AN ALGAL FLORA FROM THE LAKI (LOWER EOCENE) BEDS OF THE NAMMAL GORGE (PUNJAB SALT RANGE)—1 ARCHAEOLITHOTHAMNIUM

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INTRODUCTION.

The geology of the Nammal Gorge section (32° 40′ : 71° 48′) in the Salt Range, Punjab (Pakistan), was first made known by Wynne (1878). His palaeontological collections were later worked out by Waagen (1881) and Cowper Reed (1931, 1944). The Nammal Gorge section shows little structural complexities and includes an almost continuous record of the Tethys from the Permian Middle Productus limestones to the Lower Eocene Laki Beds. Gee (1946) has given the stratigraphy of the area which shows the following sequence, in which the beds I have noticed to be algal-bearing are marked with an asterisk.

Pleistocene conglomerates	
—— unconformity ——	
Lower Nimadrics (Miocene—Pliocene)	
——Time interval; Regional unconformity——	
* Sakesar limestones (Laki)	Eocene
Nammal limestones and shales	
Patala shales (Ranikot)	
* Khairabad limestones (Ranikot)	
Dhok Pass beds (Ranikot)	
——(Time interval; Regional unconformity)——	
Baroch limestones	Jurassic[1]
Variegated stage	
——(Regional unconformity)——	
Kingriali Dolomites	Trias (?)
Kingriali Sandstones	
——(Conformable, transitional junction)——	
Ceratite beds	Trias
Upper Productus beds	Permian
* Middle Productus limestones	

(Base of the Middle Productus beds not exposed)

My studies are based on the specimens collected by Prof. S. R. N. Rao in 1946 from these beds at fairly short intervals. In the present paper I am confining myself to an account of the various species of the genus *Archaeolithothamnium* (Rhodophyceae) found in the Laki (Lower Eocene) beds of the Nammal Gorge.

[1] An upper Cretaceous limestone at the upper part of the Baroch limestone with *Globotruncana* has been reported by Rao and Tripathi (1950) below the Ranikot (Palaeocene) beds.

The genus *Archaeolithothamnium* was first defined by Rothpletz in 1891 to include forms with isolated sporangia distributed all over the perithallium, there being no conceptacles to enclose them. Later, Lemoine (1917, p. 240; 1939, p. 37) gave a more comprehensive definition of the genus which included the following diagnostic characters: isolated sporangia, ovoid or pear-shaped, arranged in concentric zones; hypothallial cells arranged in loose files without continuous horizontal partitions as in the genus *Lithothamnium*. Each row is generally creeping or horizontal, becoming obliquely erect to merge gradually into the perithallium. In branched species of *Archaeolithothamnium* the medullary hypothallium shows a fan shaped to concentric arrangement of cells similar to that of *Lithothamnium* or *Lithophyllum* type. Mlle. Pfender (1926, p. 25) has called attention to the occurrence of secondary or recurrent basilar hypothallium in the regions of the older perithallium where the sporangia have decayed away. The presence of a recurrent hypothallium has been considered (Pia, 1936, p. 35) to be characteristic of the genus, although such a tissue has also been noticed in *Mesophyllum Savornini* Lem.

Archaeolithothamnium samanensis N. Rao has been described by him (1941, p. 44) to be 'unique in showing a tendency for concentric arrangement of the cells of the hypothallium and represents an intermediate type between *Archaeolithothamnium* and *Lithophyllum*'. It is interesting to note that Lemoine (1923, pp. 67–69) found in her species *Lithophyllum vignyense* (which she later 1928, p. 253, revised to *Mesophyllum vignyense*) an intermingling of the characters of *Lithothamnium* and *Lithophyllum*.

