

Non-geniculate coralline algae from the Uttatur Group (Early Cretaceous), south India

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ABSTRACT

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The present paper records 8 species of non-geniculate coralline algae from the Early Cretaceous of the Uttatur Group, Tiruchirappalli District, Tamil Nadu, south India. Of these, six species are distributed among three genera of the corallinaceae family: three species belong to *Amphiroa*, one species is assigned to *Lithothamnion* and two species are placed with *Lithophyllum*. Two species are referable to *Sporolithon* of Sporolithaceae. Taxonomic differentiation is based on growth form, cell fusions and nature of conceptacle pore.

The species of *Amphiroa* are recorded for the first time from the study area while *Amphiroa kaskaella* is recorded for the first time from India. *Amphiroa foliacea* and *A. guatemalense* are documented for the first time from the Uttatur Group (Cretaceous) of the Cauvery Basin. The algal association suggests depositional environments ranging from shallower to deeper parts of sea. The abundance of coralline algae indicates reefal environment.

Key-words—Calcareous algae, Rhodophyceae, Kallakudi Limestone, Uttatur Group, Early Cretaceous.

दक्षिण भारत के उत्तातुर समूह से प्राप्त अजानुनत प्रवाली शैवाल (प्रारंभिक क्रिटेशस)

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सारांश

वर्तमान शोध-पत्र दक्षिण भारत में तमिलनाडु के तिरुचिरापल्लि जिले में स्थित उत्तातुर समूह के प्रारंभिक क्रिटेशस से अजानुनत प्रवाली शैवाल की 8 जातियाँ अंकित करता है। इनकी, छः जातियाँ कोरेलिनेसी कुल के तीन वंशों में वितरित की गई हैं: तीन जातियाँ *एंफिरोआ* से संबंधित हैं, एक जाति *लिथोथेमनियन* की निर्दिष्ट की गई है तथा दो जातियाँ *लिथोफिल्लम* की हैं। स्पोरोलिथेसी की दो जातियाँ *स्पोरोलिथॉन* से संबंधित हैं। वर्गिकी विभेदन वृद्धि रूप, कोशिका संलयन और धानी छिद्र की प्रकृति पर आधारित है।

एंफिरोआ जाति पहली बार अध्ययन क्षेत्र से अंकित की गई है जबकि *एंफिरोआ कास्केल्ला* भारत से पहली बार अंकित किया गया है। *एंफिरोआ फॉलिएसीआ* तथा *ए. गुआटेमेलेन्स* कावेरी द्रोणी के उत्तातुर समूह (क्रिटेशस) से पहली

बार प्रलेखित हुए हैं। शैवाल संयोजन समुद्र के उथले से गहरे भागों की ओर निक्षेपणीय पर्यावरण प्रस्तावित करता है। प्रवाली शैवाल की बाहुल्यता शैल-भित्ति पर्यावरण दर्शाती है।

संकेत शब्द—चूनेदार शैवाल, लाल शैवाल कुल, कल्लाकुडी चूना पत्थर, उल्तापुर समूह, प्रारंभिक क्रिटेशस।

INTRODUCTION

THE present paper deals with the morphotaxonomic description of non-geniculate coralline algae from the Lower Cretaceous Kallakudi Limestone (Uttatur Group), Cauvery Basin, south India exposed in the areas around Olaipadi Mine near Govindarajapatnam of Tiruchirapalli District, Tamil Nadu (Fig. 1). The Cretaceous sediments are well exposed in isolated areas (Pondicherry, Vriddhachalam, Ariyalur, Tanjore and Sivaganga) of the Cauvery Basin (Banerji, 1972). The Cauvery Basin is the southernmost basin along the eastern margin of Peninsular India and is nearly 400 km long and 130 km wide. It is located between Latitude 12° and 9° 30' North and Longitude 78° and 80° 30' East. The Cretaceous rocks of the Tiruchirapalli area were first recognised and described by Blanford (1862). He divided Cretaceous succession of the Cauvery Basin into three groups: Uttatur Group, Trichinopoly Group and Ariyalur Group. The present calcareous algal assemblage is reported from the Kallakudi Limestone of the Uttatur Group. This group is named after the village Uttatur. It extends over a 70 km long, 4-6 km wide area and beds dip 10° due east. It is divisible into three formations, viz., Grey Shale, Kallakudi Limestone and Karai Shale/Maruvattur Clay (Govindan *et al.*, 1998; Fig. 2).

The outcrops of the Kallakudi Limestone (Aptian-Albian) occur along the western margin of the basin from the Olaipadi Mine exposed near Govindarajapatnam (Fig. 3), Asur-Kallal in the north, Kudikkadu-Varagupadi in the middle to Tirupattur in the southwest and Kallakudi in the southeast. It is a conspicuously pink, hard, compact limestone with stromatolite structures, large irregular cavemous voids, vugs filled with coarse, crystalline quartz and calcite at places. The fossils include red algae, corals, bryozoa, echinoids, ostracods, bivalves and foraminifera (Govindan *et al.*, 1998).

Significant work on stratigraphy, micropalaeontology, depositional environment and tectonic evolution of the Cauvery Basin has been carried out by Rama Rao (1956), Banerji (1972), Chiplonkar and Tapaswi (1975), Ramanathan (1979), Sundaram and Rao (1986), Jafar and Rai (1989), Govindan *et al.* (1998), Madhavaraju and Ramasamy (1999, 2002), Sundaram *et al.* (2001), Madhavaraju *et al.* (2002, 2004) and Nagendra *et al.* (2002). The Uttatur Group is important from the palaeontological point of view as it is characterised by rich assemblages of animal and plant fossils. Calcareous algae reported earlier from the Coralline Limestone of the Uttatur Group were represented by *Cayeuxia* sp., *C. fruticulosa*, *Acicularia antiqua*, *Neomeris occidentalis*, *Neomeris* sp., *Halimeda* sp., *Solenopora jurassica*, *S. coromandelensis*, *S. sahnii* and *Lithothamnion* sp. (Narayan Rao, 1944, 1946; Rama Rao & Prasanna Kumar, 1932; Rama Rao & Gowda, 1954; Rajanikanth, 1988, 1992; Gowda, 1978). Misra *et al.* (2004) reported eight species of calcareous algae from the Kallakudi mines of the Uttatur Group.

