FOSSIL ALGAE FROM THE 'INDUS FLYSCH' OF LADAKH*

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ABSTRACT

The paper records for the first time a rich algal flora from the 'Indus Flysch' Formation of Ladakh. Twelve species and eight genera are recorded from Khalsi, Sumdo, Mahe and Nidar valleys The assemblage consists of *Acicularia comanchense* Johnson, *A. khalsiensis* sp. nov., *Cayeuxia fruticulosa* Johnson, *Cayeuxia* sp., *Gymnopora indica* sp. nov., *Lithophyllum* cf. *L. antiquum* Lemoine, *Lithoporella melobesioides* (Foslie) Foslie, *Neomeris de terrae* sp. nov., *Permocalculus budaensis* Johnson, *P. ladakhensis* sp. nov., *P. texana* Johnson and *Thaumatoporella* sp. The assemblage of Khalsi indicates an Albian-Cenomanian age and the beds containing them were deposited on the continental shelf. The assemblage of Sumdo indicates a Maestrichtian age and those of Mahe and Nidar valleys are of Palaeocene-Eocene age. These assemblages were suggestive of deposition of the beds containing them in the shallow parts of the euge synclinal basin having a shallow, warm environment.

INTRODUCTION

Traditionally, the 'Indus Flysch' of De Terra (1935) or Indus Ophiolite Flysch or Ophiolite belt, Ladakh, of Gansser (1959, 1964) has been considered to include a thick sequence of greywacke, shale, limestone, conglomerate with associated volcanics which occur in the form of a long, narrow belt trending NW-SE along the course of the Indus river and is bounded on the north by the Ladakh Granite massif which also forms the basement, and in the south by the counter-thrust which separated this belt from the Cambro-Triassic sequence of Zanskar Range. This rock sequence has in the past yielded fossils only sporadically from the *Orbitolina* limestone of Dras, Burzil Pass, Khalsi and Sushal and the Nummulitic limestones in the Zanskar. De Terra (1935) mentioned a Senonian marine gastropod fauna from the Yaya Tso area, north of Mahe and *Hippurites* from the Hangru gorge, near Khalsi.

Recently, in the course of the multi-disciplinary expeditions sponsored by the Geological Survey of India in connection with geothermal exploration, a wealth of geological data were gathered in the Upper Indus Valley involving the rocks of the 'Indus Flysch' Formation. Certain tracts of the area have been mapped and a number of sections were examined. The marine sedimentaries in the Upper Indus Valley have yielded a number of macro- and micro-fossils including fossil algae.

The algae were noted mostly in the carbonate rocks. Unfortunately, the rocks are much disturbed and sometimes recrystallised to obliterate the structural details of the fossils. Efforts to separate them did not prove successful and only a study of random thin sections could be arried out. This is possibly for the first time that a systematic work on fossil algae from this formation is being published. All the described and figured slides are preserved in the Geological Survey of India, Calcutta.

PREVIOUS WORK AND GENERAL GEOLOGICAL SET UP

The term 'Indus Flysch' was introduced by De Terra (1935) for the sedimentary formations with associated volcanic rocks occurring in the Upper Indus Valley of Ladakh.

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STOLICZKA (1866) and LYDEKKER (1883) did not find any fossil in this sequence in course of their traverses and they thought them to be Tertiary fresh water deposits. However, the samples from Shushal, near Leh, collected by the Italian De Fillipi Expedition of 1913-14, revealed the presence of *Orbitolina* (MANCINI, 1928). Sven Hedin in 1899-1902 and again in 1922, led expeditions to Tibet and visited adjoining localities of Ladakh and Kashmir. This collection from Ladakh was examined by DOUVILLE (1926) who reported *Orbitolina* of Lower Cretaceous age. Thus, it may be inferred that these Indus Valley sedimentaries are marine and of Cretaceous age. DE TERRA (1935) systematically studied this sequence. On the basis of gross lithology, he compared this sequence with the flysch of Swiss Alps. More recently, SAHNI AND SASTRI (1957), MAMGAIN AND RAO (1965), NANDA AND MAMGAIN (1973) and others have reported *Orbitolina* from a number of localities, and TEWARI *et al.* (1970) noted *Globotruncana*, *Ruggoglobigerina*, *Globigerinella* and *Heterohelix* of Upper Cretaceous age from this belt.

On the western part, from Dras westward in the Astor-Deoshail-Nanga Parbat area, the sequence is dominated by immense quantities of basic and ultrabasic rocks with rather subordinate sedimentaries interstratified with them. These volcanics were originally correlated with the Panjal Volcanics (LYDEKKER, 1883). On further examination by HAYDEN (1915) these revealed the presence of *Orbitolina* (VREDENBURG, 1908 ; DOUVILLE, 1926) in the interstratified limestones and thus, confirming that the age of the Volcanics is Cretaceous and, hence, they are different from Panjal Volcanics. DE TERRA (1935) termed these volcanics as 'Dras Volcanics' and suggested them to have originated due to submarine volcanism. WADIA (1935) mapped this area in detail and his collections also revealed the presence of *Orbitolina* here.

The uppermost horizon of this sequence in the Upper Indus Valley, is marked by the presence of *Nummulites beaumonti* d'Archaic & Haime, and other foraminifera ranging in age from Danian to Lutetian. *Nummulites* from this area have been studied by D'ARCHAIC AND HAIME (1853), LA TOUCHE (1888), DAINELLI (1922) and MANCINI (1928).

GANSSER (1959, 1964) after reviewing all published works preferred to call this sequence as Ophiolitic Indus Flysch or Indus Ophiolite belt and his scheme of generalised stratigraphic sequence is shown in Figure 1.

THE FLORAL ASSEMBLAGE

The algal assemblage described here consists of eight genera belonging to twelve species and are represented by family Dasycladaceae, Codiaceae, Corallinaceae, Solenoporaceae and Gymnocodiaceae. Out of the twelve species noted here, four species namely *Acicularia khalsiensis*, *Neomeris de terrae*, *Permocalculus ladakhensis* and *Gymnopora indica* are new to the science. Except for the form *Neomeris*, which is known from Lingzi Thang area of Ladakh along with *Sphaerocodium*, all the taxa described here are reported for the first time from this region. The algal assemblages range in age from Albian-Cenomanian to Palaeocene-Eocene and indicate shallow warm marine environments in which the beds containing them were deposited.

SYSTEMATIC DESCRIPTION

Phylum—CHLOROPHYCOPHYTA

Family—DASYCLADACEAE

Genus—**Acicularia** D'Archaic, 1843

Plant consists of a slender central stem from which arise whorls of regularly arranged primary branches of two types—fertile and sterile. These are segregated into separate

