
Some observations on the occurrence of Cycadophytes and Bennettiales in the East Coast Upper Gondwana Athgarh Sandstone, Cuttack and Khurda districts of Orissa, India

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Athgarh Sandstone is rich in plant megafossils, in which the pteridophytes and conifers are dominated followed by Bennettiales and Cycadophytes. The species described in this paper are : *Ptilophyllum acutifolium*, *Ptilophyllum* sp., *Pterophyllum kingianum*, *Pterophyllum* sp. cf. *P. distans*, *Otozamites penna*, *Otozamites* sp. cf. *O. kachchensis*, *Anomozamites fissus*, *Dictyozamites* sp. and *Taeniopteris spatulata*. A comparison of this assemblage with similar other assemblages from the Lower Cretaceous of India has also been made.

Key-words— Cycadophytes, Bennettiales, Athgarh Sandstone, Upper Gondwana (India).

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सारांश

उड़ीसा (भारत) के कटक एवं खुरदा जनपदों में पूर्व तटीय उपरि क्रीटेशी गोंडवाना अथगढ़ बालुपत्थर में साइकेडोफाइटियों एवं बैत्रीटाइटेल्स की उपस्थिति पर कुछ प्रेक्षण

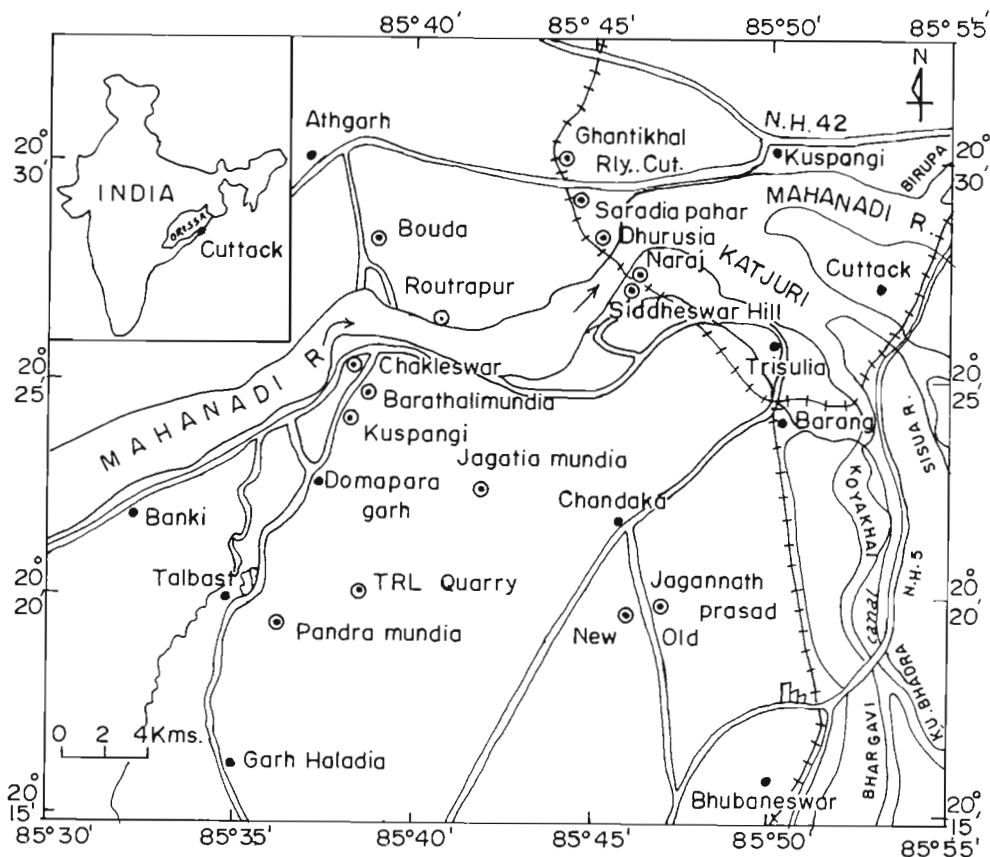
बी.पी. पत्रा एवं एन.के. साहू

अथगढ़ बालुपत्थरों में अशिमत गुरुपादपाश्र्मों की प्रचुरता है जिनमें टेरीडोफाइटों एवं कोनिफर पादप अवशेषों का आधिक्य है। इसके बाद बैत्रीटाइटेल्स एवं साइकेडोफाइटों का क्रम में आते हैं। इस शोध-पत्र में *टाइलोफिल्लम एक्व्यूटीफोलियम*, *टाइलोफिल्लम* जाति, *टेरोफिल्लम किंगिआनम*, *टे. सजातीय टे. डिस्टेंस*, *ओटोजेमाइटिस पेन्ना*, *ओ. सजातीय ओ. कच्छेन्सिस*, *एनोजेमाइटिस फिसस*, *डिक्टियोजेमाइटिस* जाति एवं *टीनोप्टेरिस स्पेटुलाटा* का वर्णन किया गया है। इस समुच्चय की तुलना भारत के अघरि क्रीटेशी कल्प से ज्ञात अन्य समकालीन समुच्चयों से की गई है।

THE East Coast Upper Gondwana sediments, exposed near Cuttack in the Mahanadi Basin, are referred to as Athgarh Sandstone from where the megafossil remains were first collected by Ball (1877). Feistmantel (1877a) described following six plant megafossils (Ball's collection) taxa, viz., *Alethopteris indica*, *Asplenites macrocarpus*, *Gleichenites bindrabunensis*, *Cycadites confertus*, *Palissya indica* and *Rhizomopteris ballii*, for the first time from the Type locality Ghantikhal (Saradiapahar) of the Athgarh Sandstone (Text-Figure 1). However, some of these names have been revised later.

