THE SIVAGANGA FORMATION : FOSSIL FLORA AND STRATIGRAPHY

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Abstract

The present paper deals with morphotaxonomic studies of the fossil flora from the Sivaganga Formation, Tamil Nadu. In this floral assemblage the Cycadophytes are dominant, conifers are quite common and pteridophytes have less representation. The pteridosperms are rare. This assemblage comprises the genera *Equisetites*, *Cladophlebis*, *Sphenopteris*, *Taeniopteris*, *Anomozamites*, *Ptilophyllum*, *Dictyozamites*, *Elatocladus*, *Brachyphyllum* and *Araucarites* in which two new species *Sphenopteris tiruchirapalliense* and *Brachyphyllum therani-ense* are recorded. The present floral finding along with other related evidences suggest an Early Cretaceous age for the Sivaganga Formation.

Introduction

The Mesozoic Gondwana exposures in the East-Coast of India occur in isolated patches extending from Athgarh Sandstone, Cuttack District, Orissa (Mahanadi Basin) to Sivaganga sediments in the Ramanathapuram District, Tamil Nadu, (Cauvery Basin). Most of these exposures have yielded fairly good micro-and mega-plant fossils; the Tirupati, Satyavedu, Budavada and Pavalur beds are floristically less known. The age of these East Coast Gondwanas is debatable. Therefore, in the present study the plant fossils belonging to Sivaganga Formation (Therani beds) have been taken up for systematic study so as to know their significance in palaeophytogeography, biostratigraphy and in the determination of age of these sediments.

The Therani sediments occur as narrow outcrops along the western edge of the marine Upper Cretaceous of Cauvery Basin and stretch over a distance of about thirty kilometres in north-south direction in five or six isolated patches in the Tiruchirapalli District, Tamil Nadu. Blanford (1862) identified the Uttatur plant beds exposed near the villages Uttatur (11°04′ : 78°55′) and Therani (11°06′ : 78°52′). Later these two outcrops and some others were studied by Foote (1878). The Uttatur plant beds and Therani (Terani) plant beds terms were later used in general. However, Acharyya, Singh and Ghosh (1977) included the Uttatur and Therani beds under Sivaganga Formation.

Geology—The Mesozoic Gondwanas in the Therani area are overlain by the Upper Cretaceous marine Uttatur sequence and underlain by the gneissic rocks. The important outcrops in the area are at one km east of Uttatur Village (11°01′ : 78°51′), near Therani Village (11°06′ : 78°52′) and east of Karai (11°08′ : 78°53′), where the clay deposits have yielded plant fossils. This clay deposit is found wedged between the charnechiktes along the western margin and gypsum clays along the eastern margin. The Therani clay deposit has an east-west strike and dip in a northerly direction at 20°-30°. It consists of alternating beds of brown cloured fire clay, ferruginous clay and ferruginous sandstones. The thickness of the clay beds vary from a few stone beds. The colour of clay is generally tan but frequently the ferruginous impurities impart rusty stains of deep red and yellow

colour. Predominantly white and ash grey clays with subordinate ferruginous and argillaceous sanstones constitute the main lithological character of Therani beds.

Faunal evidences—Mamgain, Sastry and Subbaraman (1973) recorded ammonites, such as *Gymnoplites* cf. *simplex* Spath, *Pascoites* cf. *crassus* Spath and ? *Inocemus* sp. from the Therani beds. From the subsurface Early Cretaceous sediments of the Sivaganga beds Venkatachala (1977) reported *Ammodiscus cretaceous*, *Ammobaculites humei*, *Spiroplectammina* sp., *Haplophragmoides sluzari* and *Bathysiphon taurinensis*. Arenaceous foraminifera like *Ammobaculites*, *Ammodiscus*, *Bathysiphon*, *Haplophragmoides* and *Trachammina* were recorded by Banerji and Sastry (1979). Banerji (1982) reported some arenaceous foraminifera from the samples belonging to the Upper Member (Early Cretaceous) in Sivaganga area which include *Lituola* sp., *Miliammina* sp., *Pelosina* sp., *Polychasmina* sp., *Pseudoreophax* sp. *Saccammina* sp. and *Textularia* sp.

Palaeobotany—Feistmantel (1879) listed the plant fossils found at several localities, like Naicolum, Uttatur, Therani, between Therani and Karai, north of Kullpaudy (Kalpadi) and Maravatur and felt that these plant fossils be classed on the horizon of Sriperumbudur and Raghavapuram formations. Gopal, Jacob and Jacob (1957) recorded plant fossils from Sivaganga area, near Rayani and Kattupuliyur villages and Chaudhury (1958) from Therani beds. Later Mamgain, Sastry and Subbaraman (1973) and Ayyaswami and Gururaja (1977) listed plant fossils found in different clay bands of Therani area. Jeyasingh and Sudhersan (1985) reported *Marattiopsis macrocarpa* (Old. & Morr.) Seward & Sahni from the Sivaganga area. So far a detailed study of the floral assemblage has not been done.

Palynological studies of Therani sediments are lacking. Besides, palynofossils have as yet not been recorded from Sivaganga and Uttatur outcrops. However, subsurface samples equivalent of Sivaganga beds from various localities have yielded palynofossils (Rao & Venkatachala, 1971; Venkatachala, 1974; Venkatachala, Sharma & Jain, 1972). Marine influence during Neocomian—Aptian times was inferred in the Cauvery Basin through palynofossil studies (Rao & Venkatachala, 1971).

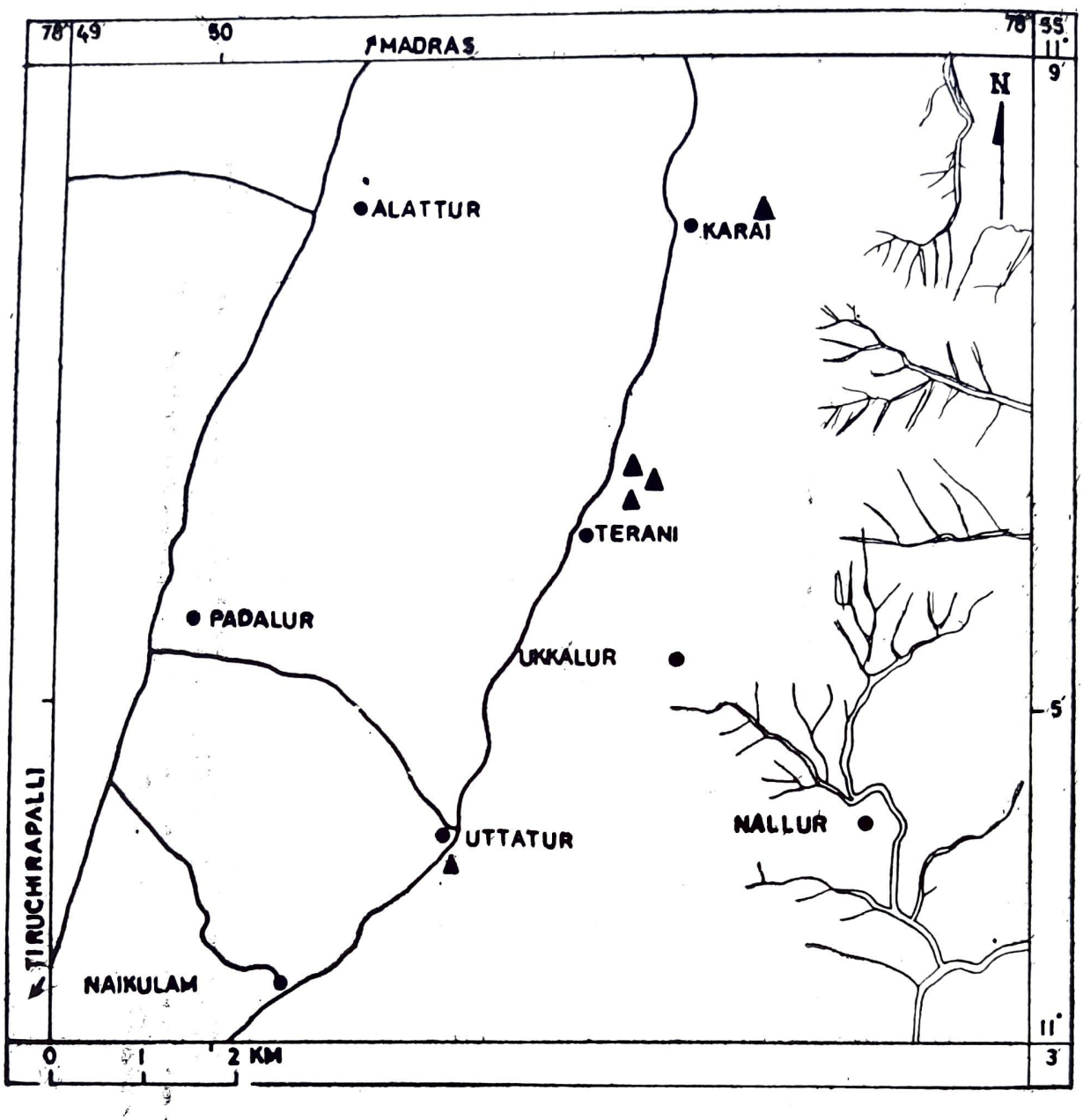
Fossiliferous localities—Plant fossils for the present study have been collected from two clay mines near the villages Therani and Karai in Tiruchirapalli District, Tamil Nadu (Map 1). They are preserved as impressions.