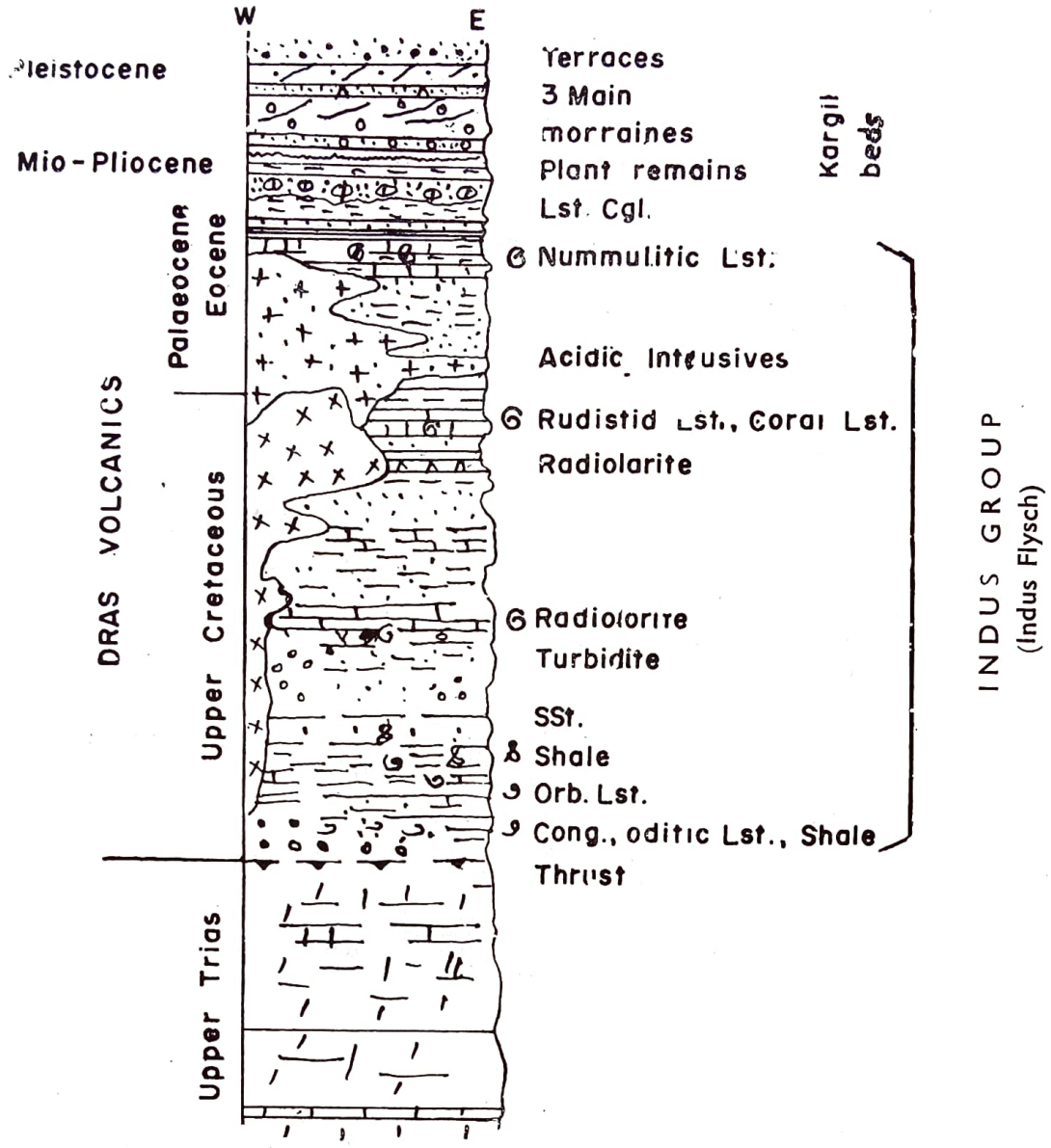

Fig. 1

whorls. Normally, the whorls of the sterile branches occur on the lower part of the central stem, and fertile whorls are above. In other cases, the sterile branches develop first, then drop off when the fertile whorl or whorls appear.

Generally the central stem and the base of the sterile branches are but feebly calcified. However, the fertile whorls are strongly calcified.

Sporangia are circular or elongated, always lateral, and borne on specially developed primary branches. Walls of the sporangia are poorly calcified. Sporangia of a branch are surrounded by calcium carbonate forming a spicule in which the spores are firmly embedded. In many cases, these spicules fuse laterally into a daisy-like or umbrella-shaped disc.

Geological history and previous Indian records

Acicularia is represented by a single living form *A. schenkii* Solms, and has over 25 fossil species. Originally reported from the Eocene of Paris basin, the genera was later on found to be widely distributed during the Cretaceous and it was considered that 'it made its first appearance in the Cretaceous' (Varma, 1954). Carozzi in 1955 discovered a Jurassic species *A. jurassica* from Upper Jurassic strata and considered the genus to have evolved during the Upper Jurassic. Pal and Gangopadhyaya (1970) reported two species,

A. elongata Carozzi and *A. cutchense* Pal & Gangopadhayaya from the Callovian of Kutch, suggesting that the genus had an earlier origin.

Geographical distribution during the Jurassic includes Switzerland, France, Japan, Texas, Alabama, Mexico and India. It was widely distributed during the Cretaceous and early Tertiary. Today the genus is restricted to tropical or near tropical waters along the coast of the America.

In India, the genus has so far been reported from the Jurassic of Kutch (Pal & Gangopadhyaya, 1970) and the Danian of Tiruchirapalli (Rao & Pia, 1936). In Pakistan, this genus is known from the Eocene of the Punjab Salt Range (Rao & Varma, 1950) and the Palaeocene of Sind (Rao & Vimal, 1955).

Acicularia cf. A. comanchense Johnson, 1968 (Pl. 1, Figs. 4a, 4b)

Description—Sporangial discs usually circular, sometimes flattened, 450—620 μ long and 450—481 μ wide (average diameter in circular discs 480 μ) inward from the periphery. Sporangial chambers circular to ovoid in section, 60-107μ long, 50-90 μ wide (diameter in circular sections 60-90 μ).

Remarks—Morphologically, the present material closely resembles *A. comanchense* Johnson reported from the Walnut Formation (Albian) of Texas (Johnson, 1968). While the number of sporangial chambers are similar to that of the type specimen, a few discs as well as the sporangial cavities in them are slightly larger in the specimens studied. However, this variation being a continuous one does not stand in the way of putting the present material in *A. comanchense*.

Dimensional data (in μ) of *A. comanchense* Johnson and *A.* cf. *A. comanchense*

Morphocharacters/ Species	*A. comanchense* Johnson	*A.* cf. *A. comanchense*
Sporangial discs		
Length	450-530 μ	450-620 μ
Width	390-450 μ	450-481 μ
Diameter		(av.) 480 μ
Sporangial cavities		
Number	12-18	12
Length	54-70 μ	60-107 μ
Width	36-50 μ	50-98 μ
Diameter		(av.) 60-90 μ

Figured slides—G. S. I. Type Nos. 19037 & 19038.

Acicularia khalsiensis sp. nov. (Pl. 1, Figs. 5a-5c)

Description—Small circular discs representing sections of sporangial spicules, spores arranged around the periphery of the disc, regularly and closely packed. Disc diameter 214 μ-267 μ. 15 to 16 spore cavities around the outer margin. Spore cavities circular to elliptical, 42 μ long, 30-32 μ wide.

Remarks—This species has the peculiarity of possessing very small sporangial discs along with a large number of regularly, close packed spores at the disc margin. Of the

known Lower Cretaceous species, *A. americana* Konishi & Epis, described from the Aptian of Arizona, has a much smaller disc (88 μ-122 μ diam.) and lesser number of spore cavities. *A. intermedia* Dragastan, known from the Barremian of Romania, though closely resembling the present material, have only 10 sporangial cavities in the disc. *A. endoi* Praturlon, from the Barremian-Aptian of Italy is a much larger species with 10 sporangial cavities in the disc. *A. khalsiensis* sp. nov. is also distinguished from *A.* cf. *comanchense* by morphology and dimensions of the disc and number and size of sporangial chambers. Table 1 shows the dimensional data of Cretaceous species of *Acicularia*.

Type Slide—Holotype—G. S. I. Type No. 19039 (Pl. 1, Fig. 5a)
Syntypes—G. S. I. Type Nos. 19040-19041 (Pl. 1, Figs. 5b-c)

Age—Albian-Cenomanian.

Locality and Horizon—Oolitic limestone of the *Orbitolina* limestone horizon, near Khalsi, Ladakh.

Genus—**Neomeris** Lamouroux, 1816

The plant consists of a central stem from which arise regular whorls of primary branches. Each primary branch ends in a tuft of secondary branches, each of which ends in terminal hair. Sporangia spherical, ovoid or pyriform, growing at the ends of specially developed secondary branches.

Calcification is light or absent around the central stem and most of the primary branches. However, calcification is strong around sporangia. Normally, the calcification envelops the secondary branches and commonly extends beyond the outer ends of the primary branches.

Geological history and previous Indian records

The genus *Neomeris* was founded on Recent species, a number of which are known in warm seas. Fossil representatives of the genus have been recorded from Lower Cretaceous upwards. Out of about 26 species of fossil *Neomeris*, 22 belong to the Tertiary formations and only 3, viz. *N. cretaceae* Steinmann, *N. pfenderi* Konishi & Epis and *N. budaense* Johnson are known from the Cretaceous. Of these, *N. cretaceae*, originally reported from the Cenomanian of Aquitaine, France, are also known from the Buda (Cenomanian) and Pre-Buda (Albian) limestones of Texas (Johnson, 1963; p. 15, 49-50). *N. pfenderae*, orignally reported from the Cenomanian of Cochise County, Arizona, has recently been recorded in the Albian-Cenomanian of Texas (Johnson, 1968) and the Burwaha Bryozoa limestone (Maestrichtian) of Bagh beds of M. P., India (Pal, 1970). *N. budaense* Johnson has been reported from the Cenomanian Buda limestone of Texas.

