

Floral diversity and implications in palaeoenvironment of Vemavaram Formation (Krishna Depression), Krishna–Godavari Basin, Andhra Pradesh, India

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ABSTRACT

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The present study deals with the plant megafossil assemblage and associated environment of the Vemavaram Formation (Krishna Depression), Krishna–Godavari Basin, Andhra Pradesh, India. The plant fossils are collected from Vemavaram (currently known as Ommevaram), Prakasam District, Andhra Pradesh. Sixteen taxa are recognised including four new species, namely *Dictyozamites ommevaramensis*, *Ptilophyllum heterophylla*, *Pagiophyllum ommevaramensis* and *Elatocladus loyolii* alongwith twelve known species. The Early Cretaceous flora from the Vemavaram Formation is compiled and compared with the floras of Budavada Formation (Krishna Depression), Golapalli and Raghavapuram formations (Godavari Depression). The floral components of the two depressions are broadly similar and together can be referred as Krishna–Godavari basinal flora. The associated environments are reconstructed by taking into account evidences from micro–flora–pollen and spores, phytoplankton and also foraminifera.

Key–words—East Coast, Early Cretaceous, Vemavaram, Krishna–Godavari, Palaeoenvironment.

भारत में आंध्र प्रदेश की कृष्णा–गोदावरी द्रोणी के वेमावरम शैलसमूह (कृष्णा अवनमन) के पुरापर्यावरण में पुष्पी विविधता एवं निहितार्थ

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सारांश

वर्तमान अध्ययन भारत में आंध्र प्रदेश की कृष्णा–गोदावरी द्रोणी के वेमावरम शैलसमूह (कृष्णा अवनमन) के गुरुपादपाश्म समुच्चय तथा सहयोगी पर्यावरण से संबंधित है। पादपाश्मों को आंध्र प्रदेश में प्रकाशम जिले के वेमावरम (अब ओमेवरम कहते हैं) से एकत्रित किए गए हैं। बारह ज्ञात जातियों के साथ चार नूतन जातियां नामतः *डिक्टीओज़ामाइट्स ओम्मेवरामेन्सिस*, *टिलोफिल्लम हेटेरोफिल्ला*, *पेजियोफिल्लम ओम्मेवरामेन्सिस* एवं *इलेटोक्लेडस लोयोलायाई* सहित सोलह टैक्सा पहचानी गई हैं। वेमावरम शैलसमूह से प्राप्त प्रारंभिक चाकमय वनस्पति—जाति बुदावद शैलसमूह (कृष्णा अवनमन), गोलापल्ली और राघवपुरम शैलसमूहों (गोदावरी अवनमन) की वनस्पति—जातों के संग समेकित व तुलना की गई है। दो अवनमनों के पुष्पी संघटक व्यापकता से सदृश हैं तथा साथ–साथ कृष्णा–गोदावरी द्रोणीय वनस्पति—जात के रूप में संदर्भित की जा सकती हैं। संबद्ध पर्यावरण सूक्ष्म वनस्पति जात–पराग व बीजाणुओं, पादपप्लवक एवं फोरैमिनीफेरा से भी प्रमाण लेते हुए पुनर्चित की गई हैं।

सूचक शब्द—पूर्वी तट, प्रारंभिक चाकमय, वेमावरम, कृष्णा–गोदावरी, पुरापर्यावरण।

INTRODUCTION

THE East Coast sedimentary basins of India are well known for their fossiliferous rocks of Upper Gondwana (Early Cretaceous). They are distributed in three Indian states, represented by several stratigraphic units, namely Sriperumbudur, Satyavedu (Palar Basin) and Sivaganga (Cauvery Basin), Tamil Nadu; Budavada, Vemavaram (Krishna Depression), Golapalli and Raghavapuram (Godavari Depression), Krishna–Godavari Basin and Gangapur/Chikiala (Pranhita–Godavari Basin), Andhra Pradesh and Athgarh (Mahanadi Basin) in Orissa. Among these, the beds exposed at Vemavaram (Ommevaram) are the most important, interesting and note worthy as they contain a large number of floral and faunal remains.

The Vemavaram Formation was named after the village Vemavaram (currently known as Ommevaram), located 19 km north of Ongole in Prakasam District, Andhra Pradesh and about 8 miles inland from the coast. The palaeobotanical work in this area was initiated during the late nineteenth century (Feistmantel, 1879; Foote, 1879). Only a few attempts have been made for the last one century to study the Geology and Palaeobotany of the area. Foote (1879) was the first to study the Geology and to some extent Paleontology (including Palaeobotany), however, he neither figured nor described the specimens. The detailed palaeobotanical study of the area was carried out by Feistmantel (1879) who reported many plant and animal fossil remains. Later, this flora was revised by Seward and Sahni (1920) and Sahni (1928, 1931). Additional fossils to this locality were added by Suryanarayana (1954), Bose and Jain (1967), Jain (1968), Bose (1974), Bose and

Bano (1978), Vagyani (1984, 1985) and Vagyani and Zutting (1986) and Pandya *et al.* (1990). Palynological investigation of this area was done by Ramanujam (1957), Kar and Sah (1970) and Venkatachala and Sinha (1986). Faunal studies carried out by Feistmantel (1879) and Spath (1933), and are represented by ammonites, brachiopods, lamellibranchs, fish scales and mammalian ribs

GEOLOGY OF STUDY AREA

Suryanarayana (1954) gave a brief description of geology of the present study area alongwith some plant fossils. Later, Sastri *et al.* (1973), Venkatachala and Sinha (1986) discussed the geology of the area alongwith the other East Coast litho–units. The fossiliferous rocks at Vemavaram are whitish–yellow–variegated, argillaceous, hard, and can be broken into thin slabs along the bedding planes, intercalated by sandstone and pebble conglomerates. The Vemavaram Formation underlies the Budavada Formation and consists mainly of sandstone with fragmentary plant remains. The Pavalur Formation overlies the Vemavaram Formation conformably and comprises of medium– to coarse–grained clayey and lateritic sandstone (Table 1). Venkatachala and Sinha (1986) considered these litho–units as facies variants and homotaxial to the Golapalli, Raghavapuram and Tirupati formations (Fig. 2). The stratigraphic sequence met within the study area is given in Table 1 and Fig. 3.

MATERIAL AND METHODS

Plant fossils were collected from the shale sequences of Vemavaram Formation, exposed towards the North West and North East about 0.5 km of the village Ommevaram (15°41'17" N; 80°09'01" E), Prakasam District, Andhra Pradesh (Fig. 1). The fossil plant material is largely fragmentary and is preserved as impressions on whitish–yellow coloured shale. Despite the preservation limitation, most morphological details are still preserved, including venation pattern in maximum number of specimens. Plant fossils were studied under an Olympus SZH 10 stereo dissecting microscope. All specimens were photographed with Canon SX 150 IS digital camera using either polarized light or low angle light to reveal surface details.