METHODOLOGY

The material was collected from the Kallakudi Limestone of the Olaipadi Mine (near Govindarajapatnam), Tiruchirapalli District, Tamil Nadu, and the calcareous algae were studied in random thin sections; about 130 slides were prepared by Logitech Machine. Thin sections used in studying the fossil corallines are of two types: one parallel to the direction of filament growth and perpendicular to the thallus surface and the other perpendicular to the direction of filament growth for measuring cell diameters. The taxonomic differentiation of the coralline algae in the present work, however, has been made on the basis of certain diagnostic anatomical features of living corallines, which are preserved even in the fossil material. A brief summary of these features and the related terminology

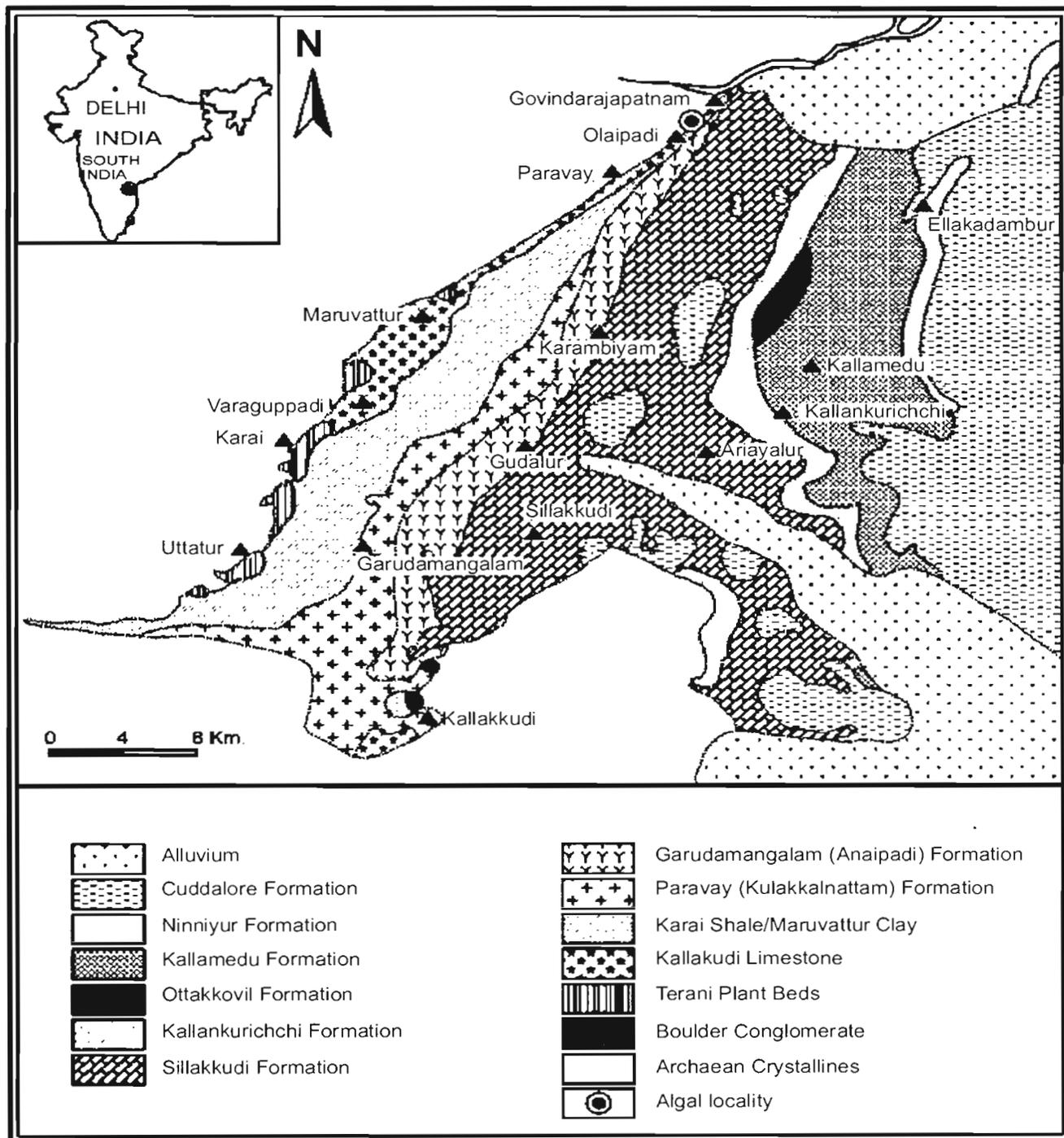


Fig. 1—Geological map of Tiruchirapalli area (after Govindan *et al.*, 1998).

SYS TEM	SER IES	STAGE	FORMATION	GROUP	
C R E T A C E O U S	Upper	Maastrichtian	KALLAMEDU Sandstone	ARIYALUR GROUP	
			KALLANKURICHCHI		
		Campanian	SILLAKUDI		
		Santonian	GARUDAMANGALAM		TRICHINOPOLY GROUP
		Coniacian	PARAVAY		
	Turonian				
	Lower	Cenomanian	MARUVATTUR Clay	UTTATUR GROUP	
		Albian	KARAI Shale KALLAKUDI St.		
		Pre Albian	TERANI		UPPER GONDWANA GROUP
		ARCHAEAN	EASTERN GHAT COMPLEX		

Fig. 2—Cretaceous lithostratigraphy (outcrops) Cauvery Basin, India (after Govindan *et al.*, 1998).

based on Rasser and Piller (1999), Bassi (1997, 1998), Braga *et al.* (1993), etc. were presented in Misra *et al.* (2001).