The plant megafossils belong to pteridophytes, cycadophytes and conifers. Adyalkar and Rao (1963) also reported following taxa: *Cladophlebis indica*, *Rhizomopteris ballii*, *Thinnfeldia* sp., *Taeniopteris*

spatulata, *Ptilophyllum acutifolium*, *Retinosporites* sp., *Araucarites* sp. and *Baiera* sp. In 1968, Pandya and Patra described three species of *Ptilophyllum* from Jagannath Prasad locality in the south of Mahanadi. Gradually, new fossil localities comprising new plant megafossils have been discovered by various workers, like Jain (1968); Patra (1973a, 1973b, 1980, 1982, 1983, 1985, 1987, 1989, 1990a, 1990b), Patra and Patnaik (1974), Patra and Sahoo (1992, 1994) and Pandya (1988). At present as many as 15 fossil localities are known from Athgarh Sandstone. They are: Ghantikhal (Saradia Pahar, the Type locality), Ghantikhal railway cut, Dhurusia, Koutrapur, Bouda, Naraj, Siddheswar Hill, Jagannath Prasad (old & new), Jagatia Mundia, Chakleswar, Barathalimundia, Pandra Mundia, Kuspangi, and Talbast (TRL's quarry) (Map 1).



Text-figure 1— Map showing fossil localities of Athgarh Sandstone, Cuttack and Khurd districts of Orissa.

The Athgarh megaf flora includes pteridophytes, pteridosperms, cycadophytes, Bennettiales, Ginkgoales, Caytoniales and conifers. The pteridophytes and conifers dominate the assemblage followed by cycadophytes and Bennettiales. Ginkgoales and Caytoniales are rare. As many as 31 taxa of Bennettiales and cycadophytes have been recorded from the entire East Coast of India. Out of these, 15 taxa have been recorded so far from the Athgarh Sandstone. However, the present paper deals with the cycadophytes and Bennettiales recorded so far from the East Coast Upper Gondwana Athgarh Sandstone.

GENERAL GEOLOGY

Athgarh Sandstone comprises sandstones with intercalations of lenticular white, pink, yellow, dark grey clays and shales, ferruginous and carbonaceous shales and fireclay. The sandstones are medium to coarse grained, arkosic and often cross bedded. Grit and conglomerate beds are also seen towards the upper part of the sequence. Athgarh Sandstones rest unconformably on Precambrian khondalite, charnockite, calcgranulite, biotite- gneiss, or rarely on khaki green shales of Talchir affinity (Tiwari *et al.*, 1987). It is overlain by laterite and

PLATE 1

1. *Ptilophyllum acutifolium* Morris, almost a complete frond showing pinnae with acute apices. Specimen no. UUGL TM 250 x 1
2. *Ptilophyllum acutifolium* Morris, another impression of a frond in the same specimen showing arrangement of pinnae. Specimen no. UUGL TM 250 x 1
3. *Ptilophyllum* sp. an incomplete frond. Specimen no. UUGL TM 219 x 1
4. *Pterophyllum kingianum* Feistmantel, pinnae shown on one side of rachis. Specimen no. UUGL C 531 x 1.
5. *Pterophyllum kingianum* Feistmantel, frond with pinnae on the right side of the rachis on the lower portion and both side of the rachis towards upper portion. Specimen no. UUGL C 514 x 1
6. *Pterophyllum* sp.cf. *P. distans*, apical portion of the frond with complete/incomplete pinnae on either side of rachis. Specimen no. UUGL C 882 x 1
7. *Otozaniites* sp.cf. *O. kachchhensis*, portion of the frond showing alternately arranged pinnae almost covering the rachis. Specimen no. UUGL J 44 x 1