Comparisons were made with material from Indian Early Cretaceous flora (Feistmantel, 1879; Jacob & Jacob, 1954; Vishnu–Mittre, 1957; Bose & Jain, 1967; Gupta & Sharma, 1968; Bose & Sukh–Dev, 1971; Bose & Kasat, 1972; Bose, 1974; Maheshwari & Kumaran, 1976; Bose & Bano, 1978; Mahabale & Satyanarayana, 1979; Bose & Banerji, 1984; Srivastava *et al.*, 1984; Sukh–Dev & Rajanikanth, 1988; Pandya *et al.*, 1990) and also with type material available in the repository of the Birbal Sahni Institute of Palaeobotany,

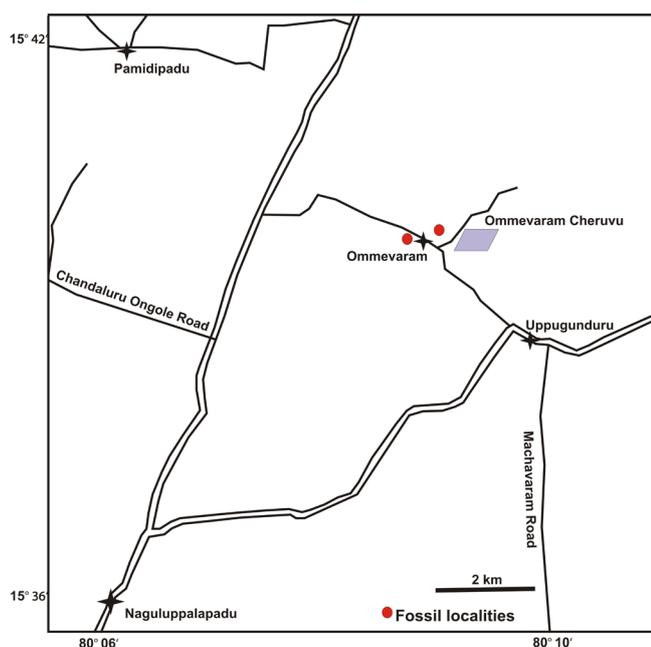


Fig. 1—Map showing fossil locality.

Lucknow. The flora is also compared with species known from Australia (White, 1981; Miller & Lapasha, 1985; McLoughlin, 1996; McLoughlin & Pott, 2009), Antarctica (Halle, 1913; Gee, 1989; Cantrill & Falcon–Lang, 2001), Japan (Oishi, 1936; Kimura & Sekido, 1976; Kimura & Ohana, 1988; Kimura *et al.*, 1991), England (Harris, 1969) South Africa (Anderson & Anderson, 1985), Iran (Barnard & Miller, 1976) and New Zealand (Arber, 1917). The material described is lodged with the BSIP fossil repository.

SYSTEMATICS

Division—SPERMATOPHYTA

Order—BENNETTITALES

Genus—OTOZAMITES (Braun, 1843) Watson & Sincock, 1992

Remarks—The present authors followed Watson and Sincock (1992) and considered this genus as a generalised morphogenus for bennettitalean foliage with asymmetrical pinnae base attached below the middle and with the acroscopic basal angle expanded as an auricle.

Otozamites vemavaramensis Bose & Jain, 1967

(Pl. 2.3)

Description—Pinnate leaf, 6 cm long and 0.4 cm wide, rachis prominent, 0.1 cm wide. Pinnae attached on upper surface of rachis at an angle of about 30°–50°, closely set, sometimes imbricate, 0.2 cm long and 0.2–0.3 cm wide, more or less circular in shape, outer margin curved and apex rounded or obtuse. Veins arising from base, 2–3 in number and spreading laterally.

Specimen No.—BSIP Museum Specimen No. 40186.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The species so far, has been reported only from the Early Cretaceous sedimentary basins of the East Coast, India (Bose & Jain, 1967; Bose, 1974). One specimen has been assigned to this species based on its gross morphological similarities with *O. vemavaramensis* described by Bose and Jain (1967).

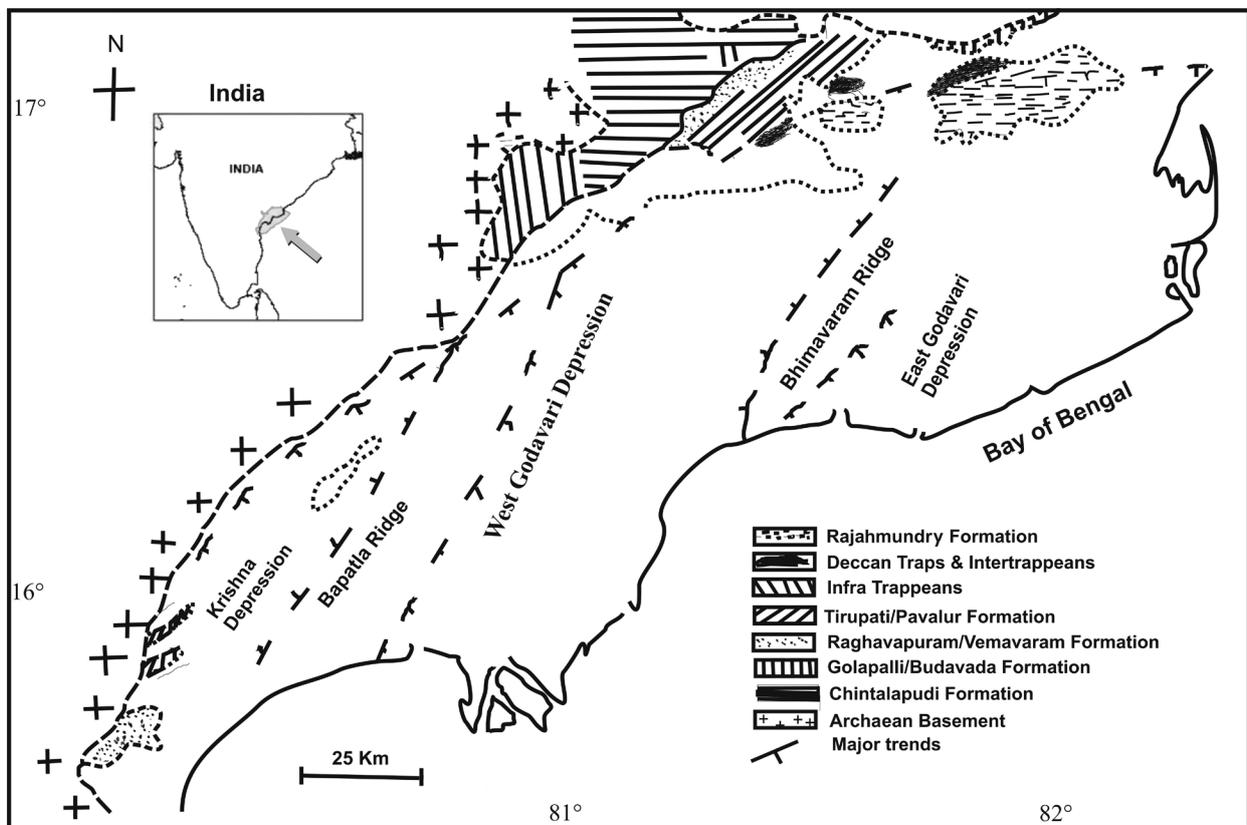


Fig. 2—Geological map of the Krishna Godavari Basin (modified after Arun Kumar, 1986).

Age	Formation	Lithology
Recent		Alluvium
Late Cretaceous	Pavalur	Medium- to coarse-grained clayey and lateritic sandstone
Early Cretaceous	Vemavaram	Shales intercalated with sandstone and pebble conglomerates
Early Cretaceous	Budavada	Sandstone

Table 1—The general lithological succession at study area.

Genus—**DICTYOZAMITES** (Oldham in Oldham & Morris, 1863) Bose & Bano, 1978

Remarks—The genus *Dictyozamites* can be easily distinguished from other members of the Bennettitales by its spectacular nature of reticulate venation. The genus is widely represented in Early Cretaceous deposits of India (Bose & Bano, 1978) and Jurassic–Cretaceous deposits of the world (Vakhrameev, 1991). It is most common in Vemavaram. However, largest number of species was recorded from the Rajmahal Formation.