The studied material is preserved at the Algology Laboratory, Department of Botany, University of Lucknow, Lucknow.

SYSTEMATICS

Division—RHODOPHYTA Wettstein, 1901

Class—RHODOPHYCEAE Rabenhorst, 1863

Order—CORALLINALES Silva & Johansen, 1986

Family—CORALLINACEAE Lamouroux, 1812

Subfamily—MELOBESIOIDEAE Bizzozero, 1885

Genus—LITHOTHAMNION Heydrich, 1897

Growth form warty to fruticose, peripheral region is well developed with distinct zonation. Filaments radially organized inside the protuberances, cell fusions conspicuous. Tetra/bisporangial conceptacles multiporate.

Lithothamnion sp.

(Pl. 2.5, 6)

Description—Growth form encrusting, thallus organisation monomerous. Core filaments non-coaxial, core portion usually 250 µm thick. Cell fusions present. Cells 15-25 µm in length and 10-14 µm in width. Peripheral cells 8-12 µm in length and 10-12 µm in width. Asexual conceptacles present, cavity 110-140 µm in height and 500-600 µm in width.

Sample no.—VL/2.

Slide no.—56.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—The present specimen resembles *Lithothamnion* cf. *L. lacroixi* Johnson and Kaska (1965) reported from the lower Miocene of the Guatemala in growth form, cell dimensions of core and peripheral filaments of the thallus. In addition, the tetra/bisporangial conceptacles also show similarity in shape, size and the nature of development of the conceptacles.

Subfamily—LITHOPHYLLOIDEAE Setchell, 1943

Genus—LITHOPHYLLUM Philippi, 1837

Growth form crustose to fruticose, composed entirely of protuberances. Crustose portion of plants and lamellae dorsiventral and dimerous or monomerous, or both in the same plant. Cell fusions absent. Tetra/bisporangial conceptacles uniporate and clearly delimited.

Lithophyllum sp. 1

(Pl. 2.7, 8)

Description—Growth form encrusting and

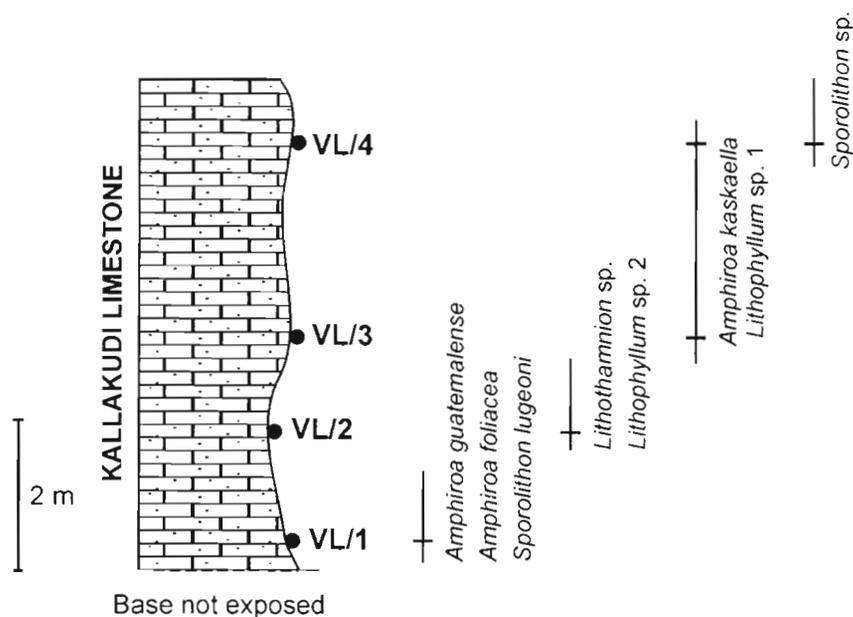


Fig. 3—The litho-biostratigraphic representation of the Olaipadi mines (Govindarajapatnam) showing position of the fossil-yielding samples (indicated by vertical line).

strongly branching, thallus organisation monomerous. Core filaments coaxial, cells of core filaments two types—long cells 30-40 μm in length and 8-12 μm in width; short cells 18-24 μm in length and 8-12 μm in width. The marginal peripheral filaments present, ranging from 250-300 μm in width. Cells of peripheral filament 12-16 μm in length and 8-12 μm in width. Tetra/bisporangial conceptacle uniporate, with cells 80-100 μm in length and 200-400 μm in width.

Sample no.—VL/3-4.

Slide no.—33.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—Thallus organization, cell size of core filaments (protuberance), peripheral filaments and uniporate nature of the conceptacles of the specimens indicate their resemblance to *Lithophyllum alternicellum* Johnson (1964). Johnson reported this species from the Miocene of Guam. However, conceptacles are larger in the present specimen and differs from *L. alternicellum*.

Lithophyllum sp. 2

(Pl. 2.9)

Description—Growth form encrusting, thallus organisation monomerous. Core filaments coaxial, cells of core filaments 15-18 μm in length and 10-12 μm in width. The marginal peripheral filaments present, ranging from 8-10 μm in width, cells not measurable. Tetra/bisporangial conceptacle uniporate, showing cells 180-200 μm in length and 300-350 μm in width.

Sample no.—VL/2.

Slide no.—6.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—Thallus organization and uniporate conceptacle morphology suggest that these specimens are broadly similar to *Lithophyllum*. The present specimens are not comparable with any known species of the genus *Lithophyllum*.