Therani area—The village Therani lies about 18 km north-east of Padalur (Map-1). From three clay quarries dug 2-3 km north of the Therani Village plant impressions were recovered from the ash grey clay. From Therani Feistmantel (1879) recorded *Angiopteridium spathulatum* McClell. sp. (Schimp), *Alethopteris indica* O. M., *Ptilophyllum acutifolium* Morr. *Otozamites angustatus* Fstm., *Dictyozamites indicus* Fstm., *Palissya conferta* O. M. sp., *P. indica* (?) O. M. sp., and *Echinostrobus*.

Chawdhuri (1958) recorded *Ptilophyllum cutchense* and Mamgain, Sastry and Subbaraman (1973) recorded ammonites along with some plant fossils like *Rhizomopteris* sp., *Pseudoctenis footeanum*, *Nilssonia fissa*, *Ptilophyllum cutchense*, *Araucarites* cf. *cutchense*, *Desmiophyllum* sp. and ? *Ginkgoites* sp. Ayyaswami and Gururaja (1977) reported *Cladophlebis indica*, *Sphenopteris* sp., *Actinopteris* sp., *Ptilophyllum acutifolium*, *P. cutchense*, *Taeniopteris spatulata*, *T. lata*, *Dictyozamites* sp., *Elatocladus plana* and *E. conferta*.

Karai area—The Karai Village lies about 20 km north-east of Padalur (Map 1). A quarry about one kilometre north-east of the village contains white and grey clays rich in plant impressions. Feistmantel (1879) recorded *Ptilophyllum cutchense* var. *minium* from an area between Therani and Karai villages.

Age of Sivaganga Formation—Feistmantel (1879) correlated the Uttatur plant beds with



Map 1—Showing plant fossil localities (▲) in Tiruchirapalli District, Tamil Nadu.

the Sriperumbudur, Vemavaram and Raghavapuram beds and assigned Jurassic age. Gopal, Jacob and Jacob (1957) while discussing the age of flora of Sivaganga Formation felt that the age might be Middle Jurassic or slightly younger. Ayyaswami and Gururaja (1977) consider the flora of Sivagana Formation to be Early Cretaceous in age. These are the main views regarding the age of Sivaganga Formation.

Description

EQUISETALES

Genus—*EQUISETITES* Sternberg, 1833

Equisetites sp.
Pl. 1, fig. 9; Text-fig. 1A

Description—Stem fragmentary, 9 cm × 3.1 cm. Nodes and internodes of about the

same breadth. Internodes showing clear ridges and grooves. Nodes having a leaf-sheath consisting of about ten leaves, free part of leaves 1.1-1.8 cm long, tip acute.

Collection—Specimen no. B. S. I. P. 36254, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—In general appearance *Equisetites* sp. somewhat resembles *E. fergunensis* Seward described by Appert (1973) from the southwest of Madagaskar. In both the species the free leaf parts are elongated and broad. However, in *Equisetites* sp. the leaves and internodes are comparatively larger. Likewise *Equisetites* sp. also shows resemblance with *E. iwamuroensis* Kimura described by Kimura and Tsujii (1980) from Japan. In both internodes are long, but in *E. iwamuroensis* internodes are smooth and leaves are more in number. *Equisetites* sp. also resembles to some extent *E. intermedius* (Erdtman, 1921).

UNCLASSIFIED FERNS

Genus—*CLADOPHLEBIS* Brongniart 1849

Cladophlebis srivastavae Gupta
Pl. 1, figs. 1, 5; Text-fig. 1 H, I

Description—Pinna imparipinnate, incomplete, 2.7 cm × 1.2 cm. Rachis slender, 0.5 mm wide, gradually tapering towards apex. Pinnules ovate to triangular, straight or slightly falcate, alternate to sub-opposite, closely set, free or connected at base, 7 mm × 3 mm in size, attached by whole base at an angle of about 50°-60°. Margin entire. Apex acute or obtuse. Venation distinct, midrib arising close to lower basal margin, traversing whole length of pinnule and giving rise to once or twice forked secondary veins.

Collection—Specimen no. BSIP 36249, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—In gross morphological features and venation pattern the presently described specimens match with *C. srivastavae* Gupta (1954) described from Rajmahal Hills, Bihar. *C. nebbensis* (Brongn.) described by Oishi (1932) from Japan shows some resemblance, but it differs having once forked secondary veins.

Cladophlebis sp. A.
Pl. 1, fig. 2; Text-fig. 1 D, E

Description—Frond pinnate, incomplete, 2.3 cm×0.9 cm. Rachis slender, 1.5 mm wide. Pinnules small, alternate, ovate to ± oblong, 3-4.5 ×3-3.5 mm, attached by whole base at an angle of about 50°-65°. Margin entire. Apex obtuse or rounded. Midrib distinct, lateral veins forking once, twice or thrice.

Collection—Specimen No. B. S. I. P. 36250, Lucknow.

Loality—Therani, Tiruchirapalli District. Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—The present specimen shows apparent resemblance with *Cladophlebis* sp. B described by Bose and Sah (1968) from the Rajmahal Hills, Bihar. However, the present species differs from *Cladophlebis* sp. B in having slightly larger pinnules with more than once forked lateral veins. In *Cladophlebis* sp. B lateral veins are only once forked. The pinnules in *Cladophlebis* sp. A somewhat resemble *Cladophlebis shensiensis* Pan described

by Sze (1956) from China and *Todites williamsonii* (Brongn.) described by Walkom (1928) from Australia, but they are smaller in size.

