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MICROBIOTA FROM THE KUSHALGARH FORMATION, DELHI SUPERGROUP, INDIA

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ABSTRACT

Well-preserved and diverse microfossils are described for the first time from the Kushalgarh Formation of Ajabgarh Group around Baraud Village in Alwar District, Rajasthan. The assemblage comprises 10 genera and 17 species belonging to filamentous and coccoid blue-green algae, of which two genera and 10 species are new. The new forms are *Myxococcoides compactus* sp. nov., *Palaeolyngbya distinctica* sp. nov., *P. elongata* sp. nov., *P. baraudensis* sp. nov., *Palaeoscytonema indica* sp. nov., *P. intermingla* sp. nov., *P. misrae* sp. nov., *Ghoshia bifurcata* gen. et sp. nov., *Primorivularia robusta* sp. nov. and *Vesicophycus problematicus* gen. et sp. nov. Morphological features and the size range of taxa suggest procaryotic nature of the assemblage. Coccoid forms are aggregated in colonies and dominated by filamentous forms. Baraud assemblage contains hormogonia, heterocysts, false branching and the most significant is the record of true branching showing Stigonematalean affinity. The composition of the microflora suggests that the rocks of Delhi Supergroup are equivalent to Vindhyans. This is also supported by the radiometric dates.

Key-words — *Ghoshia*, *Vesicophycus*, Cyanophyceae, Kushalgarh Formation, Precambrian (India).

साराँश

दिल्ली महासमूह (भारत) के कुशालगढ़ शैल-समूह से सूक्ष्मजीविता – जगन्नाथ प्रसाद मंडल, प्रभात कुमार माइती, जी० बर्मन एवं के० के० वर्मा

राजस्थान के अलवर जनपद में बड़ौद ग्राम के आस-पास अजबगढ़ समूह के कुशालगढ़ शैल-समूह से प्राप्त सुपरिरक्षित एवं विभिन्न प्रकार के सूक्ष्म-पादपाश्मों का सर्वप्रथम वर्णन किया गया है। इस समुच्चय में गोलाभ एवं तंतुवत् नील-हरित शैवालों के 10 वंश एवं 17 जातियाँ विद्यमान हैं, जिनमें से दो वंश तथा 10 जातियाँ नई हैं। ये नये प्रारूप मिक्सोकोकॉयडिस कोम्पेक्टस नव जाति, पोलियोलिंगबिया डिस्टिक्टिका नव जाति, पे० इलोंगेटा नव जाति, पे० बड़ौदेन्सिस नव जाति, पोलियोसाइटोनीमा इन्डिका नव जाति, पे० इन्टरमिंगला नव जाति, पे० मिसराई नव जाति, घोषिया बाइफर्केटा नव वंश व नव जाति, प्राइमोरिवुलेरिया रोबस्टा नव जाति एवं वेसिकोफाइकस प्रोबलेमेटिकस नव वंश व नव जाति हैं। वर्गकों के बाह्य-आकारिकीय लक्षणों एवं आमाप परिसर से समुच्चय की प्रोकैरियोटी प्रकृति व्यक्त होती है। गोलाभ-प्रारूप निवहों में पुंजित हैं तथा तंतुवत् प्रारूपों से प्रभावी हैं। बड़ौद समुच्चय में हॉर्मोगोनिया, हेट्रोसिस्ट, अवास्तविक शाखन तथा स्टिगोनिमेटेली से सजातीयता व्यक्त करने वाली वास्तविक शाखन का विशिष्टतम् अभिलेख है। सूक्ष्म-वनस्पतिजात के संयोजन से प्रस्तावित होता है कि दिल्ली महासमूह की चट्टानें विंध्य के समतुल्य हैं। उपलब्ध रेडियोमितीय आँकड़े भी इस प्रस्ताव की पुष्टी करते हैं।

INTRODUCTION

MICROBIOTA are now well known from the Proterozoic rocks of peninsular and extrapeninsular India. So far various workers like Maithy (1969), Maithy and Shukla (1977), Maithy and Mandal (1983), Maithy and Gupta (1983), Nautiyal (1978, 1980), Schopf and Prasad (1978), Salujha *et al.* (1970, 1971a, 1971b, 1972), Singh *et al.* (1978), Venkatachala and Rawat (1972) and Viswanathiah *et al.* (1975, 1976a, 1976b, 1979-80) have reported the biota from these rocks. This assemblage consists mostly of cryptarchs and a few blue-green algae.

There is no previous microfossil record from Delhi Supergroup except a report by Dutt and Shrivastava (1975) from Alwar Group, Gurgaon District. They reported *Tasmanites* other than triletes, monoletes, septate spore, acritarchs and hystrichospheres. From the illustrations of Dutt and Shrivastava (1975) it appear that the assemblage consists of only acritarchs belonging to Sphaeromorphitae and Netromorphitae except *Tasmanites*. Stromatolites have recently been reported by Verma and Barman (1980) and Negi and Ravindra (1980) from the Kushalgarh Formation near the village Baraud. The forms are *Baicalia baicalica* (Maslov) Krylov, *Collenia columnaris* Fenton & Fenton, *Kussiella kusiensis* Krylov and *Jacutophyton* Shapovalova. The investigation of microbiota in the area was taken up due to (i) occurrence of diverse stromatolite, (ii) absence of microfossil report from this rock sequence, and (iii) to correlate this thick and widespread sequence of rocks with other areas and particularly fixing the stratigraphical position of Delhi Supergroup in relation to the Vindhyan Supergroup.

In all, 27 samples from a section belonging to the Kushalgarh Formation were collected. Out of which only one siliceous dolomite yielded excellently preserved biota. Permanent slides were prepared with polyvenyl alcohol and D.P.X. mountant. Observations were made using oil imersion objective in a Leitz Dialux — 20 microscope. Long filaments were photographed in several shots at different focal depths. These photographs were superimposed to get the complete structure of filament.

The present paper deals with the systematic description of the microbiota recovered for the first time from Ajabgarh Group. All the figured specimens are housed in the Museum of Birbal Sahni Institute of Palaeobotany.

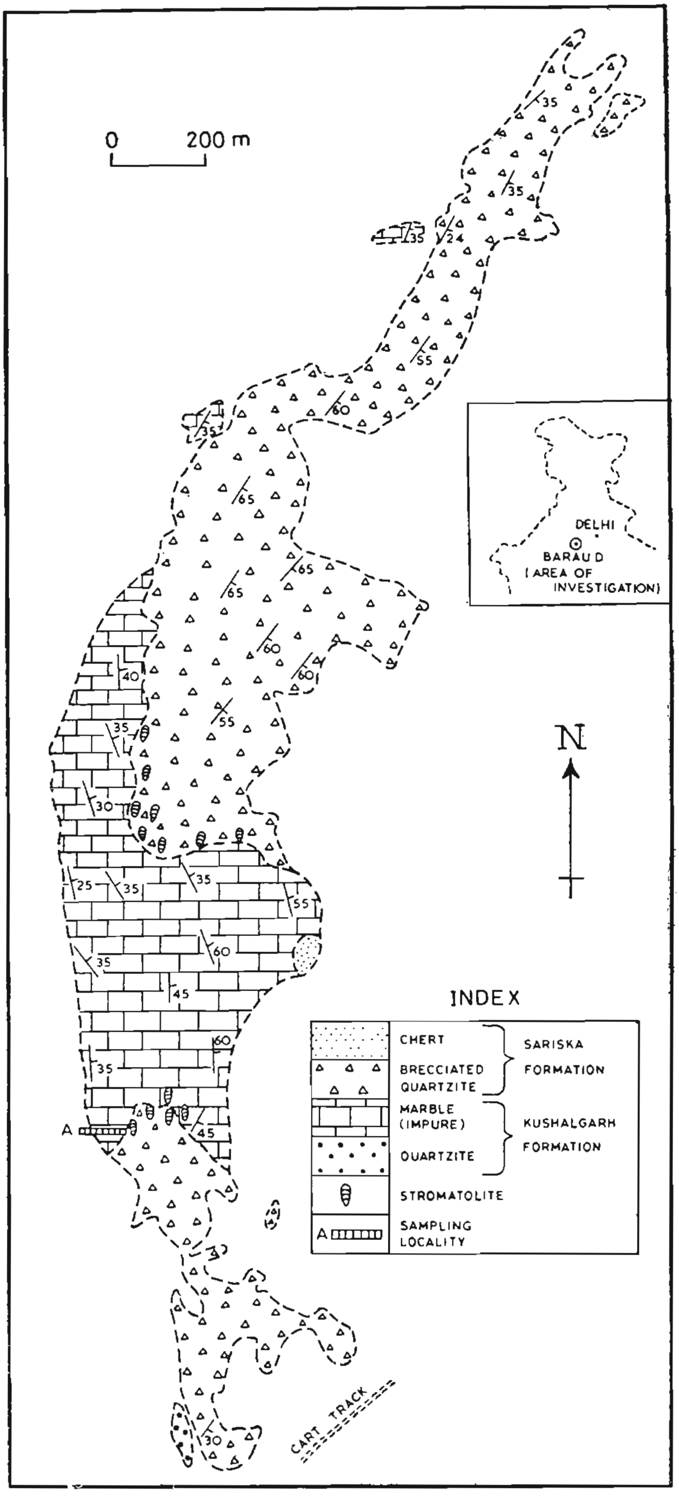
GEOLOGY

General Geology — Delhi Supergroup extends along the main axis of folding of the Aravalli mountains and is named after the city — Delhi and has a very wide geographical distribution from near Delhi in the north, through Ajmer and Mewar to Idar and Palanpur in the South (Krishnan 1982). In the north (Gupta, 1977) the, rocks of Delhi Supergroup are concealed under the alluvium and are found in the form of isolated patches. The rocks lie above the gneisses or the Aravallis or the Gwaliors or the Raialos with a great unconformity and in turn overlain unconformably by the Vindhyans. Lithologically, the rocks consist essentially of quartzites, mica schists, limestones and calcium chloride gneisses. The entire succession shows extensive folding, faulting and is affected by igneous intrusions in the form of pegmatites, granites and epidiorites.

Geology of the area — The microfossil bearing locality lies on the western flank of the north-south trending hill (Text-fig. 1), about a kilometer to the east of Baraud Village (27°54′: 76°23′, Survey of India toposheet no. 54 A/5), Alwar District, Rajasthan. The village is located on Alwar-Behror State Highway at 7th km from Behror which is locally known as 'Midway' and is situated on National Highway No. 8, halfway between Delhi and Jaipur. The area which is situated on the road side is approachable round the year as it is free from any vegetation. The rock formations which occur in this area belong to the Ajabgarh Group of the Delhi Supergroup (Precambrian). Of the Delhi Supergroup, the older Raialo and Alwar groups are missing in this area and the sequence commences directly with the Kushalgarh Formation of the Ajabgarh Group. As such, the stratigraphical succession of the area stands as shown in Table 1.

The Kushalgarh Formation comprises a sequence of marble beds (100 m in exposed section) intercalated with 3 to 5 cm thick bands of shale and chert. Bioherms of stromatolites are seen to have developed towards the top of this formation. The stromatolite forms include mostly of *Baicalia baicalica* (Maslov) Krylov, *Collenia columnaris* Fenton & Fenton, *Jacutophyton* Shapovalova and *Kussiella kusiensis* Krylov (Verma & Barman, 1980). The stromatolites, in general, are made up of milky white chert. The microfossils reported in this paper are from a thin chert band lying between marble beds, a few metres below the stromatolite bearing horizon in the upper part of the Kushalgarh Formation (Text-fig. 1).

Age of the rocks — The geological span of the deposition of Delhi Supergroup rocks



TEXT-FIG. 1 — Showing the type locality (after Verma & Barman, 1980).

TABLE 1 — STRATIGRAPHICAL SUCCESSION AROUND BARAUD, ALWAR DISTRICT, RAJASTHAN (MODIFIED AFTER NEGI & RAVINDRA, 1980)

Vindhyan Supergroup			Not developed
	(Acid, basic and ultrabasic intrusives and extrusives)		
Delhi Supergroup (Precambrian)	Ajabgarh Group	Bhakrol Formation	Interbedded quartzites and phyllite with carbonaceous bands
		Thanagazi Formation	Andalusite-biotite-sericite schist, garnet-chlorite schist
		Seriska Formation	Brecciated and ferruginous-quartzites with stromatolites at the base
		Kushalgarh Formation	Impure siliceous marble with thin bands of chert and shale and stromatolites at upper part
	Alwar Group	(Missing)	
	Raialo Group	(Missing)	
	(Granite, basic and ultrabasic intrusives)		
Aravalli Supergroup			Not developed

ranges in time from at least 1900 m.y. with two cycles of folding and a younger metamorphism (Crawford, 1970). Gupta (1977) mentioned that the rocks have been subjected to repeated granitic activity at 1660 m.y., 1010 m.y., 950 m.y., 790 m.y. and 735 m.y. Holmes (1949) carried out radiometric dating (733 m.y.) of Uraninite from a pegmatite in the biotite gneiss at Bisundri, Ajmer-Merwara and Monzanite from a pegmatite at Soniana, Mewar. According to him the date, i.e. 735 ± 30 m.y. of Bisundri Uraninite is one of the very few acceptable ages as being of first class reliability. Aswathanarayana (1959) dated 580 ± 20 m.y. from the Samarskite from a pegmatite near Kishangarh, Rajasthan. However, these younger dates support the observation of Heron (1953) that the pegmatitic intrusions all along the Delhi Synclinorium did not take place at the same time. Vinogradov *et al.* (1966a) recorded 900 ± 50 m.y. by K-Ar muscovite age from an Erinpura pegmatite near Ajmer. The total rock age of Erinpura type granite from Ajmer is approximately 930 m.y. While the Erinpura granite from Chhapoli was dated to 1000 m.y. (Crawford, 1975).

A rock sample collected from the outer flank of Baraud anticline on northern side belonging to the Bhakrol Formation has been dated 533 ± 24 m.y. by Fission Track method of biotite. The Kushalgarh Formation is the oldest formation of the Group, and obviously the age will be more than 533 m.y. of the youngest Bhakrol Formation. On the basis of stromatolite Verma and Barman (1980) commented that the Kushalgarh sedimentation started in the Lower Riphean and continued up to Middle Riphean time (1800-1000 m.y.).

On geological evidences, Delhi Group of rocks has been placed below Vindhyans and equated with Cuddapahs. However, Crawford (1969) has correlated the Cuddapah sequence with the Lower Vindhyans. Cuddapah sedimentation took place from 1400 to 980 m.y. (Aswathanarayana, 1962; Balasundaram & Balasubrahmanyan, 1973). On the other hand Vindhyans covered a span of 1400 to 900 m.y. (Misra, 1969).

While dealing with Precambrian stratigraphy in India on the basis of stromatolites, Raha and Sastry (1982) also proposed that the Delhi Supergroup may be correlated with the Lower Vindhyan. However, the new idea that Delhi is time equivalent, at last in part, with Vindhyan needs more support from various disciplines.

Palaeoenvironment — The study of stromatolites in the horizon indicates that these stromatolites building algal community grew in the form of a laminar sheet or mat in shallow marine conditions possibly in the intertidal zones. The silica rich solution buried the community very quickly and preserved the micro-organisms *in situ.*

TAXONOMY

The recorded assemblage consists of 10 genera and 17 species. The microbiota described here are taxonomically distinct from each other particularly in their characteristic morphology. Presence of branching, mode of septation, heterocyst, sheath and the reproductive structures (e.g. hormogonia) are considered to be distinctive in generic delimitation. The shape, size and detail measurements have been given secondary importance and used only for the specific identifications. The microfossils recovered here show very little or no degradation at all. According to Schopf (1977) the coccoid forms are referred to Cyanophyceae on the basis of size and morphological features. The filamentous forms are presumed to be cyanophycean in the presence of hormogonia, heterocyst in some of the forms (e.g. hormogonia in *Palaeoscytonema misrae* and heterocyst in *Primorivularia robusta*), branching (false branching in *Palaeoscytonema intermingla* sp. nov. and true branching in *Ghoshia bifurcata* gen. et sp. nov) and very thick sheath in most of the forms.

The empty sheaths of Chroococcacean colony (e.g. *Vesicophycus problematicus* gen. et sp. nov.) and of filamentous forms (e.g. *Animikiea septata*) are most likely derived from the form recovered here. It is difficult to say with certainty that to which forms they actually belong. Empty sheath of colonial form in all probability belongs to *Myxococcoides compactus* as *Vesicophycus* rarely contains few cells inside (Pl. 2, fig. 17) identical to the cells of *M. compactus* in shape and size. On the contrary, the empty sheath of filaments (e.g. *Animikiea septata*) are derived from more than one taxon as they have different types of apices.

SYSTEMATIC DESCRIPTION

ALGAE

FAMILY — CHROOCOCCACEAE

Genus — *Myxococcoides* Schopf, 1968

Type Species — *Myxococcoides minor* Schopf, 1968.

Myxococcoides inornata Schopf, 1968

Pl. 1, fig. 1

Description — Cells in cluster or rarely solitary, 9—18.7 μm in diameter (average 12.7 μm on 96 counts), spheroidal or variously shaped due to mutual compression in a colony; surface psilate; walls thick about 0.5 μm; distinct sheath around the colony, individual cells not ensheathed.

Remarks — The shape and habit of these fossils are identical to *Myxococcoides inornata* Schopf (1968, pl. 83, fig. 7) from the Bitter Spring Formation. However, the present specimens are smaller in size than the Bitter Spring. On the basis of the size the cells compare with *M. reticulata* Schopf (1968), but in *M. inornata* the cells are smooth and not finely punctate or reticulate as in *M. reticulata.*

The taxon is common in the assemblage. Solitary cells are rarely found (Pl. 1, fig. 5), which actually have originated from colonies by fragmentation. These isolated cells appear identical to *Huronispora* Barghoorn (in Barghoorn & Tyler, 1965).

Myxococcoides compactus sp. nov.
Mandal & Maithy

Pl. 1, fig. 2; Pl. 3, fig. 5

Diagnosis — Colony spheroidal up to 70 μm in diameter consisting of hundreds of cell bounded by a thick, about 1.5 μm, non-lamellated granular sheath; cells 2.7-4.4 μm (average 3.7 μm on 38 counts) in diameter, arranged irregularly; surface psilate to finely granulose; wall about 0.2 μm thick; individual cells not ensheathed. Reproduction possibly by vegetative division in more than one plane.

Holotype — Pl. 1, fig. 2; slide no. 6818; stage coordinate 12.5 × 100.

Type Locality — 1 km east of Baraud Village.

Etymology — With reference to compact arrangement of cells.

Comparison & Discussion — *Myxococcoides compactus* sp. nov. is observed frequently in the assemblage. The species differs from the known species of *Myxococcoides* in its smaller cell size and colony consisting of about hundreds of cells.

Myxococcoides minor Schopf, 1968

Pl. 1, figs 3, 4; Pl. 3, fig. 24

Description—Globular colony up to 58 μm in diameter, composed of few to 20 cells embedded within a non-lamellated sheath of about 1.2 μ thick; cell outline spheroidal or polygonal due to compression, 4.4-8.5 μm in diameter (average 6.6 μm on 16 counts); adjacent walls of cells appear to be common; wall about 0.5 μm thick; surface psilate.

Remarks — Present specimens are smaller than the specimen of Schopf (1968) from Bitter Spring. The taxon is common in the assemblage.

Genus — *Palaeoanacystis* Schopf, 1968

Type Species — *Palaeoanacystis vulgaris* Schopf, 1968.

Palaeoanacystis vulgaris Schopf, 1968

Pl. 4, figs 26-28

Description — Large colony made up of a number of coccoid cells, palmelloid or cylindrical, generally dome-shaped and apparently without any mucilage covering. Individual cells spheroidal to elliptical due to mutual compaction, not ensheathed, 4.5-11 μm in size (average 6.5 μm on 55 measurements), cells appear to have marginal walls in common with the neighbouring cells which are pronounced near the margin; surface smooth.

Discussion — *Palaeoanacystis* is the monospecific genus erected by Schopf (1968) from the Bitter Spring Formation. Baraud specimens are commonly palmelloid and marginal walls of the neighbouring cells appear to be common. The present specimens compare exactly with the photograph of *P. vulgaris* given by Schopf (1968, pl. 82, fig. 7) from the Bitter Spring Formation of Australia. The taxon is not common in the assemblage.

Genus — *Gloeocapsamorpha* Zalessky, 1916

Type Species — *Gloeocapsamorpha prisca* Zalessky, 1916.

Gloeoeapsamorpha prisca Zalessky, 1916

Pl. 1, fig. 7

Description — Colony large forming stiff mat with a number of concentric sheaths; cells form secondary colonies, 10-15 in number arranged irregularly, 9-15.2 μm in diameter, spherical or oval in shape due to compaction; sheath around the colony and individual cells present, about 1.5 μm thick.

Remarks — *Gloeocapsamorpha prisca* is uncommon in the assemblage.

Gloeocapsamorpha karauliensis Maithy & Mandal, 1982

Pl. 1, fig. 6

Description — Cells spherical to oval due to mutual compaction, thin-walled and smooth, 4.4 to 9 μm in diameter (5.5 μm on average on 27 counts). Cells form secondary colonies within the parent colony; 11 secondary colonies observed to form a big colony; individual cells and colony ensheathed, colony about 10 to 33.2 μm in diameter.

Remarks — The taxon is rare in the assemblage. Cells are smaller in size than *G. karauliensis* described from Vindhyans of Rajasthan by Maithy and Mandal (1983).

FAMILY — OSCILLATORIACEAE

Genus — *Palaeolyngbya* Schopf, 1968 emend.

Type Species — *Palaeolyngbya barghoorniana* Schopf, 1968.

Remarks — The generic diagnosis of *Palaeolyngbya* Schopf (1968) is based on the monotypic species — *P. barghoorniana*. Therefore, it has limited the scope to accommodate other forms. As our form is overlapping in all significant morphological characters with extant *Lyngbya*, the generic diagnosis of *Palaeolyngbya* is enlarged here to accommodate other forms having comparable morphology with extant *Lyngbya*.

Emended Diagnosis — Filament broad, multicellular, uniseriate, unbranched, slightly to strongly constricted at septa; cross wall distinct, either partial or complete, sheath distinct, hyaline, non-lamellated and firm. Trichomes solitary, straight to variously curved. Apical cell may be distinct. Reproduction by hormogonia.

Palaeolyngbya distinctica sp. nov. Mandal & Maithy

Pl. 2, figs 10, 11

Diagnosis — Filament in bunch, variously curved up to 200 μm long (incomplete specimen); trichome solitary, multicellular, uniseriate and unbranched; septa distinct, widely spaced towards apices, faintly to moderately constricted at septa point; basal cell swollen, 10 to 13 μm long and 5 to 7 μm broad (on 4 counts); medial cells nearly quadrangular (as long as broad), 5 to 8 μm; side walls often depressed, smooth to finely granular surface; sheath firm, thin, non-lamellated; reproduction possibly by hormogonia.

Holotype — Pl. 2, fig. 10; slide no. 6818; stage coordinates 53×103.5.

Type Locality — 1 km east of Baraud Village.

Etymology — With reference to distinct quadrangular medial cells.

Comparison & Discussion — *Palaeolyngbya barghoorniana* Schopf (1968) differs from *P. distinctica* sp. nov. in having partially septate disc-shaped medial cells whereas in present species the medial cells are quadrangular, completely septate and sheath is distinct. *P. elongata* sp. nov. compares with *P. distincta* in having broad basal cell but medial cells are discoid. On the basis of exomorphic features *P. distinctica* sp. nov. compares with the extant *Lyngbya baculum* Gomont. The taxon is rare in occurrence.

Palaeolyngbya elongata sp. nov. Mandal & Maithy

Pl. 3, fig. 20

Diagnosis — Filament up to 500 μm long, isolated, variously curved; trichome single, unbranched and septate; medial cells disc-shaped, 5.3 μm long, 7 μm broad; basal cell larger than the medial cell, spindle-shaped, granulose; sheath firm, thin and adpressed to trichome; reproduction possibly by hormogonia.

Holotype — Pl. 3, fig. 20; slide no. 6816; stage coordinates 36.8×97.

Locality — 1 km east of Baraud Village.

Etymology — With reference to long filament.

Comparison & Discussion — Only one complete specimen observed which is 500 μm long. The terminal portion of the filament is broad possibly due to compression. Reproductive structure was not observed. *P. elongata* sp. nov. is characterised by granular spindle-shaped basal cell larger than the rectangular medial cells which make the species distinct and differs from other known species of *Palaeolyngbya.*

Palaeolyngbya baraudensis sp. nov. Mandal & Maithy

Pl. 1, fig. 9

Diagnosis — Filaments in bunch, up to 200 μm long, trichome single with broad basal cell; medial cells discoid, broader than long, 2/3 to 3/4, not constricted at septa, 13-18 μm broad and 2-4 μm long, terminal cells 4-6 μm broad and 2-3 μm long, cell surface granular; septa straight or concave; sheath thick, adpressed to trichome, faintly laminated; reproduction not known.

Holotype — Pl. 1, fig. 9; slide no. 6816; stage coordinates 1×94.6.

Locality — 1 km east of Baraud Village.

Etymology — With reference to the Baraud Village from where the sample was collected.

Comparison — *Palaeolyngbya baraudensis* sp. nov. compares with *P. elongata* sp. nov. in morphology, but the former differs in having curved basal cell. Moreover, basal cell is not spindle-shaped.

Genus — *Oscillatoriopsis* Schopf, 1968

Type Species — *Oscillatoriopsis obtusa* Schopf, 1968.

Oscillatoriopsis obtusa Schopf, 1968

Pl. 3, fig. 23A

Description — Trichome multicellular, variously curved, uniseriate, unbranched, solitary, up to 175 μm long, not constricted at septa, septation complete; medial cells cylindrical, nearly isodiametric, 8 to 11.1 μm long and 8.5 to 10.1 μm broad; apical cell gum-drop shaped, cylindrical, 10 μm long and 8.5 μm broad; sheath not obscured; reproduction not known.

Remarks — Only one specimen observed in the assemblage.

Genus — *Animikiea* Barghoorn, 1965 emend. Mandal & Maithy

Synonym:

1968 *Siphonophycus* Schopf, p. 671.

Remarks — Barghoorn (1965 in Barghoorn & Tyler, 1965) proposed *Animikiea* for the multicellular unbranched filaments (without trichome) straight or curved with closely spaced septa. Individual cell much wider than long. Enclosing sheath of filament distinct, thick-walled and granular. This genus was later restudied by Awramik and Barghoorn (1977) and according to them the septate appearance may be due to the wrinkling of external sheath and actually is only surficial feature. Schopf (1968) while instituting the genus *Siphonophycus* from the Bitter Spring Formation of Australia opined that it resembles closely to *Animikiea* Barghoorn. The only difference was the presence of closely spaced septa, which Schopf (1968) considered to be closely-spaced, punctate surficial ridges, and not penetrating in the tubular lumen. According to Schopf (1968, p. 671) "the septa" of *Animikiea septata*, therefore, seem quite analogus to the finely punctate surface ornamentation of *Siphonophycus kestron* (pl. 80, fig. 2). Although morphology of these two microfossil genera seems quite similar but the apical portion of *A. septata* is unknown. The apical part can not be taken as character for generic separation, as the presence of apex is only a chance of preservation. In our study we have found specimens with and without apices. Surface features of these specimens range from psilate to granular and aseptate to septa-like structure which could be due to preservation. We, therefore, feel that the characters of *Animikiea* and *Siphonophycus* are overlapping and not distinct enough for the institution of two distinct genera. Hence, we propose here to consider *Siphonophycus* Schopf (1968) as junior synonym of *Animikiea* Barghoorn (1965).

Emended Diagnosis — Unbranched, aseptate, tubular empty sheath of filamentous algae.

Genotype — *Animikiea septata* Barghoorn, 1965.

Due to this change in the generic status of *Siphonophycus* the following transfers become necessary and is being done here accordingly.

Animikiea septata Barghoorn emend. Mandal & Maithy

Pl. 2, fig. 16; Pl. 3, figs 18, 19

Synonymy:

1965 *Animikiea septata* Barghoorn in Barghoorn & Tyler, p. 576, fig. 3.
1968 *Siphonophycus kestron* Schopf, p. 671, pl. 80, figs 1-3.
1971 *Siphonophycus kestron* Schopf in Schopf & Blacic, p. 948, pl. 109, figs 3, 4.
1977 Sheaths, Oehler, 1977, figs A, G, H.
1977 *Animikiea septata* Barghoorn in Awramik & Barghoorn, p. 139, fig. 7A.

Emended Diagnosis — Sheath (without trichome) cylindrical, tubular, aseptate, unbranched, variously curved; surface smooth to granulose; apices broad, capitate to bluntly pointed.

Type Species — Fig. 3, Part 2, Barghoorn, 1965 in Barghoorn and Tyler, 1965.

Remarks — The tubular cylindrical sheath from the Delhi Supergroup is much broader than the type specimen. The surface of the studied specimens show various surficial pattern from smooth to granulose. The granulose surface gives a pseudosepta appearance. Several specimens show the presence of apices which are variable in shape. This taxon is very common in the assemblage.

Animikiea punctata (Maithy) comb. nov. Mandal & Maithy

Synonymy:

1975 *Siphonophycus punctatus* Maithy, p. 137, pl. 1, fig. 5.

Diagnosis — As in Maithy, 1975.

Animikiea indica (Nautiyal) comb. nov. Mandal & Maithy

Synonymy:

1978 *Siphonophycus* sp. A, Nautiyal, p. 261, fig. 9

1980 *Siphonophycus indicus* Nautiyal, p. 3, fig. 1A

Diagnosis — As in Nautiyal, 1980.

Animikiea beltensis (Horodyski) comb. nov. Mandal & Maithy

Synonymy:

1980 *Siphonophycus beltensis* Horodyski, p. 654, pl. 1, fig. 4.

Diagnosis — As in Horodyski, 1980.

Animikiea crassiuscula (Horodyski) comb. nov. Mandal & Maithy

Synonymy:

1980 *Siphonophycus crassiusculum* Horodyski, p. 656, pl. 1, figs 6, 7

Diagnosis — As in Horodyski, 1980

FAMILY — SCYTONEMATACEAE

Genus — *Palaeoscytonema* Edhorn, 1973

Type Species — *Palaeoscytonema moorhousii* Edhorn, 1973.

Remarks — Edhorn (1973) and Maithy and Shukla (1977) recorded microfossils showing affinities with the living *Scytonema* and separately erected the genus *Palaeoscytonema* with different types. Later, Maithy (1980) transferred *Palaeoscytonema* of Maithy and Shukla (1977) to a new genus *Neoscytonema* to validate the same. The present taxon possesses false branch, hormogonia and thick sheath which overlap with the generic circumscription of *Palaeoscytonema* Edhorn (1973).

Palaeoscytonema indica sp. nov. Mandal & Maithy

Pl. 2, fig. 12

Diagnosis — Filament single up to 250 μm long; trichome solitary, sheathed; sheath 1.2 μm thick, multicellular and false branched laterally; trichome and branches enclosed in the same sheath; septa distinct, thin but indistinct towards terminal portion, inflated and curved at base, cells discoid, broader than long, nearly 3/4; width of trichome 11-13.2 μm at base, 5.5-8.5 μm at middle and 2 μm at tip, surface granulose; sheath adpressed to trichome and diffluent at the apices. Reproduction not known.

Holotype — Pl. 2, fig. 12; slide no. 6816; stage coordinates 62.7×95.

Locality — 1 km east of Baraud Village.

Etymology — With reference to occurrence in India.

Comparison & Discussion — The present taxon is characterised by false branching and the sheath encloses trichome and branches. However, reproductive structures have not been observed. *Palaeoscytonema indica* sp. nov. differs from *P. moorhousii* Edhorn (1973) in being the trichome and branches within the sheath, robust in form and having curved inflated base. Moreover, reproductive structures are not known. *P. intermingla* sp. nov. compares with *P. indica* in laterally false branched characters but differs in the absence of curved inflated base. *P. misrae* sp. nov. differs as it reproduces by 6-7 cells long hormognia and has a thin filament. The taxon is common in the Baraud assemblage.

Palaeoscytonema intermingla sp. nov. Mandal & Maithy

Pl. 3, figs 22, 23

Diagnosis — Filaments interwoven, 10.5 to 13 μm broad (on 6 counts), false branched; false branches lateral; sheath thick, adpressed to trichome; trichome about 5.5 to 7 μm broad; cells rectangular, septa faint, not attenuated at septa point; branches swollen at the tips with rounded apices.

Holotype — Pl. 3, fig. 22; slide no. 6816; stage coordinates 4×92.9.

Locality — 1 km east of Baraud Village.

Etymology — With reference to intermingling nature of branches.

Comparison — *Palaeoscytonema intermingla* sp. nov. differs from *P. moorhousii* Edhorn (1973), *P. indica* sp. nov. and *P. misrae* sp. nov. in possessing intermingling filaments and false branches with swollen and rounded apices. The taxon is rare in the assemblage.

Palaeoscytonema misrae sp. nov. Mandal & Maithy

Pl. 2, fig. 13

Diagnosis — Filaments isolated, variously curved, up to 50 μm long; trichome solitary, unbranched, faintly constricted at septa; cells drum-shaped, 6 to 10 μm long, 4 to 7 μm broad, side walls straight to convex, basal cells larger than medial ones, 10 to 12.2 μm long and 6.5 to 8 μm broad; sheath firm, thick about 1.2 μm; reproduction by hormogonia, 2 to 3 hormogonia formed at a time, up to 7 cells long.

Holotype — Pl. 2, fig. 13; slide no. 6816; stage coordinates 47.1 × 97.3.

Locality — 1 km east of Baraud Village.

Etymology — In honour of Prof. R. C. Misra, former Head of the Geology Department, Lucknow University for his contribution to the Precambrian research work in India.

Comparison & Discussion — *Palaeoscytonema misrae* sp. nov. is very distinct in morphology and differs from other species of *Palaeoscytonema* in possessing 6-7 cells long hormogonia formed 2-3 at a time. However, filament in the assemblage is being observed (Pl. 2, fig. 14) with broad apical cell nearly identical in measurement with *P. misrae*. In this filament the hormogonia consist of only two cells. Isolated hormogonia, as figured in Pl. 2, fig. 15, present in the assemblage are being supposed to belong to *P. misrae* on the basis of size measurements. The form is very rare in the assemblage.

FAMILY — RIVULARIACEAE

Genus — *Primorivularia* Edhorn, 1973

Type Species — *Primorivularia thunderbayensis* Edhorn, 1973.

Primorivularia robusta sp. nov. Mandal & Maithy

Pl. 3, fig. 23B

Diagnosis — Filaments solitary, up to 150 μm; trichome uniseriate, multicellular, unbranched, ensheathed fully; constricted at septa basally; sheath non-lamellated about 1 μm thick; basal cells spherical, broader than long, 12.2 μm long and 18 μm broad; medial cells rectangular, closely placed, septa faint; heterocyst basal, single hemispherical, 18 μm long and 15.5 μm broad; akinite not known.

Holotype — Pl. 3, fig. 23B, slide no. 6817; stage coordinates 61.6 × 94.2.

Locality — As noted above.

Etymology — With reference to robust morphology.

Comparison & Discussion — The taxon is represented by only three specimens. The terminal portion in all the specimens are broken, therfore, the presence of terminal hair could not be ascertained. However, the basal heterocyst, broader basal cells and gradual attenuated trichome overlap with the circumscription of *Primorivularia* Edhorn (1973) except the character of terminal hair. *Primorivularia robusta* sp. nov. differs from *P. thunderbayensis* Edhorn (1973) in being robust and the trichome fully covered by sheath.

ORDER — STIGONEMATALES

FAMILY — CAPSOSIRACEAE

Genus — *Ghoshia* gen. nov. Mandal & Maithy

Type Species — *Ghoshia bifurcata* gen. et sp. nov.

Diagnosis — Thallus heterotrichous, erect filaments arising from a basal horizontally creeping thallus, densely packed, truely laterally branched, with cells in one or two series; sheath absent; reproduction not observed.

Etymology — In honour of Prof. A. K. Ghosh, emeritus scientist, Department of Botany, Calcutta University, Calcutta.

Ghoshia bifurcata sp. nov. Mandal & Maithy

Pl. 4, figs 29-31

Diagnosis — As for the genus with the following characters; cells drum-shaped to rectangular, dark coloured, constricted at septa, 5 to 9.3 μm in diameter (average 5.5 μm on 33 counts), wall about 0.5 μm thick and surface psilate; branching irregular, *Locality* — 1 km east of Baraud Village.

Holotype — Pl. 4, fig. 30; slide no. 6817; stage coordinates 52.5×95.2.

Etymology — With reference to forking nature of erect filaments.