In India, this genus has been recorded in the Inter-trappeans (Palaeocene) of Rajahmundry (Pia, Rao & Rao, 1937), the Bagh limestones of M. P. (Singh, 1950 ; Pal, 1970), Niniyur beds of Tiruchirapally (Varma, 1954) and the Cretaceous limestones of Limzi Thang plains of Ladakh (Pascoe, 1968, vol. 2; p. 1319).

Neomeris de terrae sp. nov. (Pl. 2, Fig. 10)

Description—Cylindrical or clavate body, possibly segmented, transverse section circular with outer diameter of 321 μ; diameter of hollow, uncalcified, cyclindrical stem 128 μ ; calcification around sporangia at the ends of secondary branches ; sporangia pyriform, with diameter 64 μ and height 96 μ ; diameter of secondary branches 21 μ.

Remarks—The present species appears to be a stunted representative of the genus. While the outer diameter of it is perhaps the smallest of all known Cretaceous species, the

Table 1—Dimensional data of Cretaceous species of *Acicularia* (in μ)

Morphocharacters/Species	*A. americana* Konishi & Epis	*A. antiqua* Pia	*A. intermedia* Dragastan	*A. endoi* Praturlon	*A. comanchense* Johnson	*A. guatemalaica* Johnson	*A.* cf *A. guatemalaica* Johnson	*A.* cf. *A. comanchence* Johnson	*A. khalsiensis* sp. nov.
Length of spicule	217—335		150—225	300—540		1200—1600			
Max. breadth diam.	88—122	330			450—530 × 390 450	280—310	350—400 × 265 350	400—620 × 450 481 (av. dia. 480)	214—267
Breadth proximal end.				210—440					
Sporangial chamber									
Length					54—70		36—58	60—107	42
breadth					36—50		36—49	50—98	30—32
diam.	25—40	40—55	15—30	50—90		36—48		av. 60—90	
No. of sporangia	8—10 av. 10		10	11	12-18	12	10-13	12	15—16
Age	Aptian	Cenomanian	Barremian	Barremian-Aptian	Albian	Middle or Upper Cretaceous	Albian	Albian-Cenomanian	Albian-Cenomanian
Locality	Arizona	Tripoly, Libya	Romania	Italy	Cochise county, Texas	Guatemala	Cochise county, Texas	Khalsi, Ladakh	Khalsi, Ladakh
Reference	Konishi, K. & Epis, R. C., 1962; Micropal., V.8, no. 1, pp.71-72, pt. 1, figs. 7, 9, 11, 14	Pia, J., 1936, Jour. Pal., V. 10, no. 1, pp. 8-9, figs.1-14.	Dragastan, O., 1967, Asso. Geol. Carpato Balkanique, VIII Congr. Rap. Paleont, pp. 446-47, pt. 3, figs. 22-26.	Praturlon, A., 1964, Geol. Romania, V. 3, pp. 189-91, figs. 25-26.	Johnson, J. H., 1968, Prof. Contr. Colorado School Mines no. 4, pp.47-48, pt. 8, figs. 4-7.	Johnson, J. H. 1965, Prof. Contr. Colorado School Mines no. 1, p. 76, pt. 17, fig. 2.	Johnson, J.H., 1968.		

sporangia are rather well developed. The diamensional data of the species along with a comparative study of common Cretaceous species are shown in Table 2.

The species is named after Dr. H. de Terra whose pioneering work helped a great deal in deciphering the biostratigraphy of Ladakh.

Type Slide—Holotype - G. S. I. Type No. 19042.

Age—Campanian-Maestrichtian.

Locality and Horizon—The material comes from the limestone bed exposed near Sumdo in the Raldong nala section. The ammonoid *Hoplitoplacenticeras* sp. and corals like *Vaughanoseris* sp., *Trocharaea* sp., etc., have been recorded in this horizon and a Campanian-Maestrichtian age has been assigned.

Table 2—Dimensional data of common Cretaceous species of *Neomeris* (measurements in μ)

Morphocharacters/Species	*N.cretacea* Steinmann	*N.pfenderae* Konishi & Epis	*N.* cf. *N.pfenderae* Konishi & Epis	*N. budaense* Johnson	*N. de terrae* sp. nov.
Length	3000—4000		1125	750—1100	
Outer diameter	2000		670—960	700—800	321
Inner diameter	1200—1400		650		
Diam. central stem			412	290—400	128
Thickness Calc. Crust	500	175—210	125—300	180—250	
Distance between whorls		80—150		80—178	
Sporangia diameter	100	90—110	60—90	50—78	64
Height	130—160	150	90—115	68—100	96
Locality	Cerró Escamela Mexico; Texas	Arizona	Texas	Texas	Ladakh, India
Reference	Steinmann, G., 1899,Bot.Zlg. v. 57, pp. 127-154, figs. 14-18.	Konishi, K.& Epis, R. C., 1962, Micropal., v. 8, no. 1, p. 70, pl. 1.	Johnson, J.H., 1968, Prof. Contr. Colorado Sch. of Mines, no. 4, p. 16, pt. 3.	Johnson, J. H., 1968, pp. 16-17, pl. 3, figs. 3-4	

Family—Codiaceae

Genus—**Cayeuxia** Frollo, 1938

Plants form rounded tufts that range from a few millimetres to more than a centimetre in diameter. Each tuft is composed of a mass of loosely packed, branching tubes having a radial arrangement. The distinctive feature of the genus is the character of branching. For a short distance, the branches grow away from the straight parent stem at an angle of nearly 45 degrees and then turn and grow approximately parallel to it. Sporangia are unknown.

Geological history and previous Indian records

The geological range of the genus is from middle Jurassic to uppermost Cretaceous. A number of species have been reported from the Jurassic of Hungary, Morocco, Texas

and Austria. In the Cretaceous it became essentially worldwide in warmer seas. In India the genus has been reported from the Bagh Group of M. P. (Pal, 1968).

Cayeuxia fruticulosa Johnson, 1965 (Pl. 2, Fig. 8)

Description—Thallus rounded, nodular, up to 749 $\mu \times 535\ \mu$ across in the sections studied. Tubes 12 μ to 18 μ in diameter (commonly 12 μ—15 μ), branching at wide angle to the parent tube, then slowly curving until becoming approximately parallel near the periphery.

Remarks—The present material closely resembles the type species described by Johnson (1965) from the late Cretaceous (Maestrichtian) of Guatemala, particularly in shape, nature of branching of tubes and in dimensions of the tubes. The Guatemala form is, however, much larger, up to 2 or 2.5 mm across.

Figured slide—G. S. I. Type No. 19043.

Age—The alga occurs in association with a Campanian-Maestrichtian fauna.

Locality and Horizon—Fossiliferous limestone exposed along Raldong section near Sumdo.

Cayeuxia sp.

This is represented by only a few poorly preserved specimens developing as rounded masses, formed of fine tubes showing the type of branching characteristic of the genus. Diameter of tubes range from 30 to 40 μ.

Locality and Horizon—Fossiliferous limestone exposed along Raldong section near Sumdo.

Phylum—Rhodophycophyta

Class—Rhodophyceae

Family—Corallinaceae

Subfamily—Melobesieae

Genus—**Lithophyllum** Philippi, 1837

Plants crustose with a variable growth habit giving rise to distinct forms such as simple crusts, free or nearly free crusts (unattached), crusts with strong protuberances or mammillae or strongly branching forms. Tissue normally well differentiated into a hypothallus and a perithallus. The basal hypothallus is characteristically coaxial, i. e. formed of regularly curved or arched layers of cells. In some cases, however, it consists of a few irregular or curved threads of cells. The perithallic tissue, consists of cell threads with prominent cross partitions occurring at the same level as in adjoining threads, producing a fairly regular tissue. The sporangia are collected into conceptacles which are pierced by a single large opening in the roof for the escape of the spores.