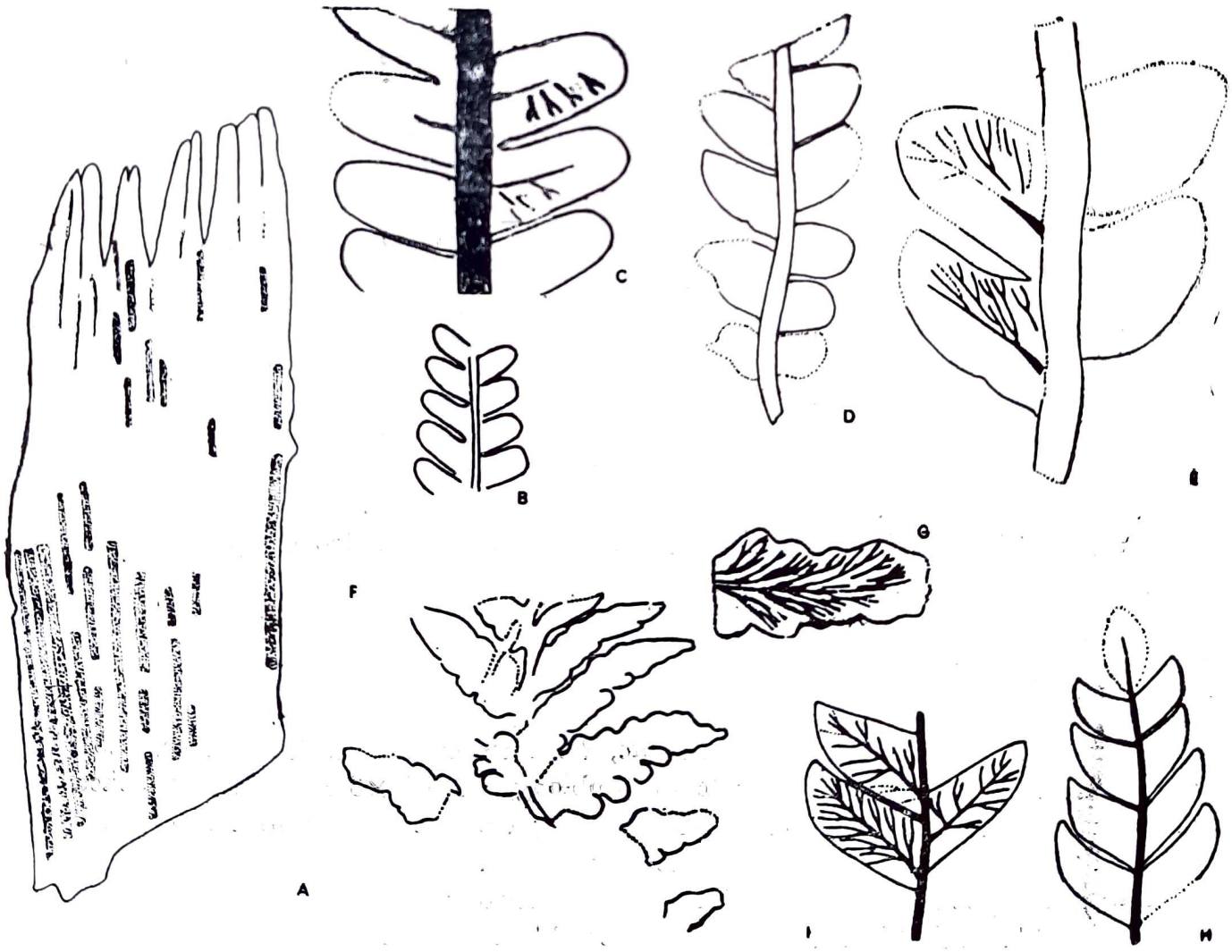
Cladophlebis sp. B
Pl. 1, figs. 3, 7; Text-fig. 1 B, C

Description—Frond pinnate, lanceolate, incomplete, 2-5.1 cm × 1.3-1.7 cm. Rachis about 1-1.5 mm wide. Pinnules alternate, 7 mm long and 3.5-4 mm wide, more or less oblong, closely attached to rachis by entire base at an angle of about 55°-85°, usually free at base, sometimes connected. Margin entire. Apex rounded. Midrib traversing up to apex of pinnule, lateral veins forking once or twice.

Collection—Specimen nos. BSIP 36251, 36253 and 199/2982, Lucknow.

Locality—Therani, Tiruchirapalli District Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.



Text-figure 1—**A**. *Equisetites* sp., Specimen No. BSIP 36254, ×1; **B**. *Cladophlebis* sp. B., Specimen No. BSIP 36253, ×1; **C**. *Cladophlebis* sp. B, venation, Specimen No. BSIP 36251, ×2; **D**. *Cladophlebis* sp. A, Specimen No. BSIP 36250, ×2; **E**. Same, a part enlarged showing venation, ×2; **F**. *Sphenopteris tiruchirapalliense* n. sp., Holotype, BSIP 36252, ×1; **G**. Same, a part enlarged showing venation, ×1; **H**. *Cladophlebis srivastavae* Gupta, Specimen No. BSIP 36249, ×2; and **I**. Same, a part enlarged showing venation, ×2.

Comparison—*Cladophlebis* sp. B has an apparent resemblance with *C. oblonga* Halle (1913, text-fig. 4) described from the Jurassic of Graham Land. However, in *C. oblonga* pinnules are also falcate with acute apices.

Genus—*SPHENOPTERIS* Sternberg, 1825

Sphenopteris tiruchirapalliense n. sp.
Pl. 15, figs. 4, 6, 8; Text figs. 1 F, G

Diagnosis—Frond bipinnate, more than 4 cm in length. Rachis distinct, grooved, 1.0-1.5 mm wide. Pinnae alternate, elongate, 2.1-2.4 × 0.8 cm, arising at an angle of about 40°-60°. Apex obtusely pointed, whereas towards the apical region lobes feebly developed, lobes rounded or oval, apical pinnae lack distinct lobes. A short vein on entering each lobe immediately forks into branched veins.

Holotype—Specimen no. BSIP 36252, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—*Sphenopteris tiruchirapalliense* shows apparent resemblance with *Sphenopteris rajmahalense* Sahni & Rao (1934) known from the Rajmahal Hills, Bihar. However, unlike *S. rajmahalense*, *S. tiruchirapalliense* lacks notch on the apical part of the pinnule and a few veins are present in each lobe of the pinnae. *S. tiruchirapalliense* also has an apparent similarity with *S. imbricata* described by Sharma (1969) from the Rajmahal Hills. In the latter leaves are imbricately arranged unlike the former. In the shape of pinnae *S. tiruchirapalliense* somewhat resembles *S. otagoensis* described by Arber (1917) from the Mesozoic of New Zealand. However, both the species differ in the venation pattern. *S. tiruchirapalliense* resembles to some extent *S. gracilis* Oishi (1940) described from Japan and *Sphenopteris* sp. described by Sitholey (1940) from Afghan- Turkistan. But, *S. gracilis* has deeply lobed pinnae and in *Sphenopteris* sp. the pinnae are smaller.

CYCADALES

Genus—*TAENIOPTERIS* Brongniart, 1832

Taeniopteris spatulata McClelland
Pl. 2, figs. 2, 7, 8; Text-fig. 2E, F

Description—Leaf simple, linear, spathulate, gradually narrowing towards base, maximum available length 7.2 cm, breadth 1.4 cm. Margin entire, sometimes uneven. Apex subacute or obtuse. Midrib distinct,1-1.5 mm wide, traversing throughout the length of lamina. Lateral veins arising at an angle of 80°-90°, parallel, simple or forked once.

Collection—Specimen, nos. BSIP 36256, 36261, 36262, and 284/2982, Lucknow.

Locality—Therani and Karai, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimens resemble *T. spatulata* McClelland emend. Bose & Banerji (1981). These specimens show greater similarity with the specimens described by Feistmantel (1879) and Gopal, Jacob and Jacob (1957) from East Coast Gondwana outcrops (Andhra Pradesh & Tamil Nadu) and by Sitholey (1944) from Ceylon in

general morphology and venation pattern of leaves. They are also similar to *T. spatulata* described from Gangapur Formation (Sukh-Dev & Rajnikanth, 1988).

BENNETTITALES

Genus—*ANOMOZAMITES* Schimper 1870

Anomozamites haburensis Bose & Banerji
Pl. 2, fig. 6; Text-fig. 2A, B

Description—Leaf pinnate, incomplete, linear-lanceolate, available length 5.1 cm, breadth 1.6 cm Rachis about 1 mm wide. Lamina segmented, segments close, free or contiguous, 5-8 mm 4-5.5 mm in size, attached by whole base at an angle of 65°-75°, nearly as long as broad or slightly longer. Margin entire, distal margin abruptly curved to an acute or obtuse apex, rarely distal margin notched. Veins 5-7, arising from base at a wide angle of about 65°-75°, parallel, mostly simple, rarely forked once.