Discussion — Stigonematales is the most evolved order among the blue-green algae. This group of algae is characterised by heterotrichous filaments with true branching and multiplication by hormogonia and hormocysts. The present taxon exhibits heterotrichous habit and lateral branching which appears to be true. Reproductive structures, however, are not known. On the basis of known vegetative characters, putting more stress upon the true branching of heterotrichous filaments, this form compares well with the living algae *Stauromatonema* Fremy (Desikachary, 1959, p. 567) belonging to Stigonematales. Thus this is the earliest fossil record of Stigonematalean algae. This group of algae is known previously from the Middle Devonian of Rhynie Chert (Croft & George, 1959). The present record will materialistically contribute to the understanding of the early evolution of form. The genus *Ghoshia* is common in the assemblage.

INCERTAE SEDIS

Genus—*Vesicophycus* gen. nov. Mandal & Maithy

Type Species — *Vesicophycus problematicus* n. sp.

Pl. 3, fig. 25; Pl. 4, fig. 32

Diagnosis — Solitary empty envelope, mainly spherical or oval due to various foldings on the surface; folds common and irregular, surface without any ornamentation but rough. No pore or mark on surface.

Etymology — With reference to nature of vesicle and possible algal affinity.

Vesicophycus problematicus sp. nov. Mandal & Maithy

Diagnosis — As for the genus.

Etymology — With reference to doubtful nature of vesicles.

Holotype — Pl. 4, fig. 32; slide no. 6816; stage coordinates 43.2×101.4.

Locality — 1 km east of Baraud Village.

Comparison & Discussion — Horodyski and Donaldson (1980) described some large envelopes as *Archaeoellipsoides* from Arctic Canada which differs from *Vesicophycus* in being ellipsoidal, pear or sausage-shaped.

In all probability, these are the empty colony sheaths of coccoid forms which are abundant in the assemblage. Two vesicles were observed where 3-5 coccoid cells are still present inside. These coccoid cells are similar to the cells of *Myxococcoides compactus* sp. nov. (Pl. 2, fig. 17). In other cases the rupture of the wall indicates possibly the path for the outlet of the coccoids. Other possibility is that some of these vesicles used to contain zygospores and after their liberation from the vesicles the empty vesicles become collapsed with crumpled surface. As no comparable structure with the present form is known a new name *Vesicophycus* is erected to accommodate the spherical empty sheaths.

DISCUSSION

Structurally well-preserved microbiota comprising blue-green algae is recorded for the first time from the Ajabgarh Group. This is the most diversified Precambrian biota from India. The assemblage comprises 10 genera and 17 species. These taxa represent four natural families belonging to three orders — Chroococcales, Nostocales and Stigonematales. The presence of Stigonematales in the assemblage has been suggested by vegetative characters.

The diversification of the assemblage is evidenced by the varying morphology they exhibit. Sheath is present conspicuously in all the forms except *Ghoshia*, which may adpressed to the trichome (e.g. *Palaeoscytonema indica*) or loose (e.g. *Palaeolyngbya distinctica*). In *Primorivularia robusta* sheath is not discernible in the apical portion of the trichome. The reproductive structure observed in the filamentous forms is hormogonia (e.g. *Palaeoscytonema misrae*). Isolated hormogonia are also found in the assemblage (Pl. 2, fig. 15) which may belong to *P. misrae* like forms. Heterocyst is rare (Pl. 3, fig. 23), but akinite or other types of spores are totally absent. Vegetative cells also show various shapes — quadrangular (e.g. *Palaeolyngbya distinctica*), rectangular (e.g. *Palaeoscytonema baraudensis*) and discoidal (e.g. *P. indica*).

Basal cells in *Palaeolyngbya indica* is bigger than the medial cell whereas they are smaller or of the same size as in *Palaeoscytonema indica*. The assemblage is dominated by the filamentous forms which constitute 65 per cent of the total assemblage. However, coccoid forms are common in occurrence. It is interesting to note that there is no taxa of a single cell. The colonial habit suggests higher level of evolutionary stage. The colonies are in the form of algal mat which ultimately form the biostrome of the stromatolite.

Branching perhaps has emerged as most significant event in the assemblage. Record of false (lateral) branching is meagre in the early rocks. Earlier Edhorn (1973) reported false branching in *Plaeoscytonema moorhousii* from Canada. Baraud microbiota frequently exhibits false branching (e.g. *Palaeoscytonema intermingla* and *P. indica*). The branching in *Ghoshia bifurcata* has been suggested to be true one and therefore it has been placed in Stigonematales, where true branching commonly occur. If the suggested affinity of *Ghoshia* with the more advanced order of blue-green algae stands right on the basis of true branching then highest level of development of vegetative characters occurred in Delhi Supergroup. No other record of true branching is known so far from the Proterozoic. The earliest record of the preserved Stigonematalean form is available from the Middle Devonian Rhynie chert by Croft and George (1959).

Comparison with other assemblages — Structurally preserved microbiota are now known from the various Proterozoic rocks of India. However, the assemblages reported earlier by Maithy and Shukla (1977), Maithy and Gupta (1983), Maithy and Mandal (1983) from Vindhyans and Nautiyal (1978) from the Kumaun Himalaya are comparable as they comprise coccoid and filamentous forms comparable with blue-green algae. Chroococcaceae and Oscillatoriaceae are also common in all the assemblages. However, the Baraud assemblage is entirely different from all the above described assemblages in the dominance of filamentous forms and total absence of cryptarchs. In the Suket Shale microflora (Maithy & Shukla, 1977) well-preserved diverse biota is known till today, which is represented by Chroococcaceae, Oscillatoriaceae and Scytonemataceae. The present assemblage also contains these families with more developed structures such as hormogonia, heterocysts and with frequently branched filaments, which make the assemblage unique. On the whole the Baraud assemblage demonstrates advancement in evolutionary level than the Vindhyan biota though on geological evidences it is believed that Vindhyans are younger than Delhi Supergroup.

The assemblage compares well with Bitter Spring flora of Australia (Schopf, 1968; Schopf & Blacic, 1971). In both the assemblages Chroococcaceae, Oscillatoriaceae and Rivulariaceae appear to be common. The Bitter Spring microflora is very rich and much more diversified which contain probable Chlorophycean and Rhodophycean algae, fungi and bacteria, which are absent in Baraud. Similarly in Scytonemataceae, true and false branching and reproductive structures are totally absent from the Bitter Spring Formation. Thus on one hand the appearance of eucaryotic organism is significant in Bitter Spring while the appearance of true branching habit is most significant feature in Baraud. This coincidence indicates that true branching and nucleated cells probably appeared within short time interval. Assemblages reported by Edhorn (1973)—Animekie, Thunder Bay, Ontario; Hofmann and Jackson (1969) —Belchar island, Hudson Bay; Hofmann (1976) — Belcher island; Oehler (1977) — H.Y.C. Pyritic Shale Member, Australia; Muir (1976)—Amelia Dolomite, Australia; and Maithy (1975)—Bushimay Supergroup, Zaire differ in the constituents of microbiota. Moreover, both false and true branching present in this assemblage is characteristic.

From the above comparison it is evident that all the assemblages resemble in common occurrence of Chroococcaceae and Oscillatoriaceae. However, all of them differ in point to point comparison due to different climatic factors and evolutionary scales. It is possible that the evolution proceeded in more or less same direction but with different forces in different basins. According to Schopf and Blacic (1971) the correlation is possible only over short distances and when factors influencing species dispersed are thoroughly considered.

The occurrence of such diverse microbiota is a significant addition to the Indian Precambrian record. Microbiota known so far from the Vindhyans is not diverse like from Baraud. However, more sampling covering wide ecologically varying strata will certainly strengthen the basis for closer correlation. It appears that serious attempt is now needed before putting any final comment on the correlation between Delhi Supergroup and Vindhyans.

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EXPLANATION OF PLATES

(All figures are × 1000 unless otherwise stated; stage coordinates given for Leitz Dialux-20)

PLATE 1

1. *Myxococcoides inornata* Schopf showing a small cluster within organic matrix, phase interference photograph, slide no. 6816, stage coordinates 53.4 × 98.2.
2. *M. compactus* sp. nov., holotype; phase interference photograph; slide no. 6817, stage coordinates 12.5 × 100.
3, 4. *M. minor* Schopf showing different number of cells in the colony, slide no. 6818, fig. 3, stage coordinates 36 × 106, fig. 4, 41 × 107.4.
5. A solitary cell, comparable with *Huroniospora* Barghoorn, seems to be detached from *M. inornata* colony, slide no. 6816, stage coordinates 44.5 × 99.
6. *Gloeocapsomorpha karandiensis* Maithy & Mandal, slide no. 6817, stage coordinates 50.7 × 106.
7. *G. prisca* Zalessky, slide no. 6818, stage coordinates 25 × 105.5.
8. *Animikiea septata* Barghoorn showing apical part, slide no. 6816, stage coordinates 49.5 × 97.
9. *Palaeolyngbya* [illegible] sp. nov., slide no. 6816, stage coordinates 51.1 × 94.6.

PLATE 2

10, 11. *Palaeolyngbya distincta* sp. nov. showing thick sheath, quadrangular cells; phase interference photograph; slide no. 6818, fig. 10, holotype, stage coordinates 51 × 103.5, fig. 11, 51.5 × 100.2.
12. *Palaeoscytonema indica* sp. nov., holotype, slide no. 6816, stage coordinates 62.7 × 95.5 × 500.
13. *Palaeoscytonema minor* sp. nov., holotype, slide no. 6816, stage coordinates 47.1 × 97.3.
14. A filament showing separated hormogonia, slide no. 6816, stage coordinates 53.7 × 109.3.
15. An isolated hormogonia comparable with the hormogonia of *P. minor*; slide no. 6818, stage coordinates 53.5 × 101.3.
16. *Animikiea septata* Barghoorn, apical portion, slide no. 6816, stage coordinates 11.2 × 97.5.
17. An empty sheath of colony identical to *[illegible]* gen. nov. still containing 3 cells inside which are similar to *Myxococcoides compactus*, slide no. 6815, stage coordinates 49.8 × 50.4.

PLATE 3

18, 19. *Animikiea septata* Barghoorn, fig. 18, without apex showing false septation, slide no. 6816, stage coordinates 38.7 × 96.4; fig. 19 showing apex, false septation, slide no. 6816, stage coordinates 43.5 × 92.1.

20. *Palaeolyngbya elongata* sp. nov., holotype, note granular nature of trichome prominent in the apical part, slide no. 6816, stage coordinates 36.8 × 97; × 750.

21, 22. *Palaeoscytonema intermingla* sp. nov., showing false lateral branching; fig. 21, holotype, slide no. 6817, stage coordinates 48.2 × 96.8; fig. 22, slide no. 6816, stage coordinates, 44.4 × 92.9.

23. A, *Oscillatoriopsis obtusa* Schopf and B, *Primorivularia robusta* sp. nov., holotype, slide no. 6817, stage coordinates 61.6 × 94.2.

24. *Myxococcoides minor* Schopf, slide no. 6818, stage coordinates 59.4 × 107.2.

25. *M. compactus* sp. nov., slide no. 6818, stage coordinates 36.5, × 107.5, × 500.

PLATE 4

26-28. *Palaeoanacystis vulgaris* Schopf, fig. 26, slide no. 6817, stage coordinates, 60 × 99, × 500; fig. 27, a portion enlarged of fig. 26, × 1000; fig. 28, slide no. 6816, stage coordinates 30.5 × 95.9, × 500.

29-31. *Ghoshia bifurcata* gen. et sp. nov., fig. 29 showing initiation of heterotrichous condition, slide no. 6818, stage coordinates 39.3 × 106.8; fig. 30, holotype showing true branching in aerial filament, slide no. 6817, stage coordinates 52.5 × 95.2; fig. 31, slide no. 6817, stage coordinates 36 × 96.4.

32. *Vesicophycus problematicus* gen. et sp. nov., holotype, slide no. 6816, stage coordinates, 43.2 × 101.4.

PLATE 1


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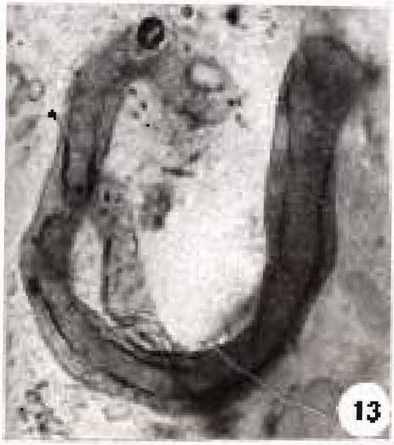
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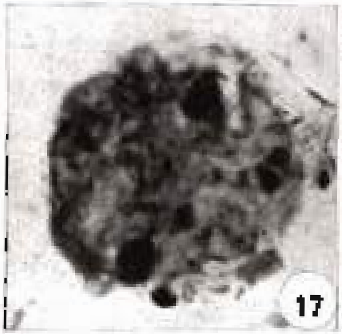
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PLATE 2

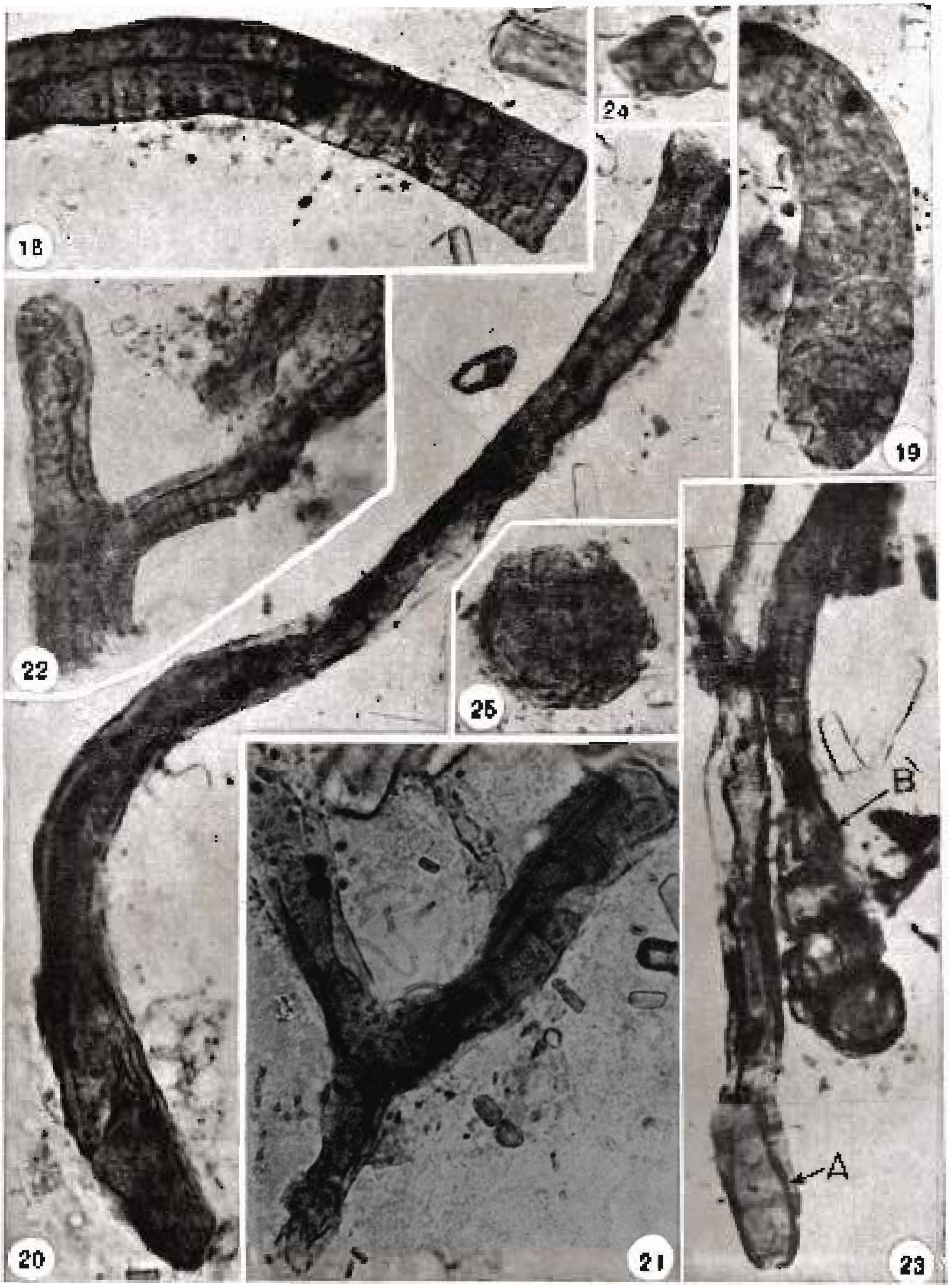

PLATE 3

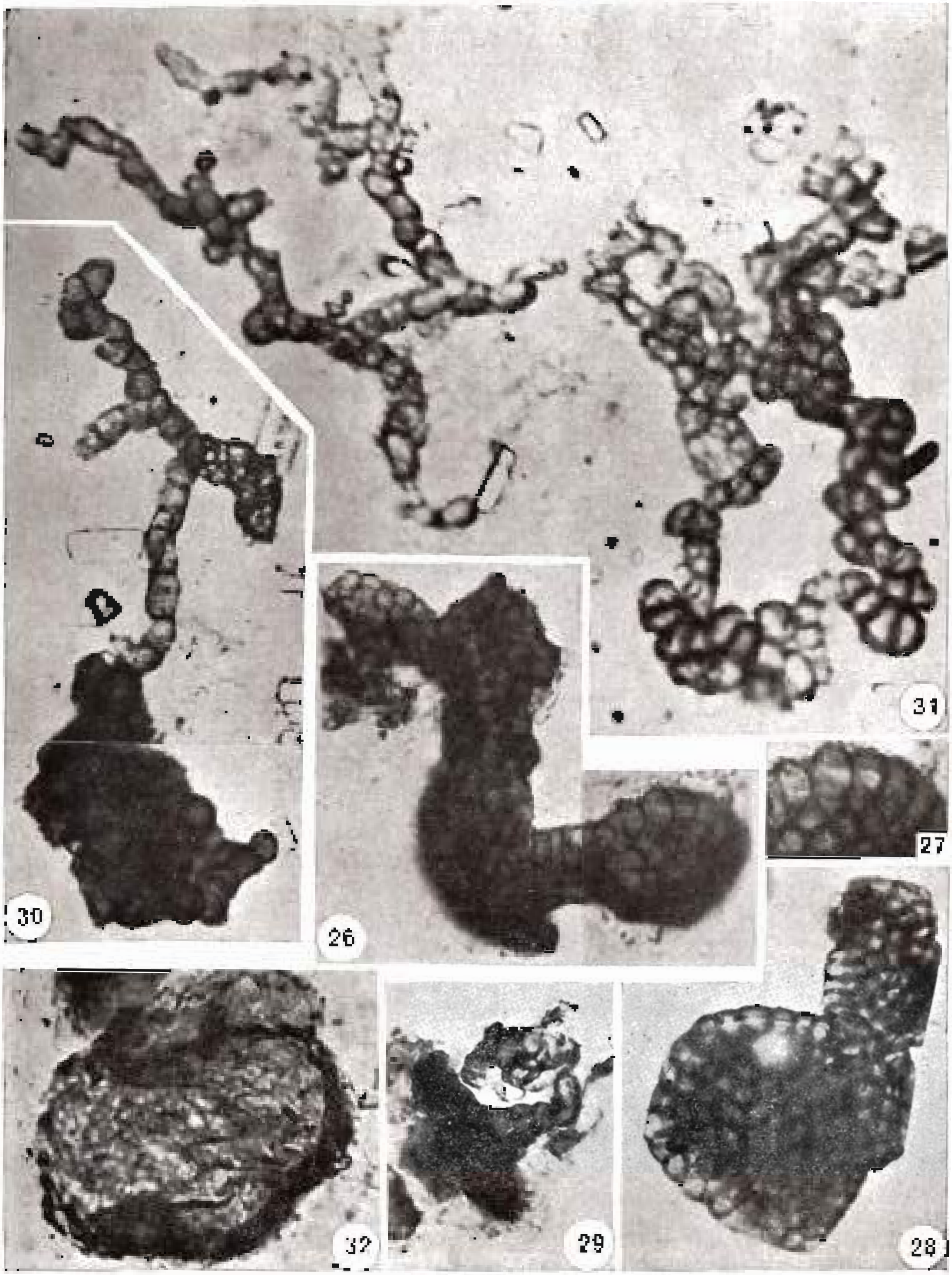

PLATE 4

SIDHIPHYLLITES: A NEW GINKGOPHYTIC LEAF GENUS FROM THE TRIASSIC OF NIDPUR, INDIA

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ABSTRACT

Ginkgophytic leaves with carbonified crust, collected from Nidpur, have been designated as *Sidhiphyllites flabellatus* gen. et sp. nov. Though the cuticle lacks the constant cuticular characters of a ginkgoalean leaf, yet, morphographically the leaves conform to the genus *Ginkgoites* Seward.

Key-words — Ginkgophytic leaf, *Sidhiphyllites*, Nidpur, Triassic (India).

साराँश

भारत में निदपुर के त्रिसंघी युग से एक नवीन गिन्क्गोफ़ाइटी पत्ती : सिधीफिल्लाइटिस – श्याम चन्द्र श्रीवास्तव

निदपुर से एकत्रित गिन्क्गोफ़ाइटी पत्तियों को सीधीफिल्लाइटिस फ्लेबॅलेटस नव वंश व नव जाति से नामाँकित किया गया है। ये पत्तियाँ कार्बनी पपड़ी से युक्त हैं। हालाँकि गिन्क्गोली पत्ती की उपचर्म में स्थायी उपचर्मी लक्षणों का अभाव है, तथापि बाह्य-आकारिकीय दृष्टि से ये पत्तियाँ गिन्क्गोइटिस सिवर्ड वंश के अनुरूप हैं।

INTRODUCTION

ALL the hitherto reported remains of ginkgoalean leaves from India are impressions. The leaves described here are the first record of compressions where the epidermal structure is preserved. Ginkgophytes were not known from the Indian Triassic until Lele (1961) who reported *Baiera indica* from the Triassic of Parsora region in South Rewa Gondwana Basin. Lele (1961) also referred some isolated segments of a frond to ginkgophytes but their fragmentary nature makes identification extremely difficult. Quite recently, Maheshwari and Banerji (1978) described a ginkgoalean leaf impression, *Ginkgoites goiraensis*, from the Triassic sediments of Kamtadand in Parsora region.

The generic name *Ginkgoites* has here been used again in view of Harris' (1976) observation that fossil *Ginkgo* or *Ginkgoites* are similar looking leaves of considerably different plants. Maheshwari and Banerji (1978) had also followed the same procedure but in 1979, Zeba-Bano, Maheshwari and Bose referring to Harris (1974) readopted the name *Ginkgo* for their forms. However, in the present paper the generic name *Ginkgoites* is revived.

Four leaf fossils revealing ginkgoalean affiliations are being described which have been collected from the Triassic sediments of Nidpur where remains of *Dicroidium* predominate and other fossils include remains of Bryophytes, Glossopteridales, Pteridospermales, Cycadales, Coniferales associated with characteristic unclassified leaves, scale-leaves, seeds and fructifications. These leaves are rather quite rare. In external form, the leaves conform to the genus *Ginkgoites* instituted by Seward (1919) but the cuticle lacks not only the remarkably constant epidermal features found in Ginkgoales but also of Czekanowskiales.

Hence, keeping in view the significance of epidermal characters which constitute the best and only safe criterion for generic assignment, the leaves are with good reason being described as *Sidhiphyllites* gen. nov.

Genus — *Sidhiphyllites* gen. nov.

Sidhiphyllites gen. nov.

Diagnosis — Leaf fan-shaped, lamina segmented, incision deep throughout, almost reaching to base, segments lanceolate, base slightly contracted, apex obtuse, margin entire. Veins bifurcating near base, fine, extending upwards, dichotomising repeatedly at acute angles, closely set, parallel to subparallel.

Lower surface slightly thicker, consisting of stomatiferous and non-stomatiferous zones, cells along the non-stomatiferous zones over the veins rectangular, serially arranged, interveinal zones wider than veinal zones, cells of interveinal bands polygonal, anticlinal walls straight or almost straight with undulations, periclinal walls generally smooth or thickened more often finely marked by ridges; stomata irregularly distributed, sparse, variably orientated, stomatal pit narrowly elongated or sometimes rhomboidal or more or less rounded, subsidiary cells scarcely different from adjoining cells, at places diffused with ordinary epidermal cells, 4-6 in number, inner margin of subsidiary cells thinly cutinized, guard-cells feebly thickened, aperture slit-like.

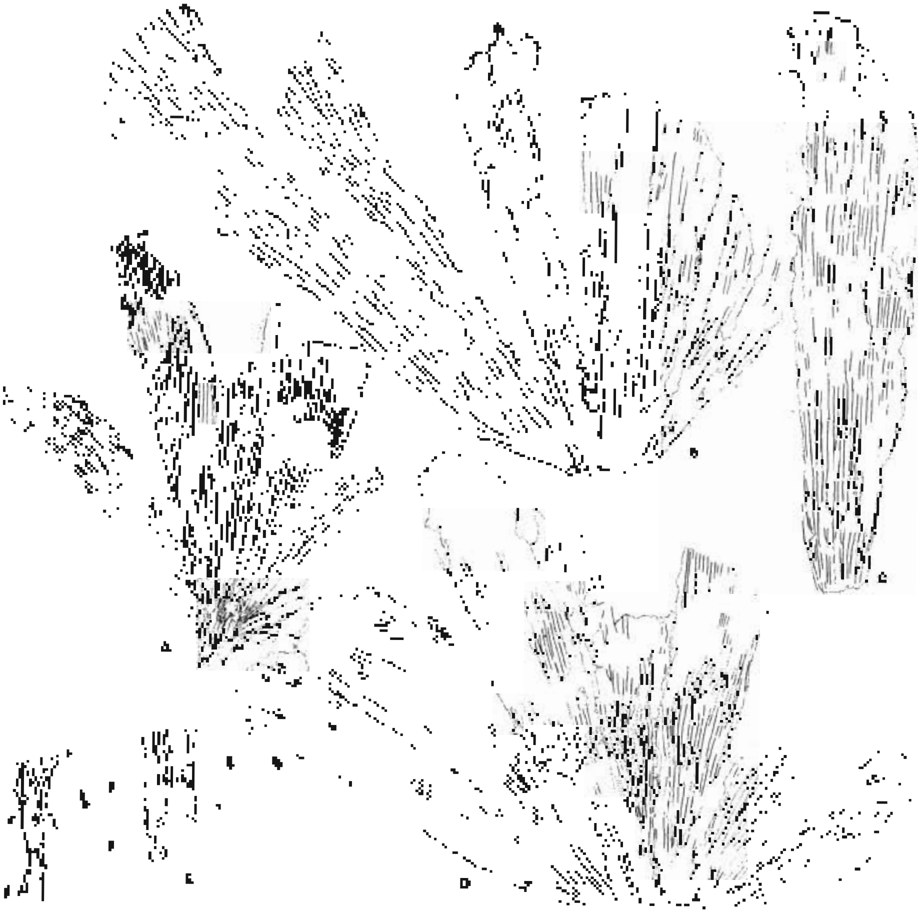
Type Species — *Sidhiphyllites flabellatus* sp. nov.

Sidhiphyllites flabellatus sp. nov.

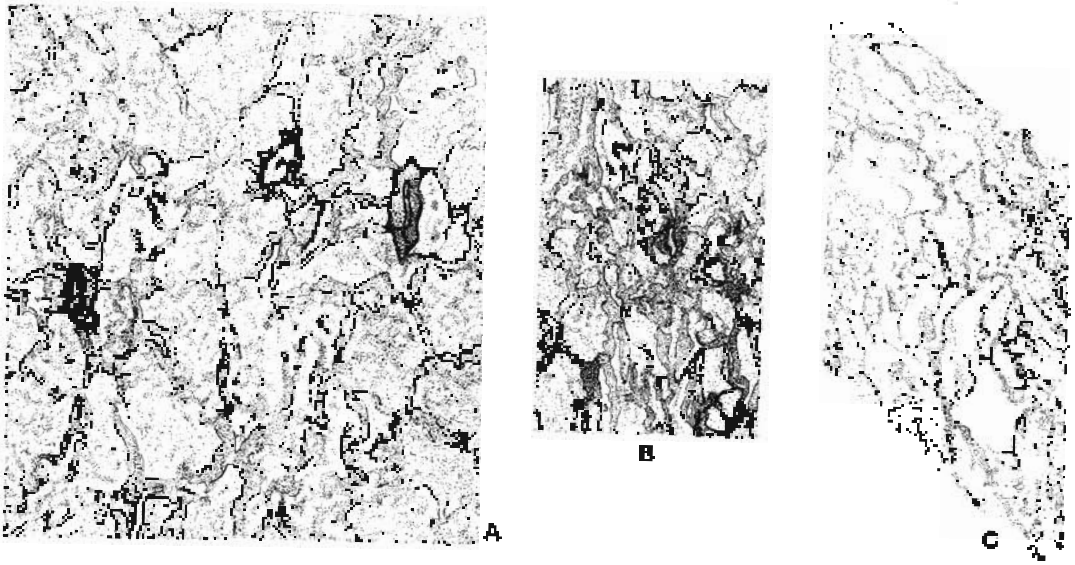
Pl. 1, figs 1-8; Text-figs 1A-E, 2A-C

1971 *Noeggerathiopsis* sp. Srivastava, p. 291, pl. 6, figs 6, 7; text-fig. 7A-B.

Diagnosis — Leaf fan-shaped, incompletely known, 3-5 cm long, petiole and



TEXT-FIG. 1 — *Sidhiphyllites flabellatus* gen. et sp. nov. A-D, showing venation; A, holotype no. 35444, × 3; B, specimen no. 35445, × 3; C, B.S.I.P. no. 33974, × 2; D, specimen no. 35446, × 2; E, slide no. 35444/5534, showing distribution of stomata; stomatiferous and non-stomatiferous zones, non-stomatiferous zones over the veins, × 250.



TEXT-FIG. 2 — A, showing a few stomata, slide no. 35444/6534, × 500; B, showing a stoma, slide no. 35444/6535, × 500; C, showing epidermal cells from the upper side, slide no. 35444/6534, × 500.

apex broken slightly wider, lamina segmented, incision equally deep throughout, almost reaching to base, segments 6 or more, symmetrically arranged, lanceolate; base slightly contracted or more or less tapering 2-3 mm in width; apex mostly imperfect, in a detached segment somewhat rounded or obtuse, margin entire. Veins fine, conspicuous, bifurcating near the base, in upper half fairly close, concentration near middle 12-16 per cm.

Cuticle about 1 μm thick, hypostomatic. Upper surface thin, veins not marked, cell outlines occasionally distinct, usually with faint undulations or sometimes inconspicuous, cells rectangular or slightly elongated, anticlinal walls more or less straight with exceedingly fine sinuosities, periclinal walls unsculptured.

Lower surface relatively thick, stomatiferous zones alternating with non-stomatiferous zones, cells along the course of veins elongate rectangular, serially arranged; zones between veins about 2-3 times as wide as zones along veins, cells between veins polygonal, occasionally isodiametric, anticlinal walls straight or almost straight with undulations, cell outlines often ill marked sometimes wall sinuosity obscured by thickenings, periclinal walls smooth or showing variously shaped thickenings, often marked by fine ridges, at places cells partly thickened; stomata irregularly distributed, well-spaced, variably orientated, stomatal pit narrow-elongate, subsidiary cells scarcely different from adjoining cells, 4-6 in number, inner margin of subsidiary cells feebly thickened; guard-cells thinly cutinized, aperture slit-like.

Holotype — No. 35444 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Gopad River near Nidpur, Sidhi District, Madhya Pradesh, India.

Age — Triassic.

Comparison & Discussion — The presence of ginkgoalean forms in the fossil flora of Nidpur is not striking because leaves like those of *Ginkgo biloba* occurred as far back as the Triassic. The genus *Ginkgo* is, however, recognized with certainty first only in the Jurassic rocks, a time when the family Ginkgoaceae is believed to have reached its widest geographic distribution in numbers and diversity. In India, too, although the record is far from complete, the genus attained its prominence during the Jurassic period.

Sidhiphyllites flabellatus has been recognized in its essential architecture with other Mesozoic ginkgoalean leaves because these are built upon a similar plan of repeated dichotomies, segmented lamina and divergent veins. But the cuticle of *S. flabellatus* lacks the constantly occurring ginkgoalean character, i.e. prominent papillae or cutinized lappets overhanging or overarching the sunken guard-cells or that appearing as a slightly raised rim. However, since the cuticular characters have proven to be more stable indicators of affinity, especially in the case of polymorphic leaves as frequent among ginkgophytes, here too, much stress has been placed on its distinctive epidermal feature.

In Krassilov's (1970) classification, *S. flabellatus* tends towards the morphological group (*Ginkgoites* & *Baiera*) which consists of fan-shaped and lobed lamina, bearing stomata only on one surface. This identity of *S. flabellatus* with the above mentioned grouping is strengthened further through close match in consistently divided lamina. However, some species like *Ginkgoites sibirica* Heer (1876), *Ginkgoites hermilinii* Harris (1935), *Ginkgoites tigrensis* Archangelsky (1965) and *Ginkgoites cascadensis* Brown (1975) are comparable to *S. flabellatus* in the incisions of lamina reaching almost or quite up to the base.

Apart from these aforesaid morphographic similarities, the two genera, *Sidhiphyllites* and *Ginkgoites*, demonstrate fundamental differences in cuticular structure. The subsidiary cells around the guard cells in the cuticles of *Ginkgoites* species show a varying degree of development of papillae projecting over the stomatal pits, a feature absent in the new genus *Sidhiphyllites*. However, *S. flabellatus* in its epidermal structure approaches closely *Baierophyllites florinii* described by Jain and Delevoryas (1967) from the Middle Triassic of Argentina in the smooth nature of epidermal and subsidiary cells and lacking the cutinized lappets overarching guard-cells. But in external morphology, *B. florinii* differs from *S. flabellatus* having linear leaves without distinction into petiole and lamina.

Of the Indian species of Ginkgoales, *G. goiraensis* Maheshwari & Banerji (1978) differs from *S. flabellatus* in having asymmetrically incised lamina along with sparse veins; *Ginkgoites lobata* (Feistmantel) Seward & Sahni (1920) in its wedge-shaped lamina; *Ginkgoites crassipes* Feistmantel (1879) in possessing undivided lamina; *Ginkgoites feistmantelii* Bose & Dev (1959) in bearing more or less reniform lamina and *Ginkgoites rajmahalensis* Sah & Jain (1965) (= *Ginkgo rajmahalensis* of Zeba Bano, Maheshwari & Bose, 1979) in having linear, club-shaped asymmetrically placed segments with veins converging towards apex.

Of the above mentioned *Ginkgoites* species only *G. feistmantelii* and *G. rajmahalensis* have yielded cuticles but their structural details are not adequately known because of imperfect preservation and hence no comparison could be made with *S. flabellatus*.

Affinity — The evidences at hand amply support the assignment of *S. flabellatus* to a new genus. Further, its morphographic data constitutes a convincing argument to settle its relationship to Ginkgoales with equal certainty. However, differences in epidermal structure of *Sidhiphyllites flabellatus* with those of other Ginkgoalean forms seem significant enough to preclude its identification with existing forms of Ginkgoaceae.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Dr Sukh Dev for his valuable comments. My thanks are also due to Mr P. K. Pal for his assistance in the preparation of some slides.

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EXPLANATION OF PLATES

Sidhiphyllites flabellatus gen. et sp. nov.

1. Segmented leaf, showing symmetrically dissected lamina. Holotype no. 35444.× 1.
2. Holotype enlarged, showing repeatedly dichotomising veins. Specimen no. 35444.× 2.
3. Specimen BSIP no. 35445.× 1.
4. Specimen figured in no. 3 enlarged, showing venation. Specimen no. 35445.× 3.
5. Specimen no. 35446.× 1.
6. Cuticle of thicker side showing a few stomata. Slide no. 35444/6534.× 500.
7. A stoma. Slide no. 35444/6535.× 500.
8. Epidermal cells of thicker side showing unusually thickened anticlinal-walls. Slide no. 35444/6536. × 500.