Genus—AMPHIROA Lamouroux, 1812

Previously, *Amphiroa* was assigned to geniculate coralline algae. Recently, Bailey (1999) transferred this genus into non-geniculate group on the basis 18S rRNA gene sequencing and indicated its relationship with *Titanoderma* of subfamily Lithophylloideae. Hence, in the present study we have

followed the Bailey's (1999) classification placing *Amphiroa* with subfamily Lithophylloideae of non-geniculate coralline algae. This genus has segments that are cylindrical to flattened in shape. The medullary tissue is characterized by one or more rows of long cells alternating with a single row of short cells and is surrounded by a distinctly layered cortical tissue. Conceptacles are marginal and lateral in position.

Amphiroa guatemalense Johnson and Kaska,
1965

(Pl. 1.1, 2)

1965 Johnson and Kaska, p. 52, pl. 24, figs 1, 2 and pl. 25, fig. 1.

Description—Segments broadly cylindrical, 1.5 mm long and up to 1.1 mm broad; medullary filaments showing one row of long cells alternating with one row of short cells; long cells 25-35 μm in length and 8-12 μm in width; short cells 15-25 μm long and 8-12 μm broad; peripheral filaments about 50 μm in diameter and cells 7-10 μm in length and 7-10 μm in width.

Sample no.—VL/1.

Slide no.—27.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—The present specimen is comparable with *Amphiroa guatemalense* Johnson and Kaska in shape and size of short and long cells of medullary region of the thallus. Johnson and Kaska (1965) reported *Amphiroa guatemalense* from the Palaeocene of Guatemala.

Amphiroa foliacea Lamouroux, 1812

(Pl. 1.3, 4)

1954 Ishijima, p. 53, pl. 37, fig. 8.

1957 Johnson, p. 238, pl. 37, fig. 2.

2003 Kundal and Dharashivkar, p. 249, pl. 1, fig. 4.

Description—Intergenicula cylindrical, flattened with a tapering end. The medullary rows of cells arched. Medulla consists of three rows of long cells alternating with one row of short cells; medullary filaments 1.1 mm long and up to 0.25 mm broad; long cells of medullary filaments 40-50 μm in length and 8-12 μm in width, short cells 20-35 μm long and 8-12 μm broad.

Sample no.—VL/1.

Slide no.—33.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—This specimen seems to be comparable with *Amphiroa foliacea* in its medullary filaments showing alternation of three rows of long cells with one row of short cells in the thallus.

Amphiroa kaskaella Johnson and Kaska, 1965

(Pl. 1.5-8)

1965 Johnson and Kaska, p. 53, pl. 25, figs 2, 3.

Description—Segments long and wide, 1.0 mm long and up to 0.5 mm broad, medullary filaments show two rows of long cells alternating with one or two rows of short cells; long cells 60-80 μm long and 10-12 μm broad; short cells 20-25 μm long and 10-12 μm broad. Marginal peripheral filaments thin, about 60 μm wide; cells 10-12 μm in length and 8-10 μm in width.

Sample no.—VL/3, 4.

Slide no.—48, 50, 71.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—The present specimen is referable to *Amphiroa kaskaella* Johnson and Kaska reported

PLATE 1



1. *Amphiroa guatemalense*. x 50.
2. *Amphiroa guatemalense*. x 130.
3. *Amphiroa foliacea*. x 50.
4. *Amphiroa foliacea*. x 130.

5. *Amphiroa kaskaella*. x 50.
6. *Amphiroa kaskaella*. x 130.
7. *Amphiroa kaskaella*. x 130.
8. *Amphiroa kaskaella*. x 50.