Collection—Specimen no. BSIP 36260, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimen from Therani matches *Anomozamites haburensis* described by Bose and Banerji (1981) from Rajasthan in shape and size of segments and venation pattern. It differs from *A. hasnapurensis* Bose & Banerji (1981) reported from a locality near Hasnapur, Madhya Pradesh in having narrow segments with mostly simple veins.

Anomozamites sp.
Pl. 2, fig 1; Text-fig. 2D

Description—Leaf pinnate, gradually narrowing towards base, maximum available length 5.3 cm and width 1.8 cm. Rachis distinct, 1 mm wide, marked with a longitudinal ridge. Segments sub-opposite, broader than long, 2-3 mm long and 3-7 mm wide, attached laterally by entire base at an angle of 80°-90°, segments towards base feebly developed, lateral margin entire, distal margin entire or sometimes uneven. Veins arising from rachis at an angle of 75°-90°, parallel, simple or forked once.

Collection—Specimen nos. BSIP 200/2982 and 36255, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

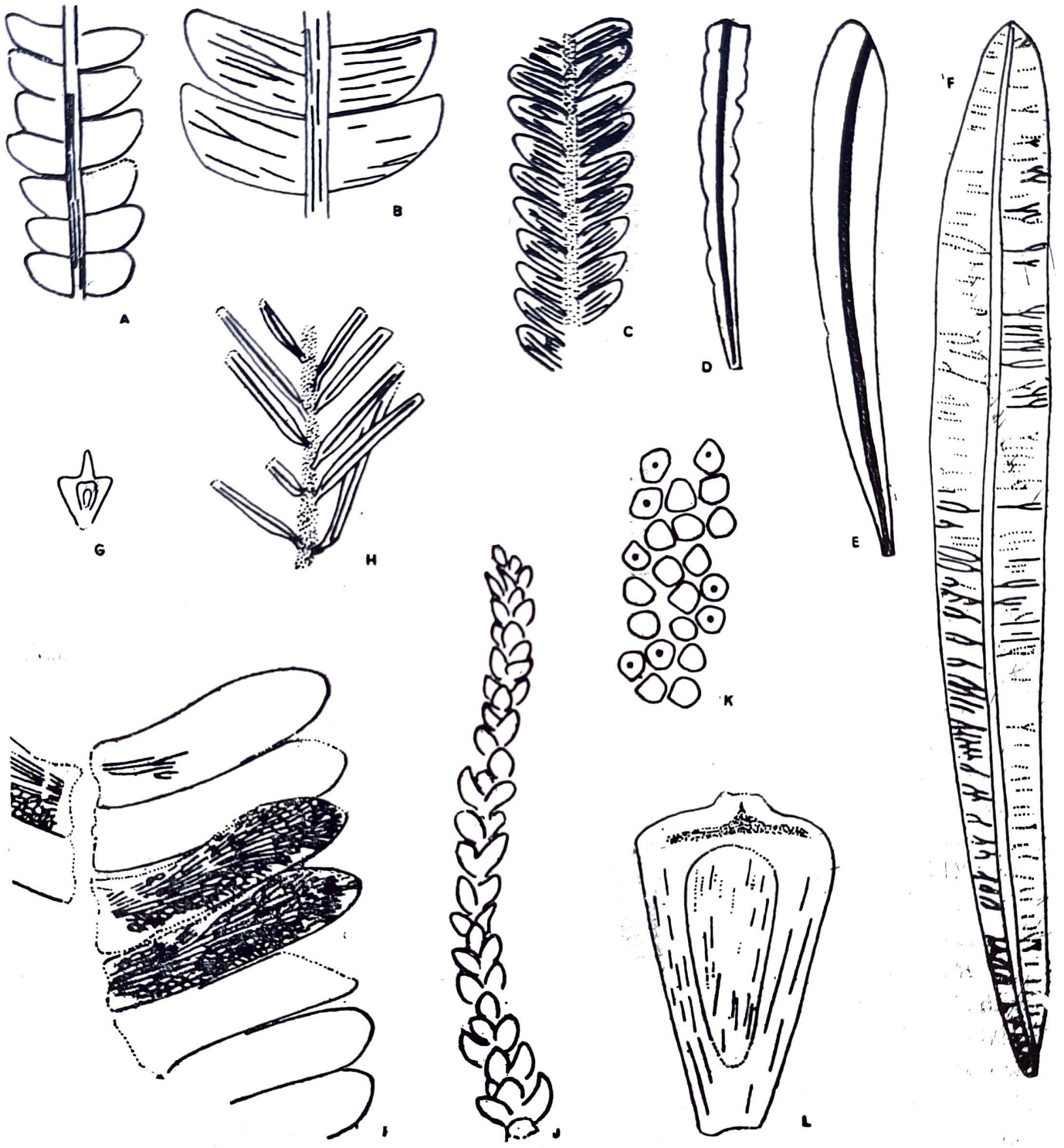
Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—*Anomozamites* sp. closely resembles *A. amorjolense* Sharma, Surana & Singh emend. Bose & Banerji (1981) described from the Rajmahal Hills, Bihar. The segments in the former species are smaller and lack notched distal margin. *Nilssonia elegans* Arber (1917) reported from New Zealand shows close resemblance in shape and size of leaves with *Anomozamites* sp. In the former species the apices of segments are sub-acute or bluntly pointed unlike the latter species.

Genus—*PTILOPHYLLUM* Morris 1840

Ptilophyllum acutifolium Morris
Pl. 2, figs. 3, 4, 9

Description—Leaf pinnate, lanceolate, maximum available length 15.7 cm, width 3.4 cm. Rachis concealed by pinnae bases. Pinnae attached on upper surface of rachis



Text-figure 2—**A**. *Anomozamites haburensis* Bose & Banerji, Specimen No. BSIP 36260, ×1; **B**. Same, a part enlarged showing venation, ×2; **C**. *Ptilophyllum* cf. *P. rarinervis* (Feistmantel) Bose & Kasat, Specimen No. BSIP 36259, ×2; **D**. *Anomozamites* sp., Specimen No. BSIP 36255, ×1; **E**. *Taeniopteris spatulata* Mc Clelland, Specimen No. BSIP 36262, ×1; **F**. *Taeniopteris spatulata* Mc Clelland, showing venation, Specimen No. BSIP 36256, ×2; **G**. *Araucarites minutus* Bose & Maheshwari, Specimen No. BSIP 19/2983, ×1; **H**. *Elatocladus tennerrimus* (Feistmantel) Sahni, Specimen No. BSIP 36270, ×1; **I**. *Dictyozamites feistmantelii* Bose & Zeba Bano, venation, Specimen No. BSIP 36268, ×2; **J**. *Brachyphyllum theraniense* n. sp., Holotype, BSIP 36272, ×2; **K**. *Brachyphyllum regularis* Borkar & Chiplonkar, Specimen No. BSIP 36271, ×1; and **L**. *Araucarites cutchensis* Feistmantel, Specimen No. BSIP 36275, ×2.

at an angle of about 40°-70°, closely set, some contiguous, basiscopic margin of pinna overlapped by ascroscopic margin of the lower pinna. Pinnae linear, lanceolate, falcate. Apex acute. Acroscopic basal margin slightly rounded, basiscopic margin running straight to rachis or slightly decurrent. Veins distinct, arising from base and mostly forking once, more or less parallel.

Collection—Specimen nos. B. S. I. P. 36251, 36258, 36263, 8/2982, 184/2982 and 264/2982, Lucknow.

Locality—Therani and Karai, Tiruchirapalli District, Tamil Nadu.

Horizin & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The specimens from Therani and Karai closely resemble *P. acutifolium* Morris described by Bose and Kasat (1972) and Bose and Banerji (1984). Some of the specimens show close resemblance with *P. acutifolium* described by Feistmantel (1879, Pl. 10, fig. 9; pl. 11, fig. 1) and Baksi (1968) from Raghavapuram.