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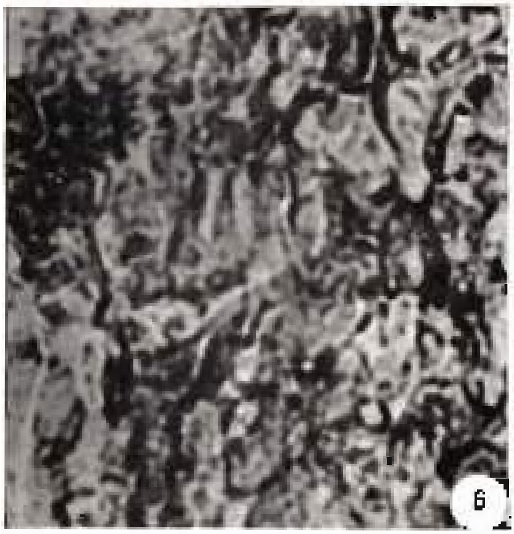
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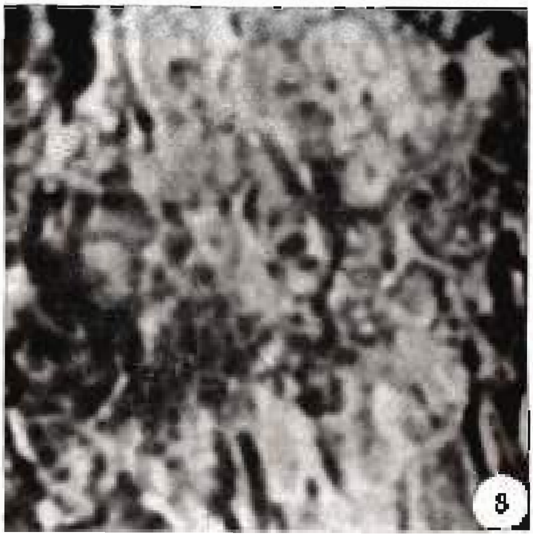
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PLATE I

The Palaeobotanist, **32**(1): 26-34, 1984.

PALYNOLOGICAL SUCCESSION OF THE LOWER GONDWANA SEDIMENTS IN UMARIA COALFIELD, MADHYA PRADESH, INDIA

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ABSTRACT

Palynological investigation of the Lower Gondwana sediments from Umrar River section and Umaria Coal Mine, Umaria Coalfield has been described. Four miofloral zones have been recognized. The first zone is characterized by the dominance of *Callumispora*+*Jayantisporites* and the second zone is marked by the dominance of *Parasaccites* and belongs to Lower and Upper Karharbari miofloras respectively. Miofloral Zone-3 has the dominance of *Scheuringipollenites*, whereas Miofloral Zone-4 shows the overall dominance of striate-disaccate pollen grains representing the Lower and Upper Barakar miofloras in succession.

Key-words — Palynology, *Callumispora*, *Jayantisporites*, *Parasaccites*, *Scheuringipollenites*, Umaria Coalfield, Lower Gondwana (India).

साराँश

मध्य प्रदेश (भारत) के उमरिया कोयला-क्षेत्र में अधरि गोंडवाना अवसादों का परागाणविक अनुक्रम – सुरेश चन्द्र श्रीवास्तव एवं आनन्द-प्रकाश

उमरिया कोयला-क्षेत्र की उमरिया कोयला-खान एवं उमरार नदी खंड के गोंडवाना अवसादों का परागाणविक अन्वेषण प्रस्तुत किया गया है। अन्वेषण के आधार पर चार सूक्ष्मवनस्पतिजातीय मंडल बनाये गये हैं। प्रथम मंडल कैल्युमिस्पोरा + जयन्तिस्पोराइटिस की बाहुल्यता से अभिलक्षणित है, दूसरा मंडल पॅरासैक्काइटिस की बाहुल्यता व्यक्त करता है तथा क्रमशः अधरि एवं उपरि करहरबारी सूक्ष्मवनस्पतिजातों से सम्बन्धित है। सूक्ष्मवनस्पतिजातीय मंडल – 3 श्यौरिंगीपॉलिनाइटिस से प्रभावी है, जबकि मंडल – 4 रेखित-द्विकोष्ठीय परागकणों की बाहुल्यता के साथ-साथ अनुक्रम में अधरि एवं उपरि बराकर सूक्ष्मवनस्पतिजातों का निरूपण करता है।

INTRODUCTION

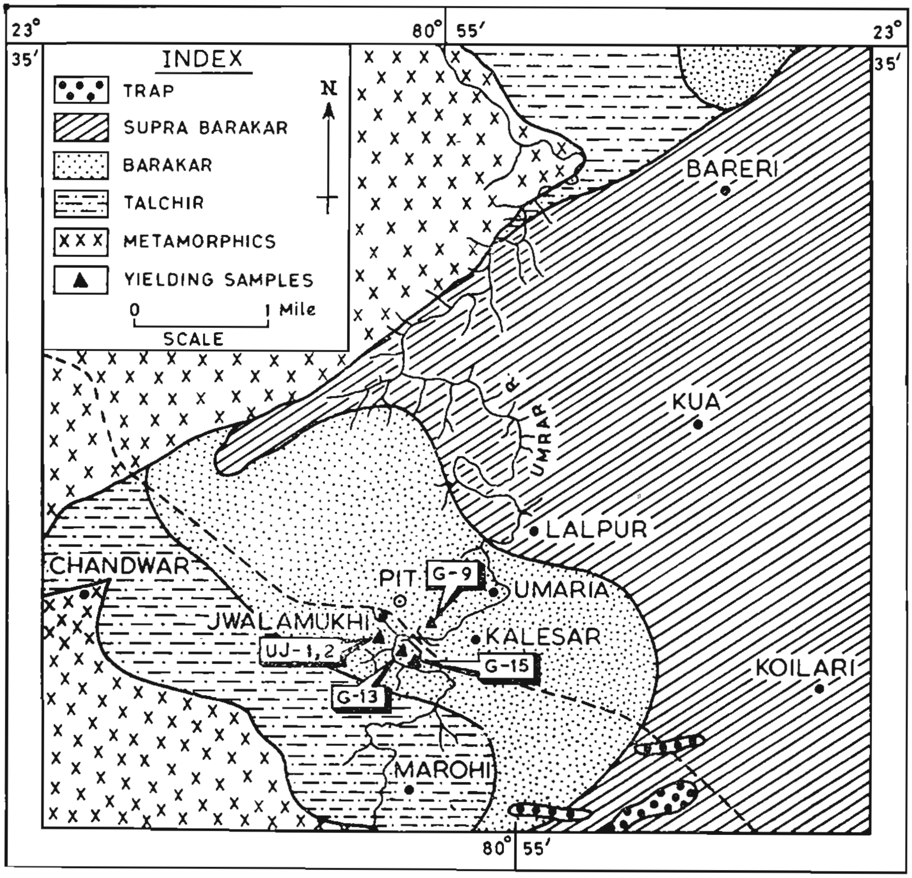
THE Umaria Coalfield is situated in South Rewa Gondwana Basin between longitudes 80°47′-80°56′ and latitudes 23°29′-23°38′. Feistmantel (1882) and Hughes (1885) first described the plant fossils from the coal-bearing beds. Maithy (1966) recorded *Gangamopteris cyclopteroides* Feistmantel, *Glossopteris indica* Schimper, *Noeggerathiopsis* sp., *Cordaicarpus zeilleri* Maithy, cf. *Gondwanidium* sp. and few equisetalean stems. He also recorded 15 miospore genera, majority of monosaccate pollen grains, and thus snggested a Karharbari age for the coal-bearing beds of Umaria Coalfield conforming to the earlier dating by Feistmantel (1882) and Hughes (1885). Chandra and Srivastava (1982) have also described three species of *Gangamopteris*, four species of *Glossopteris*, and few equisetalean stems from Umaria, and equated their assemblage with the known Karharbari assemblages. However, Fox (1931) considered them to be Barakar in age and thus the age of the coal-bearing beds remained a controversial subject. In addition to these, Tripathi (1952) discovered some megaspores from the coal horizon of Umaria Coalfield. The Talchir Formation including the marine intercalations were studied by Lele and Chandra (1969, 1972) and Chandra and Lele (1979). The miofloral records were rather poor but the marine bed yielded considerably rich acritarchs. Thus, obviously, the knowledge regarding palynological fossils of the Lower Gondwana sediments of Umaria Coalfield remains incomplete and hence to fill the lacunae an attempt has been made here to work out a palynostratigraphic succession of sediments.

GEOLOGY

The geology of the area was first studied by Medlicott (1860) and later by Hughes (1879-81). Gee in 1928 proved the existence of workable coal seams. Later, Venkatappayya, Deshmukh and Srivastava (1960) mapped the area in detail. The known geological formations in the Umaria Coalfield are as follows (Map 1):

Supra Barakar	Massive, conglomeratic, pebbly and gritty, white sandstone with intercalations of red clay
Barakar	Massive, medium to coarse grained sandstone, shale and coal seams
Talchir	Marine bed, greenish pebbly sandstone, clay and shales
……………………	……………………
Metamorphics	Gneisses and schists

The Lower Gondwana sediments are deposited over the Archeans which are exposed towards west, north and southern part of the coalfield. The oldest formation, i.e. Talchir Formation, rests over the metamorphics and is exposed along Umrar River and a few tributaries south and south-west of Umaria. The marine fossiliferous beds



MAP 1 — Geological map of the Umaria Coalfield, Madhya Pradesh (after Hughes, 1884).

are exposed in the railway cutting near Narsarha nala north-west of Umaria railway station. The Barakar Formation overlies the Talchir Formation and is the principal coal-bearing horizon in this coalfield and includes massive, medium to coarse-grained sandstones, shale and six coal seams. The succession of these sediments is exposed along Umrar River which ultimately traverses into Supra Barakar sediments in the northern part of the Umaria Coalfield.

The general succession of coal seams in this area is as follows:

Seam I	1.2-1.5 m
Parting	12.1 m
Seam II	1.5-2.4 m
Parting	24.3-27.4 m
Seam III	1.5-3.9 m
Parting	2.7-7.0 m
Seam IV	1.5-2.1 m
Parting	12.1 m
Seam V	1.0 m (Exposed near the railway bridge)
Parting	24.3 m
Seam VI	1.2 m (Exposed near the Jwalamukhi temple)

TABLE 1 — SHOWING DETAILS OF SAMPLES COLLECTED FROM THE UMARIA COALFIELD

SAMPLE No.	LOCALITY	LITHOTYPE	AGE	MIOSPORE OCCURRENCE
		Umrar River Section		
G1		Sandstone	Supra Barakar?	−
G2		Fine grained sandstone	Barakar?	−
G3		Coarse grained sandstone	Barakar	−
G4		Sandy Shale	Barakar	++
G5		Sandstone	Barakar	−
G6	Near Kalesar Ghat	Sandstone	Barakar	−
G7	,, ,,	Sandstone	Barakar	−
G8	,, ,,	Medium grained sandstone	Barakar	−
G9	Below railway bridge	Carbonaceous shale	Barakar	++
G10	,, ,,	Sandstone	Barakar	−
G11	,, ,,	Sandstone	Barakar	Spicules?
G12	,, ,,	Sandstone	Barakar	−
G13	South of railway bridge	Top sandy shale (2 m)	Barakar	++
G14	,, ,,	Carbonaceous shale	Barakar	++
G15	,, ,,	Carbonaceous shale (2 m)	Barakar	++
G16	,, ,,	Sandstone		−
G17	,, ,,	Sandstone		
G18	,, ,,	Sandstone	Talchir	+
		Railway Cutting		
G19		Sandstone	Talchir	−
G20		Boulder bed	Talchir	−
G21		Sandstone	Talchir	−
G22		Needle shale	Talchir	−
G23		Needle shale	Talchir	−
G24		Basement rock	Archean	−
		Jwalamukhi Temple		
UJ1	Tributary of Umrar River	Coal	Barakar	++
UJ2	On the bank facing the temple	Coal	Barakar	++
		Umaria Coal Mine		
1		Bottom coal+underlying shale — III seam	Barakar	+
2		Top Coal III Seam		+
3		Carbonaceous shale overlying III seam		+
4		Coal — IV Seam		+
5		Coal — V Seam		+

Note: ++, rich in miospores; +, miospores rare; −, miospores absent.

TABLE 2 SHOWING PERCENTAGE COMPOSITION OF MIOSPORE GENERA IN THE YIELDING SAMPLES UNDER STUDY, UMARIA COALFIELD

GENERA/SAMPLE No.	JWALA-MUKHI TEMPLE	UMRAR RIVER SECTION					UMARIA COAL MINE
		South of Rly. bridge			Rly. bridge		
	UJ1+2	G15	G14	G13	G9	G4	5
Leiotriletes	3.0	—	1.0	0.5			—
Callumispora	28.0	21.0	7.0	4.0	4.0	1.0	—
Hennellysporites	1.0	1.0	2.0	1.0	1.0	—	—
Cyclogranisporites	—		—	1.0	—		—
Verrucosisporites			—	—	8.5	—	—
Lophotriletes	—		1.0		—	2.0	1.0
Brevitriletes	5.0	1.5	1.0	1.0	7.0	12.0	2.0
Pseudoreticulatispora	—		—		—	1.0	—
Horriditriletes	—	—	—		1.0		1.0
Microbaculispora	5.0	16.0	23.0	6.0	2.0	—	—
Indotriradites			—	—	—		9.0
Potonieitriradites		—	—	—	11.0	1.0	—
Jayantisporites	31.5	47.0	56.0	40.0	—	—	—
Parasaccites	2.5	5.0	2.0	24.0	25.0	4.0	5.0
Caheniasaccites	—	—		2.0	—	—	0.5
Potonieisporites	—	—	—	—	2.0	—	—
Vestigisporites	1.0	1.0		2.0	5.0	1.0	1.0
Plicatipollenites	1.0	—	—	9.0	9.0	2.0	1.0
Crucisaccites			—	—	1.0	—	—
Virkkipollenites	—	—	1.0	0.5	4.0	—	2.0
Platysaccus	1.0		—	1.0	2.0	11.0	1.0
Striatites	—				—	14.0	4.0
Primuspollenites	—		—	—	—		5.0
Rhizomaspora	—	—	—		—	—	0.5
Lahirites	—	—			—	8.0	—
Striatopodocarpites	1.0	—	—	—	1.5	8.0	7.0
Hindipollenites		—	—	—	—	1.0	—
Faunipollenites	1.0	—		0.5	1.5	11.0	8.5
Illinites	—	—	1.0	—	—	2.0	2.5
Vesicaspora	5.5	1.0	1.0	4.0	5.0	9.0	17.5
Scheuringipollenites	0.5	—	—	—	2.5	3.0	24.0
Ibisporites	—	—		—		1.0	1.0
Tiwariasporis				—	—	4.0	2.0
Ginkgocycadophytus	7.0	1.0	2.0	1.0			3.0
Pilasporites	1.0	2.0	1.0	2.5	3.5	2.0	0.5
Maculatasporites	—	0.5		—	—	—	—
Leiosphaeridia	1.0	1.0	1.0	—	1.0	2.0	—

PALYNOLOGICAL SUCCESSION

The palynofossils recovered consist of following 38 genera:

Leiotriletes, *Callumispora*, *Hennellysporites*, *Cyclogranisporites*, *Lophotriletes*, *Verrucosisporites*, *Brevitriletes*, *Pseudoreticulatispora*, *Horriditriletes*, *Microbaculispora*, *Microfoveolatispora*, *Potonieitriradites*, *Indotriradites*, *Jayantisporites*, *Parasaccites*, *Caheniasaccites*, *Potonieisporites*, *Vestigisporites*, *Plicatipollenites*, *Crucisaccites*, *Virkkipollenites*, *Platysaccus*, *Striatites*, *Primuspollenites*, *Rhizomaspora*, *Lahirites*, *Striatopodocarpites*, *Hindipollenites*, *Faunipollenites*, *Illinites*, *Vesicaspora*, *Scheuringipollenites*, *Ibisporites*, *Tiwariasporis*, *Ginkgocycadophytus*, *Pilasporites*, *Maculatasporites* and *Leiosphaeridia*.

Of all the above genera *Callumispora*, *Jayantisporites*, *Parasaccites* and *Scheuringipollenites* play an important role being the dominant ones. The other genera in order of dominance are *Brevitriletes*, *Microbaculispora*, *Potonieitriradites*, *Indotriradites*, *Plicatipollenites*, *Striatites*, *Striatopodocarpites* and *Faunipollenites*. On the basis of the quantitative distribution four miofloral zones have been distinguished.

Miofloral Zone I — This is characterised by the dominance of the genus *Jayantisporites*. This taxon is present up to 31 per cent in Sample no. UJ/1+2, increases to 56 per cent in Sample no. G14, declines to 40 per cent in Sample no. G13 and finally disappears in the younger sediments. *Callumispora* shows its maximum frequency in Sample no. UJ/1+2 (30%) and then declines gradually in the younger sediments. The third taxon in significance is *Microbaculipsora* which marks an increasing tendency from Sample no. UJ/1+2 (5%) to G15 (16%) and attains maximum in G14 (23%) and then declines gradually in further younger samples. *Vesicaspora* and *Ginkgocycadophytus* although present consistently are in decreasing order from older to younger sediments.

Miofloral Zone 2 — This assemblage zone is marked by the dominance of *Parasaccites* (33% in Sample no. G9) which was subdominantly present in G13. The monosaccates are further increased by the representation of *Plicatipollenites* (9%), *Crucisaccites* (1%), *Virkkipollenites* (4%), *Vestigisporites* (5%) and *Potonieisporites* (2%) and thus bringing a total average of 54 per cent. Among the zonate triletes, *Jayantisporites* is absent and *Potonieitriradites* is present up to 11 per cent. Apiculate triletes also increase to 10 per cent.

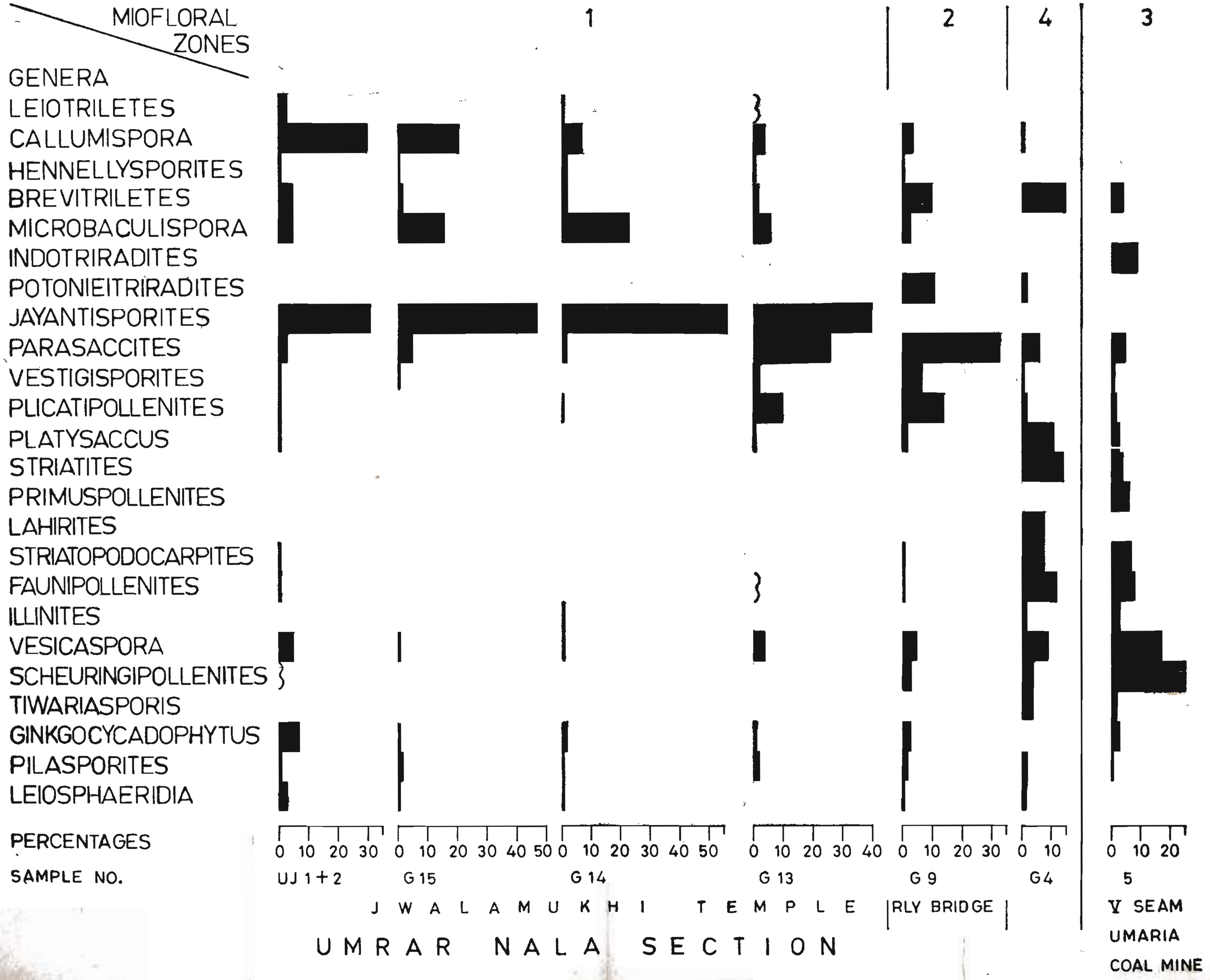
Miofloral Zone 3 — The mioflora of the coal samples (Sample no. 5) from Umaria Coal Mine shows an overall dominance of nonstriated-disaccate pollen grains (58%), maximum being represented by *Scheuringipollenites* (24%). *Vesicaspora* shows its maximum (17%). *Primuspollenites* (5%) and *Indotriradites* (9%) are present only in this sample. Apiculate triletes are, however, reduced to 4 per cent and so are the monosaccate pollen grains (8%). Striated-disaccates increase to 18 per cent.

Miofloral Zone 4 — Sample no. G4 of the Umrar River Section shows maximum development of striated-disaccate pollen grains (46%), being represented by *Striatites* (14%) and *Faunipollenites* (11%). *Tiwariaporis* rises to 4 per cent. On the other hand, *Vesicaspora* and *Scheuringipollenites* decline to subdominance in the present sample.

COMPARISON

The Talchir sediments of the railway cutting have not yielded sufficient miospores and hence a quantitative estimation of the mioflora could not be made. However, the genera identified among them resemble qualitatively with the known Talchir miofloras. Lele and Chandra (1972) also made similar observation from the marine beds of the Umaria Coalfield.

The coal seam (sample UJ/1+2) exposed in the tributary of Umrar River near Jwalamukhi Temple shows a combined dominance of *Callumispora* + *Jayantisporites*. The dominance of *Callumispora* is known from the Lower Karharbari seam of the Giridih Coalfield (Srivastava, 1973) but the percentage of *Parasaccites* and *Brevitriletes* are higher in the latter. *Jayantisporites* was first recorded from the Talchir Formation of the Jayanti Coalfield by Lele and Makada (1972) but quantitatively it was rare in the Talchir and Karharbari formations of the Jayanti Coalfield. Later on its presence in association with *Callumispora* was recorded in the Chirimiri Coalfield (Srivastava, 1980b; Lower Karharbari; Paradol-Chirimiri railway cutting, Sample no. CR/15) and also the Lower Karharbari mioflora of North Karanpura Coalfield (Srivastava, 1980a; Honhe area; Sample no. B/5). However, the dominance of *Jayantisporites* is the first record from Umaria Coalfield and its maximum development has been recorded in the sediments exposed in Umrar River (Sample nos. G15-G13) where *Callumispora* shows a declining phase. Instead the genus *Microbaculispora* attains significance. In the Lower Karharbari miofloras of Chirimiri (Srivastava, 1980b) and North Karanpura (Srivastava, 1980a) coalfields *Microbaculispora* also forms the subdominance. In Korba Coalfield (Bharadwaj & Srivastava, 1973, younger phase of Zone 1), however, *Callumispora* is associated with *Parasaccites* and *Brevitriletes*. The above comparison shows that the coal seam exposed near Jwalamukhi temple and the Sample nos. G15-G13 of Umrar River belong to the same group, the Lower Karharbari, the former being the oldest. The coal seam exposed near Jwalamukhi temple also represents the oldest coal seam (Seam VI) of the Umaria Coalfield. In this respect the carbonaceous shale (Sample no. G9) associated with a coal seam exposed below the railway bridge shows maximum development of radial monosaccates and is associated with a zonate trilete genus


MIOFLORAL ZONES
GENERA
1
2
4
3
LEIOTRILETES
CALLUMISPORA
HENNELLYSPORITES
BREVITRILETES
MICROBACULISPORA
INDOTRIRADITES
POTONIEITRIRADITES
JAYANTISPORITES
PARASACCITES
VESTIGISPORITES
PLICATIPOLLENITES
PLATYSACCUS
STRIATITES
PRIMUSPOLLENITES
LAHIRITES
STRIATOPODOCARPITES
FAUNIPOLLENITES
ILLINITES
VESICASPORA
SCHEURINGIPOLLENITES
TIWARIASPORIS
GINKGOCYCADOPHYTUS
PILASPORITES
LEIOSPHAERIDIA
PERCENTAGES
0 10 20 30
0 10 20 30 40 50
0 10 20 30 40 50
0 10 20 30 40
0 10 20 30
0 10
0 10 20
SAMPLE NO.
UJ 1+2
G 15
G 14
G 13
G 9
G 4
5
JWALAMUKHI TEMPLE
RLY BRIDGE
V SEAM
UMARIA
COAL MINE
UMRAR NALA SECTION

HISTOGRAM 1

Potonieitriradites. The apiculate triletes also increase in their percentages. The older subzone of Zone 2 in the Korba Coalfield, (Bharadwaj & Srivastava, 1973), the Kauakoh Nala Section of the Chirimiri Coalfield (Srivastava, 1980b) shows similar dominance of *Parasaccites* but do not contain zonate triletes similar to Sample no. G9 of Umrar River. The Upper Karharbari seam of the Giridih Coalfield is dominant in *Illinites* + *Vesicaspora* and is different from the present mioflora. Thus, the coal seam exposed below the railway bridge, i.e. Coal seam V of the general sequence, represents the Upper Karharbari seam of the Umaria Coalfield.

The mioflora of the coal seam (Sample no. 5) being worked out in Umaria Coal Mine shows a significant variation from the above miofloras rich in nonstriated-disaccates, chiefly *Scheuringipollenites* and *Vesicaspora*, and striate-disaccates in general follow the subdominance. Among the zonate trilete, *Indotriradites* is significant. Although the Upper Karharbari seam of the Giridih Coalfield contains a significant amount of *Vesicaspora* and thus bears a close affinity with the coal seam of Umaria Coal Mine, yet it differs in having larger percentages of monosaccates. Similar association of *Scheuringipollenites* is also described by Bharadwaj and Tripathi (1978) from South Karanpura Coalfield (Table 4, Roof Shale, Argada 'S' Seam, Assemblage Zone A). In the Barakar type area, i.e. the Raniganj Coalfield, *Scheuringipollenites* is present in Zone 4 (Tiwari, 1973) and thus compares with the present mioflora. Similar dominance is also known from Korba, (Bharadwaj & Srivastava, 1973; Zone 3), Giridih (Srivastava, 1973; Zone 1), and Pench-Kanhan coalfields (Bharadwaj, Navale & Anand-Prakash, 1974). All these assemblages are dominated by nonstriated-disaccates (*Scheuringipollenites*) and the striated-disaccates come next to them. Monosaccates are rare. Maithy (1966) described a mioflora from the shales of New Umaria Colliery showing the dominance of monosaccate pollen grains. The present mioflora being dominant in nonstriated-disaccates does not compare at all.

The youngest assemblage in the present investigation has been recorded in Umrar River Section (Sample no. G4) which shows the dominance of striated-disaccate pollen grains (*Striatites* + *Faunipollenites*). Nonstriated-disaccates form the subdominance. The apiculate triletes are chiefly represented by *Brevitriletes*. Striated-disaccate mioflora is characteristic of the Upper Barakars (Tiwari, 1973, Zone V) and similar mioflora is also reported from North Karanpura Coalfield (Kar, 1973, Zone VI). In South Karanpura Coalfield the striated-disaccate rich assemblage is present in Argada A and Argada B seams of Saunda Block, (Bharadwaj & Tripathi, 1978; Assemblage Zone B) which compares closely with those of sample no. G4 in Umrar River Section of Umaria Coalfield representing the Upper Barakar mioflora.

The palynological succession of the Umaria Coalfield in the present investigation may be summarised as follows:

BARAKAR	UPPER ZONE-4	G4 Umrar River	*Striatites* *Faunipollenites*	Dominant Subdominant
	LOWER ZONE-3	Umaria Coal Mine (sample no. 5)	*Scheuringipollenites* *Vesicaspora*	Dominant Subdominant
KARHARBARI	UPPER ZONE-2	G9 Umrar River	*Parasaccites* *Potonieitriradites*	Dominant Subdominant
	LOWER ZONE-1	G15-G13 Umrar River	*Jayantisporites* *Microbaculispora*	Dominant Subdominant
		Jwalamukhi Temple	*Jayantisporites*+ *Callumispora* *Microbaculispora*	Dominant Subdominant

CONCLUSION

The present investigation has revealed that almost a complete sequence from Talchir to Barakar (Upper) formations is developed in Umaria Coalfield, indicating the presence of a considerably reduced thickness of Barakar sediments in the area as compared to the other Lower Gondwana coalfields. The coal-bearing horizon extends from Lower Karharbari to Upper Barakar. The coal seam (youngest) being worked at Umaria coal mine compares with known Lower Barakar miofloras. Further, Supra-Barakars in the northern part of the coalfield may have concealed even younger sediments and also a good reserve of coal of economic value.

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OCCURRENCE OF ANACARDIACEOUS WOODS IN THE TERTIARY OF WESTERN INDIA

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ABSTRACT

The present paper deals with two fossil woods of the family Anacardiaceae showing closest resemblance with the woods of the extant genera *Gluta* L. and *Mangifera* L. The former is described from the Banaskantha District of Gujarat and the latter from the Jaisalmer District of Rajasthan. The occurrence of these woods during the Tertiary in the above areas indicates that the climatic conditions were definitely more humid at the time of deposition of these woods than the present dry desertic conditions.

Key-words — Anacardiaceous woods, *Glutoxylon*, *Mangiferoxylon*, Gujarat, Rajasthan, Tertiary, India.

सारांश

पश्चिमी भारत के तृतीयक युग से ऐंनाकार्डिएसी कुल की काष्ठें – जसवंत सिंह गुलेरिया

इस शोध-पत्र में ऐंनाकार्डिएसी कुल के वर्तमान ग्लूटा लिने एवं मेंजिफ़ेरा लिने की काष्ठों से घनिष्ठतम् सजातीयता व्यक्त करने वाले दो काष्ठाश्मों का वर्णन किया गया है। पहला काष्ठाश्म गुजरात के बनासकाँठा जनपद से तथा दूसरा राजस्थान के जैसलमेर जनपद से वर्णित किया गया है। उपरोक्त क्षेत्रों में तृतीयक युग में इन काष्ठाश्मों की उपलब्धि यह इंगित करती है कि वर्तमान शुष्क मरुद्भिदी परिस्थितियों की अपेक्षाकृत इन काष्ठाश्मों के निक्षेपण के समय निश्चित रूप से अधिक नम जलवायवी परिस्थितियाँ विद्यमान थीं।

INTRODUCTION

VERY little work has been done so far on the Tertiary megaflora of western India (Gujarat & Rajasthan). The earliest known megafossils from Gujarat are two palms, viz., *Palmoxylon mathurii* and *P. seriatum* and a cylindrical reed-like stem *Culmites cutchensis* belonging to the family Gramineae described by Sahni (1932, 1964) which are believed to come from the Cretaceous of district Kachchh. However, the locality and the age of these monocot fossils is doubtful and may most probably be Tertiary. Ghosh and Ghosh (1959) were the first to describe a dicot wood from the Tertiary beds of Kachchh. Subsequently, Prakash and Dayal (1968), Lakhanpal *et al.* (1975), Awasthi *et al.* (1980), Lakhanpal and Guleria (1981), Awasthi *et al.* (1982), Lakhanpal and Guleria (1982), Guleria (1983, 1984), Guleria and Lakhanpal (in press) have described a number of fossil woods, leaves and fruits. They belong to the following families: Combretaceae, Dipterocarpaceae, Lauraceae, Leguminosae, Lythraceae, Moraceae, Palmae, Pandanaceae, Podocarpaceae, Sapindaceae, Sterculiaceae and Rutaceae. The only other record of megafossil from Gujarat is a fossil wood of *Terminalia* described by Mahabalé and Deshpande (1965) from Ghala in the Surat District.

From Rajasthan, La Touche (1911, p. 34) reported the occurrence of angiosperm leaves from Barmer Sandstone. Later on, Bose (1949, 1950, 1952), Kaul (1951), Lakhanpal and Bose (1951) and Lakhanpal (1964) described a few angiospermic leaf-impressions and fruits from the Palaeocene-Eocene beds of the Barmer District. Some of them have been assigned to the families Guttiferae and Palmae. Das Gupta (1977) reported the occurrence of fossil leaves belonging to the family Combretaceae, Euphorbiaceae and Verbenaceae. Recently, Deshmukh and Sharma (1978) described a few dicot leaf impressions resembling *Alnus*, *Betula*, *Sapindus* and *Ulmus* belonging to the temperate families alongwith a vegetative twig of *Salvinia*. Without going into details, it is pointed out that the identification of the dicot leaf-impressions of Deshmukh and Sharma are wrong and need reinvestigation as they have tried to match their leaves with the European forms without giving any thought to the morphological characters of their fossils. For example, the margin of the leaves in their type ' A ' and ' B ' are entire whereas in the comparable form (*Ulmus*), the margins are serrate. In addition to these impressions, Garg (1977) reported a solitary piece of a palm wood from the Deccan Trap beds of the Banaswara District.

Thus, it is evident from the above resumé that none of the megafossils reported so far from the western India belong to the family Anacardiaceae. Hence, it was thought that the woods of this family which have been collected from two different parts of western India, viz., Banaskantha District of Gujarat and Jaisalmer District of Rajastan be reported together. The occurrence of fossil woods near the village Charanka (Map 1) in the Banaskantha District had been reported long back by Wynne (1872, p. 117). The author collected the fossils for the first time from this area in November-December, 1980. During the same field excursion he collected the Tertiary dicot woods from near village Habur (Map 1) in the Jaisalmer District. To my knowledge, this forms the first record of the Tertiary dicot woods from anywhere in Rajasthan.

The wood specimens which come from the Banaskantha District of Gujarat belong to the Khari Series which is Lower Miocene in age (Biswas & Raju, 1973). The age of the wood specimen from the Jaisalmer District is uncertain. However, the abundance of petrified dicot woods in the locality and the assemblage under investigation indicate that they belong to Tertiary. It is interesting to note that these woods were found scattered on a small hillock of the Pariwar Formation (Cenomanian). The overlying rocks are absent in the locality. Tertiary rocks in the vicinity are of Palaeocene-Eocene (Sanu & Khuiala formations) age (Das Gupta, 1977). Contrary to the Palaeogene assemblage, the dicot woods collected from this locality (which will be described elsewhere) show Neogene type of assemblage. Hence, for the time being the age of this fossil wood may be considered probably ?Upper Tertiary.

FAMILY — ANACARDIACEAE

Genus — *Glutoxylon* (Chowdhury) Prakash & Tripathi, 1969

1976 *Melanorrhoeoxylon* Prakash & Tripathi, 1976.

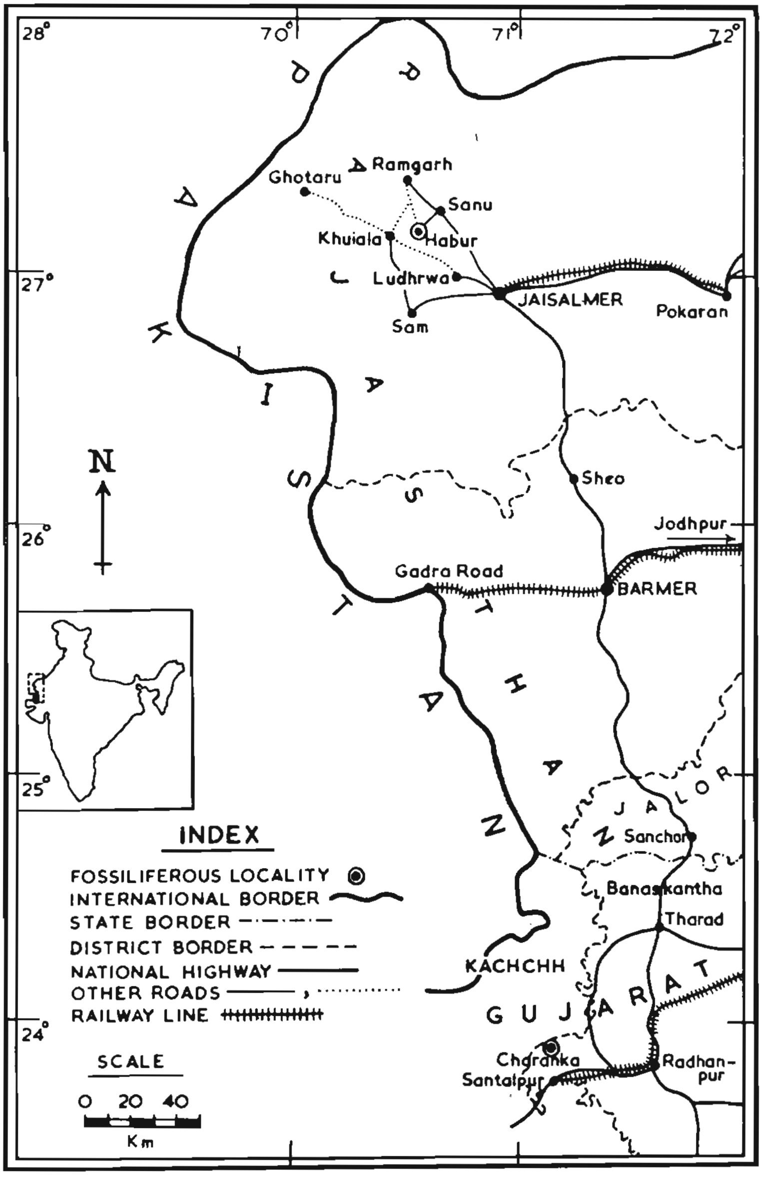
Glutoxylon burmense (Holden) Chowdhury, 1952

1978 *Glutoxylon kalagarhense* Trivedi & Ahuja, p. 135 figs 1-4.