Dictyozamites feistmantelii Bose & Bano, 1978

(Pl. 1.1, 2)

Description—Leaf pinnate, 2.5–16 cm long and 4–6.5 cm wide, rachis prominent, longitudinally striated and mostly concealed on upper surface by pinnae bases, 0.4–0.5 cm wide, gradually narrowing towards the apex. Pinnae alternate, closely set or slightly sparse, never overlapping, 2–4.7 cm long and 0.6–1 cm wide, arising at an angle of 60°–80°, linear–lanceolate in shape, sometimes falcate, towards middle region almost straight, both acroscopic and basiscopic margins auriculate, middle of the base constricted, margin entire and apex obtuse. Pinnae veins numerous, radiating from base, forking and anastomosing, 4–6 veins present in middle region form 0.4–1 cm long meshes from base to apex, remaining meshes comparatively smaller in size, meshes along the margins are the smallest size and 20–24 veins anastomose in central region of the pinnae.

Specimen Nos.—BSIP Museum Specimen Nos. 40156, 40157, 40158, 40159.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—*Dictyozamites feistmantelii* Bose and Bano (1978) is a common form in Vemavaram (Ommevaram) and it is also reported from all the Early Cretaceous basins of East Coast of India. From the recent collection, four specimens are attributed to this species. All of them are well preserved and one specimen has exceptionally long sized pinnae. These specimens, in their gross morphology, are very close to the specimens described from the East Coast of India by Bose and Bano (1978) and Vagyani and Jamane (1988).

Dictyozamites indicus Feistmantel, 1876

(Pl. 1.9, 16)

Description—Leaf pinnate, 5 cm long and 2 cm wide, rachis striated, 0.2–0.3 cm wide, concealed by pinnae base. Pinnae closely set, slightly overlapping, attached on upper surface of rachis at an angle of 70°, linear–lanceolate, 0.7–1 cm long and 0.4–0.5 cm wide, base asymmetrical, both acroscopic and basiscopic margins auriculate, basiscopic margin sometimes slightly rounded, margin entire, and apex obtuse. Veins diverging from base, forking and forming meshes, meshes are almost equal in size throughout, however, near the basiscopic margin and along margins the size of the

PLATE 1

(Scale 1 cm unless otherwise mentioned)



1. *Dictyozamites feistmantelii*, BSIP Specimen No. 40156.
2. *Dictyozamites feistmantelii*, BSIP Specimen No. 40157.
3. *D. falcatus*, BSIP Specimen No. 40161.
4. *Ptilophyllum acutifolium*, BSIP Specimen No. 40167.
5. *D. falcatus*, BSIP Specimen No. 40162.
6. *Dictyozamites ommevaramensis*, BSIP Specimen No. 40164.
7. *D. falcatus*, pinnae enlarged to show venation pattern (scale 0.5 cm), BSIP Specimen No. 40161.
8. *D. Ommevaramensis*, pinna enlarged to show venation pattern (scale 0.5 cm), BSIP Specimen No. 40164.
9. *D. indicus*, pinna enlarged to show venation pattern (scale 0.5 cm), BSIP Specimen No. 40160.
10. *Ptilophyllum acutifolium*, BSIP Specimen No. 40165.
11. *Brachyphyllum* sp., BSIP Specimen No. 40185.
12. *Ptilophyllum cutchense*, BSIP Specimen No. 40170.
13. *P. rarinervis*, BSIP Specimen No. 40175.
14. *P. rarinervis*, pinnae enlarged to show venation pattern (scale 0.2 cm), BSIP Specimen No. 40175.
15. *P. cutchense*, pinnae enlarged to show venation pattern, BSIP Specimen No. 40170.
16. *Dictyozamites indicus*, BSIP Specimen No. 40160.
17. *Ptilophyllum cutchense*, BSIP Specimen No. 40173.

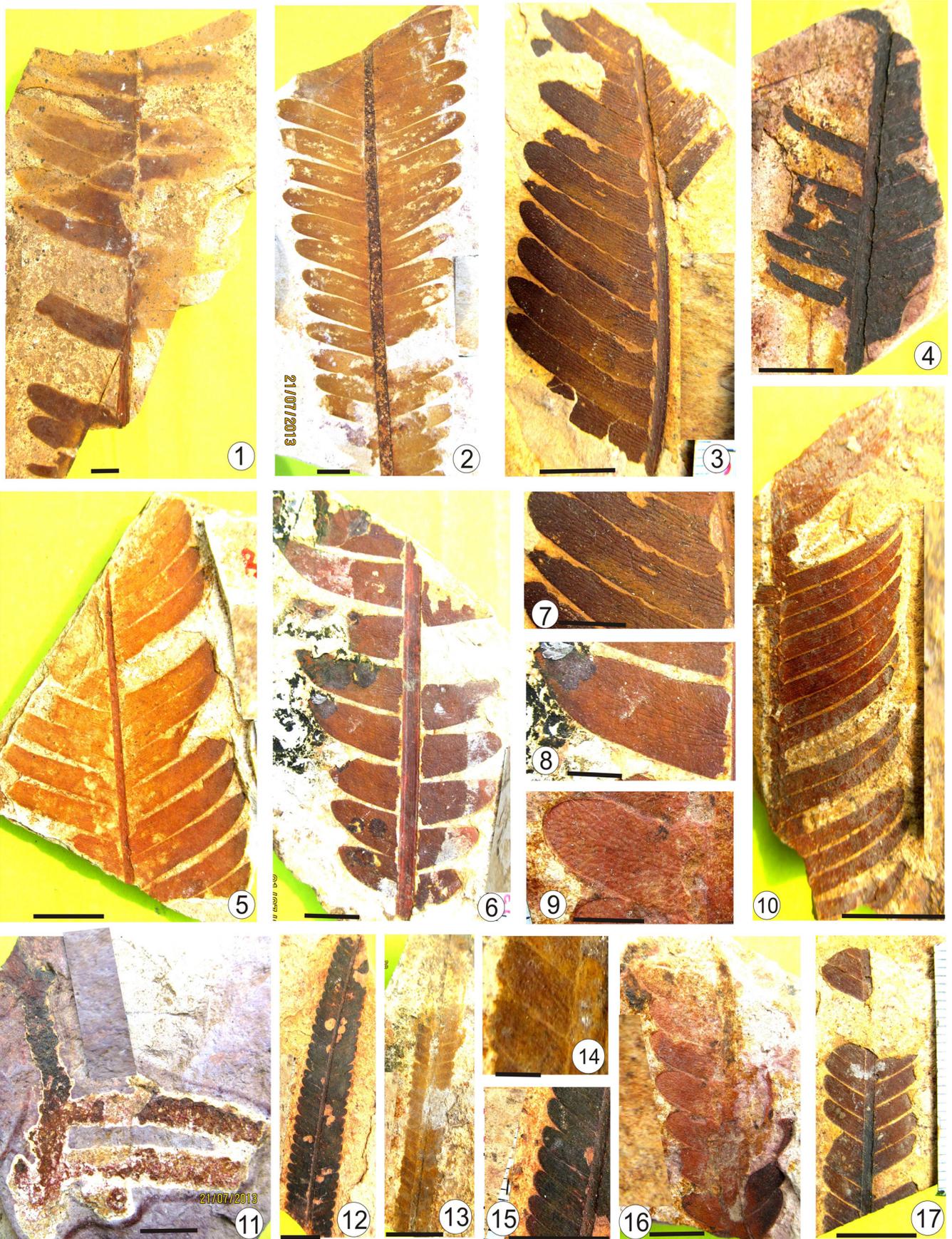


PLATE 1

meshes varies and 9–12 veins anastomose in central region of the pinnae.

Specimen No.—BSIP Museum Specimen No. 40160.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The species is common in the Rajmahal Formation, but in the East Coast basins it is not familiar except for Vemavaram. The above description is based on a single specimen, preserved as impression on hard yellow–purple variegated shale. Except for the lack of cuticular details the well preserved gross morphological characters strongly exhibit its relationship with the specimen from the Rajmahal and Vemavaram described by Bose and Bano (1978).