Geological history and previous Indian records

Very little is known about the development of *Lithophyllum* prior to Lower Cretaceous. Only two Lower Cretaceous species have been assigned to this genus definitely. These are *L. antiquum* Lemoine, 1939 and *L. catalaunicum* Lemoine, 1928. Recent work by Elliott (1959) and Johnson (1965) has revealed two more species, viz., *L. ?shebae* Elliot and *L. ?venezuelaensis* Johnson, in which the tissue is rather generalised, with distinct cell threads and only vague suggestions of layering. The differentiation into hypothallous and perithallus is not discernible and none of them is showing the nature of conceptacles. Johnson

(1969) considers these two species to belong to a small group of primitive crustose coralline algae whose generic assignment is doubtful. A third doubtful species, *L. belgicum* was described by Foslie (1909), and Lemoine (1939) after carefully checking on the age and locality of the material (Aptian-Albian of the Pyrenees) redescribed it as *L. ?belgicum*. It is a branching form with medullary hypothallus like a *Lithothamnium* but a layered marginal perithallus and the species is infertile.

A few more probable *Lithophyllum* have been described from the lower half of the Upper Cretaceous but unquestionable members of the genus are widely occurring in Santonian, Campanian and Maestrichtian. The genus developed rapidly and spread widely during Upper Cretaceous and Eocene, and by Miocene it was so thoroughly established in the warmer water that it competed actively with *Lithothamnium*, forcing the latter into the cooler waters.

As for the phylogeny of the genus, the prevalent view is that the genus *Lithothamnium* arose from some members of the genus *Archaeolithothamnium* in the late Jurassic or the early Cretaceous, and shortly thereafter *Lithophyllum* developed from *Lithothamnium*, but beyond that opinion has differed greatly.

Lithophyllum occurs in a variety of ecological niches in the present seas. Next to *Lithothamnium*, it has proved itself to be the most highly adaptable of all the genera of crustose coralline algae. It is found from the tropics to the cold waters of fairly high latitude, and vertically from above tidal level where it is kept moisted by the spray, down to a depth of at least 80 meters.

In the Indian sub-continent the genus is known from the Cretaceous and Palaeocene of Bagh Group of M. P. (Pal, 1970), Nerinea beds (Palaeocene) of Pondicherry (Sastry, *et al.*, 1965), lower Miocene of Andamans (Chatterji & Gururaja, 1972), Kutch (Pal & Ghosh, 1974), Lockhartia limestone (Ranikot) of Samana Range (Rao, 1941) and Laki beds (L. Eocene) of Punjab Salt Range (Varma, 1953).

Lithophyllum cf. L. antiquum Lemoine, 1939 (Pl. 1, Figs. 1a-1b)

Description—Tissue differentiated into a hypothallus and a perithallus. The basal hypothallus is coaxial, consisting of arched layers of squarish cells. The perithallic tissue consisting of threads of rectangular cells, longer than wide. Sporangia collected into conceptacles with single opening. Dimensional data as compared to the measurements of *L. antiquum* Lemoine is given below :

	Thallus		Hypothallic cells		Perithallic cells		Conceptacles	
	Length	Width	Length	Width	Length	Width	Diam.	Hgt.
L. antiquum Lemoine					4–6 μ 7–26 μ	6–12 μ 6–15 μ	260 μ	220 μ
L. cf. *L. antiquum*	2.78 mm	.588 mm	18 μ	18 μ	30 μ	15 μ	267 μ	160 μ

Remarks—The present material resembles *L. antiquum* Lemoine in morphology and is also the closest to it so far as dimensional data are concerned. Of the few Lower Cretaceous species, *L. catalaunicum* Lemoine is distinguished by having hypothallic cells wider than long (7-13 μ×5-17 μ). *L. ? shebae* Elliot and *L. ? venezuelaensis* Johnson are quite typical and distinctive.

Figured slide—G. S. I. Type No. 19044.

Age—Albian-Cenomanian.

Locality and Horizon—*Orbitolina* limestone horizon exposed near Khalsi, Ladakh.

Genus **Lithoporella** Foslie, 1909

Plant is small and grow attached to other algae or to hard objects, or a number may grow superimposed, forming a thin irregular crust. Thallus consists of a single layer of large cells which are vertically elongated except around the conceptacles where they thicken, and several layers of small cells may be present. The cells are normally much larger than those of other crustose coralline algae, attaining lengths of 70 or even 100 microns or more. Sporangia are collected in conceptacles with a single large aperture.

Lithoporella closely resembles *Mastophora* Decaiane, but *Mastophora* has long rhizoids for attachment, and normally the thalli do not grow superimposed. Another genus of close resemblance is *Heteroderma* Foslie which differs from *Lithoporella* in consisting of one or two layers of isodiametric cells which are not vertically elongated to form palisade-like layers. Adjacent thalli become confluent but never superimposed. *Melobesia* Lamouroux differs from *Lithoporella* in having horizontally elongated cells in the basal layer ; the thallus may be several layers thick and conceptacles have a number of openings.

GEOLOGICAL HISTORY AND PREVIOUS INDIAN RECORDS

This is a very common and widespread alga and ranges from Middle Cretaceous (possibly late Jurassic) to Recent. At present, *Lithoporella* occurs almost in all seas, but greatest development is noted in warm waters.

Only three fossil species are so far known from the Indian region. *Lithoporella* sp. is reported from the Nodular limestone (U. Albian to Cenomanian) and *L. indica* Pal occurs in the Burwaha Bryozoa limestone (Maestrichtian) of the Bagh Group of M. P. (PAL, 1969, 1970). A third species *L. melobesioides* (Foslie) Foslie was noted in the Palaeocene of South Andamans (CHATTERJI & GURURAJA, 1972).

Lithoporella melobesioides (Foslie) Foslie, 1909 (Pl. 1, Fig. 3)

Description—Thallus consisting of a single layer of rectangular cells. Cells have somewhat rounded corners, much higher than wide. Cell walls thick. Cell dimensions greatly differ even in the same specimen. The dimensional data are given below :

Sp. No.	Cell dimensions		Conceptacles
	Height (in μ)	Width (in μ)	
L1	50	27	Not seen
L2	87	28	,,
L3	107	30	,,
L4	149	64	,,

Remarks—The present form closely resembles *L. melobesioides* (Foslie) Foslie in shape and nature of cells. The cell dimensions for *L. molobesioides* is 25μ—85μ $\times$ 15μ—30 μ. In the present material some forms have cell dimensions within the range while in others, the cells are much larger. However, in the absence of information on the nature and size of sporangial conceptacles, it seems proper to place the material in this species.

Figured slide—G. S. I. Type Nos. 19045 & 1904 .

Age—*L. melobesioides* (Foslie) Foslie is a Cenozoic alga ranging from Eocene to Recent. In Ladakh the material occurs in association with *Venericardia* sp. and species of *Nummulites* and *Alveolina*, thereby fixin ; Palaeocene-Eocene age to the horizon in which the alga occurs.

Locality—Nummulitic shales and limestones of Palaeocene-Eocene horizon of Mahe and Nida valley, Ladakh

Family—SOLENOPORACEAE

Genus—**Thaumatoporella** Pia, 1927

(**Polygonella* Elliot, 1957)

ELLIOTT (1957) described this genus as a 'Calcareous alga composed of thin encrusting spreads consisting of a single layer of proportionally large cells of polygonal prismatic shape.'

PIA (1927) first observed this genus, but it was not adequately described till 1957 when ELLIOTT described it as *Polygonella*. A number of publications on the genus appeared since then and JOHNSON (1965) put *Polygonella* to the synonymy of *Thaumatoporella*.

GEOLOGICAL HISTORY AND PREVIOUS INDIAN RECORDS

The genus ranges from Jurassic to Palaeocene. *T.* (*P.*) *incrustata* (Elliott) is the only Jurassic species and is reported from Iraq, Syria, Switzerland and Austria. In Cretaceous, it was quite widespread and is known from Iraq, Italy, Algeria, Yugoslavia, Guatemala, Texas, Blake Escarpment, Atlantic Ocean. The only Indian record is from the Bryozoa limestone (Maestrichtian-Palaeocene) of Bagh Group of M. P. (PAL, 1970).

Thaumatoporella sp. (Pl. 2, Fig. 6)

Description—Thallus crustose or encrusting, consisting of a single layer of large cells of polygonal-prismatic shape. The cells are 40 to 48 μ long and 30 to 32 μ wide.

Remarks—The specimen resembles *T.* (*P.*) *occidentalis* Johnson in shape and dimensions of cells (JOHNSON, 1965, pp. 60-61). However, the state of preservation of the present material is rather poor to permit a satisfactory specific assignment.

Figured slide—G. S. I. Type No. 19052.