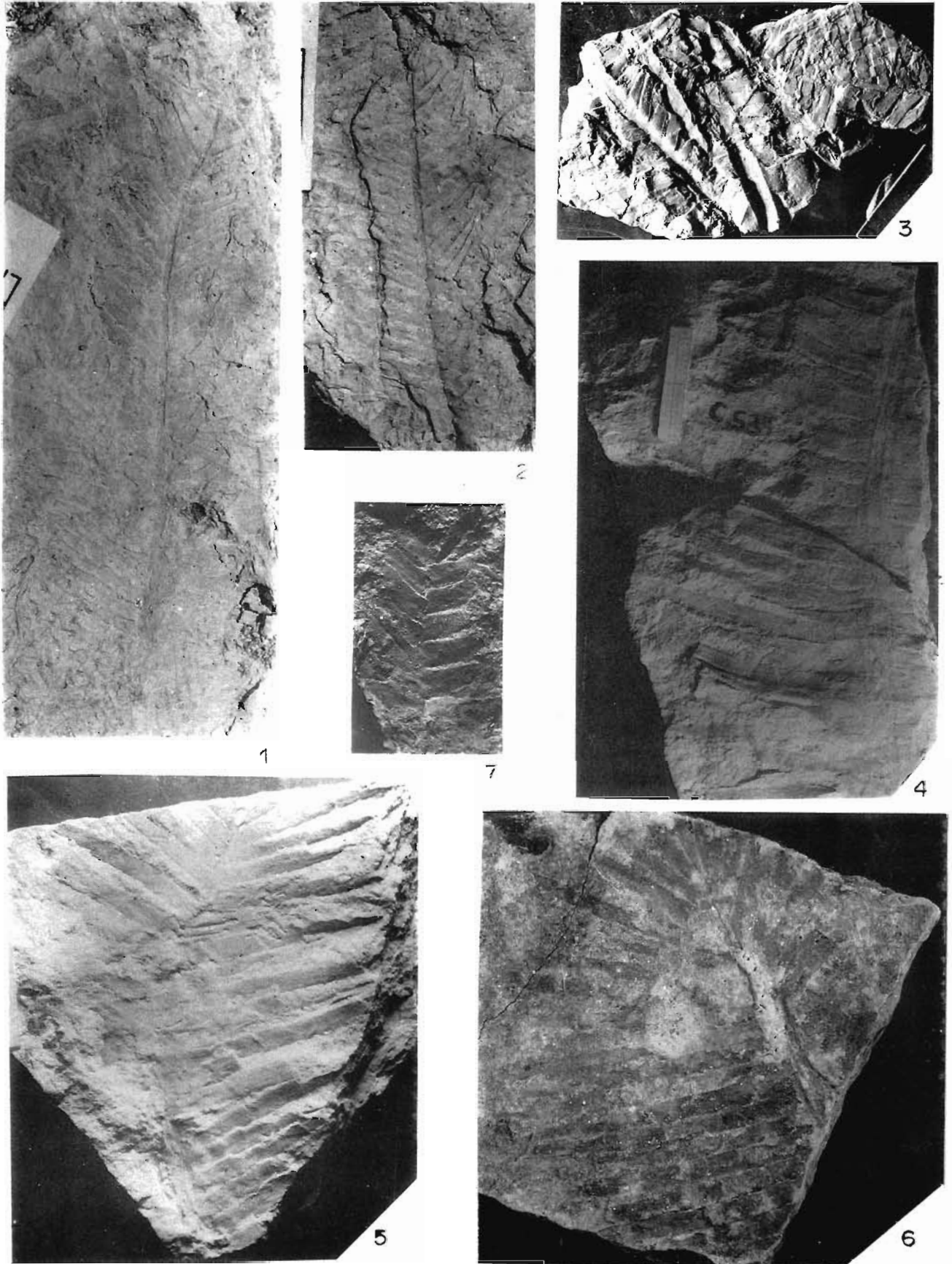


PLATE 1

alluvium. The estimated thickness of Athgarh Sandstone is about 400 meters (Kumar & Bhandari, 1973). The beds are mostly horizontal or with very low dipping as 5° to 10° in south easterly direction.

The megafossils are found in the intercalated clays, carbonaceous shales, or clayey sandstone and fireclay. They are preserved as impressions only and show little or no contrast with the matrix in which they are preserved.

BENNETTITALES

Genus — *Ptilophyllum* Morris 1840

Ptilophyllum acutifolium Morris 1840

Pl. 1, figs 1, 2

Description— Leaves fragmentary, pinnate, 8 cm long and 2.5 cm broad, lamina as a whole lanceolate, rachis 1 mm wide, pinnae attached to the upper surface of the rachis, arising at an angle of 50° - 70° , closely set (imbricating), mostly attached by entire base. Pinnae as a whole linear, elongate, narrow, margin straight or falcate, apex acute, acroscopic margin rounded, basisopic margin decurrent, veins arising from the base, parallel or forked once.

Collection— Specimen no. UUGL TM 250, containing five impressions; Geology Department Museum, Utkal University, Bhubaneswar.

Locality— Tata Refractories Ltd's fireclay quarry near Talbast, Cuttack District, Orissa.

Horizon & age— Athgarh Sandstone, Early Cretaceous.

Remarks— *Ptilophyllum acutifolium* has already been described from Athgarh Sandstone by Adyalkar and Rao (1963), Pandya and Patra (1986), Patra (1982, 1990a) from Ghantikhal, Jagannath Prasad (old), and Naraj, respectively. The present finding from Talbast indicates that this species is widely distributed in Athgarh Sandstone exposed to both north and south of Mahanadi.

Ptilophyllum sp.

Pl. 1, fig. 3

Description— Fragmentary specimens, maximum available length 3.5 cm, width 2 cm, straight, rachis

partially concealed by pinnae basis. Pinnae attached to the upper surface of the rachis at an angle of 50° - 70° by their entire bases. Size of pinnae 14 x 1.2 mm (maximum available), straight, closely set, separate, contiguous, uniform width, basal acroscopic margin rounded, basisopic margin straight, margins entire, apical portion of pinnae not preserved. Veins arising from the base of the pinnae more or less parallel or once forked.

Collection— Specimen Nos. UUGL TM 218, TM 219, TM 242; Geology Department Museum, Utkal University, Bhubaneswar.

Locality— Tata Refractories Ltd's fireclay quarry, near Talbast, Cuttack District, Orissa.

Horizon & age— Athgarh Sandstone, Early Cretaceous.

Remarks— All the present specimens are fragmentary. However, on all gross features they resemble *Ptilophyllum cutchensis* described by Sahni and Rao (1933, pl. 2, fig. 7) from Rajmahal Hills, Bihar in shape and mode of attachment, but differ from *Ptilophyllum cutchensis* in having bigger pinnules.

Genus — *Pterophyllum* Brongniart 1928

Pterophyllum kingianum Feistmantel 1877

Pl. 1, figs 4, 5

Description— Frond incomplete, broadly lanceolate; rachis 5 mm wide on basal part and 2 mm wide towards apex, smooth or longitudinally striated or grooved, maximum available length of the frond 9.5 cm, approximate width 9 cm, gradually narrowing towards apex. Frond imparipinnate, pinnae linear, straight or slightly falcate, opposite to sub-opposite, closely set but not overlapping, separated from the adjacent ones by a gap of 1 mm or less, basal part rarely touching, pinnae attached to rachis laterally at about 85° - 90° on basal part of the frond and at 60° - 70° on upper part, base neither contracted nor decurrent. Margin entire, width almost uniform throughout or gradually tapers towards apex. Apex acutely rounded. On the basal or middle part of the frond pinnae typically measure 4.3 x 3.5 mm, gradually decrease in size towards apex. Veins simple, indistinct, parallel, 7-10 veins per pinnae, originate from the rachis and continue up to apex, forking or anastomosing.

Collection— Specimen no. UUGL C6, C14, C15, C515, C529, C531; Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Chakleswar, Cuttack District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Comparison — The present specimens are closely comparable to *Pterophyllum kingianum* by their thick flattened rachis, shape, size, arrangement and venation of pinnae, as figured by Feistmantel (1877c, pl.3, fig.1; pl.4, fig.1) from Golapilli Sandstone, Andhra Pradesh. *P. kingianum* differs from *P. craterianum* Oldham & Morris 1863 by its more closely set and proportionately longer pinnae. *P. kingianum* shows some similarity with *P. medianum* Bean Zingo (1873-1885) and *P. validium* Hollick 1930. But these two species differ from *P. kingianum* respectively by more acute apices of pinnae with crowded veins and widely spaced pinnae with distinctly expanded bases. *P. incisum* Sahni & Rao 1933 and *P. bifurcatum* Suryanarayana 1954 differ from *P. kingianum* by their incised and bifurcated tips of pinnae, respectively. From *P. footeanum* Feistmantel (1879, 11-6 figs. 1-6) *P. kingianum* differs by its shorter or broader pinnae which are more closely set with parallel margin down to base.