Dictyozamites falcatus Morris (in Oldham & Morris, 1863)

(Pl. 1.3, 5, 7)

Description—Leaf pinnate, 5–6 cm long and 3–4 cm wide, rachis striated and mostly concealed on upper surface by pinnae bases, 0.1–0.2 cm wide. Pinnae attached to rachis by a minute expanded portion of middle part of lamina, alternate, arising at an angle of 60°–70°, closely set, sometimes imbricate, 1.8–2.5 cm long and 0.3–0.5 cm wide at broadest point, linear–lanceolate, falcate, base asymmetrical, acroscopic basal margin slightly expanded, rounded, weakly auriculate, basiscopic margin extending beyond point of emergence of pinnae, margin entire and apex acute to obtuse. Venation reticulate, 3–5 prominent longitudinal veins arising from point of attachment and running almost up to apex, remaining veins radiating from base and curving towards margin, all veins anastomose, meshes elongate in the middle region of pinnae, rectangular, almost parallel and they are smaller towards margin and pinnae base and 10–14 veins anastomose in central region of the pinnae.

Specimen Nos.—BSIP Museum Specimen Nos. 40161, 40162, 40163.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The species was described for the first time by Oldham and Morris (1863) from Chilgojuri, Amrapara,

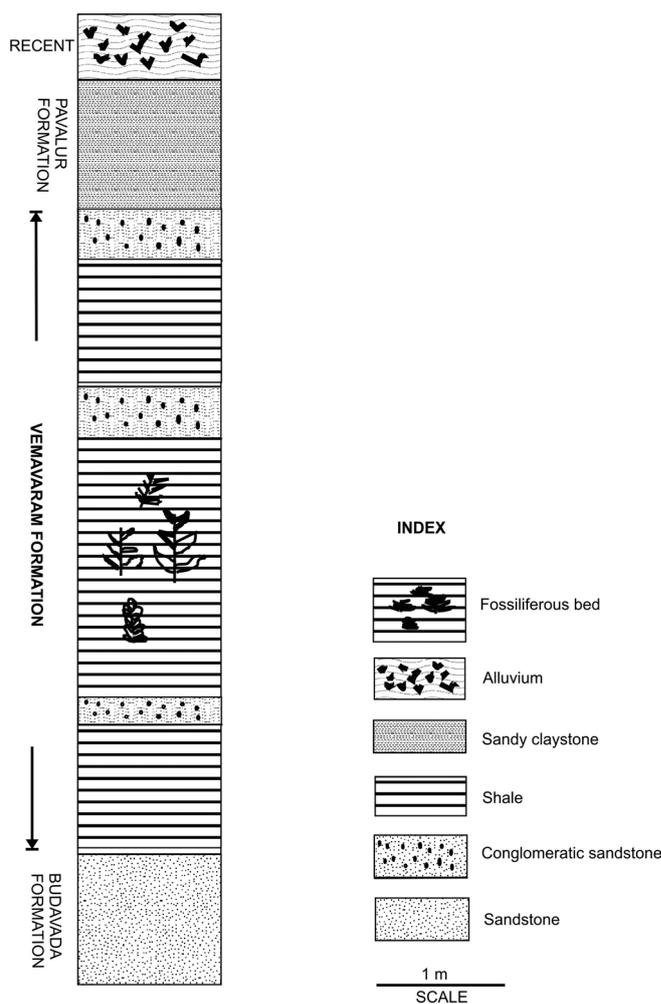


Fig. 3—Lithocolumn of the outcrop section.

Rajmahal Formation. Later, Bancroft (1913) provided little information of its petiole anatomy. The cuticle of the species was studied by Bose and Bano (1978) from one of the exceptionally preserved material of Bose and Kasat (1972) from Amarjola, Rajmahal Formation. Some of the earliest specimens (impressions) from Ommevaram, Vemavaram Formation (Vagyani & Jamane, 1988) and Suddametta, Golapalli Formation (Mahabale & Satyanarayana, 1979) were already placed under this species on the basis of their external features. The present specimens are closely comparable with the specimens described by Bose and Bano (1978) from Chilgojuri, Amarjola and Kasamu, Rajmahal Formation. The

PLATE 2

(Scale 1 cm unless otherwise mentioned)

1. *Ptilophyllum heterophylla*, BSIP Specimen No. 40179.
2. *Ptilophyllum heterophylla*, pinnae enlarged to show venation pattern (scale 0.5 cm), BSIP Specimen No. 40179.
3. *Otozamites vemavaramensis*, BSIP Specimen No. 40186.
4. *Pagiophyllum ommevaramensis*, apical portion of the branch enlarged to show imbricate leaves (scale 0.2 cm), BSIP Specimen No. 40182.
5. *Pagiophyllum ommevaramensis*, BSIP Specimen No. 40182.
6. *Elatocladus loyolii*, BSIP Specimen No. 40189.
7. *Elatocladus loyolii*, apical portion enlarged, BSIP Specimen No. 40189.
8. *Pagiophyllum* sp., BSIP Specimen No. 40181.
9. *Ptilophyllum* cf. *distans*, BSIP Specimen No. 40177.
10. *Brachyphyllum* cf. *sehoraensis*, BSIP Specimen No. 40183.
11. *Ptilophyllum* cf. *distans*, BSIP Specimen No. 40177.
12. *Elatocladus jabalpurensis*, BSIP Specimen No. 40187.



PLATE 2

earlier described specimens of Vemavaram and Golapalli formations differ from the current specimens in having large sized (4.5–4.6 cm long and 0.7–0.9 cm wide) pinnae and more number of veins (17–19) comparatively.

Dictyozamites ommevaramensis sp. nov.

(Pl. 1.6, 8)

Etymology—After the village Ommevaram, from where the specimens are collected.

Holotype—BSIP Museum Specimen No. 40164.

Diagnosis—Leaves pinnate, 7 cm long and 3.5–5 cm wide, pinnae attached to rachis at an angle of 70°, alternate to sub-opposite, conical in shape, width of the pinnae constant throughout rachis, length increases towards apex, margin entire, apex obtuse or bluntly pointed in basal pinnae, sharply pointed in central pinnae, venation reticulate.

Description—Pinnate leaf, 7 cm long and 3.5 cm wide in basal region, 5 cm wide in middle region, rachis is rigid and striated, 0.2 cm wide. Pinnae alternate or sub-opposite, free, arising at an angle of 70°, the size of the pinnae increases from base to apex; at base it is 1.2 cm long and in central region 3 cm, the width of the pinnae is almost constant (0.6–0.7 cm) throughout, pinnae broad at base and narrow towards the tip, conical in shape, slightly falcate, margin entire and apex obtuse or bluntly pointed. Venation reticulate, all veins anastomose forming meshes of equal size in most part of pinnae except near margins where they are smaller in size and 12–16 veins anastomose in central region of the pinnae.

Specimen No.—BSIP Museum Specimen No. 40164.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Comparison—The present species differs from previously published *Dictyozamites* species by its distinct nature of pinnae. It differs from *D. sahnii* Gupta and Sharma (1968) described from the Rajmahal Formation in presence of tapering leaf base, free pinnae base, narrow pinnae, and smaller size of the meshes. *D. ommevaramensis* differs from *D. feistmantelii* Bose and Bano (1978) described from India in having free pinnae, pointed apex and 12–16 areoles in central region of the pinnae. *D. mkuziensis* Anderson and Anderson (1985) known from southern Africa resembles with the present species in its external appearance but differs in smaller size and bluntly acute apex. *D. tateiwae* Oishi (1936) figured from Japan shows somewhat close resemblance in its pinnae shape and appearance but differs in having uniform pinnae throughout the rachis and size of the meshes is also bigger. *D. auriculatus* Kimura and Sekido (1976) from Japan has bigger pinnae and has different venation pattern and moreover, the nature of the apex is not known.