Ptilophyllum cutchense Morris
Pl. 3, figs. 1-5

1958 *Ptilophyllum cutchense* Feistmantel : Chowdhuri, p. 141, figs. 1-4,

Description—Frond pinnate, maximum available length 17.2 cm, width ?.2 cm, straight or slightly curved, linear-lanceolate. Rachis partially or completely concealed by pinnae bases, about 1-3 mm wide. Pinnae attached on upper surface of rachis by entire base at an angle of about 50°-85°, 0.1-1.4 cm×0.1-0.4 cm in size, lanceolate, straight, some falcate, closely set, separate, contiguous or mostly lower pinna overlapping the basiscopic margin of upper pinna, basal acroscopic margin rounded, basal basiscopic margin running straight to rachis or slightly decurrent. Margin entire. Apex acute, subacute or obtuse. Veins arising from the base of pinnae, more or less parallel, mostly once forked.

Collection—Specimen nos. BSIP 36264, 36265, 36266, 36267, 94/2982, 177/2982 and 214/2982, Lucknow.

Locality—Therani and Karai, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—In general morphological features the specimens described here agree well with *Ptilophyllum cutchense* Morris described by Bose and Kasat (1972) and Bose and Banerji (1984). These specimens show variation in shape and size of pinnae and may represent two or more species. In external morphological features these specimens also resemble *P. horridum* Roy. *P. institacallum* Bose and *P. jabalpurense* Jacob & Jacob (Bose & Kasat, 1972, Bose & Banerji, 1984), but in them cuticular features are known. The smaller specimen of *P. cutchense* from Karai (Pl. 23, fig. 3) is quite similar to the smaller ones of the same species described from Gangapur Formation (Sukh-Dev & Rajanikanth, 1988).

Ptilophyllum cf. *P. rarinervis* (Feistmantel) Bose & Kasat
Pl. 3, fig. 8; Text-fig. 2 C

Description—Leaf pinnate, incomplete, available length 3.6 cm, width 0.9 cm. Rachis slender, 1.5 mm wide. Pinnae small, 3-4×1.5-2, mm alternate, mostly separate, some-

times contiguous, attached on upper surface of rachis at an angle of about 60°-80°. Margin entire. Apex sub-acute or rounded. Acroscopic basal edge rounded, basiscopic edge slightly decurrent. Veins three to four, dividing at all levels.

Collection—Specimen no. BSIP 36259, Lucknow.

Locality—Karai, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—The specimen from Karai comes nearer to *P. rarinervis* (Feistmantel) Bose & Kasat (1972) in general appearance and venation pattern. However, in the present species the pinnae are not closely attached as in *P. rarinervis* and the veins are three to four. In having a few veins per pinna *Ptilophyllum* cf. *P. rarinervis* resembles *P. nipanica* Vishnu-Mittre (1957) described from Nipania. However, in *P. nipanica* the pinnae are larger in size and veins are rarely forked unlike the present species. One of the specimens of *P. cutchense* Morris figured by Bose and Banerji (1984, Pl. 23, fig. 7) is comparable in shape and size of pinnae, but its veins are not clear.

Genus—*DICTYOZAMITES* Oldham 1863

Dictyozamites feistmantelii Bose & Zeba- Bano
Pl. 3, figs 6,7; Pl. 4, fig. 10; Text-fig. 2I

Description: Leaf pinnate, incomplete, 1.4-5.4 × 1.6-4 cm. Pinnae alternate to sub-opposite, mostly straight, some slightly falcate, 1.7-3.2 cm × 0.4-0.9 cm, closely set, some contiguous or overlapping, arising at an angle of about 60°-80°. Bases of pinnae slightly unequal, auriculate, the middle part forming a small stalk. Margin entire. Apex obtuse to rounded. Venation distinct, veins diverging from base, forking and anastomosing to form meshes, meshes more or less hexagonal or polygonal, elongate in the middle part of pinnae, smaller towards margin and apex, about 18-22 meshes present in the middle part of pinna.

Collection—Specimen nos. BSIP 36268, 36276, 197/2982 and 17/2983, Lucknow.

Locality—Therani and Karai, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—In shape and size of pinnae and venation pattern the present specimens resemble *Dictyozamites feistmantelii* described by Bose and Zeba-Bano (1978). In two or three pinnae a small stalk appears in the middle part of the base. It is probably due to preservation factor that some pinnae appear overlapping and the stalk is not distinctly visible.

CONIFERALES

Genus—*ELATOCLADUS* Halle 1913

Elatocladus plana (Feistmantel) Seward
Pl. 4, fig. 5

Description—Leafy-shoots unbranched, incomplete, maximum available length 7.1 cm, width 3.5.cm. Stem about 1 mm in width. Leaves linear, narrow, close, typically 1-1.8 cm long and 0.1-0.15 cm wide, spirally borne, but arranged in two rows. Bases of leaves decurrent, not twisted. Margin entire. Apex acute or obtuse. Midrib present.

Collection—Specimen nos. BSIP 36273, 14/2982 and 89/2982, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimens resemble *Elatocladus plana* (Feistmantel) Seward (1919) in shape, size and arrangement of leaves. These are similar in morphological features to *E. plana* described by Sahni (1928) from Sriperumbudur by Baksi (1968) from Raghavapuram and by Sitholey (1944) from Ceylon.

Elatocladus tenerrimus (Feistmantel) Sahni
Pl. 4, figs. 2,8; Text-fig. 2H

Description—Fragmentary leafy-shoots, unbranched, maximum available length 3.5 cm, width 1.9 cm. Stem distinct, 1 mm wide, Leaves spirally borne, but arranged in two rows at an angle of 45°-75°, linear-lanceolate, stiff, 10 mm long and 1.5 mm wide. Margin entire. Apex obtuse. Base contracted, slightly twisted, decurrent, Midrib traversing the whole lamina.

Collection—Specimen nos. BSIP 36270, 229/2982 and 265/2982, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The specimens from Therani closely resemble *E. tenerrimus* (Feistmantel) Sahni (1928) in general morphological features. The present specimens also resemble *E. pseudotenerrima* Maheshwari & Kumaran (1976) described from Sehora, Narsinghpur district, in external morphological characters, but in the latter cuticular details are present. *E. jabalpurensis* (Feistmantel) Sahni (1928) also resemble *E. tenerrimus* described here, but in the former leaves are sparse. The leaves in *E. tenerrimus* reported from Gardeshwar by Bose, Banerji and Jana (1984) are comparatively narrow. *E. tenerrimus* from Taltung Formation in Nepal (Kimura, Bose & Sakai, 1985) looks somewhat similar.

Genus—*BRACHYPHYLLUM* Brongniart 1828

Brachyphyllum regularis Borkar & Chiplonkar
Pl. 4, figs. 3,7; Text-fig. 2-K

Description—Leafy-twig, measuring about 4 cm in length and 0.7 cm in width. Leaves appressed on stem, small, 1-2 mm × 1-1.5 mm in size, variously shaped, rhomboidal, more or less circular-polygonal or triangular and having a short tubercle, spirally arranged, rather sparse and leaving small interspaces amongst them. Margin entire. Apex acute, obtuse or rounded.

Collection—Specimen no. BSIP 36271, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimen resembles *Brachyphyllum regularis* Borkar & Chiplonkar (1973) described from Lower Cretaceous of Songad, Saurashtra, in possessing rhomboidal, more or less circular-polygonal or sub-hexagonal leaves. These leaves are rather sparsely arranged and possess a tubercle. The specimen from Therani somewhat resembles the smaller leaves of *B. royii* Bose & Banerji (1984) described from Kutch in the shape and size of leaves, but the leaves in the latter species are compactly arranged, in which phytolemma is also known.

Brachyphyllum theraniense n. sp.
Pl. 4. figs. 1, 4, 11; Text-fig. 2-J

Diagnosis—Branched twigs, maximum available length 6.1 cm, width 3.4 cm, branching irregularly at an angle of about 55°-70°. Leaves close, spirally borne, small, mostly appressed, short-triangular to rhomboidal, 0.5-1 × 0.3-0.5 mm, occasionally large-triangular and projecting, 4-6 × 0.5-1 mm. Margin entire. Apex acute or obtuse.

