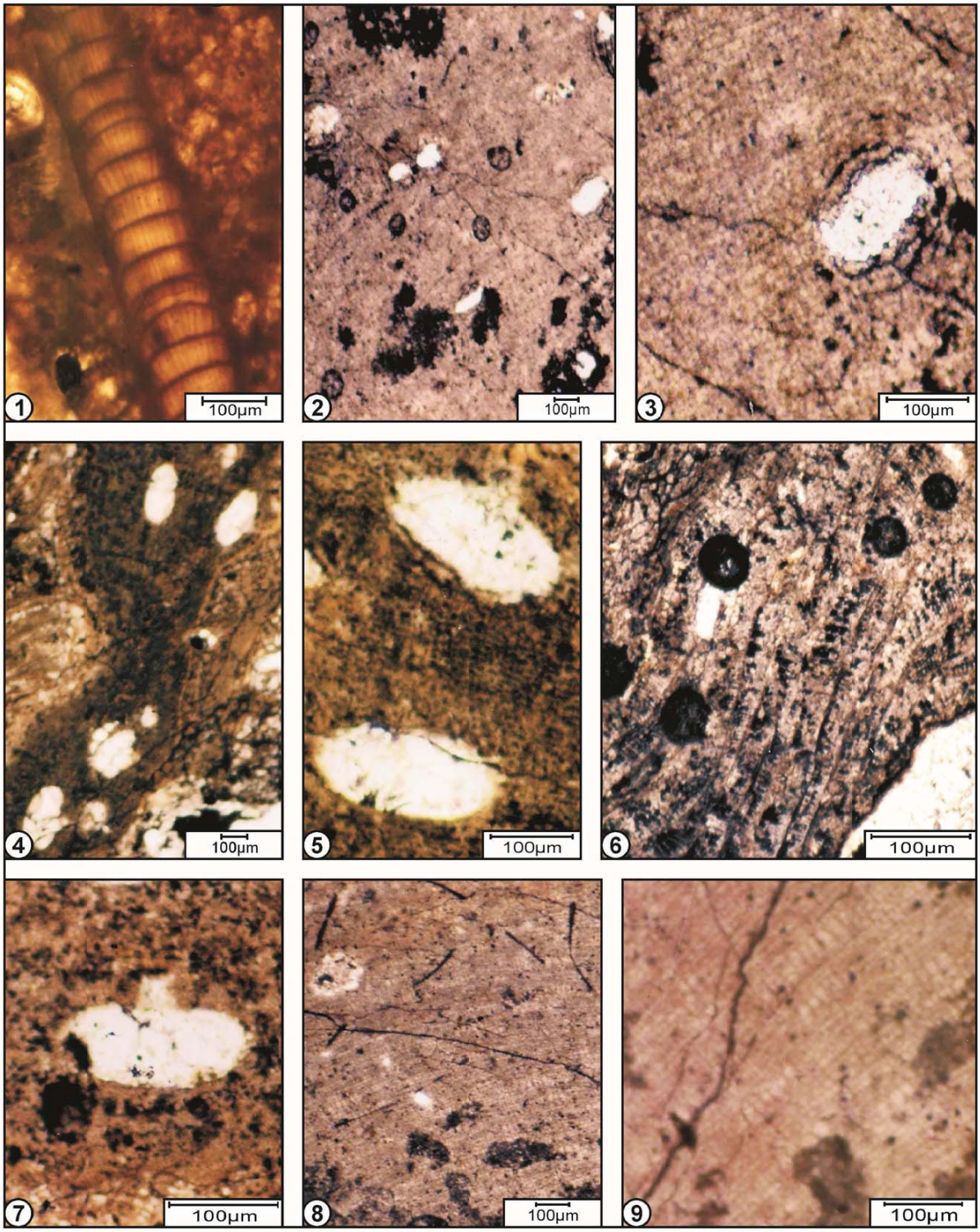

Plate 1. Fig. 1: *Amphiroa fragilisma* thallus showing long cell and short cells. Figs. 2-3: *Lithophyllum nitorum* Fig. 2: *Lithophyllum nitorum* thallus showing postigenous filaments with conceptacles. Fig. 3: *Lithophyllum nitorum* enlarged view ofconceptacle. Figs. 4-5: *Lithophyllum* incrustans Fig. 4: *Lithophyllum* incrustans thallus showing postigenous filaments with conceptacles. Fig. 5: *Lithophyllum* incrustans enlarged view ofuniporate conceptacle. Fig. 6: *Lithoporella melobesioids* thallus showing primigenous filaments. Fig. 7: *Spongites* sp thallus showing postigenous filaments with uniporate conceptacle. Figs. 8-9: *Porolithon craspedium* Fig. 8: *Porolithon craspedium* thallus showing peripheral filaments with megacells. Fig. 9: *Porolithon craspedium* enlarged view ofmegacells.