Pterophyllum sp. cf. *P. distans*

Pl.1, fig. 6; Pl. 2, fig.1

Description — Fragmentary incomplete specimen, maximum available length 6 cm and width 7 cm near middle region. Rachis 2-3 mm wide, gradually tapering towards apex, faint longitudinal striations observed. Pinnae linear, arising near middle region at 70°-80° angle which gradually decreases towards apex. Pinnae linear, straight, variable in size, 3-4 cm in the middle portion to 1-5 cm at apical portion, attached with whole base; bases of the adjoining pinnae mostly touching each other, veins simple, parallel, 6-9 per pinnae.

Collection — Specimen no. UUGL C 882, Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Chakleswar, Cuttack District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Remarks & comparison — The present specimen closely resembles *Pterophyllum distans* described by Bose and Banerji (1984, pl.16, fig.2; pl. 17, fig. 6) from Kachchh in shape and other characters. It also looks similar to *Pterophyllum distans* described by Vagyani

and Zuting (1980, pl.1, fig.1) from Uppugundru in Prakasham District of Andhra Pradesh.

Genus — *Otozamites* Braun 1842

Otozamites penna Harris 1946

Pl. 2, fig. 2

Description — Leaf as a whole not known, frond pinnate, rachis about 1 mm wide, rounded or flat, smooth, available length 2-2.5 cm, width 8-15 mm. Pinnae linear, lanceolate, alternate, obliquely set to the lateral or upper part of rachis at an angle of 50°- 60°, attachment nearer to the basiscopic basal angle, base typically asymmetric, acroscopic basal angle forms an auricle in most pinnae and covers the rachis partially, basiscopic basal angle contracted, not decurrent. Pinnae separate from each other by a gap of 0.5-1 mm. Typical pinna measures 4 x 2 mm at its widest part on basal portion of frond and 7 x 2 mm in the upper part; margins straight or slightly falcate, entire, gradually tapering to form an acute apex. Veins few, originating from the base, spreading upwards, unforked or forked at different levels before reaching the margin, concentration of veins 5-7 per mm near the middle of the pinnae.

Collection — Specimen nos. UUGL N 128, N 139, N 194, N 210, N 228, N 251, N 263, N 402, N407, Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Naraj near Siddheswar Hill, Cuttack District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Remarks — This specimen has been reported by Patra (1982, 1990a) but not figured or described.

Comparison — The present specimens closely resemble *Otozamites penna* Harris (1946, figs 4B, 6A, D) from the Jurassic of Yorkshire in shape, size, asymmetric base, almost straight pinnae and their venation. They are also comparable to *Otozamites gracilis* Oldham, Feistmantel (1877d, pl. 6, figs 5, 7) in general, but *O. penna* differs from the presently described specimens in having smaller pinnae with less acute apex and crowded veins. Harris (1946) remarks that *Otozamites penna* closely resembles in general appearance with *Ptilophyllum pecten* and *P. pectinoidium* but it differs from these species of *Ptilophyllum* in the shape of its pinnae.

Otozamites sp. cf. *O. kachchhensis* Bose & Banerji
1984

Pl. 1, fig. 7; Pl. 2, figs 4, 5

Description — Fragmentary incomplete linear leaf, maximum available length 2 cm and width 1.3 cm. Rachis 0.7 mm wide, almost concealed by pinnae bases. Pinnae alternate, closely set at an angle of 60°-80°, sometimes upper margin of pinna overlapping the lower margin of pinna lying immediately above, pinnae rhomboidal in shape, measuring 5-6 x 2-3 mm, base asymmetrical, margin entire almost parallel near middle region, apex rounded or truncate, obtusely rounded, veins 4-6 per pinna, diverging from the base, forking once.

Collection — Specimen nos. UUGL J44, J45, Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Jagannath Prasad, Khurda District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Remarks — The present specimens closely match with *Otozamites kachchhensis* described by Bose and Banerji (1984, pl. 22, fig. 5) from Kachchh, Gujarat. However, they are very small in comparison to Kachchh's specimen. It is interesting that this specimen is being reported for the first time from Athgarh Sandstone.

Genus — *Anomozamites* Schimper 1870

Anomozamites fissus Feistmantel
Pl. 2, figs 5, 6

Description — Frond as a whole not known, petiole, base of petiole slightly expanded. Petiole 2 cm long, about 2 mm wide near base, lanceolate, peripinnate, apex

emarginate, rachis stout, longitudinally striated or grooved, 2 mm wide near the middle of frond, gradually narrowing towards apex, maximum available length of frond 11.5 cm, width 1.1 cm, 2.3 and 0.6 cm at the base near middle and at apex, respectively. Lamina irregularly divided into segments (pinnae) up to rachis. Pinnae rectangular in shape, rarely squarish, subalternate to subopposite, closely set, adjacent pinnae coherent on basal and apical part of the frond, their distal end being free in the middle part; pinnae separated by a gap of 1 mm or less, bases of pinnae not contracted. Sometimes basisopic basal angle slightly enlarged. Pinnae attached to the rachis (midrib) laterally making 80°-90° angle on lower and middle portion of frond and 65°-70° on the apical part. Pinnae mostly straight, slightly falcate towards apical part of the frond, margin entire, mostly parallel, apex obtusely or acutely rounded or divided into two or rarely three unequal shallow lobes, apices of lobes acute or obtuse, typically a pinna in the middle measures 14 mm in length and 8 mm in width, adjacent pinnae are of unequal width, pinnae decrease in size towards base and apex. Veins parallel or forked once (but not anastomosing), forking of veins nearer to rachis or at times near the middle of the pinnae, concentration of veins 32-40 per cm.

Collection — Specimen nos. UUGL C 705, C 736, C 758, C 760, C 768, C 769, C 772; Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Chakleswar, Cuttack District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Remarks — The species has already been reported by Patra (1990b) from Athgarh Sandstone but he did not describe the figure.