Holotype—Specimen no. B. S. I. P. 36272, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Comparison—The leaves in *Brachyphyllum theraniense* are mostly small and triangular to rhomboidal in shape. Occasionally patches of large triangular leaves are also present here and there. In dimorphism of leaves and characteristic appearance of the twigs *B. theraniense* differs from all the known species of the genus *Brachyphyllum*. However, the smaller leaves in *B. theraniense* are somewhat comparable to those of *B. bansaensis* Sukh-Dev & Bose (1974), *B. surynarayanaii* Sukh-Dev & Bose (1974), *B. brevifolia* Srivastava, Nautiyal & Pant (1984), *B. rhombicum* (Feistmantel) Sahni (1928, pl. 2, fig. 23) and *Brachyphyllum* sp. (Feistmantel 1879, pl 16, fig. 10) known from India and *B. graciliforme* Wesley (1956) described from Italy. But in none of them distinct patches of large-triangular leaves are present amongst the smaller ones.

Genus—*ARAUCARITES* Presl 1838

Araucarites cutchensis Feistmantel
Pl. 4, fig. 9; Text-fig. 2 L

Description—Detached seed scales, measuring 2.2. 2.4 × 1.2-1.4 cm, wedge-shaped, broader towards the distal end and narrowing towards base, shoulders rounded, tip incomplete, 4 mm long and 3 mm wide. Seed medianly placed, obovate, probably immersed, 1.7 cm long and 0.5 cm broad, surface of entire seed-scale showing longitudinal striations. Ligule absent.

Collection—Specimen nos. BSIP 36275 and 155/2982, Lucknow.

Locality—Therani, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimens match with *A. cutchensis* Feistmantel described by Bose and Maheshwari (1973 b) in their size and shape. They are also similar to those described by Bose and Banerji (1984) from Kutch. The specimens of *A. cutchensis* described by Sukh-Dev and Zeba-Bano (1981) from Jabalpur Formation are slightly shorter in size. Some of the specimens of *A. cutchensis* known from Graham Land, Antarctica (Halle, 1913) closely resemble the Therani specimens.

Araucarites minutus Bose & Maheshwari
Pl. 4, fig. 6; Text-fig 2-G

Description—Detached seed-scales, about 0.9-1.3 cm long and 0.6-0.8 cm wide, distal end broad and terminating into a small pointed tip, 3 mm in length. Base truncate. Seed small, medianly placed, 3-5 mm long and 1-2 mm wide at broadest region, surface showing faintly marked longitudinal striations. Ligule absent.

Collection—Specimen nos. BSIP 36274 and 19/2983, Lucknow.

Table 1—Distribution of plant fossils in the Sivaganga Formation

Name	Therani	Karai	Naicolum	Marvattur	Uttatur	North of of Kalpadi	Between Therani & Karai	Siva-ganga area
Equisetites sp.	+							
? *Cladophlebis lobata*								+
C. reversa								+
C. srivastavae	+							
C. sp. A	+							
C. sp. B	+							
C. indica	+				+			
Sphenopteris sp.	+							+
S. tiruchirapalliense	+							+
Marattiopsis macrocarpa								
Actinopteris sp.	+							+
Rhizomopteris sp.	+							+
Taeniopteris spatulata	+			+	+	+		+
T. densinervis								+
T. lata	+							
T. ovata					+			
? *T. mcclellandi*								+
Taeniopteris sp.								+
Macrotaeniopteris ovata				+				
Nilssonia morrisiana								+
N. fissa	+							+
Anomozamites sp.	+							
A. haburensis	+							
Pseudoctenis footeanum	+							
Dictyozamites sp.	+							
D. falcatus	+							
D. indicus	+							
D. feistamantellii	+	+						
Otozamites sp.					+			
O. angustatus	+		+					
O. rarinervis					+			
Ptilophyllum acutifolium	+		+	+	+			+

Table 1—(*Contd.*)

Name	Therani	Karai	Naicolam	Marva-ttur	Uttatur	North of Kalpadi	Between Therani & Karai	Siva-ganga area
P. cutchense	+	+			+	+		+
P. cutchense var. *minimum*							+	
P. sp. cf. *P. rarinervis*		+						
? *Ginkgoites* sp.	+							
G. crassipes								+
Ginkgoites sp. cf. *G. raj-mahalensis*								+
Podozamites lanceolatus					+			
Elatocladus confertus	+							
E. plana	+				+			+
E. tenerrimus	+							
Desmiophyllum sp.	+							
Araucarites sp. cf *A. cutchense*	+							
A. cutchense	+				+			
A. minutus	+							
Brachyphyllum regularis	+							
B. theraniense	+							

Locality—Therani and Karai, Tiruchirapalli District, Tamil Nadu.

Horizon & Age—Sivaganga Formation, Early Cretaceous.

Remarks—The present specimens closely resemble *Araucarites minutus* described by Bose and Maheshwari (1973b) from Sehora and by Bose and Banerji (1984) from Kutch. These specimens are also similar to the ones described from the Gangapur Formation (Sukh-Dev & Rajanikanth 1988. However, in the present specimens tip is more prominent.

Discussion

The fossil flora from the Sivaganga Formation described here and also incorporating earlier published records comprises 19 genera and 46 species (see Table 4). The assemblage indicates dominance of cycadophytes followed by conifers, pteridophytes and Ginkgophytes. Pteridosperms and Pentoxyleae are not recorded. In this assemblage the following species have been described for the first time.

Equisetites sp.

Cladophlebis srivastavae Gupta

Cladophlebis sp. A
Cladophlebis sp. B.
Sphenopteris tiruchirapal'iense n. sp.
Anomozamites haburensis Bose & Banerji
Anomozamites sp.
Dictyozamites feistmantelii Bose & Zeba-Bano
Ptilophyllum cf. *P. rarinervis* (Feistmantel) Bose & Kasat
Elatocladus tenerrimus (Feistmantel) Sahni
Brachyphyllum regularis Borkar & Chiplonkar
Brachyphyllum theraniense n. sp.
Araucarites minutus Bose & Maheshwari

The pteridophytes are represented by the families Equisetaceae (*Equiselites*), Marattiaceae (*Marattiopsis*) and Unclassified ferns (*Cladophlebis*, *Sphenopteris* and *Rhizomopteris*). Gymnosperms are represented by Cycadales (*Taeniopteris*), Bennettitales (*Pseudoctenis*, *Anomozamites*, *Pterophyllum*, *Dictyozamites*, *Otozamites* and *Ptilophyllum*), Coniferales (*Elatocladus*, *Brachyphyllum*, *Pagiophyllum*, *Desmiophyllum* and *Araucarites*) and *Ginkgophytes* (*Ginkgoites*). On the whole the floral assemblage is characterized by the conspicuous absence of *Gleichenia*, *Onychiopsis*, *Weichselia*, *Phlebopteris*, *Cycadopteris*, *Allocladus* and abundance of cycadophytes.

The Sivaganga floral assemblage is comparable with that of Rajmahal assemblage (excluding Nipania) in the abundance of cycadophytes. The following elements are common to both the assemblages :

Cladophlebis srivastavae Gupta
Marattiopsis macrocarpa (Oldham & Morris) Seward & Sahni
Taeniopteris spatulata McClelland
Pterophyllum morrissianum Morris
Ptilophyllum acutifolium Morris
Ptilophyllum cutchense Morris
Dictyozamites falcatus (Morris) Medlicott & Blanford
Dictyozamites indicus Feistmantel
Elatocladus confertus (Oldham & Morris) Halle
Elatocladus plana (Feistmantel) Sahni
Elatocladus tenerrimus (Feistmantel) Sahni
Araucarites cutchensis Feistmantel

Fossil plants of Sivaganga Formation closely resembling the Rajmahal fossils are :

Ptilophyllum cf. *rarinervis* (Feistmantel) Bose & Kasat
Ginkgoites cf. *rajmahalensis* Sah & Jain

The following species are found in the Sivaganga Formation but not in the Rajmahal Formation. However, these genera are common to both assemblages.