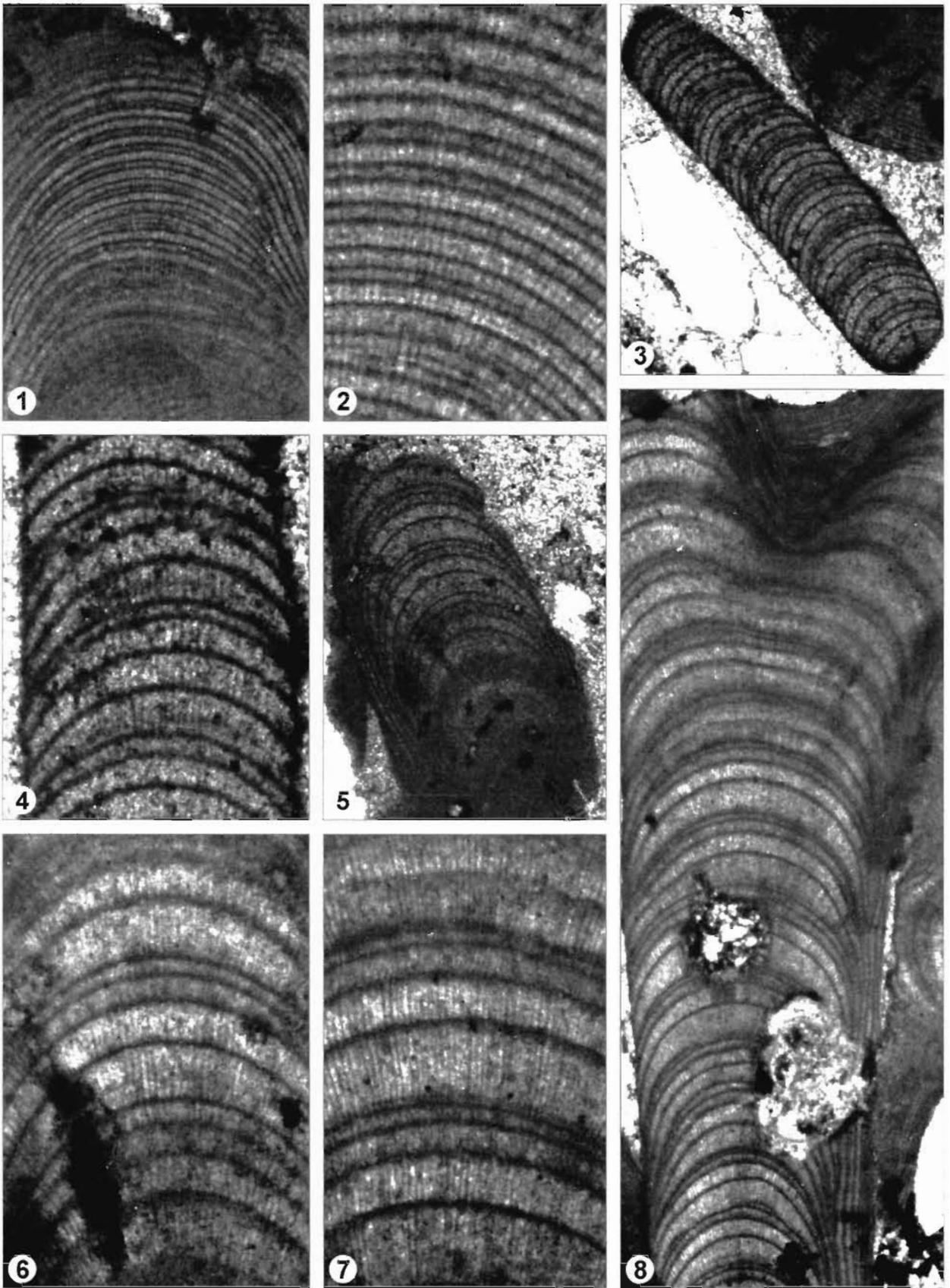


PLATE 1

from the Palaeocene of Guatemala (Johnson & Kaska 1965) in having regular alternation of long and short cells in the medullary region. Besides this character, the cells of medullary region also show similarity in shape, size and their arrangement in the thallus.

Family—SPOROLITHACEAE Verheij, 1993

Genus—SPOROLITHON Heydrich, 1897

The genus is characterized by epithallial cells with flattened and flared cells and tetra/bisporangial conceptacles separated by interspersed calcified filaments (paraphyses) (Woelkerling, 1988). According to Moussavian and Kuss (1990), *Sporolithon* is the correct generic name for the corallines earlier included in *Archaeolithothamnium* Rothpletz, 1891, since the latter name was not validly published. Verheij (1993) proposed a new family, Sporolithaceae to separate *Sporolithon* from the rest of the corallines on account of simultaneous cruciate cleaving of its tetrasporangia. Tetrasporangial chambers are surrounded by calcified paraphyses (filaments). Townsend *et al.* (1995), in order to avoid the confusing terminology of reproductive structures, regarded the family Sporolithaceae as having tetrasporangia which show cruciately arranged spores within calcified sporangial compartments (Aguirre & Braga, 1998).

Sporolithon lugeoni (Pfender) Moussavian and Kuss, 1990

(Pl. 2.1-3)

1926 Pfender, p. 324, pl. 9, 13.

1988 Misra and Kumar, p. 46, pl. 4, figs 7, 9, 11.

1990 Moussavian and Kuss, p. 929-942.

1996 Ghosh and Maithy, p. 68, pl. 1, figs 1-4.

1999 Ghosh and Maithy, p. 37, pl. 1, fig. a.

Description—Growth form encrusting to crustose and lobate, 4.5 mm long and 3.0 mm in width. Thallus organisation monomerous. Core filaments non-coaxial. Cells of core filaments 18-20 μm in length and 8-12 μm in width. The peripheral region of encrusting portion restricted to dorsal part of the thallus with cells 15-20 μm in length and 8-10 μm in width. Cell fusions present. Tetrasporangial conceptacles arranged in sori. Individual sporangial compartments rectangular, elliptical or ovoid in longitudinal section and circular in transverse section; 60-80 μm in height and 35-50 μm in width. Sori usually arise from a layer of elongated cells. Filaments (paraphyses) are interspersed between the sporangial compartments.

Sample no.—VL/1.

Slide no.—34.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—The present specimen is comparable with *Sporolithon lugeoni* (Pfender) Moussavian and Kuss recorded by Misra and Kumar (1988) and Ghosh and Maithy (1996) in shape and size of sporangia and peripheral cells. Misra and Kumar (1988) reported this form from the Cretaceous of Varagur, Tiruchirapalli District, Tamil Nadu. Ghosh and Maithy (1999) also reported possibly a very similar form from the Maastrichtian of the Kallankurichchi Formation, Ariyalur Group, Tamil Nadu.

Sporolithon sp.

(Pl. 2.4)

Description—Growth form encrusting with protuberances, thickness of encrusting thalli up to 1.7 mm. Thallus organization monomerous. Core filaments non-coaxial. Cells regular, multilayered. Medullary core filaments quite regular. Cells 18-22 μm long and 8-12

PLATE 2



- | | |
|---------------------------------------|--------------------------------------|
| 1. <i>Sporolithon lugeoni</i> . x 50. | 6. <i>Lithothamnion</i> sp. x 130. |
| 2. <i>Sporolithon lugeoni</i> . x 50. | 7. <i>Lithophyllum</i> sp. 1. x 50. |
| 3. <i>Sporolithon lugeoni</i> . x 50. | 8. <i>Lithophyllum</i> sp. 1. x 130. |
| 4. <i>Sporolithon</i> sp. x 130. | 9. <i>Lithophyllum</i> sp. 2. x 50. |
| 5. <i>Lithothamnion</i> sp. x 130. | |