Comparison — The specimens are closely comparable to *Anomozamites fissus* described by Feistmantel

PLATE 2

1. *Pterophyllum* sp. cf. *P. distans*, parts of pinnae enlarged; Specimen no UUGL C 882 x 3.
2. *Otozamites penna* Harris, a portion of frond showing complete pinnae and their arrangement. Specimen no. UUGL N 194 x 2.
3. *Otozamites* sp. cf. *O. kachchhensis*, faintly preserved portion of another specimen. Specimen no. UUGL J 45 x 1
4. *Otozamites* sp. cf. *O. kachchhensis*, some pinnae enlarged to show nature of venation. Specimen no. UUGL J 45 x 7.
5. *Anomozamites fissus* Feistmantel, a complete frond, showing petiole and forked pinnae. Specimen no. UUGL C 769 x 1.
6. *Anomozamites fissus* Feistmantel, another specimen showing the apical portion of the frond. Specimen no. UUGL C 736 x 1.
7. ? *Dicryozamites* sp., ill-preserved solitary pinna showing traces of venation. Specimen no. UUGL J 63 x 1
8. *Taeniopteris spatulata* McClelland, almost a complete frond showing traces of venation. Specimen no. UUGL 221 x 1.
9. *Taeniopteris spatulata* McClelland, middle portion of another specimen. Specimen no. UUGL 285A x 1
10. *Taeniopteris spatulata* McClelland, portion of another frond enlarge to show venation. Specimen no. UUGL G 298 x 5.

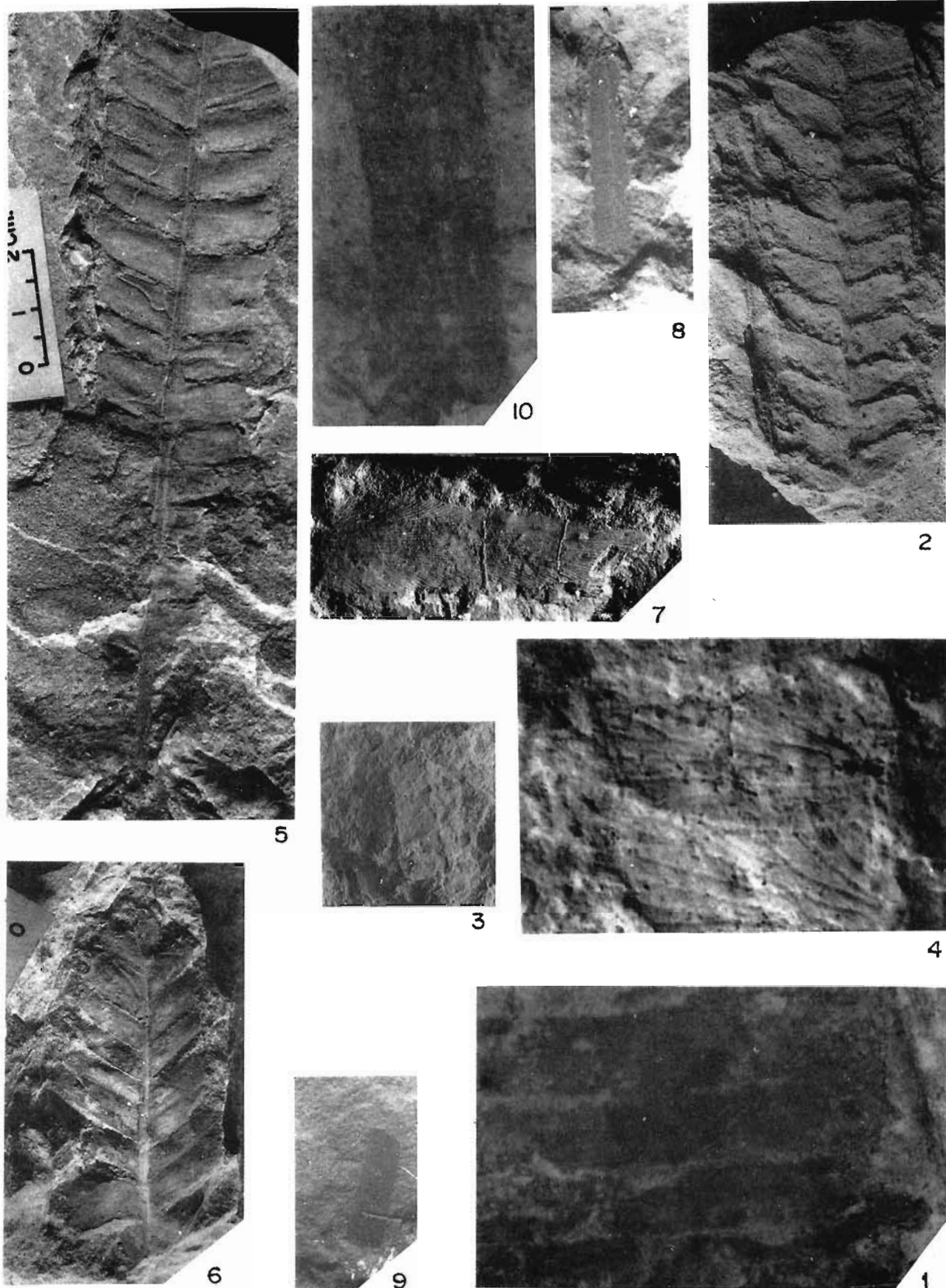


PLATE 2

(1879, pl.7, figs 11-13) in unequally incised tip of pinnae with parallel or forked venation. *Anomozamites fissus* apparently resembles *A. nilsoni* (Phillips) figured by Kawasaki (1925, pl. 21, fig. 66) from Korea, and by Harris (1969, text-fig. 37A, B) from Yorkshire, but the latter has dichotomous branched veins with branching at the middle of the pinnae along with minutely denticulate margin. Amongst the Indian specimens figured so far as *Anomozamites fissus* Feistmantel, the present specimens are comparatively bigger in size. Unlike Feistmantel's complete leaf (1877b, pl. 37, fig. 3) where almost all the pinnae have incised apices, in the present collection only few pinnae are apically incised. However, venation of the present specimens is similar to the Feistmantel's specimen.