The genus shows an encrusting habit of the thallus which may be slightly nodulated or profusely lobed. Some lobes increase more in height and look like branches. Though the excessive increase in the length of a lobe is not considered to be a branch, the truly branched forms possessing a medullary hypothallium are well known from France, e.g. *A. turonicum* Rothpl., *A. amphiroaeforme* Rothpl. etc. (see Pfender, 1926, pp. 15–26) and India, e.g. *A. samanensis* N. Rao (1941, p. 45). *Archaeolithothamnium* species with zonated thalli are seldom met with (*A. digitatum* Pfender, *A. affine* Howe, *A. langrinensis* K. S. Rao, etc.). The zonation is caused either by the superimposition of a number of thalli of the same or different species, or it may be due to the intercalation of thin streaks of limestone or by the alternation of heights in the cell rows of the perithallium but true zonation characteristic of *Lithothamnium* and *Mesophyllum* is not known.

The type of conceptacles found in *Archaeolithothamnium* (isolated sporangia arranged in files), are known to occur in a recent genus *Sporolithon* possessing cruciate tetrasporangia (see Fritsch, 1945, p. 653). Fritsch (1945, pp. 653, 655) regards that 'the kind of sorus found in *Archaeolithothamnion* may well be primitive and have led to the more defined type seen in *Lithothamnion* and *Epilithon*, which in turn, may have resulted in the conceptacle with a single aperture. Such a view is justified by certain similarities in development'. Further, he states (1945, p. 655) that the characters of the sporangial conceptacles were more useful in tracing the affinities of the genera than the sexual characters. He suggests three lines of development in the family Corallinaceae: First exemplified by *Lithothamnion* and *Epilithon*; second by *Melobesia*, *Lithophyllum*, and *Choreonema*, and the third by *Amphiroa* and *Corallina*.

The genus first appears in the Lower Cretaceous and a few living species are known.

Previous records of the genus Archaeolithothamnium in India.

The earliest record of the genus in India (Andaman Islands) goes as far back as 1926 when Gee (1926) figured and described a species under the name *Lithothamnion nummuliticum*. The forms identified by Gee under *Lithothamnion nummuliticum* have been doubted by S. R. Narayana Rao (1941, p. 44) who states '*L. nummuli-*

ticum is now recognised to be *A. nummuliticum* and Mr. Gee's description and figures leave no doubt that his species is an *Archaeolithothamnium*'.

The same year (1926, pp. 4-6) Das Gupta recorded two species of *Lithothamnium* (?) viz. *L. grandis* and *L. cherrapunjiensis* which have been recognised by K. S. Rao (1943, p. 286–287) to be the synonyms of *Corallina grandis* Rao and *Archaeolithothamnium cherrapunjiensis* Rao (p. 272) respectively. He has also recognised (1943) four new species of *Archaeolithothamnium* from the Tertiary rocks of Assam.

The genus is also known from the Upper Cretaceous of the Trichinopoly district, South India, where Pia (L. Rama Rao and J. Pia, 1936) records the presence of the following: *A. lugeoni* Pfender, *A. aff. provinciale* Pfender, *A.* c.f. *lycoperdioides* (Mich) Lem. and *A.* sp. indet.

Two new species of the genus *A. samanensis* and *A. ranikotensis* have been described from the Samana Range (Lower Eocene) Punjab, by S. R. Narayana Rao (1941).

Archaeolithothamnium zonatum sp. nov.

(Pl. XII, figs. 1 and 2.)

Diagnosis:

Thallus encrusting and slightly mammillated; perithallial lattice showing a compact mesh of cells with well-defined vertical and horizontal cell walls; zonation noticed. Cells rectangular to squarish. Hypothallium feebly represented. Sporangia big and ovoid.

Measurements:

Perithallial cells	..	.. 13–18·2 μ × 10·4 – 15·6 μ
Hypothallial cells	..	.. 13–15·6 μ × 10·4–13 μ
Sporangia	..	.. 117–148 μ × 58–78 μ
		mostly 130 μ × 65 μ

Description:

Thallus encrusting, slightly mammillated or lobed, branches not known. The perithallial lattice consists of squarish to mostly rectangular cells. The horizontal and vertical cell walls are well defined. Sometimes, squarish cells are observed below the sporangial rows. The thallus gives a distinctly zonated appearance. The hypothallium is feebly developed and consists typically of horizontal files which gradually bend into the perithallium. Most of the hypothallial cells measure 13 μ × 10·4 μ. The sporangia arranged in straight or slightly curved files. The species is characterised by a zonated perithallium, and sporangia which are the biggest among the so far known Indian species.