Pl. 1, figs 1-4

The description is based on two small pieces of petrified woods which are dark brown in colour. Although the specimens are twisted and crushed they exhibit fairly good preservation.

Topography — *Wood* diffuse porous (Pl. 1, fig. 1). *Growth rings* indistinct. *Vessels* small to large (mostly medium to large), t.d. 44-280 μm, r.d. 48-300 μm, circular to oval in shape, sometimes flattened due to compression, solitary or in radial multiples of 2-3, 5-10 per sq mm; tyloses abundant, sometimes completely occluding the vessels (Pl. 1, fig. 1); vessel members 380-860 μm in length with slightly oblique end walls; perforations simple; intervessel pits 8-10 μm in diameter, bordered, alternate, circular to oval with lenticular aperture. *Parenchyma* paratracheal as well as apotracheal (Pl. 1, fig. 1); paratracheal parenchyma scanty, forming 1-2 celled sheath around the vessels; apotracheal parenchyma in the form of narrow bands, irregularly spaced, 5-9 per mm, mostly 1-3 (4-5) cells wide; parenchyma cells circular to oval, sometimes flattened. *Xylem rays* simple and fusiform (Pl. 1, figs 2, 3), simple rays fine, 1-2 (mostly 1) seriate or 8-24 μm wide, homo-to weakly heterocellular (Pl. 1, fig. 4), 4-17 cells or 80-400 μm in height; fusiform rays 3-4 cells or 80-88 μm wide with single radial gum duct in the middle (Pl. 1, fig. 3);



MAP 1

24-36 per mm, tangential height of upright ray cells 40-56 μm, radial length 36-48 μm, tangential height of procumbent cells 16-24 μm and radial length 60-96 μm. *Fibres* aligned in radial rows between the two consecutive xylem rays, thick-walled, non-septate.

Affinities — The above characters indicate that the fossil in all its anatomical features shows close similarity with the modern wood of *Gluta*.

Chowdhury (1934, 1936) instituted the genus *Glutoxylon* for the fossil wood resembling *Gluta* and such woods of *Melanor-*

rhoea which have thin apotracheal bands of parenchyma while describing *Glutoxylon assamicum* from the Tertiary of Assam. In 1952, he transferred *Glutoxylon assamicum* to *G. burmense* (Holden) Comb. nov. alongwith many other genera and species (Chowdhury, 1952, p. 376). This species was further reported by Chowdhury and Tandon (1952), and Ghosh and Taneja (1961) from the Tertiary beds of Midnapur District, West Bengal and Tripura respectively. Prakash and Tripathi (1969) emended the diagnosis of *Glutoxylon* Chowdhury (1936) while reporting *G. burmense* from a new locality of Hailakandi in Cachar District of Assam. Further, on the basis of their study of living woods of *Gluta* and *Melanorrhoea* they observed that the woods of these two genera can be divided into two groups. One of the groups includes all the species of *Gluta* and those *Melanorrhoea* having thin apotracheal parenchyma bands 1-7 (usually 2-4) cells wide and the second group includes only some species of *Melanorrhoea* which possess thick apotracheal parenchyma bands 1-10 (usually 3-7 or 8) cells wide. From this study they suggested that the fossil woods showing resemblance with the former group be named as *Glutoxylon* and those belonging to the latter group be named as *Melanorrhoeoxylon*. They formally instituted the genus *Melanorrhoeoxylon* for accommodating the woods of the latter group in 1976. However, Hou (1978) in his latest work on the family Anacardiaceae has merged the genus *Melanorrhoea* into *Gluta* taxonomically. As the two genera are taxonomically similar and the genus *Gluta* has the priority over *Melanorrhoea* so only *Gluta* occurs in the modern flora. In the light of Hou's work the genus *Melanorrhoeoxylon* Prakash & Tripathi (1976) has become synonymous to the earlier known genus *Glutoxylon* (Chowdhury) Prakash & Tripathi (1969) hence the genus *Malanorrhoeoxylon* is superfluous. Therefore, it is being rejected vide article 63 of the International Code of Botanical Nomenclature (Stafleu, 1978). As a consequence the two known species of *Melanorrhoeoxylon*, *M. cacharense* Prakash & Tripathi (1976, pp. 82-88, pl. 1, figs 1-5) and *M. garbetaense* Roy & Ghosh (1981, pp. 338-352, pl. 4, figs 23-27) are now renamed as *Glutoxylon cacharense* (Prakash & Tripathi) comb. nov., and *Glutoxylon garbetaense* (Roy & Ghosh) comb. nov.

Mukherjee (1942 a, b, c) and Ghosh (1958) described two new species of *Glutoxylon*, viz., *G. bengalensis* from the Tertiary of Bangla Desh and *G. chowdhurii* from the Pleistocene of Manipur. However, both these species were merged into *G. burmense* by Awasthi in 1966 while recording this species and describing a new species *G. cuddalorense* from the Cuddalore Series of South India. Recently *G. burmense* has also been reported by Prakash and Awasthi (1971), Prakash (1973), Roy and Ghosh (1979) from the Upper Tertiary beds of Assam, Burma and West Bengal respectively. Further, Kramer (1974) reported this species from the Tertiary beds of Sumatra and Borneo giving its up to date synonymy. Lemoigne (1978) described a new species, *Glutoxylon symphonoides* from the Tertiary of Ethiopia. Another species, *G. kalagarhense* sp. nov., was reported by Trivedi and Ahuja (1978) from the Mio-Pliocene beds of Kalagarh, Bijnor District of Uttar Pradesh. Thus, the author is aware of only six species of *Glutoxylon* known so far. Of the six species, *G. kalagarhense* Trivedi & Ahuja (1978) shows all the characters of *G. burmense*, hence it is placed under the same. Since the anatomical characters of the present fossil are also in conformity with *G. burmense*, therefore, it is put under the same species.

On comparing the present fossil with the modern woods of *Gluta* (including former *Melanorrhoea*) it was found that *Gluta travancorica* Bedd. (F.R.I. Xylarium slide no. 7440) shows closest resemblance with the fossil.

According to Hou (1978, p. 8) *Gluta* now consists of 30 species distributed in Madagascar, India, Burma, Thailand, Indochina, China and throughout Malesia. *Gluta travancorica* is found in the south-west coast of India (in dense moist forests of South Travancore) and in the Thirunelveli District of Tamil Nadu. The present fossil wood of *Gluta* from the north-west of Gujarat shows that the genus was wide spread in India during the Upper Tertiary.

B.S.I.P. Museum Specimen nos. 35480, and 1/2379.

Locality — Charanka, 23°53′: 71°10′30″ Chorar Island), about 15 km north of Santalpur, Banaskantha District, Gujarat.

Horizon — Khari Series.

Age — Lower Miocene.

Genus — *Mangiferoxylon* Awasthi emend.

Mangiferoxylon assamicum Prakash & Tripathi, 1970

Pl. 1, figs 5-7

The description is based on a single piece of petrified wood measuring 5 cm in length and 2 cm in diameter. The preservation is fairly good.

Topography — *Wood* diffuse porous (Pl. 1, fig. 5). *Growth rings* distinct delimited by thin apotracheal parenchyma band. *Vessels* small to large (mostly small to medium) t.d. 80-220 μm, r.d. 88-220 μm, circular to oval in shape, mostly solitary or in radial multiples of 2-4, 3-6 per sq mm, sometimes filled with gummy material, tyloses not seen; vessel members 240-580 μm in length with slightly oblique end walls; perforations simple; intervessel pits bordered, 6-10 μm in diameter, circular to oval with linear to lenticular aperture. *Parenchyma* both paratracheal and apotracheal (Pl. 1, fig. 5); paratracheal parenchyma vasicentric, mostly aliform to confluent; apotracheal parenchyma forming continuous to short broken narrow bands, 1-3 cells wide also delimiting the growth rings; parenchyma cells round, oval to angular in shape or sometimes flattened near the vessels, t.d. 80-110 μm, r.d. 96-166 μm. *Xylem rays* fine, 1-2 (3) cells (approximately 60% rays are uniseriate and 40% biseriate) or 20-64 μm wide; ray tissue heterogeneous (Pl. 1, figs 6, 7); rays heterocellular consisting of procumbent cells in the middle portion and upright cells at one or both the ends of the ray (Pl. 1, fig. 6), 10-18 per mm, 4-16 (21) cells or 120-400 (480) μm in height; tangential height of upright cells 32-36 μm and radial length 20-32 μm; tangential height of procumbent cells 12-20 μm and radial length 40-60 μm. *Fibres* aligned in radial rows between two consecutive rays, oval to angular in shape, t.d. 10-20 μm, r.d. 16-24 μm, thick-walled, septa sometimes present.

Affinities — The above noted characters show that the fossil resembles the modern wood of the genus *Mangifera* Linn. of the family Anacardiaceae (Pearson & Brown, 1932, pp. 314-319, Heimsch, 1942, pp. 136-137, Metcalfe & Chalk, 1950, p. 456; Brazier & Franklin, 1961, p. 21; Anonymous, 1963, pp. 289-295; Miles, 1978).

On comparing the fossil with thin sections of the woods of *Mangifera indica* Linn., *M. altissima* Blanco, *M. sylvatica* Roxb, *M. longipes* Griff., *M. caloneura* Kurz, *M. zeylanica* Hooker, and *Mangifera* sp., it was found that the fossil shows closest resemblance with *M. sylvatica* though some of the specimens of *M. indica* also come closer to it (particularly F.R.I. Xylarium slide no. 6060). Usually these two species differ in the size of vessels, amount of parenchyma and the frequency of uniseriate and biseriate rays. *M. sylvatica* possesses relatively samaller vessels, lesser amount of parenchyma and lesser frequency of biseriate rays compared to *M. indica*.

To accommodate the fossil woods of *Mangifera*, Awasthi (1966) created the genus *Mangiferoxylon*. Only two species of this genus are known, viz., *Mangiferoxylon scleroticum* Awasthi (1966) from the Cuddalore Series of South India and *M. assamicum* described by Prakash and Tripathi (1970) from the Middle Tertiary of Cachar District in Assam. The latter has also been reported by Kramer (1974) from the Tertiary beds of Sumatra and Borneo and by Roy and Ghosh (1981) from the Miocene beds of Birbhum District, West Bengal. In addition, a fossil wood resembling *Mangifera* was reported by Ramanujam (1953) from South India who subsequently (1960) described it as *Anacardioxylon mangiferoides* showing its affinities with *Mangifera* and *Anacardium*. As *Anacardioxylon mangiferoides* does not show the characters of *Mangifera* (Awasthi, 1966, p. 134; Prakash & Tripathi, 1970, p. 24) so it is not comparable with the present fossil. *Mangiferoxylon scleroticum* (Awasthi, 1966) although shows close resemblance with the present fossil in size and frequency of the vessels, and in the amount of parenchyma yet it differs in having relatively fine, tall and almost all uniseriate rays (99%). Complete biseriate rays are altogether absent in it. Further, it differs in having abundant sclerotic tyloses and non-septate fibres. *M. assamicum* Prakash & Tripathi (1970) which shows close similarity with the wood structure of *Mangifera indica*, shows general similarity with the present fossil. However, it differs in having relatively more and bigger vessels, broader parenchyma bands and predominantly biseriate rays (approx. 70%). In view of the study of thin sections of the woods of the two species, viz., *Mangifera indica* and *M. sylvatica* which sometimes show overlapping characters (as stated earlier), the differences of the present fossil with *Mangiferoxylon assamicum* are being considered as variable. Hence, the present fossil is placed under *Mangiferoxylon assamicum*.

The genus *Mangifera* consists of 41 species (Willis, 1973) of large to very large evergreen trees confined mainly to the Indo-Malayan region. *M. sylvatica* with which the fossil is best comparable occurs in Nepal, Sikkim and North Bengal and in the Khasi Hills. It is sporadic in the evergreen forests of Upper Assam, Surma Valley and in the Andaman islands. It also occurs in Bangla Desh, Thailand and Cambodia. The other species, *M. indica*, some specimens of which also show resemblance with the fossil, grows throughout India up to 900 m excepting the north-western part.

The occurrence of septate fibres in *M. assamicum* (Prakash & Tripathi 1970; Kramer, 1974) and in the present fossil (though rare); the broader rays 1-3 seriate; the rare occurrence of short homocellular rays in *M. assamicum* (Prakash & Tripathi, 1970, p. 23) and the absence of tyloses in the present wood warrants the revision of the generic diagnosis of the genus *Mangiferoxylon* Awasthi (1966) as it fails to cover these characters. Hence the genus *Mangiferoxylon* Awasthi (1966) is emended as follows.

Mangiferoxylon Awasthi emend.

Wood diffuse-porous. *Growth rings* indistinct to distinct, when distinct delimited by apotracheal (terminal) parenchyma. *Vessels* small to large, solitary or in multiples of 2-4 or more; vessels members medium to large with truncated or tailed ends; perforations simple; intervessel pit pairs usually large, circular to oval, alternate, bordered, with linear to lenticular apertures; tyloses present or absent. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform and aliform-confluent; apotracheal parenchyma usually in fine bands sometimes short and broken; also delimiting the growth rings. *Xylem rays* fine, 1-3 seriate; ray tissue heterogeneous; rays mostly heterocellular, consisting of procumbent cells through the median thickened portion and marginal rows of upright cells; rarely short rays homocellular; crystals often present. *Fibres* thin to thick-walled, rarely septate to non-septate.

B.S.I.P. Museum Specimen no. 35481.

Locality — Isolated small mound about 1.5 km south-east of village Habur; 57 km north of Jaisalmer.

Horizon — ?

Age — Tertiary (probably ?Upper Tertiary).

The occurrence of *Gluta* and *Mangifera* in the Banaskantha District of Gujarat and the Jaisalmer District of Rajasthan, respectively, during the Tertiary indicate more humid climatic conditions as compared to prevailing xeric and desertic conditions there.

ACKNOWLEDGEMENT

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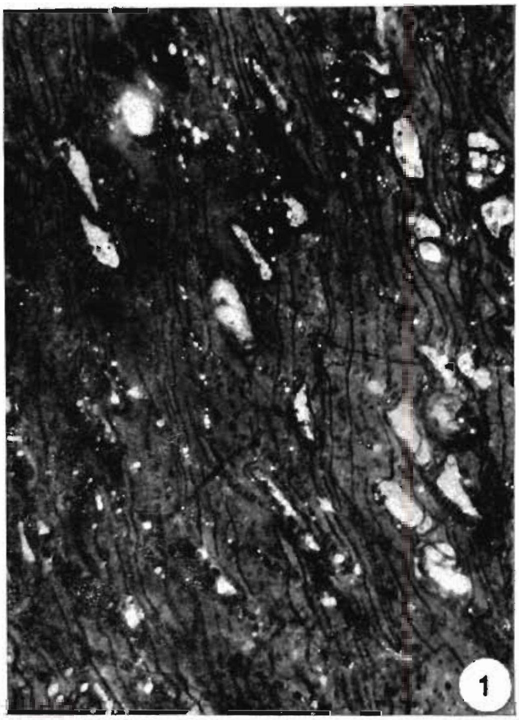
EXPLANATION OF PLATE

Glutoxylon burmense (Holden) Chowdhury, 1952

1. Cross section of the fossil wood showing the type and distribution of parenchyma and vessels with tyloses. × 30. Slide no. 6825.
2. Tangential longitudinal section of the fossil wood showing simple xylem rays. × 90. Slide no. 6826.
3. Tangential longitudinal section showing single fusiform ray with gum duct. × 90. Slide no. 6827.
4. Radial longitudinal section showing heterocellular xylem ray. × 90. Slide no. 6828.

Mangiferoxylon assamicum Prakash & Tripathi, 1970

5. Cross section of the fossil wood showing the type and distribution of vessels and parenchyma. × 15. Slide no. 6829.
6. Tangential longitudinal section of the fossil wood showing the xylem rays and their distribution. × 100. Slide no. 6830.
7. Radial longitudinal section of the fossil wood showing heterocellular xylem rays. × 90. Slide no. 6831.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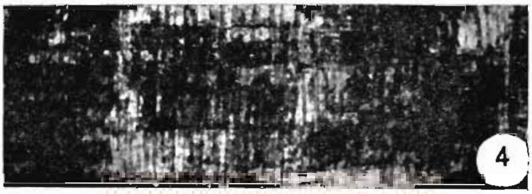
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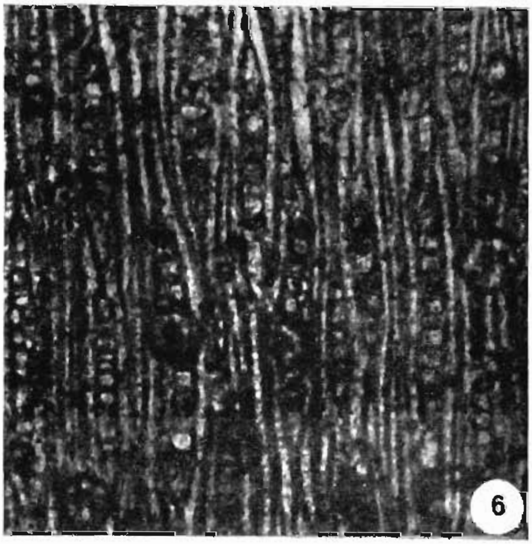
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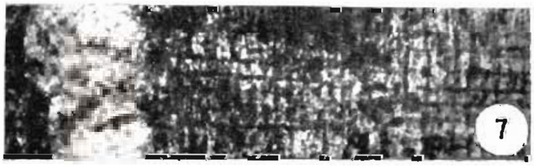
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PLATE 1

The Palaeobotanist, 32(1): 44-75, 1984.

EVOLUTIONARY TRENDS IN THE SECONDARY XYLEM OF WOODY DICOTYLEDONS FROM THE TERTIARY OF INDIA

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ABSTRACT

A large number of dicotyledonous woods have so far been described from the various Indian Tertiary formations. Based on their published data an attempt has been made to trace the evolutionary trends in the anatomical features of the secondary xylem of woody dicotyledons. The studies have shown that there is a gradual increase in the percentage of woods with advanced type of characters, especially in the axial parenchyma and the xylem rays, from the Palaeogene onwards to the successive younger floras.

Key-words — Dicotyledonous woods, Xylotomy, Evolutionary trends, Tertiary, India.

सारांश

भारत के तृतीयक युग से उपलब्ध द्विबीजपत्री काष्ठाश्मों की द्वितीयक दारू में विकासात्मक प्रवृत्तियाँ –
मोहन बलवंत बाँडे एवं उत्तम प्रकाश

भारतीय तृतीयक युगीन विभिन्न शैल-समूहों से अभी तक बृहत् संख्या में द्विबीजपत्रीय काष्ठाश्मों का वर्णन किया जा चुका है। प्रकाशित आँकड़ों पर आधारित द्विबीजपत्री काष्ठाश्मों की द्वितीयक दारू के शारीरीय लक्षणों में विकासात्मक प्रवृत्तियों के अन्वेषण का एक प्रयास किया गया है। इस अध्ययन से स्पष्ट होता है कि तृतीयक-पूर्व कल्प से लेकर अल्पायु वाले क्रमिक वनस्पतिजातों तक उन्नत प्रकार के लक्षणों से युक्त काष्ठों की, विशेषतया अक्षीय दृढ़ोतक एवं दारू-किरणों में, प्रतिशतता उत्तरोत्तर बढ़ती है।

INTRODUCTION

In the study of evolution of higher plants the role of wood anatomy cannot be overlooked. Development of a well organized wood structure, along with the evolution of reproductive organs, has played a vital role in deciding the struggle of dominance in favour of angiosperms against other contemporary plant groups.

Although there is a lot of controversy regarding the earliest record of the angiosperms, it is beyond doubt that by the end of the Cretaceous they were surely a conspicuous element of the flora and became dominant from the Tertiary onwards. If the injunction that the existing forms are the products of this evolutionary process, is accepted, then it can also be suggested that the earliest angiosperms represent the primitive stock and during the succeeding geological eras, evolution has been going on in them so as to reach the present forms. Thus, in case of evolution of the secondary xylem in angiosperms, especially the dicotyledons, it is logical to presume that the forms of earlier ages should possess a primitive type of secondary xylem with more specialized types appearing in the succeeding ages (B.S.I.P. Ann. Rep. 1973-74, pp. 17-18).

The Indian Tertiary flora is very rich in fossil woods, both in the Palaeogene as well as in the Neogene. Because a considerable data is now available regarding the dicotyledonous fossil woods of this flora, it is desirable to analyse it and compare it with the observations made on modern woods so as to have an understanding of the lines of evolution of secondary xylem in the Indian Tertiary dicotyledons. However, before the actual analysis of the Indian Tertiary dicot woods is taken up, it is advisable to classify the advanced and the primitive characters in the secondary xylem of the dicotyledons. Wood anatomists have reached, entirely independently, to certain conclusions in this respect which can be summarized as follows:

1. The vessel member with a scalariform perforation plate is more primitive than the one with a simple perforation plate (Bailey & Tupper, 1918; Bliss, 1921; Thompson, 1923; Frost, 1930a,b).
2. The vessel element with scalariform perforation plates having many bars (over 15) to a plate is primitive, the type with intermediate bars (5 to 15) comes next, and the type with few (five or fewer) bars is highly evolved amongst these (Frost, 1930b).
3. The length of vessel elements decreases as they become specialized (Bailey & Tupper, 1918; Bailey, 1920; Frost, 1930a) and there is a definite trend in some groups toward widening of vessels with increasing specialization (Carlquist, 1961). Consequently, their endwalls become less oblique until a transverse wall is formed (Bailey & Tupper, 1918; Bailey, 1920; Frost, 1930 a, b).
4. Vessels with angular cross sections are primitive while those with round outlines are advanced (Bailey, 1924; Frost, 1930a). Important exceptions to this trend occur in some highly advanced groups where the angular characteristic may be attained secondarily (Carlquist, 1958, 1961; Bailey, 1957).
5. The evolutionary development of intervascular pitting proceeds from scalariform to transitional to opposite to alternate type (Bailey & Tupper, 1918; Brown, 1918; Frost, 1930a, 1931).
6. Diffuse-porous woods usually precede ring-porous woods (Frost, 1930a). However, the degree to which ring porosity is environmentally modifiable needs investigation. Formation of ring porosity represents an evolutionary adjustment to highly seasonal climatic conditions that has occurred many times independently in groups with primitive wood as well as in groups with specialised xylem (Carlquist, 1961).
7. The solitary pores are more primitive than those in various aggregate arrangements like pore multiples, pore clusters, and pore chains.
8. Evolution has taken place from tracheids to fibretracheids to libriform wood fibres (Bailey & Tupper, 1918; Bailey, 1924, 1936).
9. According to Bailey (1920, 1924) and Bailey and Tupper (1918) the nonseptate fibrous tracheary elements precede the septate elements whose length decreases as they become more and more specialized. However, the evolutionary interpretation of septation in fibres is not very clear. Obviously the statistical studies (Metcalfe & Chalk, 1950) show that fibre septation is not related to the major trends of xylem evolution (Carlquist, 1961, p. 51).
10. Heterogeneous rays are more primitive than homogeneous rays. Kribs (1935, 1959) has classified the xylem rays of dicotyledons into following types:

Type I — Heterogeneous

(a) Uniseriate rays composed of vertically elongated cells which are unlike the cells of the multiseriate part of the multiseriate rays.

(b) Multiseriate rays with uniseriate tails or wings as long or longer than the multiseriate portion of the ray and composed of vertically elongate cells similar to those of the uniseriate rays; cells of the multiseriate portion are round to oval and radially elongated.

Type II — Heterogeneous — (Heterogeneous Type IIa of Kribs, 1935).

(a) Uniseriate rays composed of vertically elongate cells which are unlike those of the multiseriate portion of the multiseriate rays.

(b) Multiseriate rays with one large vertically elongate marginal cell or with uniseriate tails or wings shorter than the multiseriate portion of the ray and composed of vertically elongate cells similar to those of the uniseriate rays; the cells of the multiseriate portion are round to oval and radially elongated.

Type III-Heterogeneous — (Heterogeneous Type II-B of Kribs, 1935).

(a) Uniseriate rays usually of two types, some of the uniseriates are composed of vertically elongate cells and some are composed of cells which are nearly identical to those of the multiseriate portion of the the multiseriate rays.

(b) Multiseriate rays with square marginals (not vertically elongate) usually a single row; cells of the multiseriate portion are round to oval and radially elongated.

Type IV-Homogeneous

(a) Uniseriate rays composed of cells which are identical to those of the multiseriate rays.

(b) Multiseriate rays without square or vertically elongate marginal cells; the cells are all round or oval and radially elongate with or without tails.

Type V-Heterogeneous

Rays uniseriate only composed of radially and vertically elongate cells.

Type VI-Homogeneous

Rays uniseriate only.

Kribs (1935) has also shown that the evolutionary sequence is from heterogeneous type I, the most primitive through transitional heterogeneous type II (type IIA) and type III (type IIB) to homogeneous type VI. The homogeneous type IV rays are more highly specialised than uniseriate heterogeneous type V rays which are regarded as derivatives of either heterogeneous type I, II or type III. Homogeneous type VI may have evolved from any of the other types. It appears that the uniseriate types are highly specialised structures owing to the elimination of multiseriate rays (Kribs, 1935; Tippo, 1938).

Kribs' conclusions on the relative evolutionary status of the ray types may be summarized in the following way as done by Carlquist (1961). Rays in the most primitive woods exhibit the following features:

1. Both multiseriate and uniseriate rays are present.
2. Both types of rays are high (of marked vertical length).
3. Both types of rays are heterocellular.
4. Multiseriate rays have long uniseriate wings.

With advancement, the following changes occur in rays:

(a) Multiseriate rays or uniseriate rays are lost.
(b) There is a tendency for loss of heterogeneity in ray cells, particularly loss of erect cells. Thus, homocellular rays are advanced.
(c) Multiseriate rays are reduced in size and number.
(d) Uniseriate wings on multiseriate rays are reduced, ultimately to a single cell.

11. In the axial parenchyma, two main groups can be demarcated: (a) apotracheal, in which parenchyma is distributed without specific relation to vessels, and (b) paratracheal, in which parenchyma shows a close association with vessels. Based on the observations of earlier workers (Bailey, 1924; Jeffery, 1917; Kribs, 1937; Carlquist, 1961) the evolution of the axial parenchyma types may be broadly summarised as follows:

(a) Absence of parenchyma is primitive at least in some dicotyledons (Carlquist, 1961, p. 63). However, axial parenchyma is absent in a number of families having specialised types of vessels (Carlquist, 1976, p. 20).
(b) Diffuse parenchyma represents the primitive type.
(c) Diffuse-in-aggregate is slightly advanced over diffuse.
(d) Apotracheal banded parenchyma represents the most advanced type of apotracheal parenchyma. Wide bands are more advanced than narrow bands.
(e) Vasicentric, abundant parenchyma is the most highly specialised type.

12. The storied structure of various elements, namely rays, wood fibres, parenchyma, and the vessel members indicate highly specialised condition (Record, 1919, 1934; Carlquist, 1961, p. 65).

Thus it can be seen that a substantial information is now available regarding the primitive or advanced nature of a particular anatomical character. However, all the anatomical characters mentioned above were not found useful while dealing with the fossil dicotyledonous woods mainly due to the lack of uniformity in describing fossil woods by different authors. Besides, all the characters are not always available for their comparative analysis. Thus, within the limitations of the available data, the anatomical characters which were found suitable for analysis are (i) nature of perforation plates, (ii) type of intervessel pit-pairs, (iii) vessel end walls, (iv) axial parenchyma, and (v) the xylem rays.

For this analysis only those fossil genera and species have been taken into consideration whose description and identification appear to be reasonably correct. Moreover, when more than one species of a particular genus are known in a fossil assemblage the anatomical data of only well differentiated species have been taken into account.

The different Indian Tertiary strata from where the fossil dicotyledonous woods have been analysed are:

1. The Deccan Intertrappean beds of Central India (Palaeocene-Eocene — Tables 1 & 2).
2. The Lower Siwalik beds of the Himalayan foot-hills (Middle Miocene, Krishnan, 1968, p. 428 — Table 3).
3. Tipam Series of North-east India (Upper Miocene, Krishnan, 1968, p. 430 — Table 4).
4. The Neogene of West Bengal (Miocene, equivalent to the Tipams, Hunday, 1954; Hunday & Banerjee, 1967 — Table 5).
5. The Cuddalore Series of South India (Upper Miocene to Pliocene, Krishnan, 1968, p. 494 — Table 6).
6. The Dupitila Series of North-east India (Mio-Pliocene, Krishnan, 1968, p. 490 — — Table 7).

It is a well known fact that the ecological conditions quite often affect the anatomical structures. Therefore, it would be desirable to broadly consider the ecological conditions of the above mentioned Tertiary floras which form the basis of this analysis. Lakhanpal (1970), Prakash (1972) and Bande and Prakash (1982) have recently given their views regarding the past environments of these floras. Bande and Prakash (1982), while reconstructing the palaeoecology and palaeoclimate of the Deccan Intertrappean flora, concluded that this flora was growing under a warm, humid, tropical to subtropical climate. Almost similar type of climates have also been suggested for the Lower Siwalik, Cuddalore, Tipam and Deomali floras. In the West Bengal flora most of the forms are common to the different Neogene floras so far known from the Indian subcontinent. Thus, it can be said that all these floras were growing under more or less similar type of warm, humid, tropical to subtropical climatic conditions.

ANATOMICAL ANALYSIS

Dicotyledonous Woods from the Deccan Intertrappean Beds

In the Deccan Intertrappean flora a good number of fossil dicotyledonous woods are known from the following areas:

(a) Mandla District (Parapani, Samnapur Mohgaon, Ghughua, etc.).
(b) Nagpur-Chhindwara-Nawargaon area (Mohgaon Kalan, Keria, Mahurzari & Nawargaon).

Although the Deccan Intertrappean flora is usually considered as a single unit but on the evidence of fossil woods described from the above two areas it appears that these two assemblages constitute two distinct florules which may represent different geological ages and therefore, they have been treated here separately.

(a) *Fossil woods from Mandla District* — Seventeen fossil woods comparable with 16 extant genera belonging to 15 dicotyledonous families have been analysed anatomically. Their important anatomical characters have been classified in Table 1. A study of this table indicates that the perforation plates are mostly simple but scalariform with more than 10 bars in two species. Intervessel pits are bordered and alternate in most of the species with scalariform pits seen occasionally in one wood. The distribution of parenchyma is definitely of primitive type. Parenchyma is totally absent in one species, diffuse to diffuse-in-aggregate plus some vasicentric in four species, in thin apotracheal lines in two species, scanty paratracheal to 1-2 seriate, vasicentric in six species, and a well-developed aliform to aliform confluent or banded parenchyma is present in only four species.

Xylem rays also show a great deal of primitiveness. Of the 17 woods examined, heterogeneous rays occur in as many as 16 woods being heterogeneous type I in two woods, type II in twelve, and type III in two. Homogeneous type IV rays occur in only one wood.

(b) *Fossil woods from Nagpur-Chhindwara-Nawargaon area* — In all, 17 fossil woods comparable to 15 genera belonging to 14 families have been analysed (Table 2).

The perforation plates are simple in all the woods and the intervessel pits are bordered and alternate in 16 woods and scalariform in one wood. Parenchyma is absent in one wood, apotracheal diffuse to diffuse-in-aggregate with some scanty paratracheal in three, only scanty paratracheal in five, and well-developed vasicentric, aliform confluent and rarely banded in eight woods.

The xylem rays are mostly heterogeneous, being heterogeneous type I in one wood, type II or type III in 11 woods, type V in one wood, homogeneous type IV in three woods and homogeneous type VI in one wood.

DICOTYLEDONOUS WOODS FROM THE LOWER SIWALIK BEDS OF THE HIMALAYAN FOOT-HILLS

In all, 19 fossil woods comparable to 17 extant genera belonging to eight families have been anatomically analysed (Table 3). Out of them 16 woods possess bordered and alternate intervessel pits and four vasicentric tracheids. Perforation plates are simple in all the woods. Vessel elements are storied in one.

As far as parenchyma is concerned, it is apotracheal diffuse to diffuse-in-aggregate or arranged in uniseriate, tangential apotracheal lines alongwith some scanty paratracheal parenchyma in eight out of 19 woods analysed here. Scanty paratracheal parenchyma is present only in one wood, apotracheal banded with paratracheal vasicentric parenchyma is present in four woods and a well-developed paratracheal aliform-confluent to banded parenchyma is present in six woods. In one case the parenchyma strands are storied. The xylem rays are heterogeneous type II or type III in 11 woods, heterogeneous type V in three woods and homogeneous type IV in five woods.

DICOTYLEDONOUS WOODS FROM THE TIPAM SERIES OF NORTH-EAST INDIA

Thirtyfour fossil woods representing 33 living genera belonging to 19 dicotyledonous families have been analysed (Table 4). All of them possess simple perforations except in one wood where they are scalariform with 8-10 bars. Inter-vessel pits are bordered and alternate in 32, and alternate to subopposite in two woods. Vasicentric tracheids are present in four woods.

Parenchyma shows a wide range of development. It is scanty paratracheal in five woods, scanty paratracheal to vasicentric alongwith apotracheal diffuse to diffuse-in-aggregate forming thin lines in eight woods, apotracheal banded in two, paratracheal vasicentric to aliform to confluent alongwith apotracheal diffuse-in-aggregate to banded in six, and well-developed paratracheal, aliform to confluent to banded in 13 woods. The xylem rays are heterogeneous in majority of the woods. They are heterogeneous type II in 16, type III in seven, type V in three, weakly heterogeneous in one, homogeneous type IV in six and homogeneous type VI in one wood. Storied rays occur in two woods.

FOSSIL WOODS FROM THE NEOGENE OF WEST BENGAL

In this case 22 woods representing 21 extant genera belonging to seven families have been analysed from these beds (Table 5). Their anatomical analysis clearly shows an advancement towards specialization. All of them possess simple perforations and bordered, alternate intervessel pit pairs. However, vasicentric tracheids occur in at least four woods.

Scanty paratracheal to vasicentric parenchyma occurs in three woods, paratracheal vasicentric parenchyma alongwith apotracheal diffuse to diffuse-in-aggregate or short tangential lines or bands occurs in three woods, and a well-developed apotracheal banded parenchyma is present in four woods. Out of 22 woods, 12 show a well-developed paratracheal aliform, aliform-confluent to banded parenchyma. Parenchyma cells are storied in four woods. Xylem rays are heterogeneous in 11 species and homogeneous in 11 species. Heterogeneous type II is seen in nine woods and type V in two. Similarly, homogeneous type IV occurs in nine and type VI in two woods. Storied rays are present in five woods.