Age—Campanian-Maestrichtian.

Locality—Limestone band near Sumdo, Ladakh.

Family—GYMNOCODIACEAE

Genus—**Permocalculus** Elliott, 1955

Description—Thallus irregular, segmented. Segments of variable form spherical, ovoid, barrel-shaped, or may develop irregular finger-like forms, or with pinching and swelling units. Calcification varies from very thin to massive or complete. Pores small and cortical. Sporangia cortical or medullary.

PIA (1920) erected the genus *Gymnocodium* with *Gyroporella bellerophontia* Rothpletz as the type species and referred it to the family Codiaceae. Later on, he compared it with the Recent genus *Galaxaura*, a red alga with numerous species occurring in warm water seas and placed it with *Galaxaura* in the family Chaetangiaceae (PIA, 1937). ELLIOTT (1955) proved that the structure of *Gymnocodium* and *Galaxaura* are comparable if not identical, and proposed for these fossil forms a new family Gymnocodiaceae. The two

groups of species of *Gymnocodium* were each assigned a generic rank viz., *Gymnocodium* and *Permocalculus* within this family. *Permocalculus* was separated by having larger segments with smaller marginal pores.

GEOLOGICAL HISTORY AND PREVIOUS INDIAN RECORDS

Though originally reported from the Permian, representatives of the genus were subsequently reported from the Cretaceous and Palaeocene. In India, the genus is represented by one Permian species *P. piae* Rao & Varma, 1953, and seven Cretaceous-Palaeocene species from the Bagh Group of M. P. (PAL, 1970). Three species are represented in the Indus 'Flysch' Formation of Ladakh.

Permocalculus budaensis Johnson, 1968 (Pl. 1, Fig. 2)

Description—Thallus segmented. Segments subcylindrical, 0.6 to 0.8 mm in diameter and longer than 0.85 mm. Marginal notches 15 μ to 30 μ in diameter, tube diameter 6 μ to 13 μ. Sporangia subspherical and occur just below the outer margin (cortical to sub-cortical).

Remarks—The specimens are closely allied to *P. budaensis* Johnson in shape, nature and size of the segments and in dimensions of the marginal notches.

Figured slide—G. S. I. Type No. 19046

Age—The age is Albian-Cenomanian.

Locality and Horizon—This species occurs in the *Orbitolina* horizon of the Oolitic limestone of Khalsi, Ladakh.

Permocalculus ladakhensis sp. nov. (Pl. 2, Fig. 9)

Description—Subcylindrical segments, 0.64 to 0.70 mm long, 0.21 to 0.22 mm in diameter. Tubes 9 μ in diameter. Marginal notches 15 to 21 μ in diameter. Sporangia spherical, subcortical to medullary, 42 μ in diameter.

Remarks—The present species constitutes a group of beaded form, much narrower and shorter than others. It is comparable in shape to *P. budaensis* var. *pygmaea* Johnson from which it differs in having sporangia in sub-cortical to medullary position.

Type Slide—Holotype—G. S. I. Type No. 19051.

Age—Albian-Cenomanian.

Locality and Horizon—Oolitic limestone of the *Orbitolina* limestone horizon, near Khalsi, Ladakh.

Permocalculus cf. P. texana Johnson, 1966 (Pl. 2, Figs. 11-12)

Description—Irregular, finger-like, cylindrical bodies, segmented, occurring both in fragments to complete segments. Segments up to 3.745 mm long, 0.470 mm in diameter. Pores at outer surface 10 μ to 16 μ in diameter. Sporangia spherical, cortical, with a diameter of 75 μ.

Remarks—The present material closely corresponds to the descriptive details and measurements of *P. texana* Johnson cited by JOHNSON (1969). In the Texas material, sporangia was not observed which are well preserved in the present material and are spherical in shape and cortical in position.

Figured slide—G. S. I. Type No. 19048.

Age—Albian-Cenomanian.

Locality—Oolitic limestone near Khalsi, Ladakh.

Genus **Gymnopora** Pal, 1970

Gymnocodiaceae represented by thallus segmented or unsegmented, segments or units of varying size and shape, often polygonal in outline. Calcification usually massive. Pores circular, no differentiation of pore size in medullary or cortical regions. Sporangia internal, cortical or medullary. Segments or units usually larger and pores finer than those of *Gymnocodium* and *Permocalculus*.

Gymnopora differs from *Gymnocodium* and *Permocalculus* in its usually heavy calcification, finer, circular pores bounded by raised surfaces with polygonal outline, and in the nature of the pores which are rather vertical to the surface and not oblique as in the latter.

Gymnopora indica sp. nov. (Pl. 2, Figs. 7a-7b)

Description—Thallus segmented ; segments ovoid, circular or rectangular ; 0.75 mm $\times$0.85 mm ; pores fine, circular, 3 μ to 6 μ in diameter, bounded by polygonal surfaces ; sporangia sub-cortical to medullary in position, ovoid, 90 μ—110 $\mu \times$ 6p μ—88 μ.

Remarks—The present material is comparable with the genotype *Gymnopora galaxauriana* Pal (1970) from the Barwaha Bryozoa limestone horizon of the Bagh Group of M. P. However, it differs from the genotype in the dimensions of segments, pores and sporangia. The nature and measurements of the three species, known so far, are given in the Table 3.

Type Slide—Holotype—G. S. I. Type No. 19054 (Pl. 2, Fig. 7a).

Syntype—G. S. I. Type No. 19055. (Pl. 2, Fig. 7b).

Age—Albian-Cenomanian.

Locality and Horizon—Oolitic limestone of the *Orbitolina* limestone horizon, near Khalsi, Ladakh.

CONCLUSION

Fossil algae are described from three different stratigraphical horizons of the so-called Indus flysch sequence of Upper Indus Valley, Ladakh. Conclusions on the age of these horizons as well as palaeoecology, as suggested by biota and general lithology, are as follows :

1. ALBIAN-CENOMANIAN HORIZON—The oldest horizon where fossil algae are known in the 'Indus flysch' consist of Oolitic limestone and *Orbitolina* limestone near Khalsi. The algae reported are *Acicularia comanchense* Johnson, *A. khalsiensis* sp. nov., *Lithophyllum antiquum* Lemoine, *Permocalculus budaensis* Johnson, *P. ladakhensis* sp. nov., *P.* cf. *P. texana* Johnson and *Gymnopora indica* sp. nov. Of these, *A. comanchense* was originally described from the Albian of Texas (JOHNSON, 1968), while *A. ladakhensis* is a new form of Lower Cretaceous affinity. *L. antiquum* was described from the Lower Cretaceous of Algeria (LEMOINE, 1939). These occur in association with species of *Orbitolina* showing distinct Albian-Cenomanian affinity. The lithology is fossiliferous oomicrite and biomicrite. In general, the depth to which dasycladacean algae, like *Acicularia*, flourish does not normally exceed 10 metres. The oomicrite containing *Acicularia* is, thus, clearly indicative of deposition on the continental shelf subsequent to the Albian marine transgression in the area.
2. CAMPANIAN-MAESTRICHTIAN HORIZON—A number of algal forms, mostly ill-preserved, are again noted in the uppermost Cretaceous in the area. The

Table 3—Dimensional data of known species of *Gymnopora* (measurements in μ)

Morphocharacters/ Species	*G. gataxauriana* Pal, 1970	*G. elongata* Pal, 1970	*Gymnopora indica* sp.nov.
Thallus shape	Long, subcylindrical, segmented	Slender, cylindrical with pinching and swelling, branched	Long, subcylindrical, segmented
Cross section	Polygonal, rectangular or squarish	Polygonal	Squarish, polygonal or oval
Length		1440—2000	
Diameter	1280×800	480—500	750—850
Calcification	massive	massive	medium to massive
Sporangia	Sub-cortical, sub-ovate 160—240×80—160	cortical, spherical 64	sub-cortical to medullary, ovoid 90—110×60—88
Pores at outer surface	6.8—8.5	8.5—10	3—6
Character of fossils	nearly complete segments	fragments of cylindrical segments	fragments of nearly complete segments
Age	Maestrichtian to Palaeocene	U. Albian to Cenomanian	Albian-Cenomanian
Locality	Man river section, Dhar Distt., M.P.	Man river section, Dhar Distt., M.P.	Khalsi, Ladakh.

assemblage consists of *Neomeris de terrae* sp. nov., *Thaumatoporella* sp., *Cayeuxia fruticulosa* Johnson and *Cayeuxia* sp. *C. fruticulosa* was originally described from the Maestrichtian of Guatemala and is also known from the uppermost Cretaceous of the Bagh Group of Narmada valley, M. P. (Ghosh & Pal, 1968). The associated fauna includes *Hoplitoplacenticeras* sp., *Turritella multistriata* Reuss, *Ostrea (Alectryonia) ungulata* Schloth., *Vaughanoseris* sp., and *Trocharaea* sp., etc. These indicate a Campanian-Maestrichtian age for the horizon. The lithology varies from siliceous biomicrosparrite to biomicrrudite. The algal forms known in this horizon are rarely found below 15 metres. It is inferred that deposition took place in the shallower parts of the basin.