Comparison:

The three species of the genus comparable to it are: *A. lugeoni* Pfender, described from Trichinopoly district (Rao and Pia, 1936); *A. samanensis* Rao from the Samana Range, Punjab and *A. floridanum* Johnson and Ferris from Florida.

Though *A. lugeoni* shows some resemblance to the new species with regard to the dimensions of the perithallial cells it has, however, sporangia of smaller dimensions.

A. samanensis Rao, makes an approach in respect to the dimensions of the hypothallial cells but shows differences with regard to the perithallial cells and the shape and size of the sporangia which are 'ovoid rectangular in shape, the two vertical sides almost straight and parallel, the roof flat to slightly convex and the base tapering to a point' (Rao, 1941, p. 47). The sporangial measurements of this species as measured in the type slides are noted in the following table.

A. floridanum shows fairly big and ovoid sporangia but clearly differs in the perithallial and hypothallial (?) characters and the measurements of the vegetative cells and the sporangia.

Serial No.	Name.	Perithallial cells in μ	Hypothallial cells in μ	Sporangia in μ
1.	*A. lugeoni* Pf.	12–20 × 8–10	35 × 8	100 × 40–50
2.	*A. samanensis* N. Rao ..	23 × 8–12	12 × 6–9	104 × 39–52
3.	*A. floridanum* Johnson and Ferris.	33 × 14	....	84–109 × 52–67
4.	*A. zonatum* sp. nov. ..	13–18·2 × 10·4–15·6	13–15·6 × 10·4–13	130 × 65

A. zonatum, besides showing marked differences in the measurements of the vegetative thallus, is remarkable in possessing a zonated perithallium with sporangia whose dimensions surpass any of the *Archaeolithothamnium* species so far recorded from India. The specific name *zonatum* is therefore, accorded to these forms which are readily distinguished by their zonated perithallium with remarkably big and ovoid sporangia.

Archaeolithothamnium lakiensis sp. nov.

(Pl. XII, fig. 3.)

Diagnosis:

Thallus encrusting and strongly nodular; perithallial lattice very regular, compact and made up of squarish cells, sometimes vertical cell walls more prominent. Perithallium very massive, hypothallium scanty and observed with difficulty, absent in most cases. Sporangia ovoid, lenticular in vertical sections, arranged in rows.

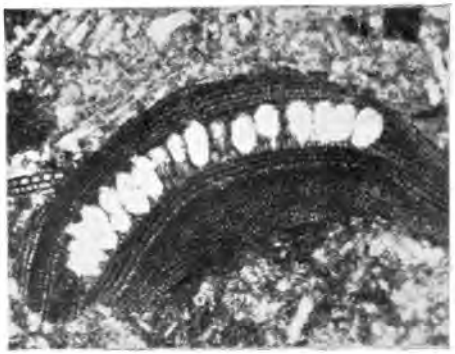
Measurements:

Perithallial cells .. 7·8–10·4 μ × 7·8–10·4 μ
Hypothallial cells .. Absent ? not observed with certainty.
Sporangia .. 65–72·8 μ × 33–39 μ. Ovoid, about twice as long as broad, giving a lenticular aspect in longitudinal vertical sections, mostly 72 μ × 33·8 μ

Description:

Thallus encrusting and strongly nodular. Thickness of the perithallium varies from 0·33 mm. (in primary thallus) to about 2·8 mm. (in a nodule). The general perithallium made up of a compact lattice of squarish cells mostly measuring 7·8 μ × 7·8 μ, while the cells of the bigger size 10·4 μ × 10·4 μ are generally observed near the fertile zones. Any structure referable to a branch is not known from this species. The sporangia are long ovoid, appearing lenticular in vertical sections and arranged in files. The sporangial rows are generally continuous. In the nodules as many as 20 or more such sporangial files may be present; in such cases these sporangial files are more or less regularly spaced, the smallest distance separating two adjoining rows being 33 μ.