TABLE 1 — FOSSIL WOODS FROM THE DECCAN INTERTRAPPEAN BEDS (MANDLA DISTRICT)

FOSSIL WOOD WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
ANONACEAE						
Polyalthioxylon paraspaniense Bande, 1973	*Polyålthia simiarum*	Simple	Bordered, alternate	Horizontal to oblique	Apotracheal, 1-2 seriate tangential lines and 1-2 seriate vasicentric	Heterogeneous Type II
FLACOURTIACEAE						
Homalioxylon mandlaense Bande, 1974	*Homalium tomentosum*	Simple	Bordered, alternate	Truncate	Scanty paratracheal	Heterogeneous Type II
Hydnocarpoxylon indicum Bande & Khatri, 1980	*Hydnocarpus wightiana*	Scalariform with 10-25 bars	Bordered, alternate to opposite sometimes scalariform	Oblique	Absent	Heterogeneous Type I
GUTTIFERAE						
Garcinioxylon tertiarum Bande & Khatri, 1980	*Garcinia* sp.	Simple	Bordered, alternate	Oblique to transverse	1-2 seriate small apotracheal tangential lines, small clusters or single cells. Paratracheal vasicentric, aliform to confluent	Heterogeneous Type I (Predominant) and Type II
STERCULIACEAE						
Sterculioxylon deccanensis Lakhanpal, Prakash & Bande, 1978	*Sterculia* sp.	Simple	Bordered, alternate to opposite	Oblique to horizontal	Apotracheal diffuse to diffuse-in-aggregate with short uniseriate lines, paratracheal 1-2 seriate vasicentric, cells showing storied tendency	Heterogeneous Type II. Sheath cells present
Sterculioxylon shahpurensis Bande & Prakash, 1980b, 1983a	*Sterculia* sp.	Simple	Bordered, alternate	Truncate	Apotracheal diffuse-in-aggregate and paratracheal 1-2 seriate vasicentric	Heterogeneous Type II. Sheath cells present
TILIACEAE						
Grewioxylon sp. Lakhanpal, Prakash & Bande, 1978	*Grewia* sp.	Simple	Bordered, alternate	Truncate	Paratracheal 1-2 seriate vasicentric	Heterogeneous Type III. Tile cells present
ELAEOCARPACEAE						
Elaeocarpoxylon mandlaensis Lakhanpal, Prakash & Bande, 1978	*Elaeocarpus* sp. *Echinocarpus sigun.*	Simple	Bordered, alternate to opposite	Oblique	Scanty paratracheal	Heterogeneous Type II. Sheath cells present
RUTACEAE						
Atalantioxylon indicum Lakhanpal, Prakash & Bande, 1978	*Atalantia monophylla-Limonia acidissima*	Simple	Bordered, alternate	Oblique	Paratracheal vasicentric to aliform and apotracheal diffuse	Homogeneous Type IV

TABLE 1 — FOSSIL WOODS FROM THE DECCAN INTERTRAPPEAN BEDS (MANDLA DISTRICT) *Contd.*

FOSSIL WOOD WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
BURSERACEAE						
Burseroxylon preserratum Prakash & Tripathi, 1975; Bande and Prakash, 1983a	*Bursera serrata*	Simple	Bordered, alternate	Truncate to tailed	Paratracheal, scanty to 1-2 seriate vasicentric	Heterogeneous Type II
ICACINACEAE						
Gomphandroxylon samnapurensis Bande & Khatri, 1980	*Gomphandra tetrandra*	Scalariform with 10-15 bars	Bordered, alternate to opposite	Oblique	Apotracheal forming 1-2 seriate tangential lines	Heterogeneous Type II
MELIACEAE						
Heyneoxylon tertiarum Bande & Prakash, 1980b, 1983a	*Heynea trijuga*	Simple	Bordered, alternate to opposite	Truncate to tailed	Paratracheal banded	Heterogeneous Type III
ANACARDIACEAE						
Dracontomelumoxylon mangiferumoides Bande & Khatri, 1980; Bande and Prakash, 1982a	*Dracontomelum mangiferum*	Simple	Bordered, alternate	Truncate	Paratracheal, 1-3 seriate vasicentric to aliform	Heterogeneous Type II
MYRTACEAE						
Syzygioxylon mandlaense Ingle, 1973	*Syzygium cumuni*	Simple	Bordered, alternate, probably vestured	Oblique	Paratracheal vasicentric, aliform to aliform confluent and apotracheal diffuse	Heterogeneous Type II
LECYTHIDACEAE						
Barringtonioxylon mandlaensis Bande & Khatri, 1980	*Barringtonia* sp.	Simple	Bordered, alternate	Oblique	Apotracheal diffuse to diffuse-in-aggregate; paratracheal vasicentric	Heterogeneous Type II
LAURACEAE						
Laurinoxylon deccanensis Bande & Prakash, 1980b	Lauraceae	Simple	—	Truncate to transverse	Scanty paratracheal	Heterogeneous Type II
EUPHORBIACEAE						
Bischofinium deccanii Bande, 1974	*Bischofia javanica*	Simple	Bordered, alternate	Oblique	Scanty paratracheal	Heterogeneous Type II. Sheath cells present

TABLE 2 — FOSSIL WOODS FROM THE DECCAN INTERTRAPPEAN BEDS (MOHGAON KALAN, KERIA, MAHURZARI, NAWARGAON)

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
TILIACEAE *Grewioxylon mahurzariense* Prakash & Dayal, 1965	*Grewia laevigata*	Simple	Bordered, alternate	Tapering	1-3 seriate vasicentric sheath, irregularly storied	Heterogeneous Type II. Tile cells present, uniseriate rays partly storied
ELAEOCARPACEAE *Elaeocarpoxylon antiqum* Prakash & Dayal, 1964	*Elaeocarpus ferrugineus*	Simple	Bordered, alternate occasionally opposite	Tapering	Scanty paratracheal	Heterogeneous Type I
RUTACEAE *Evodinium indicum* Bande & Prakash, 1983b	*Evodia roxburghiana*	Simple	Bordered, alternate	Horizontal to inclined	Vasicentric to aliform confluent	Heterogeneous Type III
SIMAROUBACEAE *Ailanthoxylon indicum* Prakash, 1959b; Shallom, 1961; Saksena, 1963; Prakash, Verma and Dayal, 1967	*Ailanthus malabarica* and *A. grandis*	Simple	Bordered, alternate	Horizontal to inclined	Paratracheal vasicentric, aliform confluent to banded and apotracheal banded	Homogeneous Type IV
Simarouboxylon indicum Shallom, 1960; Prakash, 1964	*Simarouba* sp.	Simple	Bordered, alternate	Truncate or slightly tapering	Paratracheal aliform confluent to banded; storied tendency	Homogeneous Type IV
BURSERACEAE *Boswellioxylon indicum* Dayal, 1964, 1966	*Boswellia serrata*	Simple	Bordered, alternate	Truncate to tapering	Scanty paratracheal	Heterogeneous Type III
MELIACEAE *Amooroxylon deccanensis* Bande & Prakash, 1983b	*Amoora* sp.	Simple	Bordered, alternate to opposite	Horizontal to oblique	Paratracheal vasicentric, aliform confluent to banded; apotracheal diffuse to diffuse-in-aggregate	Heterogeneous Type III
VITACEAE *Leeoxylon multiseriatum* Prakash & Dayal, 1964	*Leea* sp.	Simple	Scalariform, rarely opposite	Tapering	Scanty paratracheal	Heterogeneous Type II. Sheath cells present

TABLE 2 — FOSSIL WOODS FROM THE DECCAN INTERTRAPPEAN BEDS (MOHGAON KALAN, KERIA, MAHURZARI, NAWARGAON)

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
SAPINDACEAE						
Sapindoxylon schleicheroides Dayal, 1965	*Schleichera* sp.	Simple	Bordered, alternate	Truncate to tapering	Scanty paratracheal	Homogeneous Type IV
ANACARDIACEAE						
Anacardioxylon semecarpoides Prakash & Dayal, 1965	*Semecarpus*	Simple	Bordered, alternate	Truncate or slightly inclined	Paratracheal, 1-3 seriate vasicentric to aliform	Heterogeneous Type III
LEGUMINOSAE						
Aeschynomenoxylon tertiarum Müller-Stoll, & Mädel, 1967; Prakash, 1963	*Aeschynomene* sp.	Simple	Alternate to opposite and scalariform	Horizontal to slightly inclined	Paratracheal, 1-4 seriate tangential bands and apotracheal diffuse	Homogeneous Type VI
LECYTHIDACEAE						
Barringtonioxylon eopterocarpum Prakash & Dayal, 1965	*Barringtonia pterocarpa*	Simple	Bordered, alternate	Truncate to tapering	Apotracheal narrow irregular tangential lines and scanty paratracheal	Heterogeneous Type II. Sheath cells present
SONNERATIACEAE						
Sonneratioxylon nawargaoensis Bande & Prakash, 1983b	*Sonneratia* sp.	Simple	Vestured, alternate to opposite	Vertical to oblique to tailed	Absent	Heterogeneous Type V
DATISCACEAE						
Tetrameleoxylon prenudiflora Lakhanpal & Verma, 1966	*Tetrameles nudiflora*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric to aliform confluent	Heterogeneous Type II or Type III
EUPHORBIACEAE						
Bridelioxylon krauseli Prakash, 1959a; Mädel, 1962	*Bridelia* sp.	Simple	Bordered, alternate	Truncate to tapering	Scanty paratracheal to vasicentric	Heterogeneous Type II
Paraphyllanthoxylon sahnii Prakash, 1959b; Mädel, 1962	*Phyllanthoideae*	Simple	Bordered, alternate	Truncate to inclined	Apotracheal diffuse and scanty paratracheal	Heterogeneous Type II and III
Mallotoxylon keriense Lakhanpal & Dayal, 1964	*Mallotus phillippinensis*	Simple	Bordered, alternate	Truncate or tailed	Apotracheal diffuse or forming short uniseriate lines and scanty paratracheal	Heterogeneous Type II

TABLE 3 — FOSSIL WOODS FROM THE LOWER SIWALIK BEDS

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
ANONACEAE						
Polyalthioxylon indicum Prakash, 1978	*Polyalthia simiarum*	Simple	Bordered, alternate	Truncate or tapered	Apotracheal, uniseriate, tangential lines	Heterogeneous Type II or III
DIPTEROCARPACEAE						
Dipterocarpoxylon sivalicus Prakash, 1978	*Dipterocarpus turbinatus*	Simple	Vasicentric tracheids present	Truncate to tailed	Scanty paratracheal, apotracheal diffuse to diffuse-in-aggregate and around gum canals	Heterogeneous Type II. Sheath cells present
Dipterocarpoxylon parabaudii Prakash, 1978	*Dipterocarpus baudii*	Simple	Vasicentric tracheids present	Truncate	Scanty paratracheal, apotracheal diffuse and around gum canals	Heterogeneous Type II. Sheath cells present
Anisopteroxylon kalagarhensis Prakash, 1978	*Anisoptera scaphula, A. glabra*	Simple	Vasicentric tracheids present	Truncate	Scanty paratracheal, apotracheal diffuse to diffuse-in-aggregate and around gum canals	Heterogeneous Type II. Sheath cells present
Shoreoxylon ornatum (Trivedi & Ahuja) Prakash & Bande, 1980a *syn. Pentacmeoxylon ornatum* Trivedi & Ahuja, 1979b	*Shorea* sp.	Simple	Bordered, alternate, vasicentric tracheids present	Truncate or tailed	Scanty paratracheal, apotracheal diffuse and around gum canals	Heterogeneous Type II. Sheath cells present
STERCULIACEAE						
Sterculioxylon kalagarhensis Trivedi & Ahuja, 1978a	*Sterculia* sp.	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric, apotracheal banded	Heterogeneous Type II. Sheath cells present
ANACARDIACEAE						
Dracontomelumoxylon mangiferumoides Ghosh & Roy; Prakash, 1979a, 1979b	*Dracontomelum mangiferum*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric, aliform to confluent	Heterogeneous Type II
Glutoxylon kalagarhense Trivedi & Ahuja, 1978b	*Gluta renghas*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric; apotracheal diffuse and banded	Heterogeneous Type V
LEGUMINOSAE						
Albizzinium eolebbekianum Prakash, 1975	*Albizzia lebbek*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal vasicentric, aliform to aliform confluent, apotracheal diffuse	Homogeneous Type IV

TABLE 3 — FOSSIL WOODS FROM THE LOWER SIWALIK BEDS — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
Cassinium prefistulai Prakash, 1975	*Cassia fistula*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal thick vasicentric, aliform to confluent forming broad undulating bands	Homogeneous Type IV
Cynometroxylon holdeni (Gupta) Prakash & Bande, 1980; Prakash, 1975	*Cynometra polyandra*, *C. ramiflora*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric, apotracheal banded	Heterogeneous Type III
Millettioxylon pongamiensis Prakash, 1975	*Millettia prainii*	Simple	Bordered, alternate, vestured	Truncate, elements storied	Apotracheal banded, strands storied	Homogeneous Type IV storied
Pahudioxylon indicum Prakash, 1978	*Afzelia-Intsia*	Simple	Bordered, alternate	—	Paratracheal aliform to aliform confluent	Homogeneous Type IV
Cassinium barooahii Prakash, 1978	*Cassia siamea*	Simple	Alternate to subopposite, vestured	—	Paratracheal aliform confluent to banded	Homogeneous Type IV
Hopeoxylon eosiamensis Prakash, 1981	*Sindora siamensis*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal vasicentric, aliform to aliform confluent, apotracheal banded enclosing gum canals	Homogeneous Type IV to heterogeneous type III
COMBRETACEAE						
Terminalioxylon palaeomanii Prakash, 1981	*Terminalia manii*	—	Alternate, vestured	Truncate	Scanty paratracheal	Heterogeneous Type V
LECYTHIDACEAE						
Careyoxylon pondicheriense Awasthi; Prakash, 1979b	*Careya arborea*	Simple	Bordered, alternate	—	Scanty paratracheal, apotracheal diffuse and in irregular uniseriate lines	Heterogeneous Type II Sheath cells present
EBENACEAE						
Ebenoxylon miocenicum Prakash, 1978	*Diospyros kurzii*	Simple	Bordered, alternate	Truncate to tailed	Scanty paratracheal, apotracheal forming 1-2 seriate tangential lines	Heterogeneous Type V
Ebenoxylon siwalicus Prakash, 1981	*Diospyros brandisiana*	Simple	Bordered, alternate	Truncate	Scanty paratracheal, apotracheal forming 1-2 seriate tangential lines	Heterogeneous Type II

TABLE 4 — FOSSIL WOODS FROM THE TIPAM SERIES

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
FLACOURTIACEAE						
Homalioxylon assamicum Prakash & Tripathi, 1974	*Homalium tomentosum*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal	Heterogeneous Type II
GUTTIFERAE						
Kayeoxylon assamicum Chowdhury & Tandon, 1949	*Kayea assamica*	—	Vasicentric tracheids present	Horizontal to slightly oblique	Apotracheal, 3-13 seriate continuous tangential bands	Heterogeneous Type III
Calophylloxylon eoinophyllum Prakash, 1966; Prakash and Awasthi, 1971	*Calophyllum inophyllum*	Simple	Vasicentric tracheids present	Truncate	Apotracheal, 2-4 seriate continuous or broken tangential bands	Heterogeneous Type V
DIPTEROCARPACEAE						
Dipterocarpoxylon chowdhurii Ghosh, 1956	*Dipterocarpus*	—	Vasicentric tracheids present	—	Paratracheal vasicentric, apotracheal diffuse to diffuse-in-aggregate and surrounding gum canals	Heterogeneous Type II
Anisopteroxylon garoense (Chowdhury) Prakash & Tripathi, 1970b	*Anisoptera* sp.	Simple	Bordered, alternate, vasicentric tracheids present	Truncate or tailed	Paratracheal vasicentric, apotracheal diffuse, in short tangential lines and surrounding gum canals	Heterogeneous Type II
Shoreoxylon tipamense Prakash & Awasthi, 1970	*Shorea* sp.	Simple	Bordered, alternate, vestured, vasicentric tracheids present	Truncate	Paratracheal vasicentric, aliform to aliform confluent; apotracheal diffuse or aggregate and surrounding gum canals	Heterogeneous Type II. Sheath cells present
STERCULIACEAE						
Sterculioxylon dattai Prakash & Tripathi, 1974	*Sterculia villosa*	Simple	—	Truncate or tailed	Paratracheal vasicentric; apotracheal diffuse to 1-2 seriate tangential lines and around gum canals	Heterogeneous Type II. Sheath cells present

TABLE 4 — FOSSIL WOODS FROM THE TIPAM SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
ELAEOCARPACEAE						
Elaeocarpoxylon hailakandiense Prakash & Tripathi, 1975	*Elaeocarpus*, *Echinocarpus*	Simple	Bordered, alternate to subopposite	Tapering	Scanty paratracheal	Heterogeneous Type II
BURSERACEAE						
Burseroxylon preserratum Prakash & Tripathi, 1975	*Bursera serrata*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal, vasicentric	Heterogeneous Type III
SAPINDACEAE						
Pometioxylon tomentosum Prakash & Tripathi, 1970a	*Pometia tomentosa*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal to vasicentric	Heterogeneous Type V
ANACARDIACEAE						
Mangiferoxylon assamicum Prakash & Tripathi, 1970a	*Mangifera indica*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric, aliform, aliform confluent; apotracheal banded	Heterogeneous Type II
Glutoxylon burmense (Holden) Chowdhury; Prakash and Tripathi, 1969b	*Gluta-Melanorrhoea*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to aliform; apotracheal diffuse-in-aggregate and banded	Homogeneous Type IV
Swintonioxylon hailakandense Prakash & Tripathi, 1969a	*Swintonia floribunda*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to aliform confluent, apotracheal banded	Heterogeneous Type III
Lanneoxylon grandiosum Prakash & Tripathi, 1969a	*Lannea grandis*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal	Heterogeneous Type III
Holigarnoxylon assamicum Prakash & Awasthi, 1970	*Holigarna beddomei*	Simple	Bordered, alternate	Truncate	Paratracheal, vasicentric to aliform confluent	Heterogeneous Type III
Melanorrhoeoxylon cacharense Prakash & Tripathi, 1976	*Melanorrhoea*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric and apotracheal banded	Homogeneous Type IV
Anacardioxylon shardai Prakash & Tripathi, 1976	—	Simple	Bordered, alternate	Truncate to tailed	Paratracheal vasicentric, aliform to aliform confluent	Heterogeneous Type II

TABLE 4 — FOSSIL WOODS FROM THE TIPAM SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
LEGUMINOSAE						
Adenantheroxylon pavoninium Prakash & Tripathi, 1969a	*Adenanthera pavonina*	—	Bordered, alternate and vestured	Truncate	Paratracheal vasicentric, rarely aliform to confluent, apotracheal diffuse sparse	Homogeneous Type IV
Peltophoroxylon cassioides Prakash & Awasthi, 1970	*Cassia fistula*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal, aliform to aliform confluent	Homogeneous Type IV
Cynometroxylon holdeni (Gupta) Prakash & Bande, 1980; Prakash, 1966c	*Cynometra* sp.	Simple	Bordered, alternate	Truncate or tapering	Paratracheal vasicentric, apotracheal banded	Heterogeneous Type III
Pahudioxylon assamicum Prakash & Tripathi, 1975	*Afzelia-Intsia*	Simple	Bordered, alternate, vestured	Truncate to tapering	Paratracheal vasicentric, aliform to aliform confluent	Homogeneous Type IV. Sometime storied
Ougeinioxylon tertiarum Prakash & Tripathi, 1977	*Ougeinia* sp.	Simple	Bordered, vestured	Truncate or tailed, members storied	Paratracheal aliform to aliform confluent, apotracheal diffuse	Homogeneous Type IV. Usually storied
Hopeoxylon assamicum Lalitha & Prakash, 1980	*Sindora* sp.	Simple	Bordered, alternate to sub-opposite, vestured	Truncate to oblique	Paratracheal vasicentric, aliform to aliform confluent	Weakly heterogeneous Type III
COMBRETACEAE						
Terminalioxylon tertiarum Prakash, 1966	*Terminalia tomentosa*	Simple	Bordered, alternate to sub-opposite, vestured	Truncate	Paratracheal vasicentric to aliform confluent, apotracheal diffuse	Heterogeneous Type V
LECYTHIDACEAE						
Barringtonioxylon assamicum Prakash & Tripathi, 1972	*Barringtonia acutangula*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal; apotracheal diffuse to diffuse-in-aggregate	Heterogeneous Type II. Sheath cells present
Careyoxylon kuchilense Prakash & Tripathi, 1972	*Careya arborea*	Simple	Bordered, alternate	Truncate	Scanty paratracheal, apotracheal diffuse and short uniseriate lines	Heterogeneous Type II

TABLE 4 — FOSSIL WOODS FROM THE TIPAM SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
LYTHRACEAE						
Lagerstroemioxylon eflosreginium Prakash & Tripathi, 1970a	*Lagerstroemia flosregine*	Simple	Bordered, alternate, vestured	Truncate or tailed	Paratracheal vasicentric aliform to aliform confluent apotracheal diffuse	Homogeneous Type VI
SONNERATIACEAE						
Duabangoxylon tertiarum Prakash & Awasthi, 1970	*Duabanga sonneratioides*	Simple	Bordered, alternate, vestured	Truncate or tailed	Paratracheal vasicentric to aliform	Heterogeneous Type II
SAPOTACEAE						
Madhucoxylon cacharense Prakash & Tripathi, 1977	*Madhuca butracea*	Simple	Bordered, alternate	Truncate or abruptly tailed	Scanty paratracheal; apotracheal in 1-3 seriate lines	Heterogeneous Type II
EBENACEAE						
Ebenoxylon kartikcherriense Prakash & Tripathi, 1970b	*Diospyros ehritioides*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal, apotracheal in 1-2 seriate tangential lines	Heterogeneous Type II
VERBENACEAE						
Viteoxylon miocenicum Prakash & Tripathi, 1974	*Vitex canescens*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to aliform confluent	Heterogeneous Type II
LAURACEAE						
Laurinoxylon tertiarum Prakash & Tripathi, 1974	*Dehasia* and *Cinnamomum*	Simple and scalariform (8-10 bars)	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric, sometimes aliform confluent	Heterogeneous Type II
EUPHORBIACEAE						
Mallotoxylon assamicum Prakash & Tripathi, 1975	*Mallotus philippinensis*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal, apotracheal diffuse and in interrupted uniseriate lines	Heterogeneous Type II
MORACEAE						
Artocarpoxylon kartikcherraensis Prakash & Lalitha, 1978	*Artocarpus chapalasha*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to mostly aliform, rarely aliform confluent	Heterogeneous Type II. Sheath cells present

TABLE 5 — FOSSIL WOODS FROM WEST BENGAL

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
DIPTEROCARPACEAE						
Dipterocarpoxylon bolpurensis Ghosh & Roy, 1979c	*Dipterocarpus* sp.	Simple	Vestured, alternate	Truncate to tailed	Paratracheal vasicentric and apotracheal banded	Heterogeneous Type II
Shoreoxylon tipamense Prakash & Awasthi; Bande and Prakash, 1980a	*Shorea assamica*	Simple	Bordered, alternate	Oblique	Paratracheal aliform to confluent; apotracheal forming short tangential lines and bands	Heterogeneous Type II
Anisopteroxylon santiniketanense Ghosh & Roy, 1980b	*Anisoptera* sp.	Simple	—	Truncate	Paratracheal scanty vasicentric, apotracheal diffuse	Heterogeneous Type II
GUTTIFERAE						
Calophylloxylon bengalense Ghosh & Roy, 1979e	*Calophyllum* sp.	Simple	—	Truncate	Apotracheal banded	Heterogeneous Type V
MELIACEAE						
Chisochetonoxylon bengalensis Ghosh & Roy, 1979d	*Chisocheton paniculatus*	Simple	Bordered, alternate	Tailed	Paratracheal, thick tangential bands	Heterogeneous Type II
ANACARDIACEAE						
Dracontomelumoxylon mangiferumoides Ghosh & Roy, 1979b	*Dracontomelum mangiferum*	Simple	Bordered, alternate	Tailed	Paratracheal vasicentric	Heterogeneous Type II
Glutoxylon burmense (Holden) Chowdhury, Roy & Ghosh, 1979b	*Gluta - Melanorrhoea*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric and apotracheal banded	Homogeneous Type IV
Mangiferoxylon assamicum Prakash & Tripathi; Ghosh and Roy, 1980a	*Mangifera indica*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric, aliform to aliform confluent, apotracheal banded	Heterogeneous Type II
Melanorrhoeoxylon garbetaense Ghosh & Roy, 1980c	*Melanorrhoea glabra* and *M. lacifera*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric and apotracheal banded	Homogeneous Type IV
Buchananioxylon indicum Ghosh & Roy, 1980d	*Buchnania latifolia*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric	Heterogeneous Type II

TABLE 5 — FOSSIL WOODS FROM WEST BENGAL — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
BURSERACEAE						
Canarioxylon indicum Ghosh & Roy, 1978	*Canarium* sp.	Simple	Bordered, alternate	Truncate	Scanty paratracheal	Heterogeneous Type II or III
LEGUMINOSAE						
Pahudioxylon bankurensis Chowdhury; Ghosh and Kazmi, 1960	*Pahudia*	Simple	Bordered, alternate	Horizontal to slightly oblique	Paratracheal, aliform confluent, storied	Homogeneous Type IV tendency towards storied arrangement
Millettioxylon bengalensis Ghosh & Roy, 1979a	*Millettia pulchra*	Simple	Alternate, vestured	Truncate, members storied	Paratracheal banded bands 2-4 cells thick. Strands storied	Homogeneous Type IV to weakly heterogeneous, storied
Millettioxylon pongamiensis Prakash; Bande & Prakash, 1980a	*Millettia prainii*	Simple	Alternate, vestured	Vessel elements storied	Paratracheal banded, bands 4-8 cells thick; strands storied	Homogeneous Type IV, storied
Cassinium barooahii Prakash; Bande and Prakash, 1980a	*Cassia siamea*	Simple	Alternate vestured	—	Paratracheal tangential 4-8 seriate bands	Homogeneous Type IV
Cynometroxylon holdeni (Gupta) Prakash & Bande; Bande and Prakash, 1980a	*Cynometra ramiflora* and *C. polyandra*	Simple	Alternate, vestured	—	Apotracheal, 3-8 seriate, tangential bands	Heterogeneous Type II
Koompassioxylon elegans Kramer; Bande and Prakash, 1980a	*Koompassia malaccensis*	Simple	Bordered, alternate	Vessel elements storied	Paratracheal, aliform to confluent, cells storied	Homogeneous Type IV or weakly heterogeneous, storied
Ormosioxylon bengalensis Bande & Prakash, 1980a	*Ormosia robusta* and *O. watsonii*	Simple	Bordered, alternate to opposite	Transverse to oblique	Paratracheal aliform confluent to banded	Homogeneous Type IV to weakly heterogeneous, storied tendency present
Albizzinium eolebbekianum Prakash; Ghosh and Roy, 1981	*Albizzia lebbek*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal aliform to aliform confluent and apotracheal	Homogeneous Type IV
Peltophoroxylon ferruginoides Bande & Prakash, 1980a	*Peltophorum ferruginium*	Simple	Bordered, alternate	Transverse to oblique	Paratracheal vasicentric to aliform, also aliform confluent	Homogeneous Type VI
COMBRETACEAE						
Terminalioxylon tertiarum Prakash; Ghosh and Roy, 1980e	*Terminalia* sp.	Simple	Alternate, vestured	Truncate	Paratracheal vasicentric to aliform confluent	Homogeneous Type VI
Anogeissusoxylon bengalensis Roy & Ghosh, 1979	*Anogeissus acuminata*	Simple	Alternate, vestured	Truncate	Paratracheal vasicentric, aliform to aliform confluent	Heterogeneous Type V

TABLE 6 — FOSSIL WOODS FROM THE CUDDALORE SERIES

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
GUTTIFERAE						
Mesuoxylon arcotense Lakhanpal & Awasthi, 1964	*Mesua ferrea*	Simple	Tracheids present	—	Apotracheal, 2-5 seriate tangential bands	Heterogeneous Type V
Calophylloxylon cuddalorense Lakhanpal & Awasthi, 1965	*Calophyllum inophyllum* and *C. tomentosum*	Simple	Tracheids present, pits bordered, in vertical rows	Truncate	Apotracheal, 2-9 seriate tangential bands	Heterogeneous Type V
DIPTEROCARPACEAE						
Dryobalanoxylon holdeni (Ramanujam) Awasthi, 1971	*Dryobalanops*	Simple	Tracheids present, vessel — tracheid pits bordered, vestured	—	Paratracheal vasicentric to aliform confluent and apotracheal bands around gum canals	Heterogeneous Type II. Sheath cells present
Shoreoxylon arcotense Awasthi, 1974	*Shorea* sp.	Simple	Tracheids present, vessel — tracheid pits bordered, vestured	Truncate to tapered	Paratracheal vasicentric and apotracheal banded around gum canals	Heterogeneous Type II
Dipterocarpoxylon pondicherriense Awasthi, 1974	*Dipterocarpus indicus*	Simple	Tracheids present, vessel — tracheid pits vestured, in vertical rows	Truncate	Paratracheal vasicentric to aliform confluent and apotracheal bands around gum canals	Heterogeneous Type II. Sheath cells present
Anisopteroxylon cuddalorense Ramanujam, 1960	*Anisoptera*	Simple	Alternate, bordered	Truncate	Paratracheal, 1-2 seriate vasicentric, apotracheal diffuse to diffuse-in-aggregate	Heterogeneous Type II
Hopenium pondicherriense Awasthi, 1980	*Hopea* sp.	Simple	Tracheids present, pits alternate vestured	Truncate or tailed	Paratracheal vasicentric to aliform confluent; apotracheal parenchyma diffuse-in-aggregate to thin tangential lines	Heterogeneous Type II
SAPINDACEAE						
Sapindoxylon indicum Navale, 1957	—	Simple	Bordered, alternate	Tapering	Scanty paratracheal	Homogeneous Type IV
ANACARDIACEAE						
Glutoxylon cuddalorense Awasthi, 1966	*Gluta-Melanorrhoea*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to aliform and apotracheal banded	Homogeneous Type IV
Mangiferoxylon scleroticum Awasthi, 1966	*Mangifera altissima*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric to aliform confluent	Heterogeneous Type III

TABLE 6 — FOSSIL WOODS FROM THE CUDDALORE SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
LEGUMINOSAE						
Peltophoroxylon indicum Ramanujam 1955; Müller-Stoll and Mädel, 1967	*Peltophorum* and allied genera	Simple	Bordered, alternate	Truncate	Paratracheal aliform to aliform confluent; apotracheal diffuse and in irregular tangential bands	Homogeneous Type IV
Erythrophloeoxylon sitholeyi (Ramanujam) Müller-Stoll and Mädel, 1967	*Erythrophloem* and allied genera	Simple	Bordered, alternate	—	Paratracheal vasicentric, aliform confluent, storied	Homogeneous Type IV, storied tendency
Pterogynoxylon felexii (Navale) Müller-Stoll & Mädel, 1967	*Pteragyne* and allied genera	Simple	Bordered, alternate	—	Paratracheal vasicentric	Homogeneous Type IV to weakly heterogeneous, storied
Euacacioxylon bharadwajii (Navale) Müller-Stoll & Mädel, 1967	*Acacia*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal vasicentric, aliform and banded, apotracheal sparse, diffuse	Homogeneous Type IV
Millettioxylon indicum Awasthi, 1967, 1975a	*Millettia pendula*	Simple	Bordered, alternate, vestured	Truncate, elements storied	Paratracheal, 2-9 seriate tangential bands, strands storied	Homogeneous Type IV to weakly heterogeneous, storied
Tamarindoxylon antiqum Ramanujam, 1961	*Tamarindus*	Simple	Bordered alternate	Truncate or tailed	Paratracheal aliform to confluent	Heterogeneous Type V, storied tendency
Pahudioxylon sahnii Ghosh & Kazmi; Awasthi, 1975	*Afzelia-Intsia*	Simple	Vestured	—	Paratracheal, aliform to aliform confluent	Homogeneous Type IV
Cynometroxylon holdeni (Gupta) Prakash & Bande, 1980; Ramanujam and Rama Rao, 1966	*Cynometra*	Simple	Bordered, alternate to opposite	Tapering	Apotracheal banded	Heterogeneous Type III
Pterocarpoxylon arcotense Ramanujam, 1960	*Pterocarpus*	Simple	Alternate, vestured	Oblique	Paratracheal, aliform confluent; apotracheal 1-2 seriate tangential lines; storied	Homogeneous Type IV, storied

TABLE 6 — FOSSIL WOODS FROM THE CUDDALORE SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
Hopeoxylon arcotense Awasthi, 1977b	*Sindora* sp.	Simple	Alternate, vestured	Truncate to inclined	Paratracheal vasicentric, aliform to banded; apotracheal banded and associated with gum ducts	Heterogeneous Type II
Albizzinium pondicherriensis Awasthi, 1979	*Albizzia amara*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal vasicentric, aliform and confluent	Homogeneous Type IV
Cassinium arcotense Awasthi, 1979	*Cassia javanica*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal, aliform confluent and banded	Homogeneous Type IV
Pericopsoxylon indicum Awasthi, 1979	*Pericopsis mooniana*	Simple	Bordered, members storied	Truncate members storied	Paratracheal aliform to confluent, storied	Homogeneous Type IV storied
ROSACEAE						
Parinarioxylon cuddalorense Awasthi, 1969b	*Parinarium*	Simple	—	Truncate or tailed	Apotracheal banded	Heterogeneous Type V
COMBRETACEAE						
Terminalioxylon coromandelinum Ramanujam, 1966	*Terminalia*	Simple	Bordered, alternate	Truncate or tailed	Paratracheal aliform confluent; apotracheal diffuse	Heterogeneous Type V
Terminalioxylon traumaticum Ramanujam, 1966	*Terminalia*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal vasicentric and confluent; apotracheal around gum canals	Homogeneous Type V
Anogeissusoxylon indicum Navale, 1964	*Anogeissus*	—	Bordered, alternate	Truncate or tailed	asicentric aliform and confluent	Heterogeneous Type V
LECYTHIDACEAE						
Barringtonioxylon arcotense Awasthi, 1970a	*Barringtonia angusta*	Simple	Bordered, alternate	Truncate or tapered	Paratracheal vasicentric, aliform and aliform confluent; apotracheal diffuse and in small tangential rows	Heterogeneous Type II. Sheath cells present
Careyoxylon pondicherriense Awasthi, 1970a	*Careya arborea*	Simple	Bordered, alternate	Truncate	Scanty paratracheal and apotracheal short tangential lines	Heterogeneous Type I. Sheath cells present

TABLE 6 — FOSSIL WOODS FROM THE CUDDALORE SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
SONNERATIACEAE						
Sonneratioxylon preapetala Awasthi, 1969a	*Sonneratia apetala*	Simple	Bordered, alternate, vestured	Truncate to tapered	Absent	Heterogeneous Type V
ALANGIACEAE						
Alangioxylon scalariforme Awasthi, 1969c	*Alangium*	Scalariform	Bordered, alternate	Truncate or tailed	Apotracheal uniseriate tangential lines	Heterogeneous Type II. Sheath cells present
SAPOTACEAE						
Chrysophylloxylon pondicherriense Awasthi, 1977a	*Chrysophyllum roxburghii*	Simple	Bordered, alternate, tracheids present	Truncate to slightly tapered	Apotracheal tangential lines	Heterogeneous Type II or III
EBENACEAE						
Ebenoxylon arcotense Awasthi, 1970b	*Diospyros assimilis*	Simple	Bordered, alternate	Truncate or tapered	Scanty paratracheal, apotracheal uniseriate tangential lines	Heterogeneous Type VI
EUPHORBIACEAE						
Putranjivoxylon puratanam Ramanujam, 1956	*Putranjiva*	Simple and scalariform (4-8 bars)	Bordered, alternate	Truncate or tailed	Apotracheal diffuse and in uniseriate tengential lines	Heterogeneous Type II
Bridelioxylon cuddalorense Ramanujam, 1956	*Bridelia*	Simple	Bordered, alternate, vestured	Truncate or tailed	Paratracheal vasicentric; apotracheal diffuse	Heterogeneous Type III
Paraphyllanthoxylon tertiarum Ramanujam, 1956; Mädel, 1962	*Phyllanthoideae*	Simple	Bordered, alternate	Truncate or tailed	Scanty, apotracheal diffuse	Heterogeneous Type II
Phyllanthinium banglamodense Navale, 1962	*Phyllanthoideae*	—	Bordered, alternate	Truncate	Apotracheal diffuse or in short tangential lines	Heterogeneous Type I
ULMACEAE						
Holopteleoxylon indicum Awasthi, 1977a	*Holoptelea integrifolia*	Simple	Bordered, alternate	Truncate	Paratracheal vasicentric and aliform confluent and banded, storied	Homogeneous Type IV. Storied

TABLE 7 — FOSSIL WOODS FROM THE DUPITILA SERIES

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
GUTTIFERAE *Calophylloxylon eoinophyllum* Prakash, 1966; Prakash and Awasthi, 1971	*Calophyllum inophyllum*	Simple	Vasicentric, tracheids present	Truncate	Apotracheal banded	Heterogeneous Type V
DIPTEROCARPACEAE *Shoreoxylon deomaliense* Prakash & Awasthi, 1971	*Shorea* sp.	Simple	Bordered, alternate, vestured vasicentric tracheids present	Truncate	Paratracheal vasicentric to aliform confluent, apotracheal diffuse and enclosing gum canals	Heterogeneous Type II
STERCULIACEAE *Sterculioxylon varmaii* Lakhanpal, Prakash & Awasthi, 1981	*Sterculia alata*	Simple	Bordered, alternate	Truncate	Paratracheal aliform confluent; apotracheal banded; cells storied	Heterogeneous Type II. Sheath cells present
Heritieroxylon arunachalensis Lakhanpal; Prakash & Awasthi, 1981	*Heritiera fomes*	Simple	Bordered, small	Horizontal to oblique	Apotracheal diffuse and forming fine tangential lines	Heterogeneous Type II. Sheath cells present
BURSERACEAE *Burseroxylon garugoides* Lakhanpal, Prakash & Awasthi, 1981	*Garuga pinnata*	Simple	Bordered, alternate	Truncate	Scanty paratracheal	Heterogeneous Type II
ANACARDIACEAE *Mangiferoxylon assamicum* Prakash & Tripathi; Lakhanpal, Prakash and Awasthi, 1981	*Mangifera indica*	Simple	Bordered, alternate	Truncate or tailed	Scanty paratracheal to vasicentric, sometimes aliform to confluent, apotracheal banded	Heterogeneous Type V
LEGUMINOSAE *Cynometroxylon holdeni* (Gupta) Prakash & Bande, 1980; Prakash and Awasthi, 1971	*Cynometra polyandra*, *Cynometra ramiflora*	Simple	Bordered, alternate, vestured	Horizontal to oblique	Apotracheal banded	Heterogeneous Type III
Pahudioxylon deomaliense Prakash, 1965	*Afzelia-Intsia*	Simple	Bordered, alternate, vestured	Truncate or tailed	Paratracheal aliform to confluent	Homogeneous Type IV. Storied tendency