3. Danian-Lutetian horizon—Only one species *Lithoporella melobesioides* (Foslie) Foslie is noted in the younger horizon. This occur in association with *Venericardia* sp., *Nummulites beaumonti* d'Archaic & Haime, *Alveolina* sp., *Assilina* sp., etc. Algal remains resembling *Dissocladella savitriae* Pia and *Indopolia* sp. have also been observed in this horizon which probably range from Danian to Lutetian. The lithology is mostly biomicritic. A calm, shallow and warm sea environment of deposition is indicated.

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REFERENCES

Carozzi, A. V. (1955). Dasycladacees du Jurassic superieur du bassin de Geneve. *Eclog. Geol. Helvet.* **48**(1) : 31-67.

Chatterji, A. K. & Gururaja, M. N. (1972). Coralline algae from Andaman islands, India. *Rec. geol. Surv. India* **99**(2) : 133-144.

Dainelli, G. (1922). Spedizione Italiana de Fillippi nell Himalaia, Caracorum and Turchestan Cinese (1913-1914). *Res. Geol. Geogr.*, **3**(2)

d'Archaic, L. V. & Haime, J. (1853). Description du animaux fossils du groupe Nummulitique de l'Inde. Zaus gide et boundry. Paris.

De Terra, H. (1935). Geological studies in the N. W. Himalayas between the Kashmir and the Indus valleys. *Mem. Conn. Acad. Arts Sci.* **8**(2) : 17-76.

Douville, H. (1926). Fossiles recueillis par Hayden dans la Kashmir et les Pamirs. *Rec. geol. Surv. India* **58**(4) : 349-357.

Dragastan, O. (1967). Algues calcaires du Mesozoique de Romanie et leur importance stratigraphique. *Assoc. Geol. Carpato-Balkanique*, 8 *Congr. Rap. Paleont.* : 509-517.

Elliott, G. F. (1955). The Permian calcareous alga *Gymnocodium*. *Micropaleontology* **1**(1) : 83-90.

Elliott, G. F. (1957). New calcareous algae from the Arabian Peninsula. *Micropalaeontology* **3**(3) : 227-230.

Elliott, G. F. (1959). New calcareous algae from the Cretaceous of Iraq. *Rev. Micropaleont.* **1**(1) : 217-222.

Foslie, M. H. (1909). Algologiske Notiser. *Norsha Vidensk. Selsk. Sk.* **2**: 1-53.

Frollo, M. M. (1938). Sur un nouven genre codicee du jurassique superieur des carpates orientales. *Bull. Soc. Geol. Fr.* **6**: 269-271.

Gansser, A. (1959). Ausseralpine Ophiolithprobleme. *Eclog. Geol. Helvet.* **52**(2).

Gansser, A. (1964). *Geology of the Himalayas.* New York.

Ghosh, A. K. & Pal, A. K. (1968). *Cayeuxia frutilculosa* Johnson from the Bagh beds, Madhya Pradesh. *Curr. Sci.* **37** (14): 561-562.

Hayden, H. H. (1915). Notes on the geology of Chitral, Gilgit and the Pamirs. *Rec. geol. Surv. India* **45**(4) : 271-335.

Johnson, J. H. (1957). Geology of Saipan, Mariana Islands—Calcareous algae. *U. S. geol. Serv. Prof. Pap.* **280**(E) : 209-243.

Johnson, J. H. (1961). Jurassic algae from the sub-surface of the Gulf Coast. *J. Paleont.* **35**(1): 147-151.

JOHNSON, J. H. (1965). *in* JOHNSON J. H. & KASKA, H. V. (1965). Fossil algae from Guatemala. *Colorado School of Min., Prof. Contr.* **1**: 1-152.

JOHNSON, J. H. (1968). Lower Cretaceous algae from Texas. *Colorado School of Min., Prof.. Contr.* **4** : 1-71.

JOHNSON, J. H. (1969). A review of Lower Cretaceous algae. *Colorado School of Min., Prof. Contr.* **6** : 1-179.

JOHNSON, J. H. & FERRIS, B. J. (1950). Tertiary and Pleistocene coralline algae from Lau, Fiji. *Bull. B. P. Bishop Mus.* **201** :1-27.

JOHNSON, J. H. & KASKA, H. V. (1965). Fossil algae from Guatemala. *Colorado School of Min., Prof. Contr.* **1** : 1-152.

KONISHI, K. & EPIS, R. C. (1962). Some early Cretaceous algae from Cochise County, Arizona. *Micropaleontology* **8**(1) : 67-76.

LA TOUCHE, T. H. D. (1888). Rediscovery of *Nummulites* in Zanskar. *Rec. geol. Surv. India* **21** (4).

LEMOINE, P. (1927). Quelques algues calcaires du Nummulitique de la Haute-Savoie. *Bull. Mus. Nat. Hist.* **6** :545-551.

LEMOINE, P. (1939). Les algues calcaires fossiles de l'Algerie. *Mat. Carte geol. l'Algerie, Ser.* 1. **9** :1-128.

LYDEKKER,R. (1883). The geology of the Kashmir and Chamba Territories and the British districts of Khagan. *Mem. geol. Surv. India* **22** : 1-344.

MAMGAIN, V. D. & RAO, B. R. J. (1965). Orbitolines from the limestone intercalations of Dras Volcanics, J & K. State. *J. geol. Soc. India* **6** : 122-129.

MANCINI, E. F. (1913-14). Fossil Eocinidel Ladakh. *Sped. Ital. Fillippi Nell Himalaia, Caracorum, Turchestan Chinese, Ser.* 11. **6** : 227-321.

MANCINI, E. F. (1928). Foraminifers del calcare gigeo di Sciusciul (lago Pancheng). *Sped. Ital. Fillippi Nell Himalaia, Caracorum, Turchestan, Cinese, Ser.* 11. **8**.

NANDA, M. M. & MAMGAIN, V. D. (1973). Note on the occurrence of Orbitolines in Indus 'Flysch' and observations on its age. *Indian Min.* **27**(3).

PAL, A. K. (1968). On *Cayeuxia* Frollo from the Bagh beds of Madhya Pradesh. *Q. Jl. geol. Min. metall. Soc. India,* **40**(3) : 199-200.

PAL, A. K. (1969). On a species of *Lithoporella* Foslie from the Bagh beds of Madhya Pradesh. *Curr. Sci.* **38** (19) : 465-466.

PAL, A. K. (1970). Gymnocodiacean algae from the Bagh beds of Madhya Pradesh. *Proc. Symp. Geol. Min. Res. M. P.* (Ujjain Univ.).

PAL, A. K. & GANGOPADHYAYA, S. (1970). Two species of *Acicularia* from the Jurassic of Cutch. *J. geol. Soc. India* **11**(3) : 278-282.

PAL, A. K. & GHOSH, R. N. (1974). Fossil algae from the Miocene of Cutch. *Palaeobotanist* **21**(2) : 189-192.

PASCOE, E. H. (1963). *A manual of the geology of India and Burma,* Calcutta.

PIA, J. (1920). Die siphoneae verticillatae von Karbon bis zur Kreide. *Zool-Bot. Gessel. Wien Abh.* **11**(2).

PIA, J. (1927). Die Ehrhaltung der fossilen Pflanzen, Teil, I. Thallophyta. *in* Hirmer, M., *Handbuch der Palaeobotanik,* Berlin.

PIA, J. (1937). Die wichtgsten Kalkalgen des Jungpalaozoikums und ihre geologische Bedeutung. *c.r.* 2 *Congr. Strat. Carbon.* **21** : 765-856.