Genus — *Dictyozamites* Oldham 1863

Dictyozamites sp.

Pl. 2, fig. 7

Description — Only a single detached pinna not found. Pinna linear, lanceolate, 4 cm long, 1.2 cm wide at base, gradually tapering towards apex, which being not preserved. Margin entire, veins diverge from the base and forked veins joins with each other to form reticulate meshes.

Collection — Specimen no. UUGL J 63, Geology Department Museum, Utkal University, Bhubaneswar.

Locality — Jagannath Prasad (new), Khurda District, Orissa.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Table 1—Distribution of Bennettitales and Cycadophytes in Athgarh Sandstone, Cuttack and Khurda districts of Orissa

Taxa	Saradia Pahar (Ghantikhal)	Ghantikhal Railway cut	Dhurusia	Routrapur	Bouda	Naraj	Sidheswar Hill	Chakleswar	Barahati Mundia	Kuspangi	Jagatia Mundia	Talbast (TRL's Quarry)	Pandra Mundia	Jagannath Prasad (Old)	Jagannath Prasad (New)
<i>Ptilophyllum acutifolium</i>	+	-	-	-	-	+	-	-	-	-	-	+	-	+	-
<i>P. cutchensis</i>	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-
<i>P. indicum</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
<i>P. oldhamii</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
<i>Ptilophyllum</i> sp.	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-
<i>Pterophyllum kingianum</i>	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-
<i>Pterophyllum</i> sp. cf. <i>P. distans</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Anomozamites fissus</i>	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Nissonia (Anomozamites fissa)</i>	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
<i>Otozamites penna.</i>	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
<i>Otozamites</i> sp. cf. <i>O. kachchhensis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
<i>Otozamites</i> sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
? <i>Dictyozamites</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
<i>Taeniopteris spatulata</i>	+	-	-	-	-	-	+	-	-	-	+	-	-	+	-
<i>Taeniopteris</i> sp.	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
<i>Cycadites rajmahalensis</i>	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(+ occurrence

- Absent)

Comparison — As it is a detached solitary pinna its mode of attachment is not known; veins are diverging from base and forking but mesh is not observed at all places as usually seen in *Dictyozamites*. However, in shape of pinna it looks like *Dictyozamites* sp. described by Bose and Banerji (1984, pl. 20, figs 7, 8) from Kachchh, Gujarat.

Genus — *Taeniopteris* Brongniart 1828

Taeniopteris spatulata McClelland 1850

Pl. 2, figs 8-10

Description — Leaf almost complete, petiole not known variable in size, narrow forms only 1.5 mm wide, broader forms 9-10 mm wide. Complete leaf in narrow

forms 1.8 cm long, the portion of a wider form 3.8 cm long, gradually narrowing towards base and widens towards apex, again near apex gradually narrowed to form an obtusely rounded apex, the entire leaf being broadly spatulate in shape. Midrib distinct, 0.5 mm wide in narrow leaves to 1.5 mm wide in broad leaves, longitudinally groved or ridged. Margins entire, lateral veins not discernible in narrower leaves, visible in broader forms, arising at right angles to the midrib. Veins simple, rarely forked, concentration of lateral veins 3 per mm.

Collection — Specimen nos. UUGL G298, S210, S212, S221, S222, S235, S236, S241, S241A; Geology Department Museum, Utkal University, Bhubaneswar.

Localities — Saradia Pahar and Sidheswar Hills, Cuttack District, Orissa.

Table 2—Distribution of Bennettitales and Cycadophytes in the Lower Cretaceous of India

Taxa	Aitgarh Basin	Rajmahal Basin	Jabalpur Basin	Kachchh Basin	Rajasthan	Godavari Basin	Krishna Basin	Palar Basin	Cauvery Basin	Kota-Gangapur
<i>Ptilophyllum acutifolium</i>	+	+	+	+	+	+	+	+	+	+
<i>P. amarjolense</i>	-	+	-	-	-	-	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. amarjolense</i>	-	-	-	+	-	+	-	-	-	-
<i>Ptilophyllum cutchense</i>	+	+	+	+	-	+	+	-	+	+
<i>Ptilophyllum</i> sp. cf. <i>P. cutchense</i>	-	+	-	-	-	-	-	-	-	-
<i>P. distans</i>	-	-	+	+	-	-	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. distans</i>	-	-	-	-	-	+	-	-	-	-
<i>P. deodikarii</i>	-	-	-	-	-	+	-	-	-	-
<i>P. gladiatum</i>	-	-	+	-	-	-	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. gladiatum</i>	-	-	-	-	-	+	-	-	-	-
<i>Ptilophyllum guptae</i>	-	+	-	-	-	-	-	-	-	-
<i>Ptilophyllum horridum</i>	-	-	-	+	-	-	-	-	-	+
<i>Ptilophyllum indicum</i>	+	-	-	+	-	-	-	-	-	-
<i>P. institacallum</i>	-	-	+	+	-	-	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. institacallum</i>	-	-	-	-	-	+	-	-	-	-
<i>P. jabalpurensis</i>	-	+	-	-	-	+	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. jabalpurensis</i>	-	-	-	-	-	+	-	-	-	-
<i>P. nipanica</i>	-	+	-	-	-	-	-	-	-	-
<i>P. oldhamii</i>	+	-	-	+	-	-	-	-	-	-
<i>P. raghudevpurensis</i>	-	-	-	-	-	+	-	-	-	-