TABLE 7 — FOSSIL WOODS FROM THE DUPITILA SERIES — *Contd.*

FOSSIL SPECIES WITH FAMILY	COMPARABLE LIVING SPECIES	VESSELS			PARENCHYMA	XYLEM RAYS
		Perforations	Intervessel pits	End walls		
Albizinium eolebbekianum Prakash; Lakhanpal Prakash and Awasthi, 1981	*Albizia lebbek*	Simple	Bordered, alternate, vestured	Truncate	Paratracheal aliform to aliform confluent	Homogeneous Type IV
Millettioxylon palaeopulchera Lakhanpal, Prakash & Awasthi, 1981	*Millettia pulchera*	Simple	Bordered, alternate	Truncate, vessel members storied	Paratracheal banded, strands storied	Homogeneous Type IV, storied
COMBRETACEAE						
Terminalioxylon coriaceum Prakash & Awasthi, 1971	*Terminalia coriacea*	Simple	Bordered, alternate	Truncate	Paratracheal aliform confluent to banded; apotracheal irregularly banded	Homogeneous Type VI
Terminalioxylon tertiarum Prakash, 1966b	*Terminalia tomentosa*	Simple	Alternate to sub-opposite, vestured	Truncate	Paratracheal vasicentric, aliform to aliform confluent, apotracheal diffuse	Homogeneous Type VI
LYTHRACEAE						
Lagerstroemioxylon deomaliense Lakhanpal, Prakash & Awasthi, 1981	*Lagerstroemia villosa*	Simple	Bordered, alternate, vestured	Truncate or tailed	Paratracheal vasicentric, aliform confluent to banded	Homogeneous Type VI
SAPOTACEAE						
Siderinium deomaliense Prakash & Awasthi, 1970	*Sideroxylon grandifolium*	Simple	Bordered, alternate	Truncate	Apotracheal, uniseriate lines forming reticulum	Heterogeneous Type II or III
EBENACEAE						
Ebenoxylon indicum Ghosh & Kazmi, 1958	*Diospyros*	Simple	Bordered, alternate	—	Paratracheal vasicentric, apotracheal diffuse to diffuse-in-aggregate forming irregular uniseriate tangential lines	Heterogeneous
LAURACEAE						
Laurinoxylon namsangensis Lakhanpal, Prakash & Awasthi, 1981	—	Simple	Bordered, alternate to sub-opposite	Truncate	Scanty paratracheal	Heterogeneous Type III
Laurinoxylon deomaliensis Lakhanpal, Prakash & Awasthi, 1981	—	Simple	Bordered, alternate	—	Scanty paratracheal	Heterogeneous Type III

TABLE 8 — COMPARATIVE ANATOMICAL ANALYSIS OF DIFFERENT TERTIARY FLORAS

DECCAN INTERTRAPPEAN BEDS				LOWER SIWALIK BEDS		TIPAM SERIES		NEOGENE OF WEST BENGAL		CUDDALORE SERIES		DUPITILA SERIES	
Mandla District		Nagpur-Chhindwara-Nawargaon Area											
Woods analysed	—17	Woods analysed	—17	Woods analysed	—19	Woods analysed	—34	Woods analysed	—22	Woods analysed	—38	Woods analysed	—17
Comparable genera	—16	Comparable genera	—15	Comparable genera	—17	Comparable genera	—33	Comparable genera	—21	Comparable genera	—36	Comparable genera	—13
Families	—15	Families	—14	Families	—8	Families	—19	Families	—7	Families	—14	Families	—11
Perforations		*Perforations*		*Perforations*		*Perforations*		*Perforations*		*Perforations*		*Perforations*	
Simple	—15	Simple in all		Simple in all		Simple	—33	Simple in all		Simple	—36	Simple in all	
Scalariform	—2					Scalariform	—1			Scalariform	—2		
Intervessel pits		*Intervessel pits*		*Intervessel pits*		*Intervessel pits*		*Intervessel pits*		*Intervessel pits*		*Intervessel pits*	
Bordered, alternate	—17	Bordered, alternate	—16	Bordered, alternate	—16	Bordered, alternate	—32	Bordered, alternate in all		Bordered, alternate	—36	Bordered, alternate	—16
Scalariform (partly)	—1	Scalariform	—1	Elements storied	—1	Alternate to subopposite	—2			Alternate to opposite	—2	Subopposite	—1
—		—		*Vasicentric tracheids*	—4	*Vasicentric tracheids*	—4	*Vasicentric tracheids*	—4	*Vasicentric tracheids*	—8	—	
Parenchyma		*Parenchyma*		*Parenchyma*		*Parenchyma*		*Parenchyma*		*Parenchyma*		*Parenchyma*	
Absent	—1	Absent	—1	Apotracheal diffuse to diffuse-in-aggregate to thin lines + scanty paratracheal	—8	Apotracheal diffuse to diffuse-in-aggergate or thin tangential lines + some paratracheal	—8	Apotracheal diffuse to diffuse-in-aggregate or thin tangential lines or bands + some paratracheal	—3	Absent	—1	Apotracheal diffuse to diffuse-in-aggregate or thin tangential lines	—3
Diffuse to diffuse-in-aggregate + some vasicentric	—4	Apotracheal diffuse to diffuse-in-aggregate + scanty paratracheal	—3	Scanty paratracheal	—1	Scanty paratracheal	—5	Scanty paratracheal to vasicentric	—3	Apotracheal diffuse to diffuse-in-aggregate or tangential lines + some paratracheal parenchyma	—11	Scanty paratracheal	—3
Thin apotracheal lines	—2	Scanty paratracheal	—5	Apotracheal banded + paratracheal vasicentric	—4	Apotracheal banded	—2	Apotracheal banded	—4	Scanty paratracheal	1	Apotracheal banded with or without some paratracheal	—3
Scanty paratracheal to 1-2 seriate vasicentric	—6	Vasicentric aliform confluent to banded	—8	Paratracheal aliform confluent to banded	—6	Paratracheal vasicentric to aliform confluent + apotracheal diffuse-in-aggregate to banded	—6	Paratracheal, aliform confluent to banded	—12	Apotracheal banded with some paratracheal	—8	Paratracheal vasicentric, aliform, confluent to banded	—8
Paratracheal aliform confluent to banded	—4			Storied	—1	Paratracheal aliform confluent to banded	—13	Storied	—4	Paratracheal vasicentric, aliform confluent to banded	—17	Storied	—2
Storied	—2												
Xylem rays		*Xylem rays*		*Xylem rays*		*Xylem rays*		*Xylem rays*		*Xylem rays*		*Xylem rays*	
Heterogeneous		Heterogeneous		Heterogeneous		Heterogeneous		Heterogeneous		Heterogeneous		Heterogeneous	
Type I	—2	Type I	—1	Type II or III	—11	Type II	—16	Type II	—9	Type I	—1	Type II or III	—8
Type II	—12	Type II or III	—11	Type V	—3	Type III	—7	Type V	—2	Type II	—12	Type V	—2
Type III	—2	Type V	—1	Homogeneous		Type V	—3	Homogeneous		Type III	—3	Unknown type	—1
Homogeneous		Homogeneous		Type IV	—5	Weakly heterogeneous	—1	Type IV	—9	Type V	—8	Homogeneous	
Type IV	—1	Type IV	—3			Homogeneous		Type VI	—2	Homogeneous		Type IV	—3
		Homogeneous				Type IV	—6	Storied	—5	Type IV	—13	Type VI	—3
		Type VI	—1			Type VI	—1			Type VI	—1	Storied	—2
										Storied	—5		

The number against each anatomical character indicates the number of woods in which that particular character is present.

FOSSIL WOODS FROM THE CUDDALORE SERIES

From this area 38 fossil woods representing 36 modern genera belonging to 13 dicotyledonous families have been analysed (Table 6). The assemblage shows a well-marked structural specialisation. In almost all the woods the perforation plates are simple; scalariform perforations occur in only two. Similarly, only in two woods alternate to opposite pits have been observed, while in all other woods these are bordered and alternate. However, vasicentric tracheids are present in eight species.

Parenchyma is absent in one, scanty paratracheal in one, apotracheal diffuse to diffuse-in-aggregate or in tangential lines alongwith or without some paratracheal parenchyma in 11, apotracheal banded with or without some paratracheal parenchyma in eight, and a well-developed paratracheal vasicentric to aliform, aliform-confluent to banded parenchyma is present in as many as 17 woods.

Heterogeneous xylem rays are present in 24 woods, their distribution being heterogeneous type I in one, type II in 12, type III in three and type V in eight. However, the homogeneous rays are present in 14 woods; they are homogeneous type IV in 13 and type VI in one. Storied rays have been observed in seven woods.

FOSSIL WOODS FROM THE DUPITILA SERIES

A total of 17 fossil dicotyledonous woods representing 13 living genera and 11 families have been anatomically analysed (Table 7). Perforations are simple in all the woods and intervessel pits are bordered and alternate in almost all of them. However, the pits are subopposite in one wood. Vasicentric tracheids are present in two woods.

Parenchyma is very well-developed. It is apotracheal diffuse to diffuse-in-aggregate or forming thin tangential lines in three woods, scanty paratracheal in three, apotracheal banded alongwith or without some paratracheal parenchyma in three and a well-developed paratracheal vasicentric, aliform, aliform-confluent or banded parenchyma occurs in eight woods. Parenchyma cells are storied in two species. Xylem rays are heterogeneous type II or III in eight, heterogeneous type V in two, heterogeneous of unknown type in one, homogeneous type IV in three and homogeneous type VI in three woods. Storied rays are present in two species.

DISCUSSION

A critical survey of the anatomical data accumulated from the Indian Tertiaries reveals some interesting facts regarding the evolution of anatomical characters from the oldest to the successively younger fossil floras. Two important characters, viz., axial parenchyma and xylem rays, show a marked specialisation in different fossil floras and have been dealtwith in detail (Table 8).

Considering the types of *axial parenchyma*, it is most primitive in the fossil woods described from Mandla District. Of the 17 woods analysed from this area, in as many as 13 (about 78%), the parenchyma is either absent, diffuse to diffuse-in-aggregate, in thin apotracheal lines, apotracheal narrow banded or scanty paratracheal to 1-2 seriate vasicentric. Only in four woods (about 22%), a well-developed paratracheal aliform to aliform-confluent parenchyma is known to occur. A well-developed vasicentric, aliform to aliform-confluent and rarely banded parenchyma is much more frequent in the fossil woods from the Nagpur-Chhindwara region. This type of parenchyma is present in as many as eight woods (about 48%) out of a total of 17 woods analysed from this area. In the remaining nine woods it is of primitive type.

However, coming to the Neogene floras of India, the woods of the Lower Siwalik beds (Middle Miocene) show a further increase in the percentage of woods with an evolved type of parenchyma. Of the 19 woods analysed from these beds, the parenchyma is paratracheal, aliform to aliform-confluent to banded in six of them (about 33%). In another four woods (about 21%) it is apotracheal banded with broad bands (considered to be most advanced amongst the apotracheal types) alongwith some paratracheal vasicentric type. In the remaining forms, the parenchyma is of primitive type.

The parenchyma shows further specialization in the woods from the Tipam Series (Upper Miocene) being paratracheal aliform, confluent to banded in about 39 per cent of woods, paratracheal vasicentric to aliform-confluent alongwith apotracheal diffuse to diffuse-in-aggregate to banded in about 18 per cent, apotracheal banded in about 6 per cent and it is of primitive type in the remaining woods.

In the fossil woods so far described from the Tertiary of West Bengal (considered to be equivalent to the Tipams) the percentage of woods with paratracheal aliform-confluent to banded parenchyma is further increased to about 54 per cent with another 18 per cent woods showing a well-developed apotracheal banded parenchyma. Another conspicuous feature is the occurrence of storied parenchyma in about 18 per cent of woods of this assemblage.

In the Cuddalore Series (Upper Miocene to Pliocene) about 48 per cent of woods show a well-developed paratracheal vasicentric, aliform, aliform-confluent to banded parenchyma. However, in about 20 per cent of woods, it is apotracheal banded but in the remaining woods, it is of primitive type.

Lastly, in the Dupitila Series (Mio-Pliocene) paratracheal vasicentric, aliform, confluent to banded parenchyma occurs in about 48 per cent of woods, apotracheal banded in about 18 per cent of woods and in the remaining it is of the primitive type. Storied parenchyma constitutes about 12 per cent of woods in this assemblage.

The *xylem rays* also show stages of specialization in the successive floras of the Indian Tertiaries. In Mandla assemblage heterogeneous rays of I, II, III and V types constitute as much as about 95 per cent of the total number of woods analysed, homogeneous type V rays occur in only one wood (about 5%). However, in the Nagpur-Chhindwara-Nawargaon region the percentage of woods with homogeneous rays is increased to about 23 per cent. The remaining 77 per cent woods show heterogeneous rays. In the Lower Siwalik woods, although the percentage of homogeneous rays is not substantially increased (about 25 per cent), the rays are of heterogeneous type V in about 18 per cent of woods. This is considered to be an advanced type evolved due to the elimination of multiseriate rays. In the Tipam Series there does not appear a marked specialization in the ray structure. In only about 21 per cent of woods, the rays are homogeneous and in the remaining ones they are heterogeneous. However, out of these the rays are of heterogeneous type V in about 9 per cent of woods.

The West Bengal flora, although considered to be equivalent to the Tipams in age, exhibits a high degree of specialisation in the ray structure. In 50 per cent of woods, the rays are homogeneous and in another 9 per cent they are of heterogeneous type V. Further, about 23 per cent of the woods have storied rays.

Fossil woods of the Cuddalore Series are also quite specialized. In about 38 per cent of woods the rays are homogeneous and in another 20 per cent they are heterogeneous type V. Storied rays occur in about 17 per cent of woods.

In the Dupitila Series about 36 per cent of woods show homogeneous rays while about 12 per cent woods are with heterogeneous type V rays. The remaining woods show either heterogeneous type II or III rays. Storied rays occur in about 12 per cent of woods. Thus, there is a well-marked increase in the percentage of advanced type of rays in the various Neogene floras as compared to the Palaeogene flora of the Deccan Intertrappean Series. However, this evolutionay tendency is not conspicuous in the Tipam Series.

In the remaining three Neogene floras, although there is not much difference in the specialization of ray structure, surprisingly, the most evolved type of rays are seen in the Neogene flora of West Bengal which is considered to be equivalent to the Tipams.

Thus, from the above studies it is evident that the Indian Tertiary dicotyledonous woods exhibit a general trend towards specialization in anatomical characters in their secondary xylem from geologically older to successively younger floras. These observations find further support from the studies of Wolfe, Doyle and Page (1975, p. 820) who analysed a number of dicot woods from the Cretaceous while discussing the palaeobotanical evidence for angiosperm phylogeny. According to them an assemblage of 70 entities from the late Campanian or early Maestrichtian of California and another assemblage of five entities from the Maestrichtian of Illinois "tend to substantiate that the supposedly advanced anatomical features are, in fact, geologically more recent than supposedly primitive features. Over half these wood patterns have solitary pores or solitary with a few short radial chains, and the majority also have diffuse, axial parenchyma only; the remainder have some vasicentric parenchyma in addition. Similarly, scalariform perforation plates are found in the majority and the rays are heterogeneous in almost all the woods. Two of the entities are dicotyledons lacking vessels. Some of the woods do have some specialized elements, such as short vessels and aggregate rays, but the overall pattern of these woods is not advanced. None of the woods possess supposedly advanced features such as storied elements, included parenchyma or elaborate pore distribution ". Consequently, the observations made in the present paper along with those made by Wolfe, Doyle and Page (1975) help in the understanding and evaluation of the concept of relative primitiveness of anatomical features.

Another important conclusion which can be deduced from these studies is the fact that the Deccan Intertrappean flora was made up of a number of plant communities of different ages occurring in a wide area of Central India. This has already been suggested by Lakhanpal (1970), Prakash (1960, 1972) and Bande and Prakash (1982c) on the basis of their palaeobotanical studies of this flora. Recently Alexander (1981) has also given different ages for different Deccan Lava flows and their associated Intertrappean beds on the basis of his K-Ar studies. The present anatomical observations mark out two different plant assemblages, one in the Mandla District of Madhya Pradesh and the other in the Nagpur-Chhindwara-Nawargaon region. Of the two, the former appears to be more primitive than the latter with respect to parenchyma and xylem ray characters. Here it may be pointed out that the age of the Mohgaon Kalan beds of Chhindwara District has recently been suggested to be Palaeocene-Eocene by Bande, Prakash and Bonde (1981) due to the presence of the index fossil *Distichoplax* from this locality which has also been corroborated by Alexander (1981, p. 249) who has assigned it an age of 47 million years from his studies on Chhindwara traps.

Further, the fossil flora from the Neogene of West Bengal, usually considered equivalent to the Tipams (Hunday, 1954), is anatomically more advanced than the Tipams, especially in the structure of xylem rays. In fact, there does not appear to be any marked difference in the evolutionary status of the West Bengal flora, the Cuddalore flora (Miocene-Pliocene) and the Dupitila flora (Mio-Pliocene). The xylem rays in the Cuddalore and Dupitila woods appear to be somewhat less advanced than in the Neogene woods of West Bengal. However, some discrepancies are bound to occur in such comparisons as the number of woods available from all the different assemblages is not uniform. With the availability of more data a more correct picture can be obtained and the concepts of relative primitiveness of anatomical features and their general trends of specialization could be properly evaluated.

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AN ADDITION TO KNOWLEDGE OF *OTOZAMITES PECTEN* SAHNI & SITHOLEY

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ABSTRACT

An account of *Otozamites pecten* Sahni & Sitholey is based on richer material which permits fuller description of its form while its cuticle is figured for the first time.

Key-words — *Otozamites*, Megafossil, Jurassic (Salt Range).

सारांश

ऑटोज़ॅमाइटिस पैक्टन साहनी व सिथोले के अभिज्ञान में और योगदान – राजेन्द्र वर्मा सिथोले (संपादक – पंकज कुमार पाल एवं टॉमस मैक्सवैल हेरिस)

ऑटोज़ॅमाइटिस पैक्टन साहनी व सिथोले का यह प्रस्तुत वर्णन और अच्छे उपलब्ध प्रादर्शों पर आधारित है। इन्हीं प्रादर्शों के कारण इस प्रारूप का विस्तृत वर्णन संभव हुआ है तथा उपचर्म का भी सर्वप्रथम चित्रांकन किया गया है।

Note by editors — Dr M. N. Bose as Director of the Sahni Institute asked us to do what we could to prepare notes left by Dr Sitholey for publication. Dr Sitholey was working in the Botany Department of Lucknow University in the years around 1943 on a collection of Jurassic plants from the Salt Range, then part of undivided India, but now in Pakistan. With Professor Birbal Sahni, accounts of two species of *Phlebopteris* were published (Sahni & Sitholey, 1945) and earlier (Sahni & Sitholey, 1943) a brief note describing *Otozamites pecten*. In 1948 both Prof. Sahni and Dr Sitholey moved to the Palaeobotany Institute and as far as we know no more work was done on the Salt Range flora. Dr Sitholey left the Institute and Palaeobotany in 1954 and died in December, 1979.

We found several manuscript drafts on *Otozamites pecten* together with many photographs and drawings. Some hand specimens corresponding to these photographs are missing but we could recognize his figured cuticle slides, a few specimens and the transfers. What we did was to compile Dr Sitholey's positive statements from his notes and select and rearrange his figures so he is to be considered as sole author of this paper. We have added comparisons with later described species. But notes on other species are less satisfactory and we feel it would be unfair to Dr Sitholey's memory to offer them. They are unfinished work, and for those other species not even duplicates are available.

INTRODUCTION

OTOZAMITES PECTEN was described briefly in 1943 by Sahni and Sitholey who gave photographs of two small leaf fragments. As mentioned earlier the material was collected by Gee and Iyengar of G.S.I. from two points near Sakesar (Sheet 38P/14): (i) at about 2.5 km NE of Sakesar on a river tributary 550 m East of Point 3920, (ii) at Nala, also NE of Sakesar. The horizon is near the top of the Jurassic as represented near Sakesar.

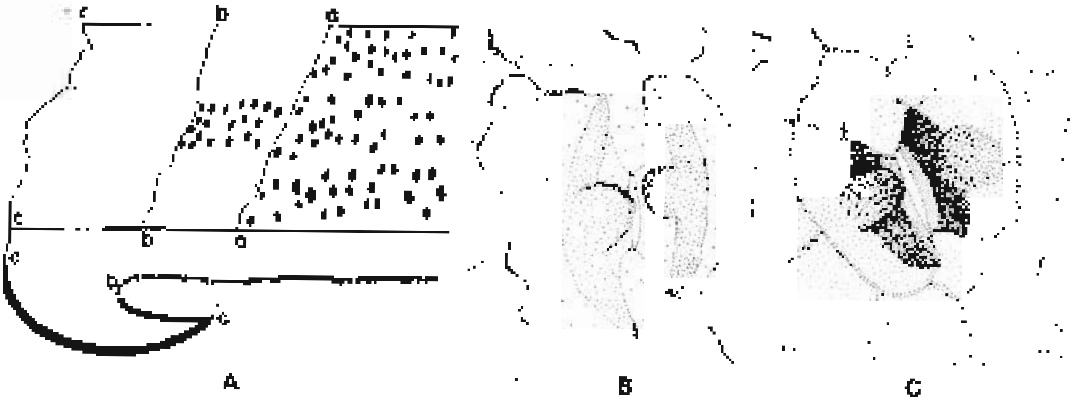
DESCRIPTION

Genus — *Otozamites* Braun

Otozamites pecten Sahni & Sitholey

Pl. 1, figs 1-9; Pl. 2, figs 10-16; Text-fig. 1A-C

1943 *Otozamites pecten* Sahni & Sitholey, p. 178, pl. 8, figs 37, 38 (brief description, two leaf fragments figured).
1963 *Otozamites pecten* Sahni & Sitholey: Sitholey *Bull. natn. bot. Gdn*, 86 pl. 6, figs 37, 38 (another figured leaf).



TEXT-FIG. 1 — A-C, *Otozamites pecten* Sahni & Sitholey. A, marginal region of lower cuticle shown above an imaginary section of its original form including stomata, a-a-a representing the sharp inner edge of the recurved margin, b-b-b is the point where the lower cuticle bends downwards to form the inner edge of the marginal fold, c-c-c is where the upper cuticle was torn in preparation. Only one stomatal band is represented under the margin. The stomata appear crowded near the line b-b; some of the stomata represented were seen only vaguely. B.S.I.P. slide no. K35 157-1, × 40; B, typical stoma, cell outlines indistinct, B.S.I.P. slide no. K35 158-1, × 500; C, stomata from a leaf giving an unusually thick cuticle, B.S.I.P. slide no. K35 317, × 500.

1976 *Otozamites pecten* Sahni & Sitholey: Ramanujam *Asp. plant Sci.*, 1 fig. 37 (sketch of Sitholey's, 1963 fig. 38).

Emended Diagnosis — Leaf 12-18 mm wide in middle region (length unknown but estimated at 24-36 cm). Leaf narrowing very gradually towards apex. Base (not available in present material), but possibly with slightly longer pinnae and a thick rachis. Pinnae alternate, normally horizontal. Pinnae in most leaves nearly round, occasionally (? near base) slightly elongated, touching or overlapping pinna in front, pinna width 5-6 mm, widest 10 mm, anterior basal margin not or scarcely auriculate but sometimes overlapping posterior basal margin of next pinna on opposite side; apex of pinna rounded (never pointed). Upper surface of lamina slightly convex, substance of lamina very thick, margin recurved and in compressed condition forming a border 0.5 mm wide round lower surface but narrower near rachis. Veins often conspicuous on both surfaces, spreading from a point near the middle of the pinna base. In some leaves upper surface smooth, in other veins sunken.

Upper cuticle thick, often about 7 µm but lower much thinner. Over pinna surface cells flat, more or less square but outlines strongly sinuous, well marked in some leaves but not in others. Stomata absent. Trichomes absent in most leaves but in some cells may bear a sac-like trichome or hole where it has been lost. Cells along veins not distinguished.

Lower cuticle forming three regions, stomatal strips, vein strips and margin. Stomatal strips about three times wider than vein strips, stomata may form 3-4 files but often files short and some stomata not in a file, nearly all transverse, rather evenly spaced, stomatal region overlapped

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Additional notes by Editor — The material studied originally consisted of a dozen large and several small fragments but the larger ones have been lost. In every specimen the rock has split exposing the upper surface of the lamina. All leaves were flat except one which had its pinnae bent downwards. In the compressed fossils the pinna margin is sharp but we imagine it was rounded in life. As the lamina exceptionally thick, microtome sections were cut. These clearly differentiated the upper part of the mesophyll, the original palisade, which formed solid blocks from the more tenuous spongy mesophyll and showed the margin well. In one cuticle preparation the subsidiary cells are unusual in having a thickened surface (Text-fig. 1C).

Sahni and Sitholey (1943) mentioned two specimens nos. K35 107 and K35 549 as syntypes, out of these specimen no. K 35 549 is available as a transfer in the Birbal Sahni Institute of Palaeobotany and selected as the lectotype of the taxon.

at margins (and stomata then obscure). At end of stomatal surface cuticle bent upward and stomata seeming congested. In stomatal bands epidermal cells sinuous but outlines usually inconspicuous, in some leaves cells bulging in others forming papillae with lateral ends thickened and forming crescents and further obscuring epidermal cells. Stomata only slightly sunken, subsidiary cells small, outer wall often obscure, each subsidiary cell bearing a papilla pointing over stomatal aperture. On vein strips cells tending to be more elongated. Trichome bases or large papillae frequent, consisting of one, two or three cells with a thick bulging surface, occasional cells of this type present in stomatal bands. In marginal region part with stomata probably normal (but details obscure) then after bending upward abruptly lacking stomata. This part in some leaves showing cells with a flat surface and cells elongated parallel with margin but in other leaves surface of most cells bulging.

Rachis cuticle very thickly cutinised on lower side, thinner above. Lower side showing transverse ridges crossing many epidermal cells, these possibly represent ramentum bases. In original unmacerated state showing tubercles (possibly ramentum bases).

Lectotype — No. K35/549 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — River tributary, 2.5 km north-east of Sakesar.

Age — Jurassic.

Comparison — Several species of *Otozamites* have small rounded pinnae. *O. bunburyanus* Zigno, 1868 (Italy) often has its pinnae obtusely pointed apically. *O. attenuatus* (England) once identified with *O. bunburyanus* (see Harris, 1964) has no reflexed margin. *O. marginatus* Saporta, 1875 has a reflexed margin but we know no microscopic details. However, an English specimen (Harris, 1964) has less clearly marked veins, more evenly distributed stomata and lacks the characteristic papillae of *O. pecten*. *O. vemavaramensis* Bose, 1966 and Bose and Jain, 1974 (India) has very small deltoid pinnae. Its margin is recurved. *O. bunburyanus* var. *indica* Seward & Sahni, 1920 belongs to *O. vemavaramensis* according to Bose (1966). *O. walkamotaensis* Bose & Zeba-Bano, 1981 (India) sometimes has nearly round pinnae (though they are usually longer). The margin has no stomata but is flat.

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EXPLANATION OF PLATES

Plate 1

Otozamites pecten Sahni & Sitholey

1. Lectotype showing abaxial surface of leaf in transfer, B.S.I.P. slide no. K35/549-1. × 1.
2. Fragment near apex of leaf, specimen missing. × 1.
3. Another fragment near apex of leaf, B.S.I.P. slide no. K35/253. × 1.
4. Abaxial surface of leaf in transfer, B.S.I.P. slide no. K35/200-1. × 1.
5. Specimen with a thick rachis and slightly elongated pinnae, specimen missing. × 1.
6. Adaxial view of leaf, specimen missing. × 1.
7. Lectotype (see fig. 1). × 3.
8. Same specimen as fig. 3. × 4.
9. Magnified view of the adaxial surface of leaf, part of specimen shown in fig. 6. × 4.

PLATE 2

Otozamites pecten Sahni & Sitholey

10. Lower surface of pinna-cuticle, showing veins and stomatal strips, B.S.I.P. slide no. K35/157-1. × 9.
11. Pinna margin showing the bulging epidermal cells, B.S.I.P. slide no. K35/157-1. × 38.
12. Upper cuticle of Pinna, B.S.I.P. slide no. K35/100-1. × 240.
13. Upper cuticle of pinna showing perforations (?trichome bases), B.S.I.P. slide no. K35/484-1. × 240.
14. Lower cuticle of pinna showing distribution of stomata vein strips rather obscure in this specimen, B.S.I.P. slide no. K35/157-1. × 38.
15. Lower cuticle of pinna showing a few stomata, clear subsidiary cell papillae are seen on the top left stoma. Papillae scarcely developed on ordinary epidermal cells, B.S.I.P. slide no. K35/484-1. × 240.
16. Lower cuticle of pinna with strongly developed papillae on ordinary cells, B.S.I.P. slide no. K35/157-1. × 240.

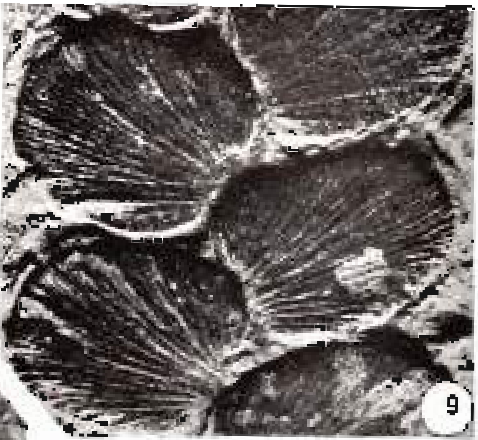
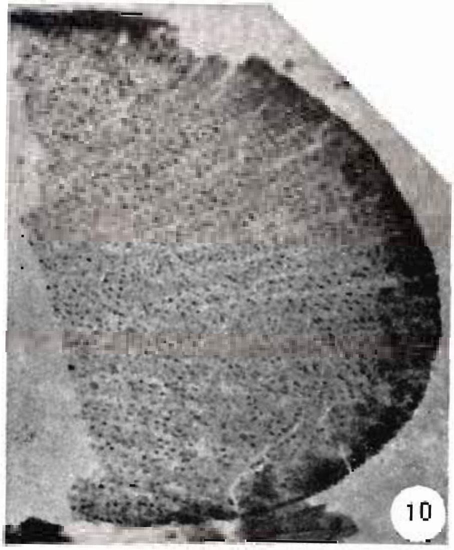


PLATE 1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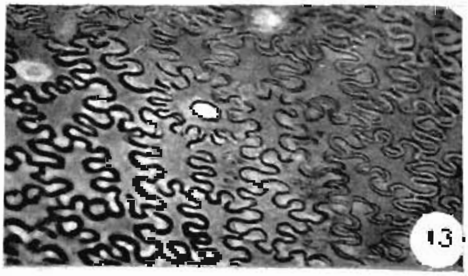
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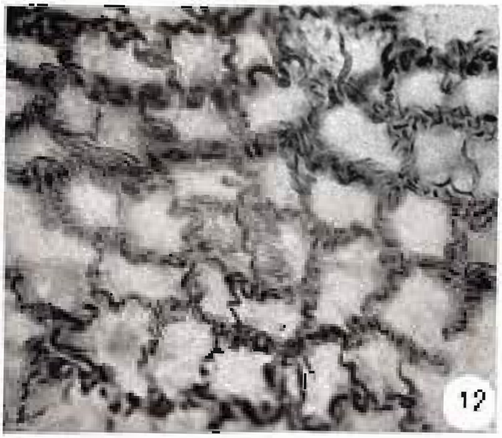
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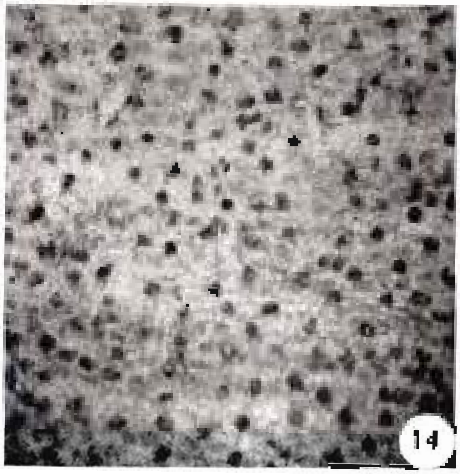
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PLATE 2

The Palaeobotanist, **32**(1): 82-85, 1984.

MICROBIOTA FROM STROMATOLITE-*STRATIFERA* OF THE BILARA GROUP (MARWAR SUPERGROUP), WESTERN RAJASTHAN

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ABSTRACT

Three types of microbiota referable to *Nanococcus vulgaris*, *Huronispora psilata* and *Kakabekia umbellata* are reported from the stromatolite—*Stratifera* collected from near Bhadora. The biota suggests that the stratified stromatolite may have been formed due to exogenic activities of the recorded algae.

Key-words—Microbiota, *Nanococcus*, *Huronispora*, *Kakabekia*, Marwar Supergroup, Precambrian (India).

साराँश

पश्चिमी राजस्थान में बिलारा समूह (मारवाड़ महासमूह) के स्ट्रेमेटोलाइट-स्ट्रेटिफेरा से सूक्ष्मजीविता – प्रभात कुमार माइती

भदौरा के समीप से एकत्रित स्ट्रोमेटोलाइट-स्ट्रेटिफेरा से नैनोकोकस वल्गेरिस, ह्यूरोनिस्पोरा साइलेटा एवं काकाबेकिया अम्बॅलेटा से निरूपणीय तीन प्रकार की सूक्ष्मजीवितायें अभिलिखित की गई हैं। प्राप्त सूक्ष्मजीविता से यह प्रस्तावित होता है कि स्तरित स्ट्रोमेटोलाइट अभिलिखित शैवालों की बाह्यजनित गतिविधियों के परिणाम स्वरूप बने हैं।

INTRODUCTION

THE Marwar stromatolites are best developed in the Jodhpur and Nagaur districts, although they have also been found in parts of the Jaisalmer and Pali districts. Their lateral distribution is considerable as they cover about 50,000 km² area on the western side of the Aravalli range. The stratigraphic succession is summarised as follows.

Badhaura Formation

…………………… Unconformity ……………………

Nagaur Group	Tunkalian Formation Nagaur Formation
Bilara Group	Pondlo Formation Gotan Formation Dhanapa Formation Giar Bhakar Formation
Jodhpur Group	Soina Formation Pokaran Boulder Bed

The stromatolites occur only in the Bilara Group. The thickest stromatolite deposits are found in the Dhanapa Formation. According to Burman (1980) and Verma and Burman (1980) the records of stromatolites are *Collenia*, *Colleniella*, *Conocollenia*, *Cryptozoon*, *Irregularia*, *Stratifera* and Oncolites.

In the present paper, it is aimed to record the microbiota found in the stromatolite-*Stratifera* collected from near Bhadora from the Dhanapa Formation. The material was studied in thin sections obtained along the plane of vertical deposition.

DESCRIPTION

TYPE 1

Large circular enveloping sheaths (Pl. 1, figs 1-3), measuring up to 60-180 μm, encompasing hundreds of circular cells with smooth surface, arranged in irregular groups, measuring ± 3 µm. At times cells are also found without enveloping sheath, either scattered or in groups due to disorganisation of the enveloping sheath (Pl. 1, figs 4, 5).

This form is identical to *Nanococcus vulgaris* Oehler (1977) recorded from the H.Y.C. Pyrite Shale Member, Australia (1500 m.y.).

TYPE 2

Spherical cells, solitary (Pl. 1, figs 6, 7) or in groups of 2-5 cells, measuring 10-20 µm, surface smooth, enveloping sheath or lamellated organic matrix around cells absent.

The present forms compare with *Huroniospora psilata* Barghoorn (1965) recorded from the Gunflint Iron Formation, Canada (1900 m.y.) and *H. psilata* by Muir (1978) from the Amelia Dolomite, Australia (1500 m.y.).

TYPE 3

Spherical cells with a narrow neck-like body expanding into umbrella like-structure (Pl. 1, fig. 8). Spherical cells measuring 8-10 µm, neck 2 µm broad and umbrella 4-8 µm long.