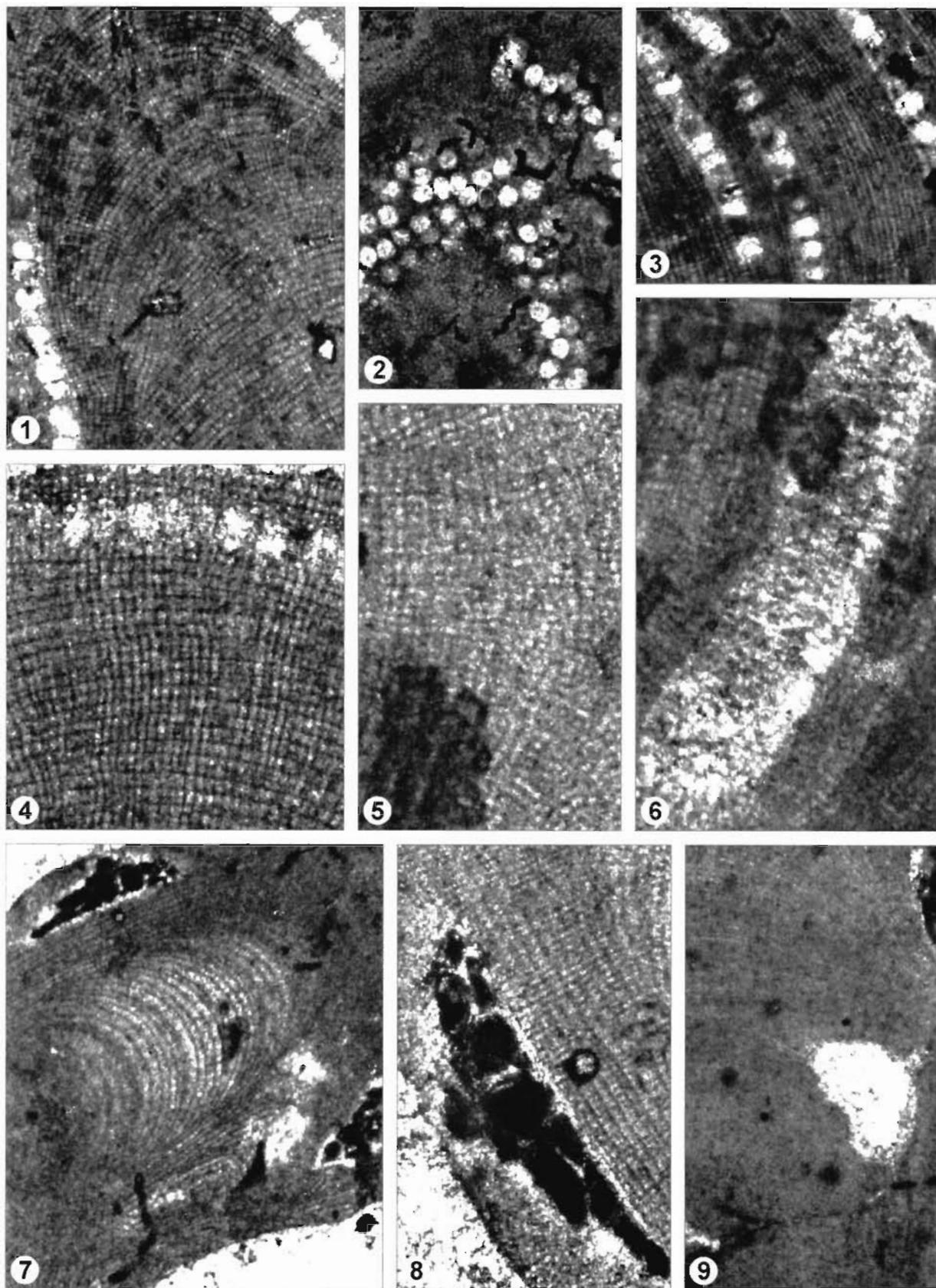


PLATE 2

µm wide. Peripheral filament marginal with cells 12-18 µm in length and 8-10 µm in width. Sporangia ovoid, 40-60 µm long and 30-40 µm in width. Filaments (paraphyses) interspersed between the sporangial compartments.

Sample no.—VL/4.

Slide no.—50.

Locality—Olaipadi Mine, Govindarajapatnam.

Occurrence—Uttatur Group.

Discussion—The present specimen differs from *Sporolithon lugeoni* in shape and arrangement of tetra/bisporangial compartments and cell size. However, orientation of thallus of present specimen is similar.

DISCUSSION

The present paper records eight species of the families Corallinaceae and Sporolithaceae of class Rhodophyceae from the Lower Cretaceous succession of the Uttatur Group. These taxa assigned to four genera are *Amphiroa kaskaella*, *A. foliacea*, *A. guatemalense*, *Sporolithon lugeoni*, *Sporolithon* sp., *Lithothamnion* sp., *Lithophyllum* sp. 1 and *Lithophyllum* sp. 2. The taxonomic features such as growth form, cell fusions and nature of conceptacle pore have been used in discriminating between different genera. The species of *Amphiroa* documented here are recorded for the first time from the study area. Of these, the presence of *Amphiroa kaskaella* is recorded for the first time in the Lower Cretaceous successions of India.

Studies on the variable morphology of the present-day coralline algae and their preferences to different climates and water depths have provided useful data for palaeoenvironmental inferences. The abundance of coralline algae in the Kallakudi Limestone indicates reefal environment. Reefs and adjacent facies are characterised by corals and different coralline algal forms which carry out cementing and framework-binding function in this environment. Important coralline genera in the present assemblage are *Lithothamnion*, *Sporolithon* and *Lithophyllum*. Presence of *Sporolithon* and *Lithothamnion* is indicative of depths more than 20 m (Adey *et al.*, 1982; Minnery, 1990; Perrin *et al.*, 1995), while *Lithophyllum*

(*Lithophylloideae*) prefers warm, shallow waters at depths < 20 m (Braga & Martin, 1988). Ecological data indicate that *Amphiroa* generally lives in water less than 30 m (Cloud, 1952) but is common at depths between 20 and 25 m (Johnson, 1957). Though poorly known from the Albian sediments of the world, the species of *Amphiroa* in the present assemblage are dominant.