<i>P. rarinervis</i>	-	-	-	-	-	+	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. rarinervis</i>	-	-	-	-	-	-	+	-	+	-
<i>P. rewaensis</i>	-	-	+	-	-	-	-	-	-	-
<i>P. sahnii</i>	-	+	-	-	-	-	-	-	-	-
<i>Ptilophyllum</i> sp. cf. <i>P. sahnii</i>	-	-	-	-	-	+	-	-	-	-
<i>P. sakarigaliensis</i>	-	-	-	+	-	-	-	-	-	-
<i>P. sparsifolium</i>	-	+	-	-	-	-	-	-	-	-
<i>P. tenerrimum</i>	-	+	-	-	-	+	+	-	-	-
<i>Ptilophyllum</i> sp.	+	+	+	+	-	-	+	-	-	+
<i>Pterophyllum braunianum</i>	-	-	-	-	-	+	-	-	-	-
<i>P. distans</i>	-	+	+	+	-	+	-	-	-	-
<i>Pterophyllum</i> sp. cf. <i>P. distans</i>	+	-	-	-	-	+	-	-	-	-
<i>Pterophyllum footeanum</i>	-	-	-	-	-	+	+	+	-	-
<i>P. guptai</i>	-	+	-	-	-	-	-	-	-	-
<i>P. incisum</i>	-	+	-	-	-	-	+	-	-	-
<i>P. kingianum</i>	-	+	-	-	-	+	+	+	-	-
<i>P. morrisianum</i>	-	+	-	-	-	+	+	-	+	-
<i>P. nerbuddaicum</i>	-	-	+	-	-	-	-	-	-	-
<i>P. princeps</i>	-	+	-	+	-	-	-	-	-	-
<i>P. rajmahalense</i>	-	+	-	-	-	-	-	-	-	-
<i>Pterophyllum</i> sp.	-	+	-	-	-	+	+	+	+	-
<i>Nilssonia</i> (<i>Anomozamites</i> '') <i>fissa</i>	+	-	-	-	-	-	-	-	-	-
<i>Nilssonia</i> sp.	-	+	+	-	-	-	-	-	-	+
<i>Anomozamites amarjolense</i>	-	+	+	-	-	-	-	+	-	+
<i>A. crenata</i>	-	+	-	-	-	-	-	-	-	+
<i>A. fissus</i>	+	-	-	-	-	-	+	-	+	+
<i>Anomozamites</i> sp. cf. <i>A. fissus</i>	+	-	-	+	-	-	-	-	-	-
<i>Anomozamites haburensis</i>	-	-	-	-	+	-	-	-	+	-
<i>A. hasnapurensis</i>	-	-	+	-	-	-	-	-	-	-
<i>A. jugens</i>	-	-	-	-	-	-	-	-	-	+
<i>A. lindleyanus</i>	-	-	-	-	-	-	-	-	-	+
<i>Anomozamites</i> sp.	-	-	-	-	-	+	-	-	+	+
<i>Otozamites acutifolius</i>	-	-	-	-	-	-	+	-	-	+
<i>O. angustatus</i>	-	-	+	-	-	+	+	+	-	-
<i>O. bengalensis</i>	-	+	-	+	-	+	-	+	-	-
<i>Otozamites</i> sp. cf. <i>O. contiguus</i>	-	-	-	+	-	-	-	-	-	-
<i>O. exhislopi</i>	-	-	+	-	-	-	+	-	-	-
<i>Otozamites</i> sp. cf. <i>O. goldai</i>	-	-	-	+	-	-	-	-	+	+
<i>O. gondwanensis</i>	-	+	-	-	-	-	+	-	-	-

<i>O. gracilis</i>	-	-	+	-	-	-	-	-	-	-
<i>O. histopi</i>	-	-	+	-	-	-	+	-	-	-
<i>O. imbricatus</i>	-	+	+	+	+	-	+	-	-	-
<i>Otozamites</i> sp.cf. <i>O. imbricatus</i>	-	-	-	-	+	-	-	-	-	-
<i>Otozamites kachchhensis</i>	-	-	-	+	-	-	-	-	-	-
<i>Otozamites</i> sp. cf. <i>O. kachchhensis</i>	+	-	-	+	-	-	-	-	-	-
<i>O. parallelus</i>	-	+	-	-	-	-	-	+	-	-
<i>O. penna</i>	+	-	-	-	-	-	-	-	-	-
<i>O. rarinervis</i>	-	-	-	-	-	+	+	-	-	-
<i>O. venavarmensis</i>	-	-	-	-	-	-	+	-	-	-
<i>O. walkamotaensis</i>	-	-	-	+	-	-	-	-	-	-
<i>Otozamites</i> sp.	+	+	-	+	+	-	-	+	-	-
<i>Dictyozamites falcatus</i>	-	+	-	-	+	+	-	-	+	+
<i>D. feistmantelii</i>	-	-	+	-	-	+	+	+	+	+
<i>D. gondwanensis</i>	-	-	-	-	-	-	-	-	-	+
<i>D. hallei</i>	-	+	-	-	-	-	-	-	-	-
<i>D. indicus</i>	-	+	-	-	-	+	+	+	+	-
<i>D. sahmii</i>	-	+	-	-	-	+	-	-	-	-
<i>Dictyozamites</i> sp.	+	+	+	-	-	-	-	-	-	-
<i>Taeniopteris crassinervis</i>	-	-	+	-	-	-	-	-	-	-
<i>T. ensis</i>	-	+	-	-	-	+	-	-	+	-
<i>Taeniopteris densinervis</i>	-	-	+	-	-	-	-	-	+	-
<i>T. lata</i>	-	-	-	-	-	-	-	-	+	-
<i>T. haburensis</i>	-	-	-	-	+	-	-	-	-	-
<i>T. oldhamii</i>	-	+	-	-	-	-	-	-	-	-
<i>T. spatulata</i>	+	+	+	+	+	+	+	+	+	+
<i>T. vittata</i>	-	-	+	+	-	-	-	-	-	-
<i>T. mcClelandi</i>	-	-	-	-	-	+	+	+	-	-
<i>T. ovata</i>	-	-	-	-	-	-	-	-	+	-

+ Occurrence - Absent

+ Occurrence - Absent

Rajmahal Basin—Rajmahal Formation and Dubrajpur Formation.

Jabalpur Basin—Jabalpur Formation, Chaugan beds and Bansa beds.

Kachchh Basin—Bhuj Formation, Umia Formation.

Rajasthan—Pariwar Formation, Lathi Formation.

Godavari Basin—Tirupati Sandstone, Raghavapuram Shale, Golapilli Sandstone.

Krishna Basin—Pavalur Sandstone, Vemavaram Shale, Budavada Sandstone.