Sporangia approximately twice as long as broad and in majority measure 72 μ × 33·8 μ. The presence of the hypothallium has not been noticed with



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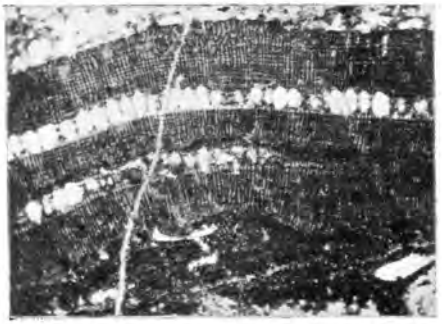

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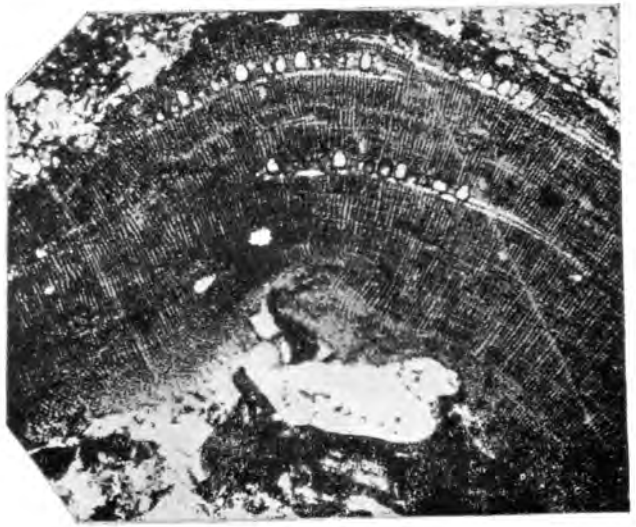

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certainty though in one specimen some obliquely cut cells could be observed below the perithallium. In all others no hypothallium is noticed.

Comparisons:

A. lakiensis makes an approach more or less to the following forms known from India: *A. aff. provinciale* Pf., *A. ranikotensis* N. Rao and *A. nongsteinensis* K. S. Rao with respect to its sporangial measurements.

The present species approaches *A. aff. provinciale* described from Cretaceous of S. India with regard to the sporangial measurements (60–70 $\mu \times 30\ \mu$ in *A. aff. provinciale* while differing from it in having the perithallium made up of small and perfectly square cells (15–30 $\mu \times 7$–10 μ in *A. aff. provinciale*; 7·8–10·4 $\mu \times 7$·8–10·4 μ in *A. lakiensis*) and in the absence of the alternating zones of bigger and smaller cells in the protuberances which are described in *A. aff. provinciale* by Pia. He states (1936, p. 37), 'It may be pointed out, however, that it fairly resembles *Archaeolithothamnium provinciale* as described by Pfender. It is mainly distinguished from this species by the alternation of thicker and thinner cell strata described above. Pfender states positively with respect to the cells of the protuberances: 'Les rangées sont régulières et leur hauteur ne varie qu' insensiblement'.

A. ranikotensis N. Rao differs from *A. lakiensis* in having regularly ovoid sporangia of 42 $\mu \times 68\ \mu$ in size, in having comparatively bigger perithallial cells 8–10 $\mu \times 20$–30 μ and in the presence of the hypothallial tissue with 'cells nearly square measuring 6 $\mu \times 8\ \mu$' (1941, p. 48).

Among the Assam forms of *Archaeolithothamnium*, *A. langrinensis* K. S. Rao and *A. archisporangia* K. S. Rao are ruled out by the shape of their sporangia, the former with trapezoid and the latter with sporangia having parallel lateral sides, flat base and arched roof.

A. nongsteinensis K. S. Rao differs in having considerably smaller sporangia (50 $\mu \times 25\ \mu$), presence of hypothallial cells 30 $\mu \times 10\ \mu$ and rectangular cells 20 $\mu \times 11\ \mu$ forming the perithallium. *A. hemchandri* K. S. Rao is also very different in possessing spherico-ovoid to nearly spherical sporangia (50–55 $\mu \times$ 40–45 μ) and the thallus with rectangular perithallial cells (10–12 $\mu \times 8$–10 μ) showing secondary hypothallium, though the primary hypothallium is not present.