Sphenopteris tiruchirapalliense n. sp.
Anomozamites haburensis Bose & Banerji
Anomozamites fissus Feistmantel
Pseudoctenis footeana (Feistm.) Seward & Sahni
Otozamites angustatus Feistmantel
Araucarites minutus Bose & Banerji
Brachyphyllum theraniense n. sp.
Brachyphyllum regularis Borkar & Chiplonkar
Ginkgoites crassipes Feistmantel

The flora of Sivaganga Formation is distinct from the Nipania floral assemblage. The latter is characterized by the dominance of conifers and Pentoxyleae and in the presence of *Nipanioruha*, *Nipaniostrobus*, *Sitholeya*, *Mehtaia*, *Indophyllum* and *Podostrobus* (Vishnu-Mittre 1958, 1959a, 1959b). Nipania floral assemblage is younger than the Rajmahal floral assemblage. Similarly the floras of Bansa, Himmatnagar, Than and Gardeshwar are quite distinct in the abundance of conifers and very less/absence of cycadophytes and in the presence of characteristic ferns and *Weichselia* and *Onychiopsis*.

The flora of Pariwar Formation has some floral elements common with the Sivaganga Formation. These are *Taeniopteris spatulata*, *T. densinervis*, *Anomozamites haburensis*, *Elatocladus tenerrimus*, *E. conferta*, etc. The Pariwar floral assemblage is differentiated by the presence of *Gleichenia* and *Phlebopteris* and in the absence of *Cladophlebis*, *Marattiopsis*, *Dictyozamites*, *Brachyphyllum* etc.

Among the East Coast Mesozoic Gondwana equivalents the Sriperumbudur Shale of Palar Basin comprises more or less a similar flora as found in the Sivaganga Formation. It has also wood genera such as *Podocarpoxylon*, *Cupressinoxylon* and *Araucarioxylon* (Feistmantel, 1879; Sahni, 1928, 1931; Suryanarayana, 1954, 1955). The palynological and faunal evidences advocate a Lower Cretaceous age to the Sriperumbudur beds (Ramanujam & Verma, 1977; Varma & Ramanujam, 1984; Murthy & Sastry, 1961).

The Vemavaram beds too possess abundance of cycadophytes and less conifers. However, they comprise many species of *Otozamites*. Palynological studies advocate an Upper Jurassic age for Vemavaram beds (Ramanujam, 1957; Kar & Sah, 1970). Equivalent subsurface samples, yielded paynoflora indicative of an Early Cretaceous age (Venkatachala & Sinha, 1986). Similarly Raghavapuram floral assemblage is also not so different from the flora of Sivaganga Formation except the record of wood genera *Araucarioxylon*, *Cupressinoxylon* and some differences in the floral composition. The palaeontological studies support a Lower Cretaceous age (Sastry, Chandra & Pant 1963, Bhalla 1965, 1972).

The flora of Gollapalli Sandstone comprises abundant conifers and cycadophytes followed by a few pteridophytes. It is differentiated from the Sivaganga floral assemblage in the presence of broad leaved cycadophytes. The Athgarh and Sivaganga floral assemblages consist of common forms, e.g., *Marattiopsis macrocarpa*, *Cladophlebis srivastavae* and *Anomozamites fissus*. However, the Athgarh flora has in addition *Gleichenia*, *Hausmannia*, *Phlebopteris* and *Onychiopsis*. Palynological evidences support Upper Jurassic-Lower-Cretaceous age for the Athgarh beds (Maheshwari, 1975; Jana & Tiwari, 1986).

The Gangapur flora of Pranhita-Godavari Valley is closer to the Sehora flora and is characterised by the abundance of conifers and some distinct elements such as *Pachypteris gangapurensis*, *Dictyozamites gondwanaensis*, *Ptilophyllum distans*, *P. horridum*, *Pagiophyllum marwarensis* and *Allocladus bansaensis*. The mega-and microfloras of Gangapur Formation are considered Early Cretaceous in age (Bose *et al.*, 1982, Rajeshwar Rao *et al.*, 1983, Sukh Dev & Rajanikanth, 1988). Both the Sivaganga and Gangapur floral assemblages have common forms like *Taeniopteris*, *Ptilophyllum*, *Dictyozamites*, *Elatocladus*, *Brachyphyllum*, *Pagiophyllum* and *Araucarites*.

Palynological and faunal evidences advocate a Lower Cretaceous age for the Sivaganga Formation.The subsurface samples from sediments equivalent of Sivaganga Formation of Cauvery Basin, yielded palynofossils indicating Neocomian-Aptian age (Venkatachala *et al.*, 1972; Venkatachala, 1977). Ammonoid and foraminiferal evidences are suggestive of an Early Cretaceous age (Banerji & Sastri, 1979; Banerji, 1982).

Stratigraphically the position of Sivaganga Formation is in between the underlying

Archaean rocks and the unconformably overlying Dalmiapuram Formation consisting of marine shales and reefoidal limestones of Albian age Chawdhari (1958) suggested that the plant beds of Therani seems to be homotaxial with the Jabalpur-Tirupati sequence. Considering the overall evidences the age of Therani beds is suggestive of an Early Cretaceous age.

The fossil floral assemblage of the Sivaganga Formation also shows close resemblance with flora of Tabbowa Series of Ceylon. The Tabbowa fossil assemblage comprises *Cladophlebis*, *Sphenopteris*, *Taeniopteris*, *Ptilophyllum*, *Anomozamites*, *Nilssonia*, *Elatocladus* and *Brachyphyllum* (Sitholey 1944). The forms like *Cladophlebis reversa*, *Taeniopteris spatulata*, *Anomozamites* sp. and *Elatocladus plana* are some of the closely resembling species in both the assemblages of Tabbowa and Sivaganga beds.

The abundance of cycadophytes in the Sivaganga floral assemblage may suggest their presence in the seaward margins of fluviodeltaic palaeoenvironment of Cauvery Basin.

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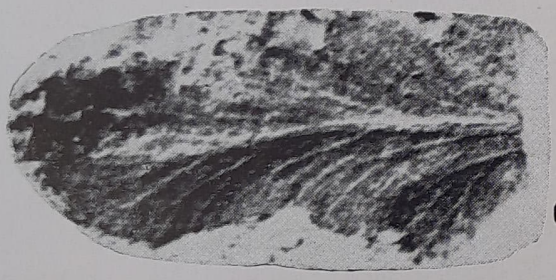

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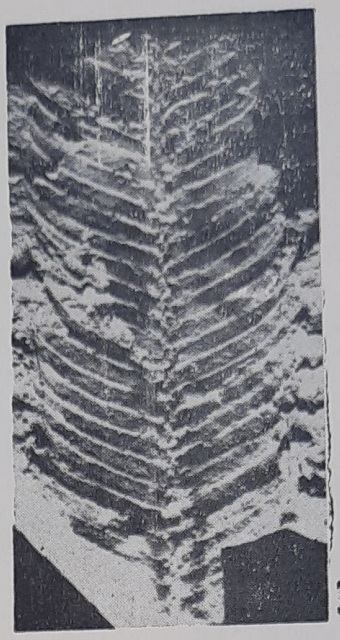