Genus—**PTILOPHYLLUM** (Morris in Grant, 1840) Bose & Kasat, 1972

Remarks—*Ptilophyllum* differs from the other bennettitaleans in having decurrent basisopic margin (Harris, 1969; Watson & Sincock, 1992). The genus has been reported from all the Early Cretaceous sedimentary basins of India and Middle Jurassic–Early Cretaceous sedimentary basins of most parts of the world (Vakhrameev, 1991). Recent reports of the genus from the Oligocene sedimentary basins of Australia by McLoughlin *et al.* (2011) indicate that it survived even after K–T extinction event.

Ptilophyllum acutifolium (Morris in Grant) Bose & Kasat, 1972

(Pl. 1.4, 10)

Description—Pinnate leaf, 3–5.2 cm long and 2.2–3 cm wide, lamina lanceolate with prominent rachis up to 0.3 cm wide, partially covered by pinnae base. Pinnae arising from rachis at an angle of 50°–70°, attached by entire base, closely set, pinnae in the central part of the leaf 5–5.5 cm long and 2.2–3 cm wide, linear–lanceolate to elongate, narrow, falcate, base asymmetrical, acrosopic margin slightly rounded and basisopic margin decurrent, margin entire and apex acute. Veins arise from entire base, 6–8 in number, more or less parallel and forked or unforked.

Specimen Nos.—BSIP Museum Specimen Nos. 40165, 40166, 40167, 40168, 40169.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The present description is based on five specimens preserved incompletely, only the central portion of the leaf was available with enough characters to identify at species level. The specimens described here show similar gross morphological features figured by Bose and Kasat (1972). The species is common in all the Early Cretaceous basins of India and it also been reported from the other Gondwanic continents (Arrondo & Petriella, 1980; Longobucco *et al.*, 1985; McLoughlin, 1996). The species from South America and Australia tend to have longer pinnae than the Indian specimens (McLoughlin, 1996).

P. cutchense (Morris in Grant) Bose & Kasat, 1972

(Pl. 1.12, 15, 17)

Description—Pinnate leaf, 5–8 cm long and 1–1.3 cm wide in central part of leaf, attenuating towards the base and apex of the leaf, rachis slender, 0.1–0.15 cm wide, concealed by pinnae base. Pinnae attached on upper surface of rachis by

its entire base at an angle of 50°–70°, closely set or imbricate, linear–lanceolate, 0.6–0.7 cm long and 0.1–0.2 cm wide, acroscopic margin round and basiscopic margin slightly decurrent, margins straight to slightly falcate and apex obtuse. Veins arising from entire base, 4–6 in number, running parallel to the margin and forking at all levels.

Specimen Nos.—BSIP Museum Specimen Nos. 40170, 40171, 40172, 40173.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The above description is based on four specimens; two of which are preserved most of their length, but complete leaf is not preserved. Base of the pinnae can be observed in two specimens and it is round and decurrent. The specimens are similar to specimens described by Bose and Kasat (1972). The species got wide range of distribution during Early Cretaceous sedimentary basins of India. The specimens attributed to the comparative form of this species from Toyora Group, south west Japan and Shishiori Group (Late Jurassic) in the outer zone of northeast Japan are having small fronds with pinnae size greater than the Indian specimens (Kimura & Ohana, 1987; Kimura *et al.*, 1991).

P. rarinervis (Feistmantel) Bose & Kasat, 1972

(Pl. 1.13, 14)

Description—Pinnate leaf, 5.8–6.8 cm long and 0.6–0.8 cm wide, substance of lamina fairly thin, rachis slender, 0.1 cm wide. Pinnae attached to rachis at an angle of 60°, alternate, closely set, 0.35–0.45 cm long and 0.1 cm wide, base asymmetrical, acroscopic margin round, basiscopic margin straight or slightly decurrent; basiscopic margin of pinnae overlapped by acroscopic margin of pinnae below, margin entire and apex bluntly acute or rounded. Veins 2–4 in number and divide at all levels.

Specimen Nos.—BSIP Museum Specimen Nos. 40174, 40175.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The present species so far, has been reported from the Vemavaram (Ommevaram), Vemavaram Formation (Bose & Kasat, 1972), Sudda Metta, Raghavapuram, Raghavapuram Formation (Bose & Kasat, 1972; Mahabale & Satyanarayana, 1979), Karai, Sivaganga Formation (Sukh–Dev & Rajanikanth, 1988) and Onthea, Rajmahal Formation (Bose & Kasat, 1972). In the original holotype, the number of veins are restricted to 2–3, but the present specimens have 2–4 but mostly 3 veins. Two specimens presently described

show gross morphological resemblance with the specimens described by Bose and Kasat (1972).

Ptilophyllum cf. distans (Feistmantel) Jacob & Jacob, 1954

(Pl. 2.9, 11)

Description—Pinnate leaf, 2.5–7 cm long and 6–2 cm wide at middle of leaf, major part of the lamina uniformly broad, leaf as a whole linear–lanceolate with a prominent rachis up to 0.2–0.3 cm wide, longitudinally striated. Pinnae attached to rachis at an angle of 50°–70°, pinnae in the central part of the leaf 0.8–1 cm long and 0.3–0.4 cm wide, linear, slightly recurved apically, closely set and apex bluntly acute. Veins arising from base, running parallel to the margins, 6–8 in number and forking once or twice.

Specimen Nos.—BSIP Museum Specimen Nos. 40176, 40177, 40178.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—*Ptilophyllum distans* was earlier described from the Jabalpur Formation, Sehora (Jacob & Jacob, 1954), Kutch Formation, Trambau (Bose & Kasat, 1972) and Gangapur Formation, Butarmal Nala (Sukh–Dev & Rajanikanth, 1988). The gross morphology of specimens here described broadly conform to *P. distans* figured by Bose and Kasat (1972) and Bose and Banerji (1984) but the lack of cuticular details only allowed assignment to comparative form status. The species is being reported for the first time from this locality.

Ptilophyllum heterophylla sp. nov.

(Pl. 2.1, 2)

Etymology—After the heterogeneous nature of the pinnae.

Holotype—BSIP Museum Specimen No. 40179.

Diagnosis—Leaf pinnate, slender, 5.5 cm long and 0.7 cm wide, tapering towards the base and apex, rachis 0.1 cm wide, uniform, heterogeneous pinnules attached on either side of the rachis, macropinnules on one side and micropinnules on other side, veins few and forked or unforked.

Description—Pinnate leaf, slender, 5.5 cm long and 0.7 cm wide, linear lanceolate in shape, tapering towards the base and apex, rachis slender and about 0.1 cm throughout the leaf. Pinnae attached on the upper surface of rachis by their entire base, alternate, closely set, imbricate, linear in shape. The variability of the pinnules is distinguishable with two types of pinnules one on each side of the rachis. On one side of the rachis pinnules are 0.35–0.5 cm long and more than 0.1 cm wide can be referred as “macropinnules”, arising

at an angle of 50°–60°, whereas, on the other side they are 0.1–0.2 cm long and less than 0.1 cm wide and referred as “micropinnules”, arising at an angle of 30°–40°, margin entire and apex obtuse. Veins arising from base, 3–4 in number, run parallel to the margins, nature of forking of veins very distinct in macro- and micro-pinnules. Generally, basicopic (lower) veins of the macro-pinnules are once forked after the emergence from base, while rest of the veins are unforked; whereas, micro-pinnules are mostly unforked.