PIA, J., RAO, S. R. N. & RAO, K. S. (1937). Dasycladacean aus Zwischenalgen des Dekkantrapps bei Rajahmundry in Südindien. *Sitz. Akad. Wissen. Wien.*

PRATURLON, A. (1964). Calcareous algae from Jurasic—Cretaceous limestone of Central Apenines (Southern Latium). *Geol Romana.* **3** :171-202.

RAO, L. R. & PIA, J. (1936). Fossil algae from the uppermost Cretaceous beds (Niniyur Group) of the Trichinopoly district, S. India. *Mem. geol. Surv. India, Palaeont. Indica, New Ser.* **21**(4) : 1-49.

RAO, S. R. N. (1941). An algal flora from the Lockhart limestone (Ranikot Series) of the Samana Range (N. W. India). *J. Mysore Univ.* **II** : 41-53.

RAO, S. R. N. & VARMA, C. P. (1950). Palaeobotany in India VII. *J. Indian bot. Soc.* **28** : 28.

RAO, S. R. N. & VARMA, C. P. (1953). Fossil algae from the Salt Range. *Palaeobotanist* **3** : 19-23.

RAO, S. R. N.& VIMAL, K. P. (1955). Fossil algae from Sind, Pakistan. *Micropalaeontology* **1**(1) : 91-92.

SAHNI,M. R. & SASTRI,V. V. (1957). A monograph of the Orbitolinas found in the Indian continent (Chitral, Gilgit, Kashmir), Tibet and Burma with observations on the age of the associated volcanic series. *Mem. geol. Surv. India, Palaeont. Indica., New Ser.* **33**(3) : 1-44.

SASTRY, M. V. A., RAO, B. R. J. & IQBALUDDIN (1963). Coraline algae from the Nerinea beds of Pondicherry, S. India. *J. geol. Soc. India* **4** : 60-67.

SINGH, S. N. (1950). Microfossils from the Bagh beds of Barwaha near Indore. *Curr. Sci.* **19**(6) : 174-175.

STOLICZKA, F. (1866a). Geological sections across the Himalayan mountains from Wangtu bridge on the river Sutlej to the Sungdo on the Indus. *Mem. geol. Surv. India* **5**(1) : 1-154

STOLICZKA, F. (1866b). Summary of geological observations during a visit to the provinces—Rupshu, Karnag, South Ladakh, Zanskar, Suro and parts of western Tibet in 1865. *Mem. geol. Surv. India* **5**(3) : 303-354.

TEWARI, B. S., GUPTA, V. J. *et al.* (1970). Some forminifera from the Indus flysch, Ladakh. *Publs. Cent. Adv. Stud. Panjab Univ.* **7** : 191-196.

VARMA, C. P. (1953). On *Lithophyllum wynnei* sp. nov. (Corallinaceae) from the Laki (Lower Eocene) beds of Nammal Gorge, Punjab Salt Range. *J. sci. indstr. Res.* **12B** :86-87.

VARMA, C. P. (1954). On the algal genera *Neomeris* and *Acicularia* from the Niniyur (Danian) beds, Trichinopoly (S. India). *Proc. natn. Inst. Sci. India* **20** : 298-304.

VREDENBURG, E. (1908). Occurrence of the genus *Orbitolina* in India and Persia. *Rec. geol. Surv. India* **36**(4) : 314.

WADIA, D. N. (1935). On the Cretaceous and Eocene volcanic rocks of the Great Himalayan Range in north Kashmir. *Rec. geol. Surv. India* **58**(4) : 419-421.

WADIA, D. N. (1937). The Cretaceous Volcanic Series of Astor-Deosai, Kashmir and its intrusions. *Rec. geol. Surv. India* **72**(2) : 151-161

WEBER, V. B. A. & FOSLIE, M. H. (1904). The corallinaceae of the Shiboga Expedition. *Shiboga Exped. Mon.* **61** :1-110.

EXPLANATION OF PLATES

PLATE 1

1. *Lithophyllum* cf *L. antiquum* Lemoine. Longitudinal section showing nature and position of conceptacle, ×30. 1b—Same, showing details of tissue, ×70. 2—*Permocalculus budaensis* Johnson. Oblique longitudinal section, ×45. 3—*Lithoporella melobesioides* (Foslie) Foslie. Oblique section, ×45. 4a—*Acicularia* cf. *A. comanchense* Johnson. Transverse section, ×45. 4b—Same, showing details of sporangial cavities, ×70. 5a *Acicularia khalsiensis* sp.nov. Transverse section, ×100. 5b,c—Same, oblique sections, ×100. 6—*Thaumatoporella* sp, ×70.

PLATE 2

7a—*Gymnopora indica* sp. nov. Oblique longitudinal section, showing details of pores, ×70. 7*b*—Same. Tangential section, showing nature and position of sporangia, ×100. 8—*Cayeuxia fruticulosa* Johnson, ×70. 9—*Permocalculus ladakhensis* sp. nov. ×100. 10—*Neomeris de terrae* sp. nov. Transverse section, ×40. 11—*Permocalculus texana* Johnson. Oblique longitudinal section, ×70. 12—*Lithothamnium* sp. Vertical section of a thoroughly recrystallised specimen (not described), ×35.

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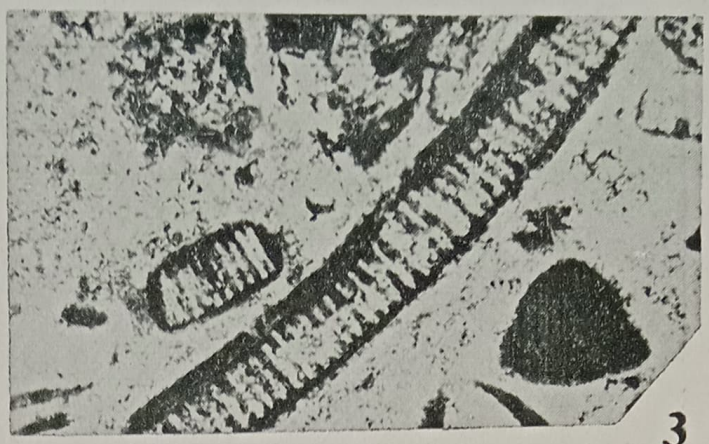

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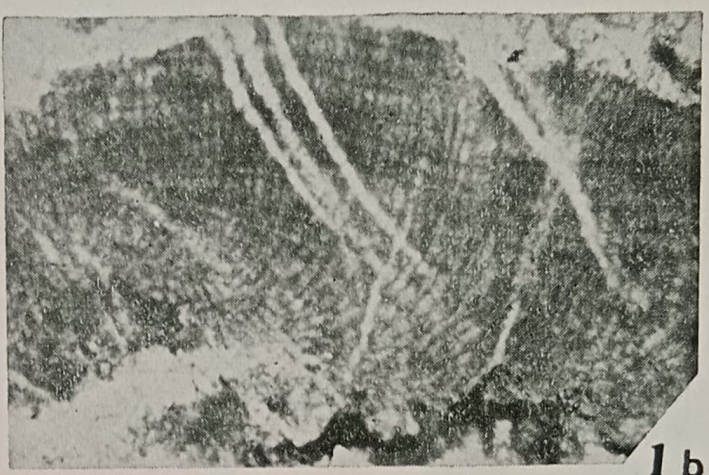

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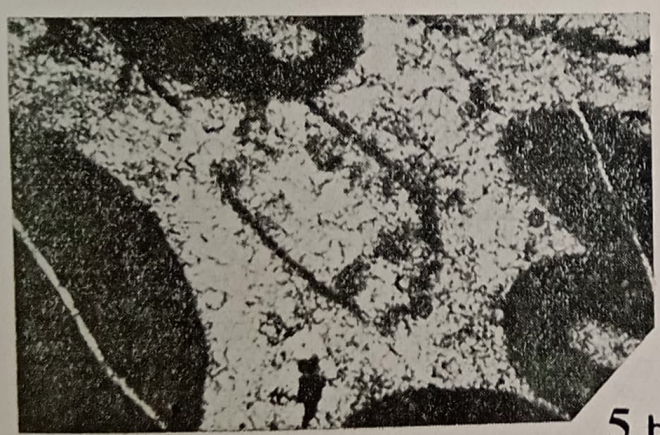