width. Epithallial cells not observed. Tetra/bisporangial conceptacles uniporate with cylindrical pore canal. Pore canal 40-50 μm long and 30-35 μm in diameter. The conceptacles buried within the thallus. Conceptacle size ranges from 180-200 μm in diameter and 70-100 μm in height.

Sample No.: Kal 12/1

Slide No.: Kp 4/5

Locality: Kalpitti islet

Remarks: The present specimen shows non-coaxial core filaments and roof canal cells around uniporate conceptacles suggest inclusion of the present specimen in *Spongites*.

Genus *Porolithon* Foslie 1909

Porolithon craspedium (Foslie) Foslie

(Pl. 1; figs. 8, 9)

Porolithon craspedium (Foslie) Foslie: Johnson, 1957, p.232, pl. 56, figs. 1-3.

Description: Growth form encrusting to warty. Thallus monomerous, core filaments poorly preserved. Postigenous filaments well preserved. Cells of the filaments distinct, hence cell fusions abundant. Cells 14-18 mm in length and 8-10 mm in width. Heterocysts occur in horizontal rows within the postigenous filaments. Epithallial cells not observed. Tetra/bisporangial conceptacles not preserved.

Sample No.: Kal 12/2

Slide No.: Kp/14/18

Locality: Kalpitti islet

Remarks: The present specimens are identified as*Porolithon* on the basis of heterocysts. It is a characteristic feature of this genus. At specific level, it is comparable with*Porolithon craspedium* in shape and size of peripheral cells of filaments and size of heterocysts. According to Johnson (1957) it is ranges from late Miocene to Recent and abundantly represented today in the tropical Pacific seas.

Family Hapalidiaceae Gray, 1864

Subfamily Melobesioideae Bizzozero, 1885

Genus *Aethesolithon* Johnson, 1961

Aethesolithon problematicum Johnson, 1961

(Pl. 2; figs. 1, 2)

Aethesolithon problematicum Johnson: Johnson, 1961, p. 50,64, pl. 10A.,fig1

Description: Growth form encrusting to warty. Thallus monomerous, core filaments poorly preserved. Postigenous filaments well preserved. Cells of the filaments distinct, hence cell fusions abundant. Cells are polygonal or rounded in shape, 18-20mm in length and 12-16mm in width. Epithallial cells not observed. Tetra/bisporangial conceptacles' pore not distinct, its size ranges from 270-280 μm in diameter and 170-180 μm in height.

Sample No.: Kal 12/2

Slide No.: Kp/ 7/11

Locality: Kalpitti islet

Remarks: The present specimens are identified as *Aethesolithon* on the basis of polygonal shape of cells of peripheral filaments and referable to *Aethesolithon problematicum* in general shape, size of core and peripheral filaments. Besides these characters, conceptacles also show similarity in shape, size and their arrangement in the thallus.Johnson (1964) has reported this species from the Miocene of Guam and Philippine Islands.

Clathromorphum parcum (Setchell and Foslie) Adey and Johansen, 1972

(Pl. 2; figs. 3, 4)

Clathromorphum parcum (Setchell and Foslie) Adey and Johansen, 1972: p. 159.

Clathromorphum parcum (Setchell and Foslie) Adey and Johansen: Woelkerling, 1988, p. 166.

Description: Plant non-geniculate and semi-endophytic, anchored to substrate by the cell adhesion or by a small core of endophytic filaments which are embedded within in the host, haustoria unknown. Thallus organisation monomerous, with non-coaxial core filaments. Cells of core filaments 34-46mm in length and 12-18 mm in width. Cells of upper postigenous filaments 18-24 mm in length and 12-14 mm in width. Epithallial cells not observed. Tetra/bisporangial conceptacles multiporate. Conceptacle size ranges from 180 to 200 μm in diameter and 70 to 100 μm in height.