Specimen Nos.—BSIP Museum Specimen Nos. 40179, 40190.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Comparison—The present species can be easily separated from the known species of *Ptilophyllum* based on their heterogeneous nature of the pinnules. In general morphology and number of veins it is similar to *P. rarinervis* (Feist.) Bose and Kasat (1972) and *P. indicum* Jacob and Jacob (1954) described from India. However, in the two species pinnule is homogeneous with different venation pattern. In the nature of venation, it is comparable with *P. nipanica* Vishnu-Mittre (1957) known from the Rajmahal Formation, but differs in rest of the features. The present species closely resembles *P. choshiensis* Kimura *et al.* (1991) from the Early Cretaceous Choshi Group in external appearance, but differs in the presence of heterogeneous and small size pinnules with distinct venation pattern. *P. heterophylla* differs from *P. pectin* (Philips) Harris (1969) recorded from the Middle Jurassic of Yorkshire and *P. vasekghahense* Barnard and Miller (1976) known from the Middle Jurassic of Iran, in having heterogeneous pinnules.

Order—CONIFERALES

Genus—PAGIOPHYLLUM (Heer 1881) Harris, 1979

Remarks—Heer (1881) erected the form genus *Pagiophyllum* for the sterile foliage of Araucarian like conifers. Later Seward (1919) slightly modified the diagnostic characters of this form genus as “an artificial genus reserved for vegetative branches of conifers possessing foliage like that of *Araucaria excelsa* and allied species, which in the absence of cones cannot safely be referred to *Elatides* or other genera based in part at least on strobilar characters”. Subsequently, Harris (1979) simplified the definition “leaf is about as broad as its basal cushion and the length exceeds the width of the leaf”.

Pagiophyllum ommevaramensis sp. nov.

(Pl. 2.4, 5)

Etymology—After the village name Ommevaram, from where the specimen collected.

Holotype—BSIP Museum Specimen No. 40182.

Diagnosis—Shoot regularly branched at an angle of 40°–50°. Leaves spirally arranged, diverging at an angle of 40°–50°, measuring 0.3–0.4 cm long 0.1–0.2 cm wide, rhomboidal, sometimes falcate, base keeled, decurrent, concealed by apices of leaves lying below, margin entire, apex acute or bluntly pointed and free part of the leaf directing forward.

Description—Shoot regularly branched, branches emerging at an angle of 40°–50° with consistency in the branch spacing. Leaves univeined, born in close helix, arising from axis at an angle of 40°–50°, measuring 0.3–0.4 cm long and 0.1–0.2 cm wide, mostly rhomboidal in shape, sometimes falcate, base keeled, decurrent, and mostly concealed by apices of leaves lying below, margin entire and apex acute or bluntly pointed. Leaves similar in size throughout the axis except at apical portion where comparatively smaller, spreading forward. Branches end in enclosed imbricate leaves.

Specimen No.—BSIP Museum Specimen No. 40182.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Comparison—*Pagiophyllum ommevaramensis* can be easily separated from other species of *Pagiophyllum* on the basis of correlation between the branch angle and leaf angle. The angle ranges from 40°–50° and shows consistency in branch spacing. The branch angle resembles with *P. chawadensis* Bose and Banerji (1984) described from Gadhsisa and Chawad River, Kutch Formation. However, it differs in leaf angle and size. In having almost similar range of leaf size, *P. ommevaramensis* is comparable with *P. sherensis* Maheshwari and Kumaran (1976) known from Sehora, Jabalpur Formation, but differs in other characters such as branching pattern, leaf arrangement and insertion angle. *P. grantii* Bose and Banerji (1984) is closely comparable with the present species in the arrangement of branches and leaf insertion angle, but differs in leaf size. *P. indicum* Srivastava *et al.* (1984) known from Jabalpur Formation, Sher River differs from the present species in its reduced size of leaves from base to apex of axis, faint longitudinal striations on the surface of leaf and appressed nature of leaves to axis. *P. marwarensis* Bose and Sukh-Dev (1971) described from Bansa, Jabalpur Formation differs by its longer leaves and lanceolate shape. The tightly enclosed imbricate leaves at the branch tips of *P. ommevaramensis* show close relationship with *P. amanguanus* McLoughlin and Pott (2009) from Western Australia. However, *P. ommevaramensis* differs in other characters. The lateral branches in *P. ommevaramensis* are closely spaced and do not overlap but maintain a consistent orientation suggesting that they were arrayed in ranks extending laterally on each side of the main axis. Similar architecture is evident in a range

of modern conifers from different families, e.g. *Araucaria heterophylla* (Araucariaceae) and *Dacrydium cupressinum* (Podocarpaceae) (McLoughlin & Pott, 2009).

Pagiophyllum sp.

(Pl. 2.8)

Description—Twig repeatedly branched, branches emerging at an angle of 70°–80° at basal region and 40°–50° at apical region. Leaves spirally arranged, diverging at an angle of 40°–55°, measuring 0.3–0.4 cm long and 0.1–0.2 cm wide, leaves closer to apical region are smaller in size and less spreading or appressed, deltoid–ovate in shape, broad at base and gradually narrowing towards tip, base keeled, mostly concealed by apices of leaves lying below, margin entire and apex acute or pointed.

Specimen Nos.—BSIP Museum Specimen Nos. 40180, 40181.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—Two specimens are assigned to *Pagiophyllum* sp. One of them is (BSIP 40180) poorly preserved without any branching pattern, whereas the second one (BSIP 40181) is well preserved with repeated branching pattern. The latter has some similarities with *P. grantii* described from Trambau, Kutch Formation, by Bose and Banerji (1984). The other one shows close affinity with *P. morrisii* from Chawad River, Kutch Formation described by Bose and Banerji (1984). However, the two species of Kutch are solely based on their cuticular details.

Genus—BRACHYPHYLLUM Brongniart, 1828

Remarks—The present authors followed Harris (1979) and considered the genus as a generalised morpho-type for conifer foliage with short broadly attached leaves.

Brachyphyllum cf. *sehoraensis* Bose & Maheshwari 1973

(Pl. 2.10)

Description—Shoot irregularly branched, branches emerging at an angle of 30°–50° rarely at 80°. Leaves spirally arranged, attached to axis at an angle of 40°–50°, thick, mostly rhomboidal in shape, keeled, 0.2 cm long and 0.1 cm wide, base cushioned and rhomboidal in shape, margin entire, apex bluntly acute and free part of the leaves mostly leaning towards lateral side.

Specimen Nos.—BSIP Museum Specimen Nos. 40183, 40184.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—The early reports of the species are from the Jabalpur Formation, Sehora (Bose & Maheshwari, 1973) and Gangapur Formation, Butarmal Nala (Sukh–Dev & Rajanikanth, 1988). The specimens described from the Gangapur Formation are isolated, fragmentary leaves and differ from the present specimens in leaf size. The present species exhibits close morphological similarities with that of *B. sehoraensis* Bose and Maheshwari (1973) described from the Jabalpur Formation, Sehora.

Brachyphyllum sp.

(Pl. 1.11)

Description—Shoot about 0.3–0.4 cm wide, irregularly branched, branches arising at right angle to the main axis, leaves arranged in a loose helix, attached to the axis by leaf base cushion at an angle of 25°–35°, rhomboidal shape, 0.2 cm long and 0.1 cm wide, margin entire and apex acute.

Specimen No.—BSIP Museum Specimen No. 40185.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—Though the size of the leaves is comparable that of *B. sehorensis* Bose and Maheshwari (1973) described from the Jabalpur Formation, Sehora and *B. brevifolia* Srivastava *et al.* (1984) from the Jabalpur Formation, Bansa, the rest of the characters specially angle of leaf divergence largely differ from the above two species. Moreover, lack of cuticular information makes it difficult to assign it to a particular species.