The present investigation suggests that the Kallakudi Limestone deposited on a carbonate platform in which a number of algal biofacies could possibly be distinguished and represent depositional environments ranging from shallower (< 20 m) to deeper (> 30 m) parts of sea.

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REFERENCES

- Adey WH, Townsend RA & Boykins WT 1982. The crustose coralline algae (Rhodophyta: Corallinaceae) of the Hawaiian Islands. *Smithson. Contribution Marine Science* 15: 1-74.
- Aguirre J & Braga JC 1998. Redescription of Lemoine's (1939) Types of coralline algal species from Algeria. *Palaeontology* 41: 489-507.
- Bailey JC 1999. Phylogenetic positions of *Lithophyllum incrustans* and *Titanoderma pustulatum* (Corallinaceae, Rhodophyta) based on 18S rRNA gene sequence analyses with a revised classification of Lithophylloideae. *Phycologia* 38/3: 208-216.
- Banerji RK 1972. Conflicting stratigraphical ranges observed in the Miocene planktonic foraminifera from the Cauvery Basin, South India. *Proceedings of the II Indian Colloquium on Micropalaeontology and Stratigraphy*: 40-49.
- Bassi D 1997. Vegetative anatomy and palaeoecology of *Polystrata alba* Pfender, 1968 (Cryptonemiales, Peyssonneliaceae) from the Upper Eocene of northern Italy. *Review Paléobiol Genève* 16: 309-320.
- Bassi D 1998. Coralline red algae (Corallinales, Rhodophyta) from the upper Eocene Calcare di Nago (Lake Garda,

- Northern Italy). *Annali dell' Università di Ferrara* 7 : 1-50.
- Bizzozero G 1885. *Flora Veneta Criptogamica*. Part II. Seminario, Padova I I : 255p.
- Blanford HF 1862. On the Cretaceous and other rocks of S. Arcot and Trichinopoly districts, Madras. *Memoir Geological Survey of India* 4 : 1-217.
- Braga JC & Martin JM 1988. Neogene Coralline-Algal Growth-Forms and their Palaeoenvironments in the Almanzora River Valley (Almeria, S.E. Spain). *Palaeogeography Palaeoclimatology Palaeoecology* 67 : 285-303.
- Braga JC, Bosence DWJ & Steneck RS 1993. New anatomical characters in fossil coralline algae and their taxonomic implications. *Palaeontology* 36 : 535-547.
- Chiplonkar GW & Tapaswi PM 1975. Biostratigraphy of the inoceramids in the upper Cretaceous of Trichinopoly District, South India. *Biovigyanam* 1 : 11-15.
- Cloud Jr PE 1952. Facies relationships of organic reefs. *Bulletin American Association of Petroleum Geologists* 36 : 2125-2149.
- Ghosh AK & Maithy PK 1996. On the present status of Coralline red algae *Archaeolithothamnium* Roth. from India. *Palaeobotanist* 45 : 64-70.
- Ghosh AK & Maithy PK 1999. Fossil algae from the Maastrichtian of Kallankurichchi Formation, Ariyalur Group. *Geoscience Journal* 20 : 35-40.
- Govindan A, Yadagiri K, Ravindran CN & Kalyansunder R 1998. A field guide on Cretaceous sequences of Tiruchirapalli area, Cauvery Basin. O.N.G.C., Chennai, 53 pp.
- Gowda SS 1978. Fossil algae *Solenopora* and *Amphiroa* from Trichinopoly Cretaceous rocks of South India. *Current Science* 47 : 502-503.
- Heydrich F 1897. Corallinacea, insbesondere Melobesieae. *Berlin Deutsch. Botane Gesteine*, 15 : 4-70.
- Ishijima W 1954. Cenozoic coralline algae from the western pacific: Tokyo, 1-87 p.
- Jafar SA & Rai J 1989. Discovery of Albian Nannoflora from type Dalmiapuram Formation, Cauvery Basin, India-Paleoceanographic remarks. *Current Science* 58 : 358-363.
- Johnson JH 1957. Calcareous algae in Geology of Saipan, Mariana Islands: U. S. Geological Survey Professional Paper 280-E : 209-246.
- Johnson JH 1964. Fossil algae from Guam: U.S. Geological Survey Professional Paper 403-G : 1-40.
- Johnson JH & Kaska HV 1965. Fossil algae from Guatemala. *Colorado Schools of Mines Professional Contribution* 1 : 152 p.
- Kundal P & Dharashivkar AP 2003. Genuiculate coralline alga *Amphiroa* from Lower Pliocene of Dwarka-Okha area, Gujarat, India. *Gondwana Geological Magazine Special Volume* 6 : 245-259.
- Lamouroux JVF 1812. Extrait d'une memoire sur la classification des plyphiers coralligenes non entierement pierreux. *Nouvelle Bulletin des Sciences de la Societe de Philomatermatique* : 181-188.
- Madhavaraju J & Ramasamy S 1999. Microtextures on quartz grains of Campanian-Maastrichtian sediments of Ariyalur Group of Tiruchirapalli Cretaceous, Tamil Nadu- implication on depositional environments. *Journal Geological Society of India* 54 : 647-658.
- Madhavaraju J & Ramasamy S 2002. Petrography and major element geochemistry of Late Maastrichtian-Early Palaeocene sediments of Tiruchirapalli, Tamil Nadu-Palaeoweathering and Provenance Implications. *Journal Geological Society of India* 59 : 133-142.
- Madhavaraju J, Ramasamy S, Ruffell A & Mohan SP 2002. Clay mineralogy of the Late Cretaceous and early Tertiary successions of the Cauvery Basin (southern India): implication for sediment source and palaeoclimates at the K/T boundary. *Cretaceous Research* 23 : 153-163.
- Madhavaraju J, Kolosov I, Buhlak D, Armstrong-Altrin JS, Ramasamy S & Mohan SP 2004. Carbon and Oxygen Isotopic signatures in Albian-Danian limestones of Cauvery Basin, Southern India. *Gondwana Research* 7 : 519-529.
- Misra PK & Kumar P 1988. Fossil algae from the Cretaceous of Varagur, Tiruchirapalli District, Tamil Nadu. *Palaeobotanist* 37 : 36-51.
- Misra PK, Jauhri AK, Singh SK, Kishore S & Chowdhury A 2001. Coralline algae from the Oligocene and Eocene of Kachchh, Gujarat, India. *Journal of Palaeontological Society of India* 46 : 59-76.
- Misra PK, Rajanikanth A, Jauhri AK, Kishore S & Singh SK 2004. Albian limestone building algae of Cauvery Basin, South India. *Current Science* 87 : 1516-1518.
- Minnery GA 1990. Crustose coralline algae from the Flower Garden Banks, northwestern Gulf of Mexico and growth morphology. *Journal of Sedimentary Petrology* 60 : 992-100.
- Moussavian E & Kuss J 1990. Typification and status of *Lithothamnium aschersonii* Schwager, 1883 (Corallinaceae, Rhodophyta) from Palaeocene limestone of Egypt. A contribution to the priority of the genera *Archaeolithothamnium* Rothpletz and *Sporolithon* Heydrich. *Berliner geowiss. Abh.*, 120 : 929-942.
- Nagendra R, Nagendran G, Narasimha K, Jaiprakash BC & Reddy AN 2002. Sequence stratigraphy of Dalmiapuram Formation, Kallakudi Quarry- II, South India. *Journal Geological Society of India* 59 : 249-258.
- Narayan RSR 1944. Upper Jurassic marine algae from Tiruchirapalli Cretaceous rocks of S. India. *Current Science* 13 : 101-102.
- Narayan RSR 1946. On two species of *Solenopora* from the Cullygoody Limestone of the Trichinopoly District, S. India. *Journal of Indian Botanical Society (M.O.P. Iyengar Comm. Vol.)* : 331-337.
- Perrin C, Bosence DWJ & Rosen B 1995. Quantitative approaches to palaeozonation and palaeobathymetry of corals and coralline algae in Cenozoic reefs. *In*: Bosence DWJ & Allison PA (Editors)—*Marine Palaeoenvironmental*