Sample No.: Kal 12/2

Slide No.: Kp/15/6

Locality: Kalpitti islet

Remarks: The present specimens closely resemble the forms described by Woelkerling (1988) as *Clathromorphum parcum* in semi-endophytic nature of thallus. Multiporate nature of conceptacles, shape and size of conceptacles, cells of core filaments and peripheral filaments establish closeness with this species.

Melobesioideae gen. et spec. indet.

(Pl. 2; figs. 5)

Description: Growth form encrusting, thallus

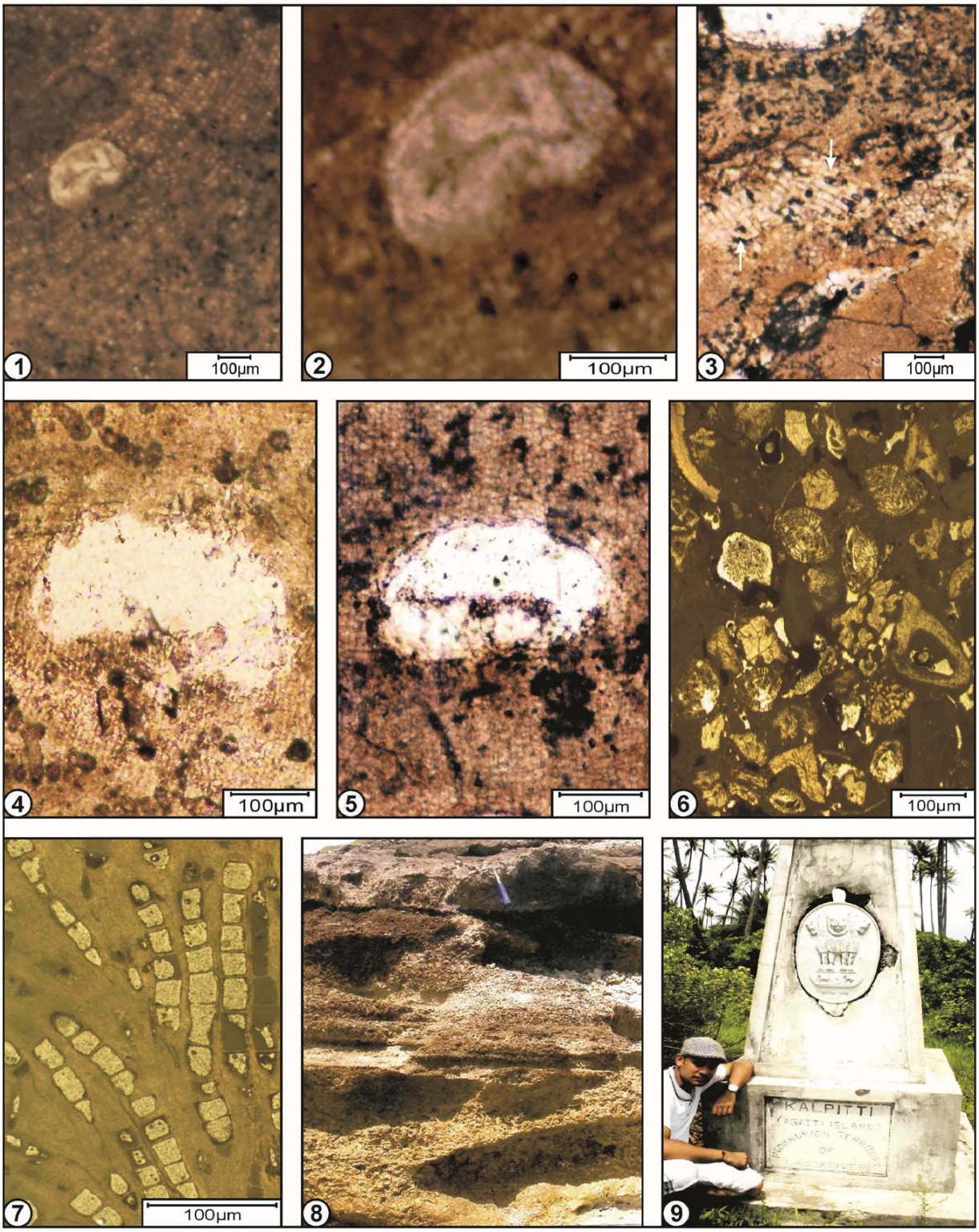

Plate 2. Figs. 1-2: *Aethesolithon problematicum.* Fig. 1: *Aethesolithon problematicum* thallus showing postigenous filaments with conceptacles. Fig. 2: *Aethesolithon problematicum* enlarged view of conceptacle. Figs. 3-4: *Clathromorphum parcum.* Fig. 3: *Clathromorphum parcum* showing endophytic thallus. Fig. 4: *Clathromorphum parcum* enlarged view of conceptacle. Fig. 5: *Melobesoides* gen.et spec. indet thallus showing postigenous filaments with conceptacle. Fig. 6: Thin section showing foraminifera (miliolids)(slide no. Kal-12/2). Fig. 7: Longitudnal section of coral, (slide no. Kal-12/1). Fig. 8: Locality of sample collections. Fig. 9: Field photograph of Kalpitti Islet.

organisation monomerous. Core filaments non-coaxial, cells usually 10-15μm in length and 16-24 μm in diameter. Peripheral filaments well developed. Cells of the peripheral filaments rectangular in shape and 8-24 μm in length and 6-20 μm in diameter. Epithallial cells not observed. Conceptaclesusually large and multiporate , 150-250μm in diameter and 80-125μm in height.

Sample No.: Kal 12/2

Slide No.: Kp/4/5

Locality: Kalpitti islet

Remarks: The exact generic identification of the present specimens is not presently possible because of absence ofepithallial cells. The presence of cell fusions in the core filaments and multiporate nature of the conceptacle indicates its relationship with Subfamily Melobesioideae.

DISCUSSION AND CONCLUSIONS

The taxonomic observations of the present study have indicated presence of nine species of coralline algae from the Kalpitti area of Agatti island. These includes: *Amphiroa fragilisma, Lithophyllum nitorum, Lithophyllum incrustans*, *Lithoporella melobesioids, Spongites* sp*., Porolithon craspedium, Aethesolithon problematicum*, *Clathromorphum parcum* and *Melobesoideae* gen. et spec. indet. Out of these, seven