The specimens resemble *Kakabekia umbellata* Barghoorn (1965) recorded from the Gunflint Iron Formation.

DISCUSSION

Biota from the Prephanerozoic stromatolite has been reported by Awramik (1977) from the stromatolitic sequence in the Gunflint Iron Formation, Canada (1900 m.y.). According to his observations the microbiota plays an important role in the deposition of stromatolites. Further in *Stratifera*, the microbiota is dominated by coccoidal cells comparable with *Huroniospora* Barghoorn whereas on the other hand in columnar stromatolite the filamentous form, comparable with *Gunflintia* Barghoorn, is dominant. The present study supports the fact that the stratified stromatolites are formed by the biogenic activity of the Chroococcacean type.

Schopf *et al.* (1977) described microbiota from the algal laminated sediments of cf. *Stratifera* from the Sherikha Formation (approximately 950 m.y.) in the Nizhnyaya Tunguska River Valley, U.S.S.R. and also from the Min'yar Formation (approximately 700 m.y.) about 5 km upstream from the village of Bakeyevo, U.S.S.R. Two principal types of microfossils, (a) solitary algal unicells containing some intracellular organic bodies, and (b) filamentous microfossils, tubular and unbranched comparable to extracellular sheaths produced by modern mat building Oscillatoriacean blue-green algae have been identified. Though, the stromatolitic biota from Bhadora resemble in the presence of solitary algal unicells but differs in the absence of filamentous microfossils.

The presence of *Kakabekia* and other Chroococcaceans suggests that the organo-sedimentary structures have been deposited in shallow water and in anoxygenic conditions.

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EXPLANATION OF PLATE

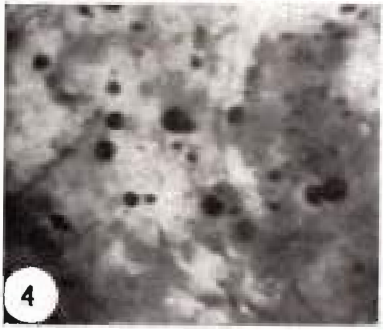
(All photomicrographs are × 1000; figured slides are preserved at the Birbal Sahni Institute of Palaeobotany Museum; Stage coordinate on Leitz-Dialux Microscope)

1-3. Type 1. cf. *Nanococcus vulgaris* Oehler, slide no. 6934; Stage coordinates 21.6 × 102.5 (fig. 1), 21.4 × 102.4 (fig. 2) and 22.1 × 100.6 (fig. 3).

4, 5. Isolated cells of *Nanococcus vulgaris* Oehler, slide no. 6935; Stage coordinate 42.9 × 96.7.

6, 7. Type 2. cf. *Huronispora psilata* Barghoorn, slide no. 6935; Stage coordinates 42.0 × 103.5 (fig. 6) and 46.4 × 101 (fig. 7)

8. Type 3. cf. *Kakabekia umbellata* Barghoorn, slide no. 6936; Stage coordinate 42·1 × 95·4.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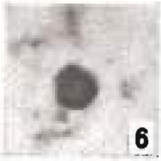
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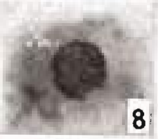
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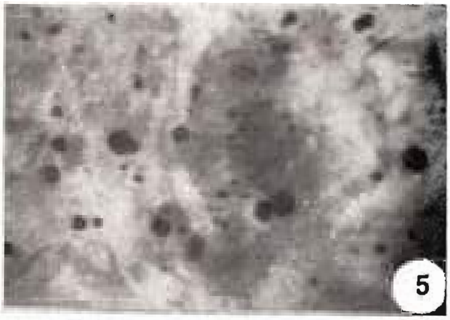
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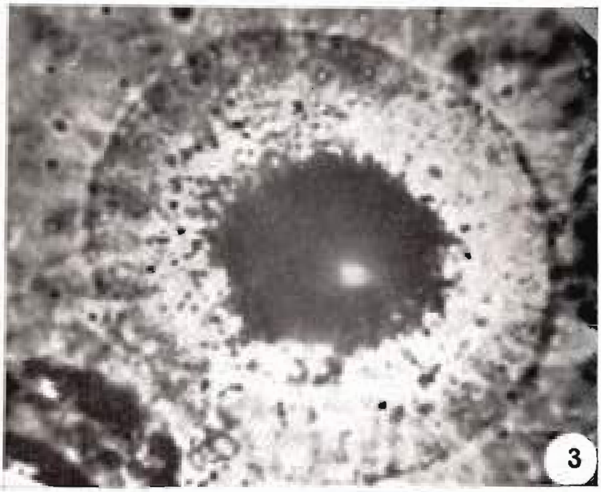
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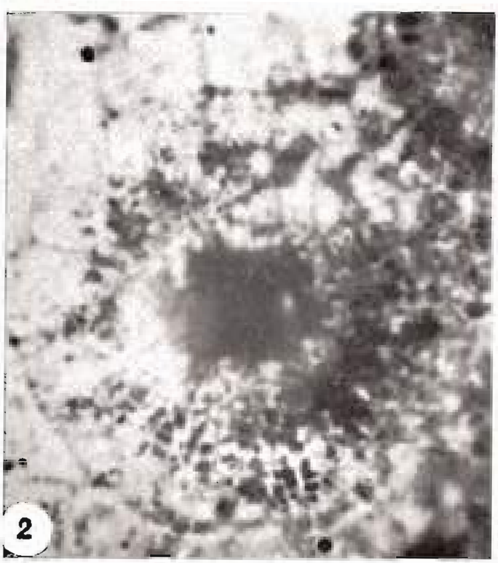
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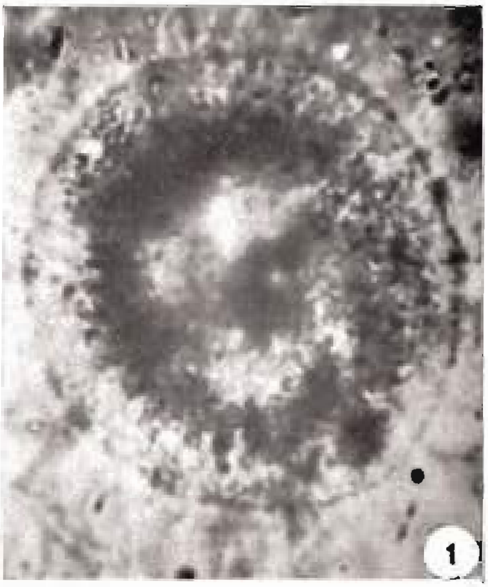
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PLATE 1

The Palaeobotanist, **32**(1): 86-90, 1984.

LELESTROBUS: A NEW MICROSPORANGIATE ORGAN FROM THE TRIASSIC OF NIDPUR, INDIA

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ABSTRACT

Lelestrobus pennatus gen. et sp. nov. is a compact strobilus having spirally arranged quill-like microsporophylls. Each microsporophyll is composed of an expanded base bearing abaxially inserted sporangium, and an attenuated distal portion. A sporangium is ovoid in shape and contains nonstriate-bisaccate pollen grains. This has close affinity to Coniferales.

Key-words — *Lelestrobus*, Strobilus, Microsporophyll, Coniferales, Triassic (India).

सारांश

भारत में निदपुर के त्रिसंधी कल्प से एक नवीन लघुबीजाणुधानिक अवयव . लेलेस्ट्रोबस – श्याम चन्द्र श्रीवास्तव

लेलेस्ट्रोबस पैन्नेटस नव वंश व नव जाति सर्पिलाकार विन्यस्त पंख-सदृश लघुबीजाणुपर्णों से युक्त एक संहत शंकु है। प्रत्येक लघुबीजाणुपर्ण का फैला हुआ आधारीय भाग अपाक्ष की ओर प्रविष्ट एक बीजाणुधानी को जन्म देता है तथा इसका दूसरा सिरा कम संकीर्ण है। लघुबीजाणुधानी आकार में अंडाकार है तथा इसमें अरेखित-द्विकोष्ठीय परागकण मिलते हैं। यह कोनिफॅरेल्स से घनिष्ठ सजातीयता प्रदर्शित करता है।

INTRODUCTION

SINCE a compressed cone (*Conites* sp.) from the Indian Triassic was first recorded by Srivastava (1971) from the *Dicroidium*-bearing bed of Nidpur, several pollen producing organs, namely, *Nidistrobus* Bose & Srivastava, 1973; *P. nidpurensis* Srivastava, 1974; *Pteruchus indicus* Pant & Basu, 1973; *Bosea* Srivastava, 1975; *Rugatheca* Pant & Basu, 1977; and *Nidpuria* Pant & Basu, 1979 have been discovered and described.

A few more fructifications, viz., *Satsangia* Srivastava & Maheshwari, 1973; *Chakrea* Srivastava, 1976; *Pteruchus thomasii;* and *P. gopadensis* Pant & Basu, 1979 have also been reported but these have not yielded any pollen grains.

This paper records an additional strobilus bearing quill-like microsporophylls.

Lelestrobus gen. nov.

Diagnosis — Strobilus consisting of spirally arranged quill-like sessile microsporophylls having broad expanded base with an attenuated distal portion. Sporophyll base with an abaxially inserted median sporangium, sporangium oblong-ovoid, accentuated by flap or wing-like structure. Sporophyll cuticle differentiated into non-stomatic and stomatic sides, thinner surface bearing a few longitudinally oriented stomata, marked in tapering part of sporophyll. Sporangial wall thin, composed of smooth rectangular-polygonal cells; pollen grains bisaccate, non-striate.

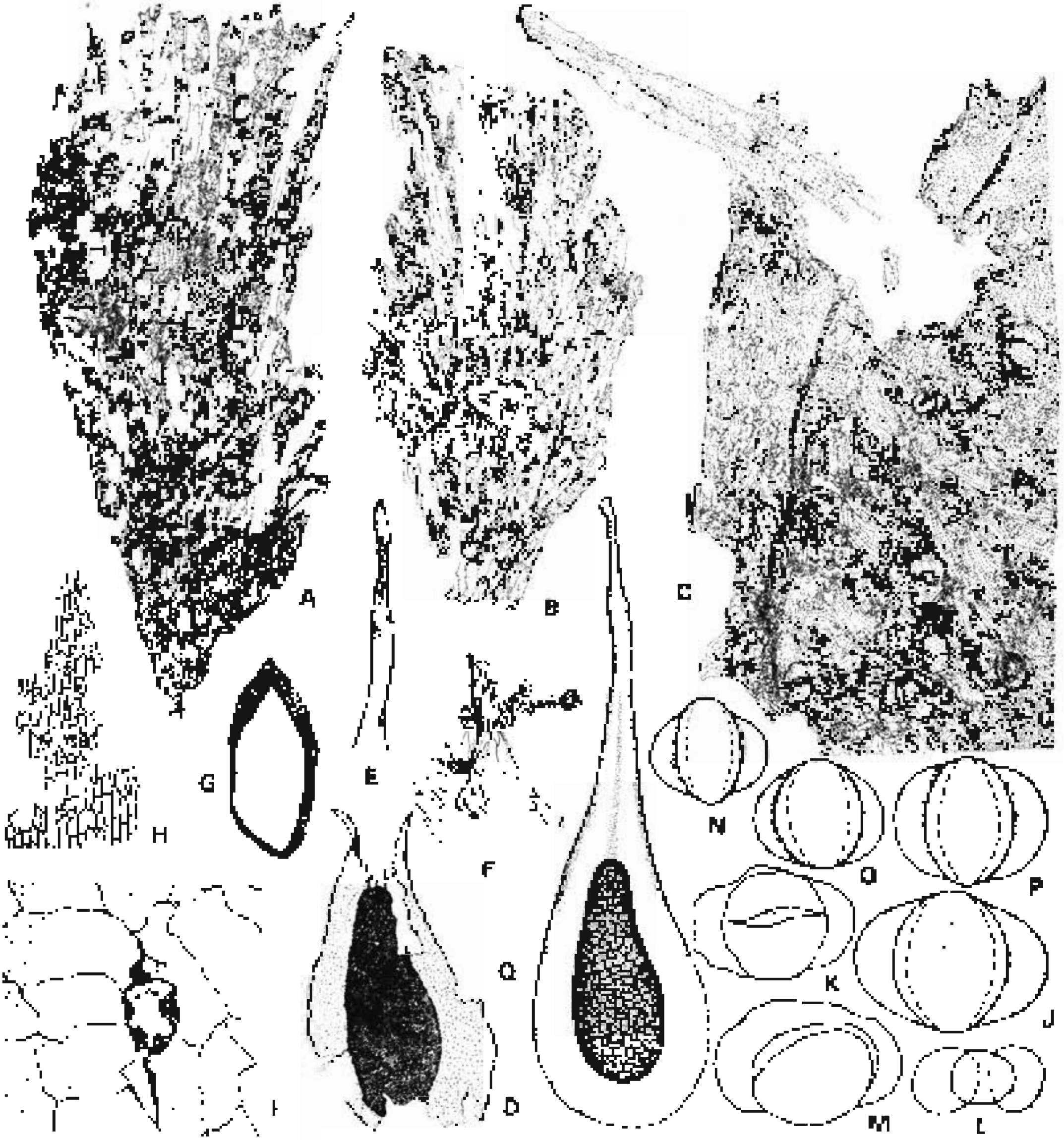
Type Species — *Lelestrobus pennatus* sp. nov.

Derivation of Name — After late Dr K. M. Lele.

Lelestrobus pennatus gen. et sp. nov.

Pl. 1, figs 1-16; Text-figs 1A-Q

Diagnosis — Detached strobilus, 1.5 cm long, consisting of spirally arranged sessile microsporophylls, microsporophylls abaxially with an inserted oblong-ovoid sporangium accentuated by flap or wing-



TEXT-FIG. 1 — *Telestrobus gemmatus* gen. et sp. nov. — A, a microstrobilus showing spirally arranged microsporophylls with its attenuated distal portion, Holotype no. 35469, × 4; B, counterpart of Holotype no. 35469, × 4; C, a broken microsporophyll showing a part of sporangium containing pollen grains associated with attenuated distal portion in broken state, slide no. 6598/35469, × 40; D-E, an approximately complete microsporophyll exhibiting conspicuously midpart broken but expanded basal portion bearing abaxial sporangium with a few pollen grains and attenuated distal portion preserved respectively, slide nos. 6600/35469, × 20, 6597/35469, × 20; F, a part of sporangium with both surfaces associated with pollen grains, slide no. 6599/35469, × 50; G, an empty sporangium where the entire pollen mass is shed off, slide no. 6599/35469, × 20; H, non-stomatic surface showing spirally arranged epidermal cells, slide no. 6600/35469, × 75; I, thinner surface showing a single stoma with feebly developed papillae projecting over stomatal pit, slide no. 6598/35469, × 500; J, a typical nonstriate, bilateral, disaccate grain showing zone of saccus attachment associated with vertically oblong-oval cap, distally sacci free area (where sacci not free from laterally) bearing linear diffused sulcus-like area (monolete) in the centre, slide no. 6599/35469 ca. × 400; K-M, varied forms of pollen grains respectively showing, K — central body with horizontal or two parallel folds, L — one pollen diploxylonoid with circular central body in distal focus, M — a pollen grain in monosaccoid condition, slide no. 6599/35469 ca. × 500; N-P, showing variation in saccus attachment, slide no. 6599/35469 ca. × 500; Q, a diagrammatic restoration of a microsporophyll.

like structure. Sporophyll cuticle differentiated into stomatic and non-stomatic surfaces, non-stomatic surface slightly thicker composed of serially arranged rectangular-narrower, occasionally polygonal cells, cell walls usually straight, at places end-walls oblique, surface generally smooth; stomatic surface thinner bearing a few stomata, usually marked in tapering part of sporophyll, cells generally polygonal, cell walls extremely thin, at times inconspicuous, lateral-walls straight, end-walls usually oblique, at places straight, surface smooth or unsculptured, stomata orientated longitudinally, mostly marked only by thinly cutinized, feebly developed papillae projecting over the inner stomatal pit, subsidiary cells 5, stomatal aperture indistinct. Sporangial-wall membranous, cells elongated-rectangular or polygonal, cell-walls thin, at times not clearly distinct, surface smooth. Pollen grains non-striate, bisaccate, haploxylonoid, size range 60-70 × 50-60 μm with a well defined vertically oval-rounded central body measuring 36-48 μm in size, finely intrapunctate-infrareticulate in structure, sacci small 8-12 μm wide, sacci proximally attached on equator and distally inclined to cover 1/6 part of central body, distal zone of saccus attachment clearly marked but without any fold or ridge, distal saccus free area 14-25 μm wide, vertically oblong-ovoid showing the presence of a linear tenuitas or diffused sulcus-like area in the centre, sacci mediumly or finely intrareticulate, less than 1 μm wide muri, 10-24 μm laterally apart.

Holotype — No. 35489 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Gopad River near Nidpur, Sidhi District, Madhya Pradesh.

Age — Triassic.

Remarks — Only one detached specimen with a slightly imperfect base has been found. The sporophylls are so closely clasped that only a small sporophyll with its apical broken end could be separated with difficulty. Even in doing so the pollen grains were shed in water. However, in other preparations the tapering part of sporophyll attached with sporangium could be detected and the reconstruction of microsporophyll given in Text-fig. 1Q has been based on all the preparations.

The position and attachment of sacci in the pollen grains are variable. Mostly the sacci are crescentic and smaller than the central body; but in a few specimens they are equal to the central body. Sacci are usually continuous laterally round the central body and sometimes there are notches at the meeting points. Occasional diploxylonoid pollen grains with circular central body have also been marked. One or two folds have also been observed on proximal surface of some monosaccoid grains. These grains are variants of the same general type. Variation in pollen grains is known in some coniferous cones (Grauvogel-Stamm, 1969, 1972, 1973, 1976) as well as in other fossil plant groups.

Such type of dispersed pollen grains have earlier been recorded from the Nidpur shale as a variable form of *Alisporites indicus* Bharadwaj & Srivastava, 1969.

COMPARISON AND DISCUSSION

In general, *Lelestrobus pennatus* is a compact strobilus bearing abaxial sporangia with nonstriate-bisaccate pollen grains. These characters are suggestive of its relationship with Coniferales. In having quill-like microsporophylls, *L. pennatus* seemingly approaches the genus *Isoetes* but it is clearly different because of the aforesaid characters.

Lebachia piniformis described by Florin (1938-45) differs in having two microsporangia on each sporophyll and monosaccate pollen grains with baloon-like sacci completely surrounding the central body except at distal pole.

Lelestrobus pennatus markedly differs from the extant conifers in its microsporophylls exhibiting only a single sporangium abaxially inserted in the basal region while in the latter the microsporophylls bear two to many, fused or free sporangia.

Because of a single sporangium *Lelestrobus pennatus* probably represents an early phase in the evolutionary history of conifers.

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EXPLANATION OF PLATE

Lelestrobus pennatus gen. et sp. nov.

1. Holotype. BSIP specimen no. 35469. × nat.
2. Counterpart of the holotype. × nat.
3. Holotype showing spirally clasped microsporophylls. × 6.
4. Holotype (counterpart). × 4.
5. A part of microsporophyll showing a portion of sporangium containing pollen grains associated with a broken attenuated distal portion. BSIP slide no. 6598/35469. × 40.
6. A broken microsporophyll showing an embedded abaxial sporangium placed in middle of expanded basal part. BSIP slide no. 6600/35469. × 40.
7. An under macerated incomplete sporangium filled with pollen grains. BSIP slide no. 6599/35469. × 100.
8. An empty sporangium from which the pollen have been shed off. BSIP slide no. 6598/35469. × 40.
9. Spirally clasped microsporophylls. BSIP slide no. 6597/35469. × 100.

10-12. Pollen grains retrieved from a sporangium. BSIP slide no. 6599/35469. × 500.

13. A dissected sporangium with liberated pollen grains adhering to its thin cuticle. BSIP slide no. 6599/35469. × 100.
14. Non-stomatic thicker surface. BSIP slide no. 6601/35469. × 150.

PLATE 1

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PALYNOLOGICAL INVESTIGATIONS OF RAMSHAHR WELL 1, HIMACHAL PRADESH, INDIA

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ABSTRACT

The palynofloral assemblage mainly consists of algal colonies — *Pediastrum*, fungal spores and microthyriaceous ascostromata, pteridophytic spores, and gymnospermous and angiospermous pollen grains. In all, 25 species belonging to 20 genera have been recorded. A few microplanktons have also been recovered but they are thought to be reworked. On the basis of the palynological assemblage, three distinct palynological zones have been established within the Ramshahr Well 1. The Ramshahr palynofloral assemblage has been compared with those known from the Mio-Pliocene sediments of India. In addition, the palynological data have been interpreted throwing light on its dating potential, identification of various depth levels and environment of deposition.

Key-words — Palynology, Algae, Microplanktons, Fungal spores, Pollen grains, Mio-Pliocene (India).

सारांश

हिमाचल प्रदेश (भारत) में स्थित रामशहर कुआँ-1 का परागाणविक अन्वेषण – हरीपाल सिंह एवं समीर सरकार

उपलब्ध परागाणविक वनस्पतिजात समुच्चय में मुख्यतया शैवालीय कॉलोनी – पैडिआॅस्ट्रम, कवकीय बीजाणु, सूक्ष्मथाइरियेसीय ऐस्कोपीठिकायें, टेरिडोफ़ाइटी बीजाणु तथा अनावृतबीजी एवं आवृतबीजी परागकण विद्यमान हैं। कुल मिलाकर 20 वंशों से सम्बन्धित 25 जातियाँ अभिलिखित की गई हैं। कुछ सूक्ष्मप्लवक भी वर्णित किये गये हैं परन्तु इनका अभी पुनः अध्ययन होना है। परागाणविक समुच्चय के आधार पर रामशहर कुआँ 1 में तीन सुस्पष्ट मण्डल बनाये गये हैं। रामशहर परागाणविक समुच्चय की तुलना भारत के मध्यनूतन – अतिनूतन से ज्ञात अवसादों से की गई है। इसके अतिरिक्त उपलब्ध आँकड़ों के माध्यम से सम्भाव्य काल-निर्धारण, विभिन्न गहराइयों पर स्थित स्तरों के अभिनिर्धारण तथा निक्षेपणीय वातावरण पर प्रकाश डाला गया है।

INTRODUCTION

THIS paper is based on the material supplied by Oil and Natural Gas Commission, Dehradun from the Ramshahr Well 1 (1,340 to 2,650 m depth) drilled near Ramshahr, Solon District, Himachal Pradesh. The objective of the investigation was to find out palynological basis for the identification of different stratigraphic horizons and also to know the dating potential of the palynomorphs together with reflection on the environment of deposition. Ramshahr Well 1 drilled by the Oil and Natural Gas Commission, Dehradun is situated at approximately 30°57′14·5″ latitude and 76°52′53″ longitude near Ramshahr in Solon District. The dunes and terrace gravel deposits of recent and subrecent sediments cover the Tertiary rocks in this area. The Tertiary sediments, in turn, rest over the pre-Tertiary rocks, i.e. Shali sediments. The geological setting in the sub-Himalayan region between Nalagarh (31°2′: 76°43″) and Arki (31°9′: 76°58″) has the following sequence of rocks.

Recent and subrecent—The dunes and terrace gravel deposits.

Tertiary — Siwalik Group
1. Middle Siwaliks
Sutlej Formation
2. Lower Siwaliks
Nalagarh Formation
Kundlu Formation
Sirmur Group
Kasauli Formation
Dagshai Formation
Subathu Formation

..................Unconformity............................

Pre-Tertiary

Very little palynological work has so far been done on the Neogene palynostratigraphy of Himachal Pradesh. Some of the important contributions have been made by Banerjee (1968), Nandi and Bandyopadhyay (1970), Singh and Saxena (1980, 1981), Saxena and Singh (1982), etc.

In the present investigation palynomorphs have been studied morphologically and assigned to various spore pollen genera and species. Based on the qualitative and quantitative analyses of the assemblage, biozonation of the strata has been carried out. An attempt has also been made to compare the palynoflora with the known Mio-Pliocene assemblages of India and on the basis of this the approximate age of these sediments has been determined.

MATERIAL AND METHODS

All together 29 well cutting samples, supplied by the Oil and Natural Gas Commission, Dehradun, from different depths were studied (Table 1). Out of these, 24 samples proved to be productive. Majority of the samples are not very rich in miospores but the preservation of organic matter is reasonably good. The rock samples of Ramshahr Well 1 are mostly claystones or siltstones. In its upper part the claystones and siltstones are very hard, compact, generally ash gray to dirty white in colour while in the lower part they are characterized by having sandy siltstones which are micaceous in nature and brownish to greenish-gray in colour.

The palynomorphs were recovered from the samples by employing the conventional technique of maceration, i.e. HCl, HF, HNO_3 and KOH. The palynofossils were separated by floatation method using Potassium iodide and Cadmium iodide (sp. gr. 2.3) heavy liquid. The slides were prepared in polyvenyl alcohol and mounted in D.P.X. The slides and negatives of the palynomorphs have been deposited in the repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC DESCRIPTION

Anteturma — *Proximegerminantes* Potonié, 1970
Turma — *Triletes* Reinsch emend. Dettman, 1963
Supra Subturma — *Acavatitriletes* Dettman, 1963
Subturma — *Azonotriletes* Luber emend. Dettman, 1963
Infraturma — *Laevigati* Bennie & Kidston emend. Potonié, 1950

Genus — *Cyathidites* Couper, 1953

Type species — *Cyathidites australis* Couper, 1953.

Cyathidites australis Couper, 1953

(not illustrated)

Remarks — Most of the specimens recovered are ill-preserved and broken.

Botanical affinity — The probable affinity of *Cyathidites australis* lies with the family Cyatheaceae or Dicksoniaceae.

Infraturma — *Muronati* Potonié & Kremp, 1954.

Genus — *Lycopodiumsporites* Thiergart, 1938

Type species — *Lycopodiumsporites agathoecus*.

Lycopodiumsporites palaeocenicus Dutta & Sah, 1970

Pl. 1, fig. 8

Remarks — Specimens referred here as *L. palaeocenicus* Dutta & Sah, 1970 are slightly bigger in size range than those

TABLE 1 — SHOWING LITHOLOGICAL DETAILS OF THE SAMPLES OF RAMSHAHR WELL 1

SAMPLE No.	LOCATION OF SAMPLE	DESCRIPTION	PALYNOMORPH OCCURRENCE
1.	1340-45 m	Ash gray claystone, slightly calcareous in nature	(−)
2.	1355-60 m	Ash gray to dirty white hard compact siltstone	(−)
3.	1400-05 m	Gray to medium gray hard compact siltstone with greenish to ash gray calcareous clay	(+)
4.	1460-65 m	Colourless to dirty white, medium to fine grained silty sandstone	(+)
5.	1475-80 m	Gray coloured, hard and compact siltstone, black minerals present	(+)
6.	1840-45 m	Gray, fine grained, loose friable, uncemented sand with few specks of brown silt	(+)
7.	1885-90 m	Light brown, moderately hard compact, sandy siltstone, micaceous in nature	(+)
8.	1930-35 m	Brownish moderately hard compact, sandy siltstone, micaceous	(+)
9.	1955-60 m	Brownish gray, moderately hard fractured silty clay stone	(+)
10.	1975-80 m	Brownish, compact, fine grained silty clay stone	(+)
11.	2005-10 m	Brown, moderately hard, compact argillaceous siltstones	(+)
12.	2021-25 m	Brownish, moderately hard, compact, very fine grained sandy siltstone	(+)
13.	2065-70 m	Brownish, moderately hard compact micaceous siltstone	(+)
14.	2110-15 m	Brownish, fine grained compact clay stone	(+)
15.	2130-35 m	Grayish loose, friable medium grained sandstones	(+)
16.	2155-60 m	Grayish, medium to fine grained sandstone with few mica specks	(−)
17.	2200-05 m	Loose and friable sandstone, fine grained clay stone also present	(−)
18.	2245-50 m	Gray, moderately hard fine grained micaceous sandstone	(+)
19.	2290-95 m	Light gray, moderately hard compact, fine grained micaceous sandstone	(+)
20.	2335-40 m	Gray, loose friable sandy siltstone, micaceous in nature	(+)
21.	2350-55 m	Gray, fine grained sandstones slightly micaceous	(+)
22.	2380-85 m	Earthy gray, moderately hard, compact, very fine grained micaceous sandstone	(+)
23.	2425-30 m	Gray siltstone	(+)
24.	2480-85 m	Light gray, loose fine grained micaceous sandstone	(+)
25.	2515-20 m	Moderately hard siltstone with fine grained clay stone	(+)
26.	2560-65 m	Grayish, coarse grained sandstones micaceous in nature	(+)
27.	2605-10 m	Gray sandstone, slightly micaceous	(+)
28.	2620-25 m	Gray, silty clay stone	(+)
29.	2645-50 m	Light gray, moderately hard, micaceous sandstone	(+)

described by Dutta and Sah from the lower horizons of Cherra Sandstone Stage, Assam. In our case exine is also comparatively thicker.

Botanical affinity — Lycopodiaceae.

Lycopodiumsporites sp.

Pl. 2, figs 22, 23

Description — Miospores roundly triangular, size range 60-66 μm, interapical margin convex, apices broadly rounded. Trilete mark distinct, Y-rays long and straight, extending up to the equator. Exine 3 μm in thickness, reticulate, muri thin, lumina irregular to polygonal in shape, 7 to 10 μm in diameter.

Comparison — *Lycopodiumsporites* sp. can be compared with *Lycopodiumsporites eocenicus* Venkatachala & Rawat (1972) in general shape and appearance but it differs from the latter in having a long laesurae which extend up to the equator. *Lycopodiumsporites facetus* Dettmann (1963) possesses granulose exine and hence is not comparable with the present specimen.

Botanical affinity — Lycopodiaceae.

Genus — *Striatriletes* van der Hammen, 1956

Type species — *Striatriletes susannae* van der Hammen, 1956 emend. Kar, 1979.

Striatriletes susannae van der Hammen, 1956 emend. Kar, 1979

Pl. 1, figs 14, 15

Botanical affinity — Parkeriaceae.

Turma — Monoletes Ibrahim, 1933
Infraturma — *Sculptatomonoleti* Dybova & Jachowitz, 1957

Genus — *Polypodiisporites* Potonié, 1934

Type species — *Polypodiisporites favus* Potonié, 1934.

Polypodiisporites sp.

Pl. 1, fig. 7

Description — Miospores bilateral, bean-shaped, concavo-convex in lateral view. Size range 58-64 × 46-48 μm. Monolete, laesurae thin, extending up to 3/4 of the longer axis along the concave crest, laesurae bordered by slightly raised ridges. Exine 2 μm thick, ornamentation granulose, grana small, sparsely placed all over the surface.

Comparison — In general shape and size *Polypodiisporites* sp. is comparable to *P. ornatus* Sah (1967) but differs from it in having sparsely distributed grana.

Remarks — Previously monolete polypodiaceous spores with verrucose ornamentation were kept in 3 different genera, viz., *Polypodiisporites* Potonié (1934), *Polypodiites* Ross (1949) and *Verrucatosporites* Thomson & Pflug (1953) but Khan and Martin (1971) suggested that these genera should be treated in one genus, viz., *Polypodiisporites*. Sah (1967), Dutta and Sah (1970) and Rao and Ramanujam (1976) also supported this view that monolete spores possessing verrucose to gemmate or bluntly baculate sculptural elements should be placed under the genus *Polypodiisporites*. The present species, therefore, has been placed under this genus, as it possesses granulose ornamentation of the exine. Saxena (1978, pl. 2, fig. 34) described granulose type of spore under the genus *Polypodiaceaesporites* sp. from Matanomadh area of Kachchh but we suggest that it should be transferred to *Polypodiisporites*.

Botanical affinity — Polypodiaceae.

Anteturma — *Pollenites* Potonié, 1931
Turma — *Saccites* Erdtman, 1947
Subturma — *Disaccites* Cookson, 1947
Infraturma — *Podocarpoiditi* Potonié, Thomson & Thiergart, 1950

Genus — *Podocarpidites* Cookson, 1947

Type species — *Podocarpidites ellipticus* Cookson, 1947.

Podocarpidites ellipticus Cookson, 1947

Pl. 2, fig. 27

Remarks — The present specimens have a narrower furrow as compared to the size range exhibited by the specimens described by Cookson (1947).

Botanical affinity — Pollen grains are morphologically similar to those of *Podocarpus* of the family Podocarpaceae.

Podocarpidites sp.

Pl. 2, fig. 26

Description — Pollen grain free, anisopolar, tetrasaccate, body of the pollen grain spherical. Exine of the body thin, 1.5 μm thick, marginal ridge absent, psilate. Sacci small in relation to the body, well-separated, variable in shape. Exine 1.5 μm thick, indistinctly intrareticulate.

Dimension — Over all breadth 70 μm; body breadth 48 μm, body length 40 μm; saccus breadth 20-24 μm, saccus length 30-36 μm.

Comparison — *Podocarpidites* sp. can be differentiated from its any other known species in having four sacci. Saccus size is also smaller in comparison to the body size.

Remarks — Only a single specimen has been recovered from the present assemblage and hence its identification up to specific level has not been possible.

Botanical affinity — Podocarpaceae.

Genus — *Pinuspollenites* Raatz, 1938 ex Potonié, 1958

Type species — *Pinuspollenites labdacus* (Potonié) Raatz ex Potonié, 1958.

Pinuspollenites sp.

Pl. 2, fig. 25

Description — Pollen grains bisaccate, equisaccate. Body spherical to subspherical, marginal cap 3-4 μm thick. Saccus subequatorially attached, small in relation to the body, kidney-shaped. Exine 2 μm thick, intrareticulate ornamentation, heterobrochate, reticulum finer towards the peripheral region.

Dimensions — Observed range: overall breadth 76-80 μm, body breadth 40-60 μm, body length 44-46 μm; saccus breadth 26-30 μm, saccus length 40-44 μm.

Comparison — The present species differs from *P. labdacus* Potonié (1958) in having smaller size of saccus and different saccus-body ratio. Further, it can be compared with *Pinuspollenites* sp. Nandi (1972) in general shape, size and reticulation pattern as found in the saccus. However, the present specimens differ from it in having comparatively thicker marginal cap.

Botanical affinity — Pinaceae.

Genus — *Cedripites* Wodehouse, 1933

Type species — *Cedripites eocenicus* Wodehouse, 1933.

Cedripites sp.

Pl. 20, fig. 28

Description — Pollen grain bisaccate, flattened. Body circular in outline, margin undulating, marginal frill crescent, 2.5 μm in thickness. Exine laevigate, sacci small in relation to body size, kidney-shaped, intrareticulate ornamentation, meshes larger at the margin and finer towards the root region.

Dimensions — Overall breadth 54 μm; body breadth 44 μm, body length 46 μm; saccus breadth 26 μm, saccus length 35 μm.

Comparison — The present specimen closely resembles *Cedripites parvus* Norton (1963) but differs from it in the presence of thick marginal frill. *Cedripites* sp. Nandi (1972) is different by being bigger in size.

Remarks — Only a single specimen of *Cedripites* sp. has been recovered from Ramshahr Well no. 1. The size of the present specimen is smaller than that given for the type species described by Wodehouse (1933).

Botanical affinity — The overall appearance of this grain seems to be related to *Cedrus* belonging to the family Pinaceae.

Turma — *Aletes* Ibrahim, 1933
Subturma — *Azonaletes* (Luber) Potonié & Kremp, 1954
Infraturma — *Psilonapiti* Erdtman, 1947

Genus — *Laricoidites* (Potonié) Potonié, Thomson & Thiergart, 1950

Type species — *Laricoidites magnus* (Potonié) Potonié, Thomson & Thiergart, 1950.

Laricoidites sp.

Pl. 1, fig. 16

Description — Pollen grains subcircular to circular, size range 48-52 μm in diameter. Nonaperturate. Exine 2 μm thick, laevigate, a distinct peripheral fold present.

Remarks — The specimens described here as *Laricoidites* sp. resemble very closely with *Laricoidites* sp. Singh (1977). This species differs from all other known species in having a distinct peripheral fold.

Botanical affinity — Pinaceae.

Subturma — *Triptyches* Naumova, 1937

Genus — *Psilatricolpites* (van der Hammen) Pierce, 1961

Type species — *Psilatricolpites incomptus* (van der Hammen) Pierce, 1961.

Psilatricolpites sp.

Pl. 1, fig. 1

Description — Pollen grains subspherical, size range 30×38-34×42 μm. Tricolpate, colpi small, thin. Exine 1 to 1.5 μm thick, laevigate.

Comparison — This species can be differentiated from *Psilatricolpites* sp. 1 and sp. 2 of

Adegoke *et al.* (1978) by its shorter colpi and bigger in size range. It closely resembles *Psilatricolpites* sp. 3 in colpi structure but differs from it in having bigger size of colpi.

Botanical affinity — Uncertain.

Genus — ***Retitrescolpites*** Sah, 1967

Type species — *Retitrescolpites typicus* Sah, 1967.