Genus—ELATOCLADUS (Halle, 1913) Harris, 1979

Remarks—Halle (1913) created an artificial genus to avoid the problem of placing sterile conifer foliage that could not be placed in any genera where fertile material was known. “Spirally inserted dorsiventrally flattened sterile foliage that could not be assigned to better defined genera should be attributed to this genus”. Seward (1919) slightly modified the definition, using it for conifer shoots with spreading leaves. Later, Florin (1958) incorporated cuticular information in the diagnosis and considered it as ‘natural’ genus. Subsequently, Harris (1979) emended this form genus and excluded the morphology of the leaf base as diagnosis character, thus incorporating specimens previously assigned to both *Elatocladus* and *Rissikia* Townrow. It is worthwhile to mention that, however, some workers (Anderson & Anderson 1989) have maintained a distinction between these genera

Depression Stratigraphic Unit	Krishna		Godavari	
	Bud	Vem	Gol	Rag
Plant Taxa				
Pteridophytes				
<i>Cladophlebis medlicottiana</i> (Oldham) Pascoe	–	–	–	+
<i>Cladophlebis</i> cf. <i>longipennis</i> Seward	–	–	+	–
<i>Cladophlebis</i> sp.	–	+	+	+
<i>Gleichenia bosahii</i> (Bose) Pant & Srivastava	–	–	+	–
<i>G. nordenskioldii</i> Heer	–	–	–	+
<i>Marattiopsis macrocarpa</i> (Oldham & Morris) Seward & Sahni	–	–	+	+
<i>Onychiopsis psilotoides</i> (Stopes & Webb) Ward	–	–	–	+
<i>Todites indicus</i> (Oldham & Morris) Bose & Sah	–	–	+	–
<i>Sphenopteris specifica</i> (Feistmantel) Roy	–	–	+	–
<i>Sphenopteris</i> sp.	–	+	+	–
Gymnosperms				
Pteridosperms				
<i>Thinnfeldia feistmantelii</i> Lele	–	+	–	–
<i>Thinnfeldia</i> sp.	–	+	–	–
<i>Pachypteris indica</i> (Oldham & Morris) Bose & Roy	–	+	+	+
Cycadales				
<i>Morrisia dentata</i> (Rao & Jacob) Bose & Banerji	–	+	–	+
<i>Taeniopteris spatulata</i> McClelland	+	+	+	+
Bennettitales				
<i>Anomozamites amarjolense</i> Sharma <i>et al.</i>	–	+	–	–
<i>A. fissus</i> Feistmantel	–	+	–	–
<i>A. jungens</i> Feistmantel	–	+	–	–
<i>Bucklandia</i> sp.	–	–	+	+
<i>Cycadolepis</i> sp.	–	+	–	–
<i>Dictyozamites falcatus</i> Medlicott & Blanford	+	+	–	+
<i>D. feistmantelii</i> Bose & Bano	+	+	+	+
<i>D. indicus</i> Feistmantel	+	+	+	–
<i>D. ommevaramensis</i> sp. nov.	–	*	–	–
<i>D. sahnii</i> Gupta & Sharma	–	–	–	+
<i>Otozamites acutifolius</i> Feistmantel	–	+	–	–
<i>O. bengalensis</i> Schimper	–	+	–	+
<i>O. exhislopi</i> Bose	–	+	–	–
<i>O. gondwanensis</i> Bose	–	+	–	–
<i>O. imbricatus</i> Feistmantel	–	+	–	–
<i>O. vemavaramensis</i> Bose & Jain	–	+	–	+
<i>Otozamites</i> sp.	+	+	–	+
<i>Pterophyllum braunianum</i> Goppert	–	–	+	–
<i>P. distans</i> Morris	+	–	–	+
<i>P. footeanum</i> Feistmantel	–	+	–	–
<i>P. incisum</i> Sahni & Rao	–	+	–	–
<i>P. kingianum</i> Feistmantel	–	–	+	–
<i>P. morrisianum</i> Oldham	–	–	+	–
<i>Pterophyllum</i> sp.	–	+	+	–
<i>Ptilophyllum acutifolium</i> Morris	+	+	+	+
<i>P. cutchense</i> Morris	–	+	+	+
<i>P. deodikarii</i> Mahabale & Satyanarayana	–	–	+	–

<i>P. heterophylla</i> sp. nov.	–	+	–	–
<i>Ptilophyllum</i> cf. <i>distans</i> (Feistmantel) Jacob & Jacob	–	*	–	+
<i>Ptilophyllum</i> cf. <i>institaallum</i> Bose	–	–	+	–
<i>Ptilophyllum</i> cf. <i>amarjolense</i> Bose	–	–	+	–
<i>Ptilophyllum</i> cf. <i>gladiatum</i> Bose & Sukh–Dev	–	–	+	–
<i>Ptilophyllum</i> cf. <i>horridum</i> Roy	–	–	+	–
<i>Ptilophyllum</i> cf. <i>jabalpurensis</i> Jacob & Jacob	–	–	+	–
<i>P. rarinervis</i> (Feistmantel) Bose & Kasat	–	+	–	+
<i>P. tenerrimum</i> Feistmantel	–	–	+	–
<i>Williamsonia blandfordii</i> Feistmantel	–	–	+	–
<i>W. indica</i> Seward	–	–	+	–
<i>Zamites</i> sp.	–	+	–	–
Ginkgoales				
<i>Ginkgocycadophytus deterius</i> var. <i>majus</i> (Balme) Sukh–Dev	–	+	–	+
<i>Ginkgo crassipes</i> Feistmantel	–	–	–	+
<i>G. feistmantelii</i> Bose & Sukh–Dev	–	–	–	+
Coniferales				
<i>Araucarites cutchensis</i> Feistmantel	–	+	+	+
<i>A. fibrosa</i> Sukh–Dev & Bose	–	–	+	–
<i>A. macropteris</i> Feistmantel	–	–	+	+
<i>A. minutus</i> Bose & Maheshwari	–	+	–	–
<i>Brachyphyllum expansum</i> (Sternburg) Seward	–	+	+	–
<i>B. feistmantelii</i> (Halle) Sahn	–	+	–	+
<i>B. regularis</i> Borkar & Chiplonkar	–	–	+	–
<i>B. rhombicum</i> Feistmantel	–	–	–	+
<i>Brachyphyllum</i> sp.	–	*	+	+
<i>Cheirolepis</i> cf. <i>muensterii</i> Schimper	–	–	+	–
<i>Conites sessilis</i> Sahn	–	+	–	+
<i>Conites</i> sp.	–	+	–	+
<i>Desmiophyllum indicum</i> Sahn	–	+	–	–
<i>Echinostrobus</i> sp.	–	–	+	–
<i>Elatocladus confertus</i> Seward & Sahn	–	–	+	+
<i>E. jabalpurensis</i> (Feistmantel) Sahn	–	+	–	–
<i>E. loyolii</i> sp. nov.	–	*	–	–
<i>E. plana</i> (Feistmantel) Seward	–	+	+	+
<i>E. vemavaramensis</i> Pandya <i>et al.</i>	–	+	–	–
<i>Elatocladus</i> sp.	–	+	–	–
<i>Pagiophyllum feistmantelii</i> Halle	–	+	–	–
<i>P. gollapallensis</i> Pandya & Sukh–Dev	–	–	+	–
<i>Pagiophyllum</i> cf. <i>grantii</i> Bose & Banerji	–	–	+	–
<i>Pagiophyllum</i> cf. <i>marwarensis</i> Bose & Sukh–Dev	–	–	–	+
<i>P. ommevaramensis</i> sp. nov.	–	*	–	–
<i>Pagiophyllum</i> sp.	–	+	–	–
<i>Torreyites constricta</i> (Feistmantel) Seward & Sahn	–	+	–	–

Table 2—Showing the distribution of plant taxa in Early Cretaceous sequences of Krishna–Godavari Basin.