One other species *A. gosaviense* Rothpl. shows certain similarities with the present form. *A. gosaviense* is similar in general appearance of the nodules and in abundance of the zones of sporangia in them. It is described as possessing cubic cells which would certainly appear almost squarish in sections. But it differs from *A. lakiensis* in having a very well developed (Pfender, 1926, p. 12) basilar hypothallium, and in the smaller size of the sporangia 60 $\mu \times 30\ \mu$.

Archaeolithothamnium nammalensis sp. nov.

(Pl. XII, fig. 4.)

Diagnosis:

Thallus encrusting and thin, running for several centimetres in length. Perithallial lattice less distinct, occasionally a little lobed or mammillated. An ill developed hypothallium present, small circular to ovoid sporangia seen in vertical sections and arranged in files among the rectangular perithallial cells.

Measurements:

Perithallial cells	.. 9·1–13 $\mu \times 10$·4 $\times$ 14·3 μ
Hypothallial cells	.. 9·1–13 $\mu \times 9$·1–10·4 μ
Sporangia	.. 46–52 $\mu \times 31$–39 μ ovoid, mostly 52 $\mu \times 33$·8 μ.

Description:

Thallus very thin, generally 132–297μ wide, running for 2–3 cms. or more, occasionally nodulated to lodge the sporangial rows which are 2 to 3 in number. Perithallial tissue composed of an imperfect lattice of rectangular cells. The biggest nodule shown here (pl. XII, fig. 4) measures a little more than a millimetre and bears only two rows of sporangia separated by about 215 μ. The sporangia as seen in vertical section are ovoid to circular, the latter aspect of the sporangia may be the result of the oblique plane in which the thallus and the sporangia are cut. Sporangia mostly measure 52 $\mu \times 33{\cdot}8\,\mu$. Hypothallium present, ill developed in most cases but is very well seen in one specimen (pl. XII, fig. 4).

Comparisons:

A. nammalensis offers a little comparison with *A. nongsteinensis* in general aspect of the thallus while it differs in the shape and size of the sporangia (circular to ovoid, 52 $\mu \times 33{\cdot}8\,\mu$ in *A. nammalensis*; ovoid, 50 $\mu \times 25\,\mu$ in *A. nongsteinensis*) and in having smaller cells in the perithallium and hypothallium (those in *A. nongsteinensis* being: perithallial cells 20 $\mu \times 11\,\mu$, hypothallial cells 30 $\mu \times 10\,\mu$) and in other minor details.

Appendix.

Table for the determination of *Archaeolithothamnium* species from India (based on Lemoine's classification).

1st Section. Tissue Homogeneous.

(a) Species crustaceous :

(1)	Perithallium	.. 12–20 $\mu \times 8$–10 μ
	Hypothallium	.. 35 $\mu \times 8\,\mu$
	Sporangia	.. 100 $\mu \times 40$–50 μ, ovoid
	Age and Locality	.. Danian, Trichinopoly. *A. lugeoni* Pfender.
(2)	Perithallium	.. Present
	Hypothallium	.. Absent
	Sporangia	.. 65 $\mu \times 40\,\mu$ ovoid
	Age and Locality	.. Danian, Trichinopoly. *A.* c.f. *lycoperdioides* (Mich) Lem.
(3)	Perithallium	.. 20–30 $\mu \times 8$–10 μ
	Hypothallium	.. 6 $\mu \times 8\,\mu$
	Sporangia	.. 68 $\mu \times 42\,\mu$, ovoid to irregular
	Age and Locality	.. Palaeocene, Samana Range, Punjab. *A. ranikotensis* S. R. N. Rao
(4)	Perithallium	.. 20 $\mu \times 11\,\mu$
	Hypothallium	.. 30 $\mu \times 10\,\mu$
	Sporangia	.. 50 $\mu \times 25\,\mu$, ovoid
	Age and Locality	.. Lower Eocene, Assam. *A. nongsteinensis* K. S. Rao.
(5)	Perithallium	.. 10–12 $\mu \times 8$–10 μ
	Hypothallium	.. Absent
	Sporangia	.. 50–55 $\mu \times 40$–45 μ. Spherico-ovoid to nearly spherical
	Age and Locality	.. Lower Eocene, Assam. *A. hemchandri* K. S. Rao.