Kota-Gangapur—Kota Formation and Gangapur Formation.

Cauvery Basin—Sivaganga Formation.

Palar Basin—Satyavedu Formation and Sri-Perumbudur Formation.

Horizon & age — Athgarh Sandstone, Early Cretaceous.

Comparison — The broader leaves as described above are comparable in form and venation with *Stangerites (Taeniopteris) spatulata* figured by Oldham

and Morris (1863, pl. 23, figs 1-3) from Rajmahal Hills, Bihar. Both narrower and broader leaves can be compared well with *T. spatulata* Sitholey (1944, pl. 3, figs 11-14) described from Tobbawa Series of Ceylon (Sri Lanka). The wider leaves also closely resemble in shape

and size with *T. spatulata* figured by Ganju (1946, pl. 1, fig. 3; pl. 4, fig. 26) from Rajmahal Hills, Bihar. The present leaves are also comparable with *T. spatulata* (Gopal *et al.*, 1957, pl. 8, figs 4, 5) described from Sivaganga Formation of Ramnad District, Tamil Nadu in the width of lamina, but in the present specimens the midribs are wider and longitudinally grooved and ridged.

DISCUSSION AND CONCLUSION

So far, fifteen fossiliferous localities are known from the Athgarh Sandstone. Table 1 shows the distribution of Bennettitales and cycadophytes in the Athgarh Sandstone which comprises 13 species, viz., *Ptilophyllum* (5), *Pterophyllum* (2), *Anomozamites* (1), *Otozamites* (3), *Dictyozamites* (1) and *Taeniopteris* (1). Of them, the most widely distributed taxon is *Ptilophyllum*, followed by *Taeniopteris*. From Jagannath Prasad locality (old and new both) maximum number of taxa (seven) have been reported.

Table 2 shows the distribution of Bennettitales and cycadophytes in all the Upper Gondwana basins of India. On comparing them with the Athgarh Sandstone it is observed that the representation of Bennettitales and cycadophytes in Athgarh basin is poor in comparison to other basins. A total number of 104 taxa have been reported so far from all the Upper Gondwana basins of India. Rajmahal Basin (Dubrajpur and Rajmahal formations) contains the highest number of Bennettitales and cycadophytes. These are characterised by broad leaves which is a unique feature for the forms recovered from Rajmahal Basin.

Godavari Basin contains maximum representation of *Ptilophyllum*. Rajmahal basin comprises maximum species of *Pterophyllum*, *Dictyozamites* and *Taeniopteris*. Kota-Gangapur assemblage shows the dominance of *Anomozamites*, while in Kachchh Basin *Otozamites* represents its dominance.

It is observed that *Ptilophyllum acutifolium* and *Taeniopteris spatulata* are present in all the Upper Gondwana basins of India. Each basin characteristically consists of few taxa which are exclusively confined to that basin only, e.g., *Ptilophyllum* sp. cf. *P. cutchense*, *Ptilophyllum guptae*, *P. nipanica*, *P. sahnii*, *P. sparsifolium*, *Pterophyllum guptae*, *Pterophyllum rajmahalense*, *Dictyozamites hallei*, *Taeniopteris oldhamii* in Rajmahal Basin; *Ptilophyllum rewaensis*, *Pterophyllum*

narbuddeicum, *Anomozamites hasnapurensis*, *Otozamites gracilis* in Jabalpur Basin; *Ptilophyllum horridum*, *P. sakarigaliensis*, *Otozamites* sp. cf. *O. contiguus*, *Otozamites kachchhensis*, *O. walkamotaensis* in Kachchh Basin; *Otozamites* sp. cf. *O. imbricatus*, *Taeniopteris haburensis* in Rajasthan; *Ptilophyllum* sp. cf. *P. distans*, *P. leodikarii*, *P. raghudevpurensis*, *P. rarinervis*, *Ptilophyllum* sp. cf. *P. gladiatum*, *Ptilophyllum* sp. cf. *P. institacallum*, *Ptilophyllum* sp. cf. *P. jabalpurensis*, *Ptilophyllum* sp. cf. *P. sahnii*, *Pterophyllum braunianum* in Godavari Basin; *Otozamites vemavaramensis* in Krishna Basin; *Anomozamites jugens* and *Anomozamites lindleyanus* in Kota-Gangapur assemblages. It is interesting to note Yorkshire species *Otozamites penna* recorded from Athgarh Sandstone, has not been recorded from elsewhere in India.

All the above discussed megafossils are of long ranging nature. The Upper Gondwanas are characterised by the appearance of the genus *Ptilophyllum* along with *Thinnfeldia* (Krishnan, 1968; Sasty *et al.*, 1977).

Sukh-Dev (1988) has recognised 10 megafloristic zones in the Mesozoic formations of India. In the Lower Cretaceous, there are three zones. Zone-8 is *Dictyozamites-Pterophyllum-Anomozamites* Zone, which is characterised by dominance of cycadophytes over pteridophytes. Hence, Rajmahal Formation (including Dubrajpur Formation), Sivaganga Formation, Samu Hill Formation and Pariwar Formation of Rajasthan, all belong to this zone. Zone-9, i.e., *Allocladus-Brachyphyllum-Pagiophyllum* Zone shows richness of conifers, less cycadophytes and pteridophytes. However, the next Zone - 10, i.e., *Weichselia-Onychiopsis-Gleichenites* assemblage zone has rich pteridophytes and conifers and less cycadophytes and pteridosperms. Athgarh megafloral assemblage characterised by rich pteridophytes and conifers with less cycadophytes, Bennettitales and pteridosperms (Patra & Sahoo, 1994) reasonably fits well to zone-10 of Sukh-Dev (1988).

According to Bose (1974) in the Lower Cretaceous beds, viz., Bansa, Himmatnagar and Songad in Kathiawar, *Ptilophyllum* is extremely rare. Further, besides *Ptilophyllum* no other bennettitalean remains (megafossils) are known from the Lower Cretaceous of India. But the present study indicates that all these East Coast Upper Gondwana units (Lower Cretaceous) are considerably rich in Bennettitales and cycadophytes.

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