species belong to the family Corallinaceae, while theother two species belong to Hapalidiaceae of the Class Rhodophyceae. Among these, *Clathromorphum parcum*is an endophytic coralline alga and it is the first report of this species from the Indian subcontinent. The discovery of endophytic coralline algae is important, as till date, only lithophytic and epiphytic fossils forms of corallines are known. This change in habit merits investigation and could be a strategy among recent corallines for better survival.

The recorded coralline algae are associated mainly with branching corals and foraminifera. Two associations of coral and coralline algal forms can be broadly differentiated: one is dominated by coralline algae and large size of branching corals developed in the lower part, while the other one, developed in the upper part, is representing smaller branching corals with less diversified coralline algae (see Figure 3; Pl. 2, Fig. 8, 9). The present assemblage is modern and most of the recorded species are derived from the reef of Agatti Island.

The coralline algae is composed of three subfamilies: (i) Lithophylloideae consisting of *Lithophyllum* and *Amphiroa* adapted to shallow water environment (possibly intertidal reef flat and the backreef) and commonly growing in the upper photic zone marked by well-illuminated, high-energy water.The fruticose growth-forms of *Lithophyllum* prefer high-energy conditions, (ii) Mastophoroideae consisting of *Lithoporella, Spongites* and *Porolithon* associated with shallow, warm-water environment with high intensity of light and (iii) Melobesoideae consisting of *Aethesolithon, Clathromorphum* and unidentified melobesioids. These prefer deep-water conditions.

Porolithon and *Aethesolithon* are well known reef-forming recent genera which live on reef flat in high-energy conditions. Their presence in the lagoonal setting of the present area indicates that they may be the redeposited broken fragments from the reef of Agatti. The unidentified Melobesioidean genus also seems to be transported from the reef. The depth-wise distribution of these taxa cannot be determined because of admixture of both the lagoonal and reefal forms. The well-developed branching coral associations indicate warm-water, low-turbidity, well-protected lagoonal environment.

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