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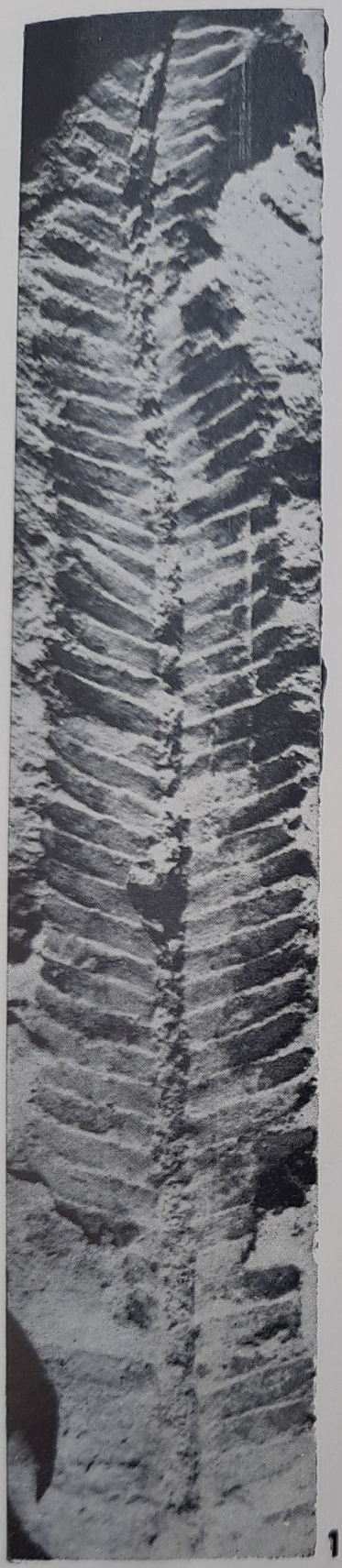

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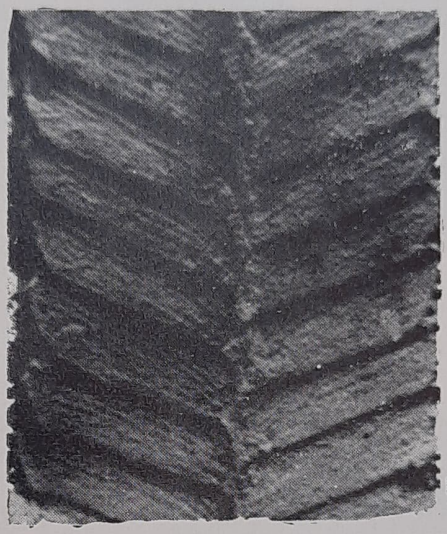

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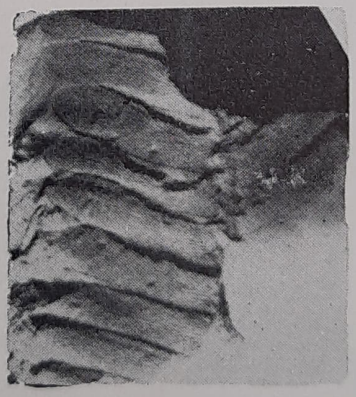

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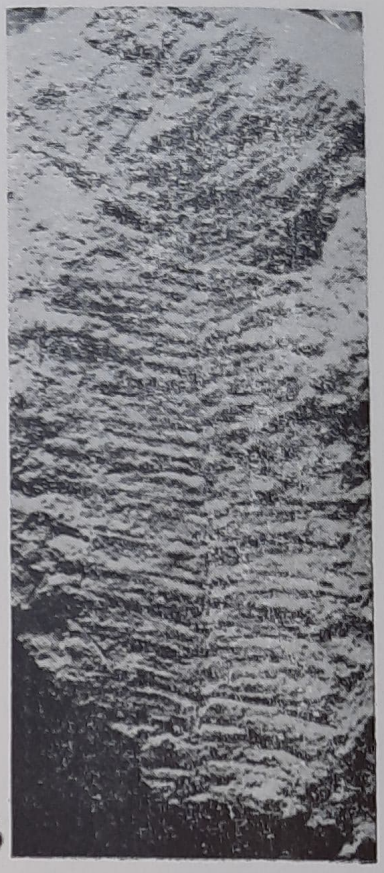

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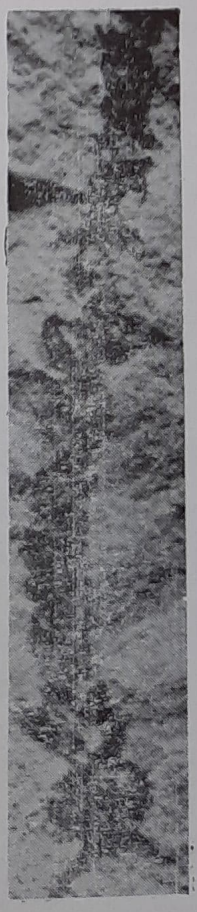

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Explanation of Plates

Plate 1

1. *Cladophlebis srivastavae* Gupta, Specimen No. B. S. I. P. 36249, × 1.
2. *Cladophlebis* sp., Specimen No. B. S. I. P. 36250, × 1.
3. *Cladophlebis* sp. B, Specimen No. B. S. I. P. 36251, × 1.
4. *Sphenopteris tiruchirapalliense* n. sp., holotype, Specimen No. 36252, × 1.
5. *Cladophelebis srivastavae* Gupta, a pinna enlarged showing venation, Specimen No. B. S I P. 36249, ×4
6. *Sphenopteris tiruchirapalliense* n. sp., pinna showing venation, Specimen No. B. S. I. P. 36252, ×4.
7. *Cladophlebis* sp. B., Specimen No. B. S. I. P. 36253, × 1.
8. *Sphenopteris tiruchirapalliense* n. sp., Specimen No. B. S. I. P. 36252, ×2.
9. *Equisetites* sp., Specimen No. B. S. I. P. 36254, ×1.

Plate 2

1. *Anomozamites* sp., Specimen No. B. S. I. P. 36255, × 1.
2. *Taeniopteris spatulata* Mcclelland, Specimen No. B. S. I. P. 36256, × 1.

3,4. *Ptilophyllum acutifolium* Morris, Specimen Nos. B. S. I. P., 36257, 36258, × 1.

5. *Ptilophyllum* cf. *P. rarinervis* (Feistmantel) Bose & Kasat, Specimen No. B. S. I. P. 36259, × 1.
6. *Anomozamites haburensis* Bose & Banerji, Specimen No. B. S. I. P. 36260, × 1.

7,8. *Taeniopteris spatulata* Mcclelland, Specimen No. B. S. I. P. 287/2982, × 1., 36262, ×2.

9. *Ptilophyllum acutifolium* Morris, Specimen No. B. S. I. P. 36263, × 1.

Plate 3

1,4. *Ptilophyllum cutchense* Morris, Specimen Nos. B. S. I. P. 36264, 36265, 36266, 36267, × 1.

5. *Ptilophyllum cutchense* Morris, a portion of pinna enlarged, showing venation, Specimen No. B. S. I. P. 36265, ×4.

6,7. *Dictyozamites feistmantelli* Bose & Zeba-Bano, Specimen No. B. S. I. P. 36276, 36268, 113/2982, ×2.

8. *Ptilophyllum* cf. *P. rarinervis* (Feistmantel) Bose & Kasat, venation, Specimen No. B. S. I. P. 36259, ×4.

Plate 4

1. *Brachyphyllum theraniense* n. sp., Specimen No. B. S. I. P. 36269, × 1.
2. *Elatocladus tennerrimus* (Feistmantel) Sahni, Specimen No. B. S. I. P. 36270, ×2.
3. *Brachyphyllum regularis* Borkar & Chiplonkar, Specimen No. B. S. I. P. 36271, × 1.
4. *Brachyphyllum theraniense* n. sp., Holotype, Specimen No. B. S. I. P. 36272, × 1.
5. *Elatocladus plana* (Feistmantel) Seward, Specimen No, B. S. I. P. 36273, × 1.
6. *Araucarites minutus* Bose & Maheshwari, Specimen No. B. S. I. P. 36274, × 1.
7. *Brachyphyllum regularis* Borkar & Chiplonkar, a portion of a leafy-twig enlarged, Specimen No. B. S. I. P. 36271, ×6.
8. *Elatocladus tennerrimus* (Feistmantel) Sahni, Specimen No. B. S. I. P. 36270, × 1.
9. *Araucarites cutchensis* Feistmantel, Specimen No. B. S. I. P. 36275, × 1.
10. *Dictyozamites feistmantelii* Bose & Zeba-Bano, venation, Specimen B. S. I. P. 36268, ×8.
11. *Brachyphyllum theraniense* n. sp., Specimen No. B. S. I. P. 36272, ×2.