(6) Perithallium .. 7·8–10·4 $\mu \times 7{\cdot}8$–10·4 μ
Hypothallium .. Absent (?)
Sporangia .. 65–72·8 $\mu \times 33$–39 μ, ovoid to lenticular
Age and Locality .. Palaeocene, Nammal Gorge, Punjab.
A. lakiensis sp. nov.

(7) Perithallium .. 9·1–13 $\mu \times 10{\cdot}4$–14·3 μ
Hypothallium .. 9·1–13 $\mu \times 9{\cdot}1$–10·4 μ
Sporangia .. 52 $\mu \times 33{\cdot}8\,\mu$, ovoid
Age and Locality .. Palaeocene, Nammal Gorge, Punjab.
A. nammalensis sp. nov.

(*b*) Species branched :

(1) Perithallium .. 8–12 $\mu \times 23\,\mu$
Hypothallium .. 6·2–9 $\mu \times 12{\cdot}4\,\mu$
Sporangia .. 93–104 $\mu \times 39$–52 μ, ovoid rectangular, vertical sides straight and parallel, the roof flat to slightly convex and base tapering to a point.
Age and Locality .. Palaeocene, Samana Range, Punjab.
A. samanensis S. R. N. Rao.

2ND SECTION. TISSUE SHOWING AN ALTERNATION IN THE HEIGHTS OF ROWS.

(1) Perithallium .. 15–30 $\mu \times 7$–10 μ
Hypothallium .. Absent
Sporangia .. 60–70 $\mu \times 30\,\mu$, ovoid
Age and Locality .. Danian, Trichinopoly.
A. aff. provinciale Pfender

(2) Perithallium .. 35–40–44 $\mu \times 22$–15–40 μ
Hypothallium .. ..
Sporangia .. 55 $\mu \times 44\,\mu$, trapezoid
Age and Locality .. Middle Eocene, Khasi Hills, Assam.
A. langrinensis K. S. Rao

3RD SECTION. TISSUE ZONATED.

(1) Perithallium .. 20–25 $\mu \times 20$–28 μ
Hypothallium .. Absent
Sporangia .. 60 $\mu \times 30$–35 μ Parallel sides, flat base and arched roof.
Age and Locality .. Lower to middle Eocene Khasi Hills, Assam.
A. archisporangia K. S. Rao.

(2) Perithallium .. 13–18·2 $\mu \times 10{\cdot}4$–15·6 μ
Hypothallium .. 13–15·6 $\mu \times 10{\cdot}4$–13 μ
Sporangia .. 130 $\mu \times 65\,\mu$, ovoid
Age and Locality .. Palaeocene, Nammal Gorge, Punjab.
A. zonatum sp. nov.

SUMMARY.

General remarks on the characters of the genus *Archaeolithothamnium*, together with its previous records in India, are made. Three new species of the genus discovered from the Laki beds exposed at the Nammal Gorge (32° 40′ : 71° 48′) in the Punjab Salt Range (Pakistan) are described. In the appendix a table for the determination of the Indian species of *Archaeolithothamnium* is given.

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Explanation of Plate.

Plate XII.

Archaeolithothamnium.

Fig. 1. *A. zonatum* sp. nov. Nearly vertical section through a thin crust showing the sporangia arranged in a continuous arched row. The two cell rows below it show somewhat squarish cells. ×50.

,, 2. *A. zonatum* sp. nov. Obliquely vertical section passing through the fertile zone, showing the zonated perithallium and the ovoid sporangia in the upper part. In the lower part the sporangia are seen cut somewhat crosswise. ×50.

,, 3. *A. lakiensis* sp. nov. Nearly vertical longitudinal section through a primary thallus showing lenticular sporangial rows. ×50.

,, 4. *A. nammalensis* sp. nov. Nearly vertical section passing through a nodule, showing the arched rows of circular to ovoid sporangia and the hypothallial tissue. ×50.