- Analysis from Fossils. Geological Society Special Publication 83 : 181-229.
- Pfender J 1926. Les Mélobésiées dans les calcaires créacés de la Basse- Provence. Mémoire Societe Géologie France nova sér. 3 : 32.
- Philippi R 1837. Beweis dass di Nulliporen Pflanzen sind. Arch v fur Naturgeschichte 3 : 387-393.
- Rabenhorst L 1863. Kryptogamen-Flora von Sachsen, der Ober-Lausitz, Thuringen und Nordböhmen, Leipzig (E. Krummer) 20 : 653 pp.
- Rajanikanth A 1988. Fossil calcareous algae from Kallakudi (Dalmiapuram) Limestone, Cauvery Basin. Symposium Vistas in Indian Palaeobotany (Abst.) : 49. Birbal Sahni Institute of Palaeobotany, Lucknow.
- Rajanikanth A 1992. Rock building Cretaceous-Tertiary algae from India – an ecological perspective. Palaeobotanist 40 : 399-412.
- Ramanathan S 1979. Tertiary formations of South India. Geological Survey of India, Miscellaneous Publication 45 : 165-180.
- Rao LR & Gowda SS 1954. Solenoporaceae in the Cretaceous rocks of south India. Current Science 23 : 177-178.
- Rama Rao L & Prasannakumar C 1932. Occurrence of *Lithothamnion* in the South Indian Cretaceous. Nature 129 : 776-777.
- Rama Rao L 1956. Recent contributions to our knowledge of the Cretaceous rocks of South India. Proceedings of Indian Academy of Science B44 : 185-245.
- Rasser M & Piller WE 1999. The coralline algae of the Upper Austrian Molasse zone (Late Eocene): application of neontological taxonomy to the fossil record. Micropalaeontology 18 : 67-80.
- Rothpletz A 1891. Fossile Kalkagen aus den families der codiaceen und der Corallinaceen.-Z. Deutsch. 54/14 : 1-2 Cassel.
- Setchell WA 1943. *Mastophora* and Mastophoreae : genus and subfamily of Corallinaceae. Proceedings of the National Academy of Sciences of the United State of America 29 : 127-135.
- Silva PC & Johansen HW 1986. A reappraisal of the order Corallinales (Rhodophyceae). British Phycological Journal 21 : 245-254.
- Sundaram R & Rao PS 1986. Lithostratigraphy of Cretaceous and Palaeocene rocks of Tiruchirapalli District, Tamil Nadu, South India. Records Geological Survey of India 115 : 9-19.
- Sundaram R, Handerson RA, Ayyasami K & Stilwell JD 2001. A lithostratigraphic revision and palaeoenvironmental assessment of the Cretaceous System reported in the onshore Cauvery Basin, South India. Cretaceous Research 22: 743-762.
- Townsend RA, Woelkerling WJ, Harvey AS & Borowitzka M 1995. An account of the red algae genus *Sporolithon* (Sporolithaceae, Corallinales) in Southern Australia. Australian Systematic Botany 8 : 85-121.
- Verheij E 1993. The genus *Sporolithon* (Sporolithaceae fam. Nov., Corallinales, Rhodophyta) from the Spermonde Archipelago, Indonesia. Phycologia 32 : 184-196.
- Wettstein RR 1901. Handbuch der systematischen Botanik, Vol. 1, Leipzig (Deuticke) v : 201 pp.
- Woelkerling WJ 1988. The Coralline red algae: An analysis of the genera and subfamilies of nongeniculate Corallinaceae. British Museum (Natural History), Oxford University Press, London & Oxford, 268 pp.