Legend: Bud: Budavada, Vem: Vemavaram, Gol: Golapalli and Rag: Raghavapuram
 – Absent, + Present, * Added in this study.

based on the presence of contracted leaf base in *Elatocladus* and decurrent base in *Rissikia*. The diagnostic characters currently followed by palaeobotanists in general are that of Harris (1979)—“Fossil conifer shoots bearing elongated, dorsiventrally flattened leaves with a single vein, leaves divergent from the stem”. The same is followed here.

Elatocladus loyolii sp. nov.

(Pl. 2.6, 7)

Etymology—After the Andhra Loyola College, Vijayawada, where the first author studied.

Holotype—BSIP Museum Specimen No. 40189.

Diagnosis—Shoots bearing long linear leaves, spirally inserted at an angle of 70°–80° at basal and central regions, 40°–50° at terminal position, 2–2.5 cm long and 0.1 cm wide, base twisted. The species mainly diagnosed on the basis of its narrow, long foliage and variations in the degree of insertion of leaves at basal and terminal position.

Description—Leafy axes up to 5 cm long, 0.1 cm wide, bearing spirally spreading leaves, inserted at angle of about 70°–80° at basal and central region, 40°–50° at terminal position. Leaves are very narrow and linear measuring 2–2.5 cm long and 0.1 cm wide, spreading sideways at base and central position, forward at terminal position, base decurrent and twisted. Leaves possess single mid vein running from base to apex, margin entire and apex acuminate.

Specimen Nos.—BSIP Museum Specimen Nos. 40188, 40189, 40191, 40192.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Comparison—The foliage is readily distinguished from all the other species of *Elatocladus* in presence of narrow, long leaves and variation in the insertion angle of leaves, at basal and terminal position. *E. loyolii* closely resembles with *E. longifolia* Borkar and Chiplonkar (1973) from Kathiawar, Kutch Formation in having long foliage, but it differs from the latter in the absence of scaly leaves. *E. vemavaramensis* Pandya *et al.* (1990) differs from the present species in its thick and stout, small leaves (0.4–0.6 cm long) with thick midrib. *E. linearis* Cantrill and Falcon–Lang (2001) known from Antarctica differs from the present species in uniform leaf insertion angle, persistence of mid vein just below the leaf apex. *E. giginensis* McLoughlin (1996) described from Western Australia shows some similarities with *E. loyolii* in its leaflet size and insertion angle. However, *E. giginensis* shows uniform insertion angle (40°–90°) from the base to apex of the axis, moreover, the base is constricted and apex is round. *Rissikia talbragarensis* White (1981) has either substantially longer or broader leaves with regular insertion angle not evident in present species. Non–Gondwanan species

of *Elatocladus* are more readily distinguishable on gross leaf morphology (Miller & Lapasha, 1985; Kimura & Ohana, 1988; Kimura *et al.*, 1991)

Elatocladus jabalpurensis (Feistmantel) Sahni, 1928

(Pl. 2.12)

Description—Length of the available specimen is 1.2 cm and width is 0.6 cm, leaves spirally disposed, generally attached at an angle of 70°–80°, linear–lanceolate in shape, typically 1 cm long and 0.1 cm wide, base constricted, slightly decurrent, margin entire and apex acute. Midrib distinct, runs from base to apex.

Specimen No.—BSIP Museum Specimen No. 40187.

Locality—Ommevaram (Vemavaram), Prakasam District, Andhra Pradesh, India.

Horizon—Vemavaram Formation.

Age—Early Cretaceous.

Remarks—In gross morphology, the specimen from Vemavaram is comparable with specimens figured by Sahni (1928) and Bose and Banerji (1984) from India.

DISCUSSION

The macro–flora from the Early Cretaceous sequences of Vemavaram Formation is characterised by rich assemblage of Bennettitalean–Coniferous association (Table 2 and Fig. 4). Pteridophytes are hardly represented except for *Cladophlebis* sp. and *Sphenopteris* sp. The plant group such as pteridosperms consists of two genera namely, *Thinnfeldia* and *Pachypteris* with two and one species respectively. The bennettitaleans are represented by members of *Anomozamites* (3 spp.), *Cycadolepis* (1 sp.), *Dictyozamites* (4 spp.), *Otozamites* (7 sp.), *Pterophyllum* (3 sp.), *Ptilophyllum* (5 spp.) and *Zamites* (1 sp.). The members of conifers constitute

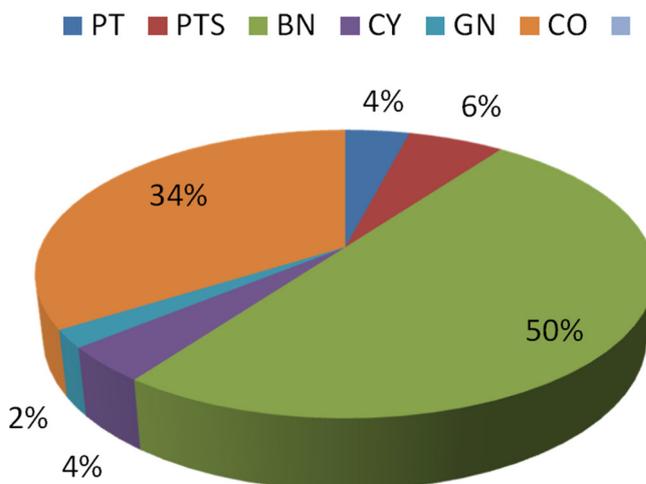


Fig. 4—Showing the diversity of plant groups in Vemavaram Formation.

Araucarites (2 spp.), *Brachyphyllum* (3 spp.), *Conites* (2 spp.), *Desmiophyllum* (1 sp.), *Elatocladus* (5 spp.), *Pagiophyllum* (3 spp.) and *Torreyites* (1 sp.). Members belong to Cycadales and Ginkgoales are scarce. The Cycadales include two genera, namely *Morrisia* and *Taeniopteris* with one species each whereas, the Ginkgoales include *Ginkgocycadophytus* with a single species.

The macro-flora from the Early Cretaceous sequences of Vemavaram is broadly similar to the Early Cretaceous flora of the Budavada (Krishna Depression), Golapalli and Raghavapuram formations (Godavari Depression) of Krishna Godavari Basin. Together, they can be referred as Krishna–Godavari basinal flora (KGF). This KGF is comparable to floras of western India such as Kutch Basin. The relative distribution of floral elements is subjected to the depositional and taphonomic constraints (Spicer, 1991). The similarities of KGF and Kutch flora indicate the existence of coeval floras with some local/regional elements. The rich composition of Bennettitalean–Coniferous association indicates that the flora was probably growing on drained and relatively dry slopes gently descending towards the sea (Vakhrameev *et al.*, 1970).

The micro-flora represents relative abundance of gymnospermous (saccate and non-saccate) pollen as well as pteridophytic spores (Ramanujam, 1957; Kar & Sah, 1970; Venkatachala & Sinha, 1986). The pteridophytic spores are represented by Schizaeaceae, Osmundaceae, Cyatheaceae, Lycopodiaceae, Selaginellaceae, Matoniaceae and Gleicheniaceae. The presence of pteridophytic and non-saccate spore–pollen assemblage designates swampy environments whereas, phytoplankton and foraminifera indicate shallow marine palaeoenvironments (Venkatachala & Sinha, 1986). The overall distribution of macro–and micro–flora including marine invertebrates, phytoplankton and foraminifera indicate a shallow marine swampy setting (Spath, 1933; Arun Kumar, 1986; Venkatachala & Sinha, 1986).

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