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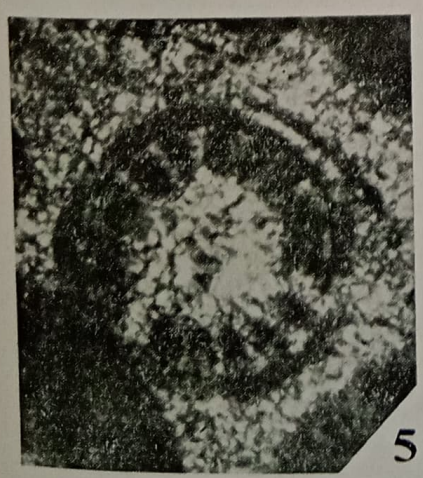

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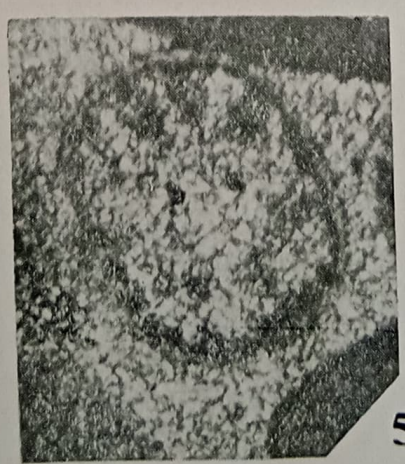

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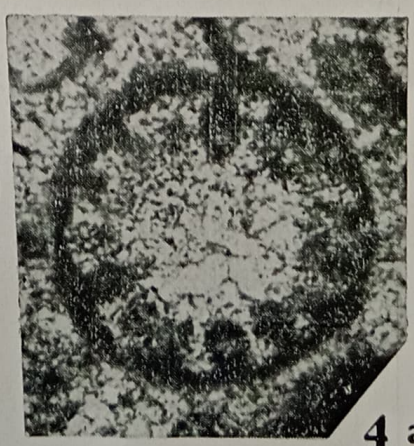

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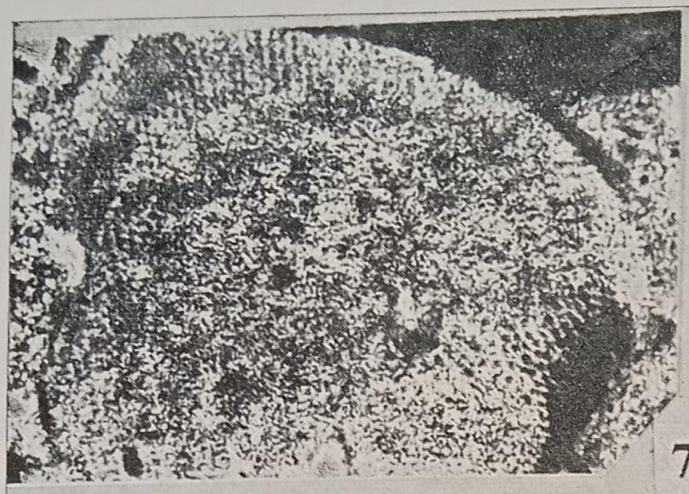

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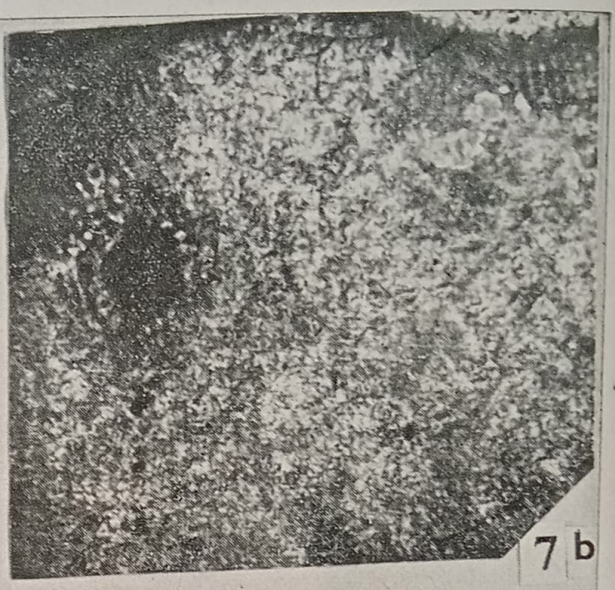

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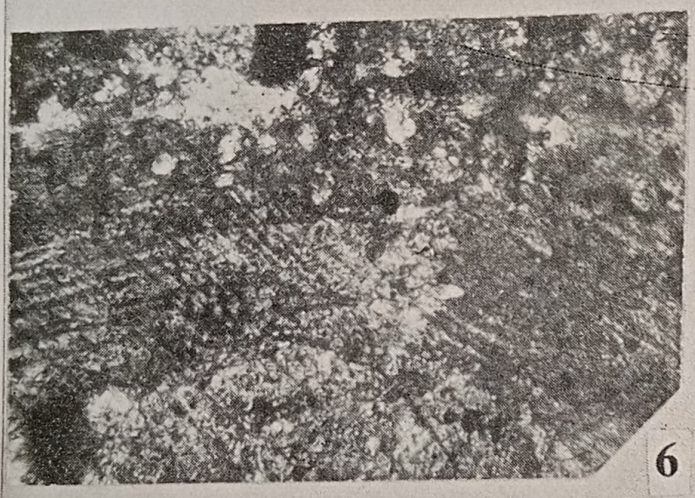

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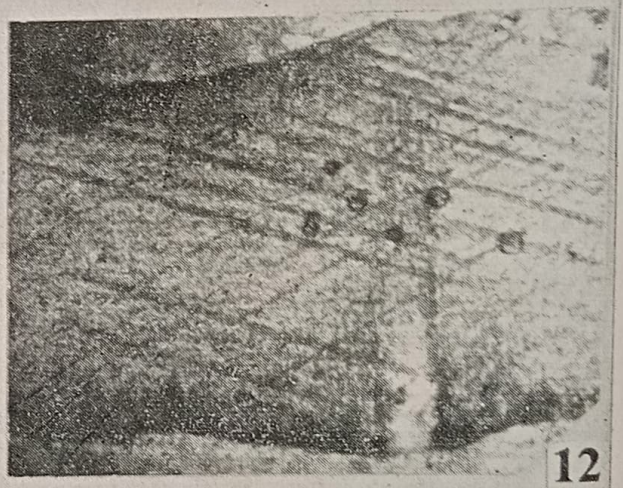

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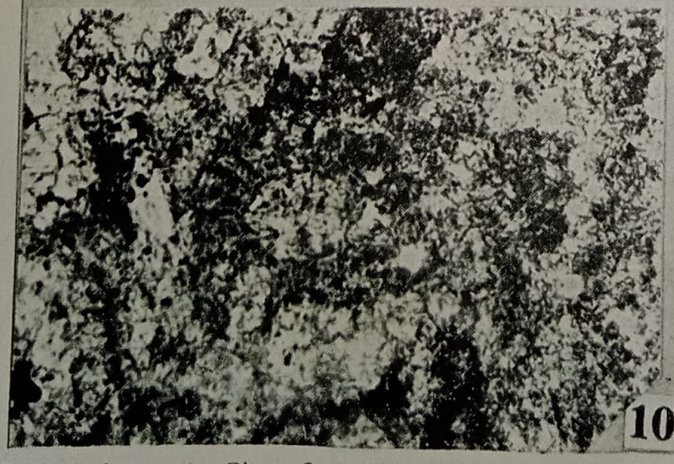

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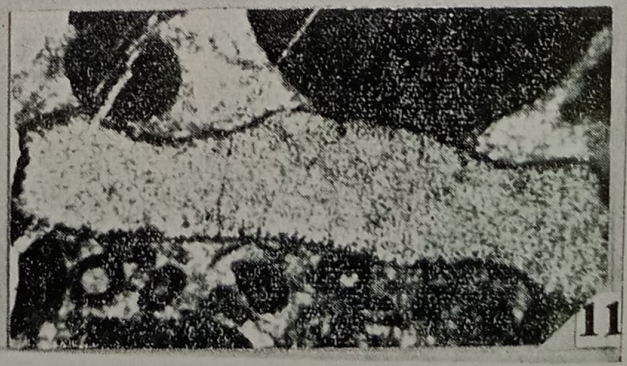

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Pal & Chatterji—Plate 2