Retitrescolpites sp.

Pl. 1, figs 5, 6

Description — Pollen grains ± spheroidal, size range 36-45 μm. Tricolporate, colpi long and thin extending almost the whole length. Exine 4-5 μm in thickness, retipilate, surface distinctly reticulate, lumina usually polygonal to hexagonal in shape, pila very distinct, length of the pila varies from 3 to 5 μm.

Comparison — The present specimen can be compared with *Retitrescolpites typicus* Sah (1967) in having similar type of sculpturing pattern. However, it differs from the latter by its smaller size range. It also differs from *R. splendens* Sah (1967) in having thicker exine and coarser reticulum.

Botanical affinity — In general shape and exine ornamentation it shows considerable similarity with the pollen grains of some members of Oleaceae.

Subturma — *Ptychotriporites* (Naumova) Potonié, 1960
Infraturma — *Prolati* Erdtman, 1943

Genus — ***Paleosantalaceaepites*** (Biswas) Dutta & Sah, 1970

Type species — *Paleosantalaceaepites ellipticus* Sah & Kar, 1970.

Paleosantalaceaepites ellipticus Sah & Kar, 1970

Pl. 1, fig. 17

Remarks — Only a single specimen of this species has been recovered from the upper part of Ramshahr Well 1.

Botanical affinity — Santalaceae?

Genus — ***Tricolporopollenites*** Thomson & Pflug, 1953

Type species — *Triporopollenites dolium* R. Pot.

Tricolporopollenites sp.

Pl. 1, figs 10-12

Description — Pollen grains subcircular, size range 42-48 μm in diameter. Tricolporate, colpi long, thin, overlapping, pore small circular. Exine 2 μm in thickness, laevigate, some peripheral folds present.

Comparison — *Tricolporopollenites* sp. compares favourably with *Tricolporopollenites prolatus* (Pierce) Norton in Norton & Hall (1969) in general appearance but it differs from the latter in having laevigate exine.

Remarks — Most of the pollen grains recovered from Ramshahr Well 1 are found in folded condition.

Botanical affinity — Uncertain.

Turma — *Poroses* (Naumova) Potonié, 1960
Subturma — *Monoporinus* (Naumova) Potonié, 1960

Genus — ***Monoporopollenites*** Meyer, 1956

Type species — *Monoporopollenites gramineoides* Meyer, 1956.

Monoporopollenites gramineoides Meyer, 1956

Pl. 2, fig. 21

Remarks — In the present assemblage, exine in most of the pollen grains is folded.

Botanical affinity — Gramineae.

Monoporopollenites sp.

Pl. 2, fig. 35

Description — Pollen grain oval in shape, size 102 μm in diameter. Monoporate, pore circular, 10 μm in diameter, margin of the pore slightly thickened. Exine 2 μm thick, laevigate.

Comparison — The present specimen differs from the other known species by its bigger size.

Remarks — Only a single specimen has been recorded from Ramshahr Well 1.

Botanical affinity — Gramineae.

Subturma — *Polyporines* (Naumova) Potonié, 1960
Infraturma — *Stephanoporiti* (van der Hammen) Potonié, 1960

Genus — *Malvacearumpollis* Nagy, 1962

Type species — *Malvacearumpollis bokonyensis* Nagy, 1962.

Malvacearumpollis rudis Kar, 1979

Pl. 1, figs 2, 3

Remarks — The size of the present specimens are comparatively smaller than the species described by Kar (1979). The number of pores in the specimens recovered from this assemblage are not very clearly discernible due to heavy ornamentation of the exine.

Botanical affinity — Malvaceae.

Malvacearumpollis sp.

Pl. 1, fig. 4

Description — Pollen grains oval, size range 36×38-37×41 μm. Porate, pore small, numerous. Exine 1.5 μm thick, spinose ornamentation, spines small, spine with bulbous base and a pointed tip, sparsely distributed all over body.

Comparison — The illustrated specimen can be compared with *Malvacearumpollis rudis* Kar (1979) in general shape and size but it differs from the latter in having very sparsely distributed small spines all over the surface. It differs from *M. grandis* Sah (1967) in having a smaller size range and less number of spores. *M. africana* Sah (1967) is also distinct by its bigger size range and the shape of spines.

Remarks — Only a few specimens referable to *Malvacearumpollis* sp. have been recovered from Ramshahr Well 1 but are badly preserved.

Botanical affinity — Malvaceae.

Turma — *Jugates* Erdtman, 1943
Subturma — *Polyadites* Pant, 1954
Infraturma — *Oblàti* Erdtman, 1943

Genus — *Polyadopollenites* Pflug & Thomson, 1953

Type species — *Polyadopollenites multipartitus* Thomson & Pflug, 1953.

Polyadopollenites sp.

Pl. 1, fig. 13

Description — Polyad consisting of nine pollen grains, oval to circular in shape. Individual pollen grain pentagonal to hexagonal in shape, pollen grains of the outer region are bigger in size than the central one, size range 20-32 μm in length and 12 to 18 μm in width. Exine 2 μm in thickness.

Comparison — The illustrated specimen differs from *Polyadopollenites psilatus* Norton & Hall (1969) in having pentagonal shape of its part pollen with lesser number.

Remarks — The specimen recovered from the Ramshahr Well 1 is not very clear due to dark pigmentation.

Botanical affinity — Mimosae.

ALGAE

Class — Chlorophyceae Kutzing, 1843
Order — Chlorococcales Marchand orth. mut. et emend. Pascher, 1915
Family — Hydrodictyaceae (S. F. Gray) Dumortier orth. mut. CoHN, 1880

Genus — *Pediastrum* Meyen, 1829

Pediastrum compactum Singh & Khanna, 1978

Pl. 2, fig. 33

Remarks — Specimens referred to *P. compactum* from the present assemblage have less number of marginal coenocytes as compared to the range given by Singh and Khanna (1978) for the same species occurring in the Eocene sediments of the Subathu Formation.

Pediastrum diffusus Singh & Khanna, 1978

Pl. 2, fig. 32

Remarks — Specimens recovered from the present assemblage are slightly bigger in size than those described by Singh and Khanna (1978).

FUNGI

Genus — *Phragmothyrites* Edwards emend. Kar & Saxena, 1976

Type species — *Phragmothyrites eocaenica* Edwards emend. Kar & Saxena, 1976.

Phragmothyrites eocaenica Edwards emend. Kar & Saxena, 1976

Pl. 20, fig. 30

Remarks — A large number of microthyriaceous fungal remains have been isolated. Their size ranges in between 70 and 80 µm. The incipient centripetal development of radial walls is the characteristic feature of these forms. In mature ascostromata pores are present.

Botanical affinity — Dilcher (1965) described such type of elements and considered them to be microthyriaceous in nature.

Genus — *Pluricellaesporites* (van der Hammen) Elsik, 1968

Type species — *Pluricellaesporites typicus* van der Hammen, 1959.

Pluricellaesporites sp.

Pl. 20, fig. 24

Description — Darkly pigmented, six-celled spores, size 40×75 µm. Spore wall 2 µm thick, psilate. Monoporate, a stalk present at the basal portion of the spore, 20 µm in length. Central cells are wider than those on the ends, rectangular in shape.

Comparison — The present specimen resembles *P. tenuis* Sheffy & Dilcher (1971) in having six-celled condition but differs from it in exhibiting a bigger size range and absence of constriction between some cells. *Pluricellaesporites*? sp. Elsik (1968) differs in having scabrate and granulose spore wall and smaller size.

Remarks — Due to dark pigmentation, pores of the specimen are not very clearly visible.

Genus — *Inapertisporites* (van der Hammen) Elsik, 1968

Type species — *Inapertisporites typicus* van der Hammen, 1954.

Inapertisporites kedvesii Elsik, 1968

Pl. 2, fig. 36

Remarks — The specimens referred here possess bigger size range than the type specimen.

Genus — *Aplanosporites* Kar, 1979

Type species — *Aplanosporites robustus* Kar, 1979.

Aplanosporites sp.

Pl. 2, fig. 29

Description — Miospores normally subcircular, assuming various forms due to folding; inaperturate. Exine 2 µm thick, laevigate, a tail-like appendage present, 12 µm in length, 4 µm in width.

Comparison — *Aplanosporites* sp. can be easily distinguished from the type species by its smaller tail-like appendage and size.

Remarks — Jen (1958) described a fungal-like spore from the Lower Cretaceous of southern China, which resembles very closely *Aplanosporites*. Kar and Sah (1970) described pollen type I from Vemavaram (Upper Jurassic) which also resembles *Aplanosporites*.

Botanical affinity — Uncertain.

Genus — *Tetraploa* Berk & Br.

Tetraploa sp.

Pl. 2, fig. 37

Description — Conidia unicellular, quadrangular in shape, with four setae, body 26×18 µm in size, wall psilate, setae 48-50 µm long, 4 µm broad at the base, apex pointed.

POLLEN TYPE 1

Pl. 1, fig. 19

Description — Pollen grain spherical to subspherical, 74-76 µm in diameter; porate.

Exine 2 μm thick, undulating, surface densely and coarsely wrinkled.

Remarks — Pollen grains described under pollen type 1 seem to have ulmaceous affinity though it has not been confirmed. In most of the pollen grains pores are not clearly visible.

POLLEN TYPE 2

Pl. 2, fig. 34

Description — Pollen grains elliptical in shape, size 64×114 μm, furrow-like structure conspicuous, extending from one pole to another, 16 μm in width. Exine thin, smooth to very finely scabrate.

Remarks — Pollen type-2 compares well with the pollen grains of the family Magnoliaceae. *Magnolia scotica* Simpson (1961) is comparable to the present specimen in shape and appearance but possesses much thinner exine.

POLLEN TYPE 3

Pl. 1, fig. 9

Description — Pollen grains subcircular, size 42×45 μm; polycolporate, colpi long, uniformly thick ±40 μm in length, lalongate, ora small. Exine thin ±1.5 μm thick, laevigate.

Remarks — Only a single specimen has been recovered thus the detailed study has not been possible.

MICROPLANKTON TYPE 1

Pl. 2, fig. 35

Description — Skolochorate cysts, central body subspherical, size 38 to 42 μm in diameter, periphragm and endophragm closely appressed together, intratabular processes more than 20 in numbers, slender, tubiform, 14-20 μm in length, distally open, flattened with furcating tips. Archeopyle not very clear, paratabulation indistinct.

QUALITATIVE ANALYSIS OF THE ASSEMBLAGE

The Ramshahr Well 1 palynoflora is composed of plant groups belonging to algae, fungi, pteridophytes, gymnosperms and angiosperms. The algal and fungal remains have been recorded in appreciable quantity. The pteridophytic and angiospermic elements form the dominant constituents in the palynological zones A and C; the representation of gymnospermous elements being comparatively low. The palynological zone B is conspicuously rich in having gymnospermous elements. The bryophytic elements have not been recorded. Besides, some forms which could not be identified have been described under *Incertae sedis*.

Systematic botanical analysis of the Ramshahr Well 1 assemblage is discussed below to interpret the possible environment of deposition and palaeoclimatic conditions which might have existed at that time.

1. ALGAE

The algal forms represented by *Pediastrum* are found only in the palynological zone A. It is represented by two species, viz., *P. compactum* and *P. diffusus*. They constitute an important part of the assemblage from 1,400 to 1,845 m level. Different types of microplanktons have also been recorded from palynological zones A and C.

2. FUNGI

Fungal spores and epiphyllous microthyriaceous fungi are present in almost all the productive samples. Among the microthyriaceous fungi *Phragmothyrites eocaenica* is well represented. Most of them are found in germling condition. A large number of fungal conidia and spores have also been recovered from different depth levels, viz., *Inapertisporites kedvesii*, *Pluricellaesporites* sp., *Tetraploa* sp., etc. But it seems difficult to assign any definite affinity to them.

3. PTERIDOPHYTA

Pteridophytic spores constitute one of the most important elements in all the samples studied. Miospores assignable to four families have been identified, viz., Lycopodiaceae, Cyatheaceae, Polypodiaceae and Parkeriaceae.

The family Lycopodiaceae is represented by the presence of *Lycopodiumsporites palaeo-*

cenicus and *Lycopodiumsporites* sp. The members of this family are found in both tropical and temperate regions, mostly favouring moist and humid climate.

Cyathidites australis is related to the family Cyatheaceae. This family is tropical to subtropical in distribution.

Miospores described under the genus *Polypodiisporites* compare with those of *Polypodium* belonging to the family Polypodiaceae. The distribution of the family is restricted from tropical to subtropical regions. They prefer moist climate. The family Parkeriaceae is represented by the occurrence of high frequency of costate spores. The forms have been described under *Striatriletes susannae*. The members of this family prefer marshy habitat.

4. Gymnosperms

The Ramshahr Well 1 assemblage represented by palynological zone B is dominated by gymnospermous elements. Gymnospermous pollen grains recovered from this well are related to two families: Pinaceae and Podocarpaceae.

In the family Pinaceae two genera, *Pinuspollenites* and *Laricoidites*, are well represented. The present day distribution of this family is in temperate regions of the world. Genus *Podocarpidites* is referable to the family Podocarpaceae, most probably to the genus *Podocarpus*. It is found in tropical and temperate zones of the southern hemisphere.

5. Angiosperms

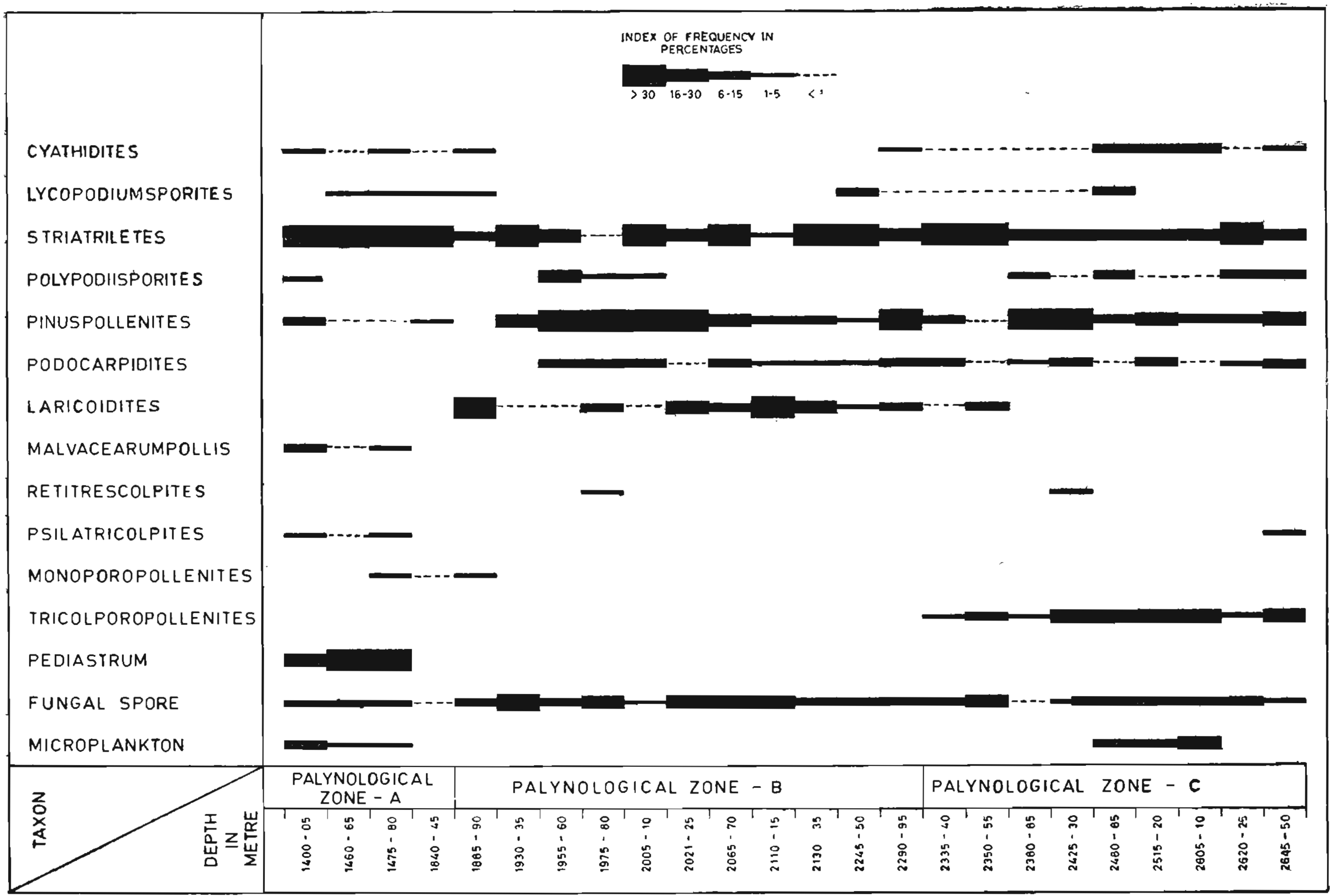
The palynological zones A and C of Ramshahr Well 1 assemblage have the following angiosperms forms: (i) *Tricolporopollenites*, (ii) *Retitrescolpites*, (iii) *Psilatricolpites*, (iv) *Malvacearumpollis*, and (v) *Polyadopollenites*. The other forms show very low frequency of occurrence. Among the angiospermous pollen the monocots, represented only by the presence of *Monoporopollenites*, are less represented than dicots.

The dicots form an important constituent which is represented by the families Mimosae, Malvaceae, Oleaceae and Santalaceae? etc. The families, viz., Mimosae and Malvaceae are richly represented in the present day tropical and subtropical vegetation of the world. Pollen grains referred to *Retitrescolpites* sp. have undoubted oleaceous affinity. This genus has a wide geographical distribution ranging from tropical to warm temperate climate. *Ulmus* and *Magnolia* type of pollen grains have also been recorded but they have been placed under *Incertae sedis* because the number of pollen grains is too less for proper identification and morphological study. Members of the families, viz., Ulmaceae and Magnoliaceae are found both in tropical and temperate regions.

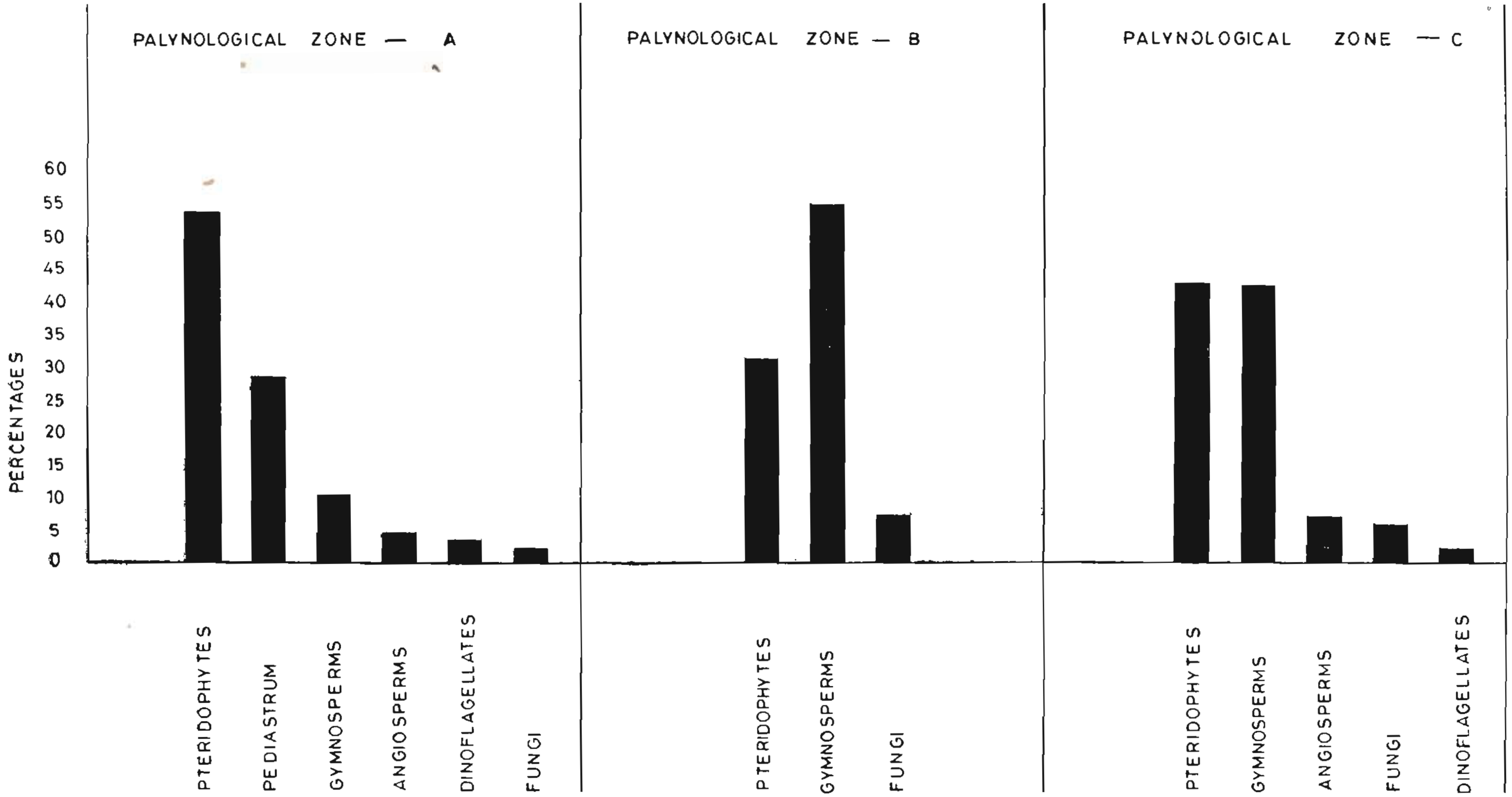
QUANTITATIVE ANALYSIS OF THE ASSEMBLAGE

The present palynological assemblage comprises pteridophytic spores, gymnospermous and angiospermous pollen grains, fungal spores, microthyriaceous ascostromata and algal colony. All these forms have been placed under 20 dispersed genera and 24 species. Among them 4 genera and 5 species belong to pteridophytes, 4 genera and 5 species to gymnosperms, 7 genera and 9 species to angiosperms, and 3 genera and 3 species to fungi. Algae are represented by two species of *Pediastrum*. Few forms have been described under *Incertae sedis*. The distribution of various plant groups in Ramshahr Well 1 has been shown in Text-fig. 1.

The stratigraphic interval covered by palynological zone A is characterized by the abundant occurrence of pteridophytic spores (53%) followed by fresh water algae *Pediastrum* (28%). The gymnospermous and angiospermous pollen grains constitute 10 and 4 per cent respectively of the assemblage. Among the pteridophytic spores *Striatriletes susannae* is the most dominant form and constitutes about 80 per cent of the pteridophytic assemblage. *Lycopodiumsporites* (8%) and *Polypodiisporites* (8%) are also very common. Of the gymnosperms, inaperturate pollen grains, viz., *Laricoidites* sp. (60%) is the most common form although bisaccate forms are also present in appreciable amount. The angiosperms (4%) are poorly represented in this zone. Among the angiospermous pollen grains *Monoporopollenites gramineoides* (65%) is the most common.



TEXT-FIG. 1 — Distribution of palynomorphs in Ramshahr Well 1, Himachal Pradesh, India.



TEXT-FIG. 2 — Distribution of various plant groups in Ramshahr Well 1, Himachal Pradesh, India.

TABLE 2 — FREQUENCY DISTRIBUTION OF PALYNOMORPHS IN RAMSHAHR WELL 1, HIMACHAL PRADESH

SAMPLES POSITION AT DEPHTS PALYNOMORPHS	1400-05 m	1460-65 m	1475-80 m	1840-45 m	1885-90 m	1930-35 m	1955-60 m	1975-80 m	2005-10 m	2021-25 m	2065 75 m	2110-15 m	2130-35 m	2445-50 m	2290-95 m	2335-40 m	2350-55 m	2380-85 m	2425-30 m	2480-85 m	2515-20 m	2605-10 m	2620-25 m	2645-50 m
Cyathidites australis	2·5		3		2·5										7					7	11	8·5		5
Lycopodiumsporites		5	4·5	5·5										15						7				
Palaeocenicus																								
Lycopodiumsporites sp.	+				4·5															6				
Striatriletes susannae	40	35·5	38·5	92	12	50	20		34	27	30	12	60	60·5	23	68	58	20	17	20	16·5	25	56	24·5
Polypodiisporites sp.	2·5		+				20	7	4·5									4·5		12			8	7·5
Podocarpidites ellipticus							10	15	13		12	4	3		7	7		5			5		5	10
Podocarpidites sp.												+												
Pinuspollenites sp.	13·5			2·5		25·4	40	35	34	31	28	8	12	3	38	15		62	51	7	22	8·5	13	27
Cedripites sp.																								
Laricoidites sp.					65			15	10	17	10	56	10	6	10		7							
Psilatricolpites sp.	2·5		1·5																	+				2·5
Retitrescolpites sp.		+		+																				
Paleosantalacaepites ellipticus			+																					
Tricolporopollenites sp.																								
Monoporopollenites gramineoides			2·5		2·5											41	13		16	30	22·5	28	6	18
Monoporopollenites sp.				+																				
Malvacearumpollis rudis	6·5		5																	+				
Malvacearumpollis sp.	+			+																				
Polyadopollenites sp.		+																						
Pediastrum spp.	18	52	39																					
Phragmothyrites eocaenica		+			+						+							+			+			
Inapertisporites kedvesii	4·5	5	4		13·5	24·6	10	28	4·5	25	20	20	15	12·5	15	6	22	4		10	12	11·5	12	5·5
Pluricellaesporites sp.					+																			
Aplanosporites sp.			+																		+			
Microplanktons	10	2·5	2·0																	7	11	16·5		

+, Denotes the presence of palynomorph in the same but not encountered in count.

On the other hand, palynological zone B is characterized by the abundance of gymnospermous pollen grains (54%) followed by pteridophytic spores (30%). Among the gymnospermous pollen grains bisaccate pollen, viz., *Podocarpidites ellipticus* (35%) and *Pinuspollenites* sp. (45%) are the dominant forms. Inaperturate pollen grains of *Laricoidites* sp. constitute about (20%) of the assemblage. A few angiospermous pollen grains have also been recovered in this horizon but their number is so poor that they remain unrepresented in the percentage count.

In palynological zone C the occurrence of pteridophytic spores and gymnospermous pollen is almost at the same level, i.e. 42.5 per cent each. Among the pteridophytic spores *Striatriletes susannae* (75%) is highly represented; other forms, viz., *Cyathidites australis* (7%), *Lycopodiumsporites palaeocenicus* (8%) and *Polypodiisporites* sp. (10%) are common forms. Gymnospermous pollen grains are mostly represented by bisaccate pollen grains, viz., *Podocarpidites ellipticus* (45%) and *Pinuspollenites* sp. (55%). Inaperturate pollen grains are poorly represented in this zone. The angiospermous pollen constitute about 7 per cent of the palynological assemblage. Among the angiosperms *Tricolporopollenites* sp. is overwhelmingly dominating (85%). *Malvacearumpollis rudis* (5%) and *Psilatricolpites* sp. (5%) have also been represented. Fungal spores and microthyriaceous ascostromata constitute about 6 per cent of the assemblage. Dinoflagellate cysts (2%) are also present.

BIOSTRATIGRAPHICAL ANALYSIS OF ASSEMBLAGE

On the basis of palynological investigations of the samples of Ramshahr Well 1 between depths of 1340-2650 m, three palynological zones have been identified. Each palynological zone is represented by a distinct assemblage although quantitative representation of palynofossils is generally not rich in most of the samples. The palynological assemblages of these zones have been categorized as A, B and C.

PALYNOLOGICAL ZONE-A

The palynological zone-A has been identified between 1400 and 1845 m depth levels. This zone is represented mainly by pteridophytic spores and fresh water alga *Pediastrum*. The dominance of *Striatriletes susannae* and *Pediastrum* sp. is the most striking feature of this zone. *Cyathidites australis* and *Lycopodiumsporites palaeocenicus* are also commonly found in this palynological zone. Different types of gymnospermous and angiospermous pollen, viz., *Pinuspollenites* sp., *Psilatricolpites* sp., *Malvacearumpollis rudis* etc. are quite common. *Monoporopollenites gramineoides*, *Polyadopollenites* sp. and *Paleosantalaceaepites ellipticus* are sporadically present. The presence of microplanktons in this zone is also noteworthy.

PALYNOLOGICAL ZONE-B

The palynological zone-B ranges from 1845-2295 m depth levels. It is represented mainly by gymnospermous pollen grains followed by pteridophytic spores. Angiospermic pollen grains are also found in this zone but their frequency is very insignificant. The frequency of occurrence of fungal spores and sclerotia is quite high. Microplanktons have not been observed in this zone. *Podocarpidites ellipticus*, *Pinuspollenites* sp. and *Laricoidites* sp. are the dominant forms in this zone. The frequency of *Striatriletes* is comparatively low as compared to the palynological zone-A. *Polypodiisporites* sp. is commonly found. Angiospermic pollen grains, viz., *Monoporopollenites gramineoides* and *Retitrescolpites* sp. are sporadically present. Young microthyriaceous fungal forms are abundantly present in this zone.

PALYNOLOGICAL ZONE-C

This zone ranges from 2295-2650 m depth levels. It is represented mainly by pteridophytic spores and gymnospermous pollen grains. A high percentage of angiospermous pollen has been recorded from this zone. *Striatriletes susannae* is the dominant taxon in this zone followed by *Pinuspollenites* sp. and *Tricolporopollenites* sp. *Cyathidites australis*, *Lycopodiumsporites palaeocenicus* and *Polypodiisporites* sp. are commonly found in this zone. The most interesting feature of this palynozone is the presence and common occurrence of *Tricolporopollenites* sp. Its presence is restricted to this zone only. Microplanktons of unknown affinity have also been observed in this zone.

The distributional pattern of spores and pollen grains reveals that *Polyadopollenites*, *Malvacearumpollis* and *Tetraploa* are restricted to palynological zone-A. Alga *Pediastrum* is also strictly restricted to palynological zone-A. The frequency of occurrence of *Striatriletes susannae* varies considerably in different horizons though they are widely distributed. Pollen grains of *Pinuspollenites* and *Podocarpidites* are represented almost at all depth levels but their occurrence in palynological zone-B is quantitatively striking. Their frequency sharply declines near and at the contact zones B and A. Same distributional pattern is also exhibited by *Laricoidites*. It attains its climax in the upper most part of zone B. In the palynological zone-C the restricted occurrence of angiospermic pollen grains *Tricolporopollenites* whose affinities are not certain, is noteworthy. The frequency of *Tricolporopollenites* tends to sharply decline towards the upper horizons of palynological zone-C, vanishing completely in the lower part of zone B. *Polypodiisporites* sp. is also found quite commonly in the lower most part of zone C.

Palynomorphs in common between the palynological zones A and C are *Cyathidites*, *Polypodiisporites*, *Striatriletes*, *Lycopodiumsporites*, *Pinuspollenites*, *Psilatricolpites* and microplanktons.

The samples from the lowermost portion of the well contains a rich assemblage of pteridophytic spores, and gymnospermous and angiospermic pollen grains. The gymnospermous pollen grains dominate the middle portion with rare occurrence of two type of angiospermic pollen grains. Gymnospermous pollen grains decline in number giving way to pteridophytic and angiospermic pollen grains in the upper part of Ramshahr Well 1. Regarding the distributional pattern of fungal spores and sclerotia a gradual increase in their numbers has been observed from zone C to zone B. In fact, zone B is the richest in having epiphyllous fungi.

The qualitative and quantitative analyses of the spore pollen genera and their mode of distribution show that the vegetation under investigation belongs to two climatic types. The floral assemblage contains elements usually characteristic of subtropical and temperate regions. The assemblages of palynological zones A and C exhibit similarity in having some common forms whereas zone B is quite distinct palynologically. The temperate elements representing colder climate in all the palynological zones A, B and C (subtropical-tropical) seem to have come from the high hills lying mostly on the northern side.

ENVIRONMENT OF DEPOSITION AND PALAEOECOLOGY

Based on the distribution of palynomorphs in the Ramshahr Well 1, it seems possible to recognize two types of palynoassemblages, one conforming to the terrestrial mixed type and the other to the terrestrial type. The former, typified by palynological zones A and C, contains elements of terrestrial and aquatic habitat. The terrestrial forms are further of mixed type, representing subtropical, tropical as well as temperate elements. The temperate elements mainly of gymnospermous affinity seem to have been derived from the high hills which got preserved along with the local subtropical-tropical forms growing in close proximity to the basin. The aquatic forms are represented by the high frequency of *Pediastrum* in palynological zone-A indicating fresh water environment of deposition. The abundant occurrence of pteridophytic spores along with tropical angiosperm pollen grains indicates a moist tropical vegetation at that time. Microplanktons represent the aquatic habitat and seem to have been recycled from the Subathu sediments in this zone.

The second palynological assemblage is of terrestrial type only. It is being typified by palynological zone B. The assemblage is characterized by a significant change in its composition. The dominance of coniferous pollen grains indicates colder and drier climate. The percentage of pteridophytic spores and angiospermic pollen grains becomes less significant. The present palynological evidence indicates fresh water environment of deposition for palynological zone-B as well.

The palynoassemblage of palynological zone-C is comparable to palynological zone A excepting in the absence of *Pediastrum* and some other forms. Here also the occurrence of microplanktons is suspected to be recycled from the Subathus. Thus the entire sequence under investigation has been thought to be deposited under fresh water environment of deposition.

PALYNOFLORAL COMPARISON

Palynological information published from the Mio-Pliocene sediments of northern India is rather meagre. However, a comparison of the Ramshahr Well 1 assemblage with other Mio-Pliocene assemblages known from the different equivalent sedimentafy horizons of India has been carried out in order to assess the dating potential of the palynomorphs.

Himachal Pradesh — The palynofloral assemblage recorded from the Lower and Middle Siwalik sediments of Bhakra-Nangal area (Banerjee, 1968) is poorly preserved. However, the dominance of gymnospermous pollen grains a feature which is so very characteristic of the Middle Siwalik of Bhakra-Nangal is also exhibited by the present assemblage.

A qualitatively rich palynofloral assemblage has been reported by Nandi (1975) from various formations of Siwalik rocks in Himachal Pradesh, recognizing four palynofloral assemblages. The Ramshahr Well 1 assemblage resembles the one described from the zone III (Nandi, 1975) which is of Middle Siwalik age. Many forms, viz., *Pinuspollenites*, *Podocarpidites*, *Cyathidites*, *Polypodiisporites*, *Polyadopollenites* are in common between the two assemblages. Composition of palynological zone I and palynological zone II of Nandi (1975) differs considerably from the present assemblage both qualitatively and quantitatively inspite of the fact that some forms, viz., *Cyathidites*, *Polypodiisporites*, *Monoporopollenites*, *Pinuspollenites*, *Podocarpidites*, etc. are commonly shared by these assemblages.

Recently Singh and Saxena (1981) reported a palynofloral assemblage from the Upper Siwalik sediments exposed along Gagret-Bharwain Road Section in Una District, which consists of 10 genera and 14 species along with few reworked phytoplanktons. Although a few forms, viz., *Pinuspollenites*, *Laricoidites*, *Aplanosporites* and *Inapertisporites* are common between the two assemblages but the most distinctive features of the Gagret-Bharwain assemblage is the complete absence of pteridophytic spores.

Punjab — Saxena and Singh (1980) recorded a rich palynofloral assemblage from the Pinjor Formation (Upper Siwalik) near Chandigarh. A comparison between the two assemblages reveals that some forms, viz., *Cyathidites*, *Striatriletes*, *Podocarpidites*, *Pinuspollenites*, *Cedripites*, *Laricoidites*, *Inapertisporites* are shared by both the assemblages. However, the Pinjor assemblage is distinctly different by having abundant occurrence of *Laricoidites* complex and Magnoliaceous of pollen grains besides having some other characteristic forms.

Uttar Pradesh — The Mohand East field (Middle Siwaliks) assemblage has been described by Nandi (1972). The spores of pteridophytes represented by Polypodiaceae, Schizeaceae, Lycopodiaceae, Cyathiaceae etc. have been recorded. The gymnospermous pollen grains are represented by *Podocarpus*, *Pinus*, *Abies*, *Picea*, *Cedrus* and *Tsuga* type. Angiospermic pollen grains are less in number. They are represented by two families: Palmae and Liliaceae. The elements common between the two assemblages are *Cyathidites*, *Polypodiisporites*, *Pinuspollenites*, *Podocarpidites*, *Cedripites* and *Tricolporopollenites*. The present assemblage is largely comparable to the one described from Mahand though it lacks some of the important forms occuring in the latter, viz., *Gleicheniidites*, *Todisporites*, *Leptolepidites*, *Tsugaepollenites* and *Abiespollenites*, etc.

Bihar — Lukose (1969) reported miofloral assemblage from Raxaul (Middle Siwaliks) in Bihar which consists of pteridophytes, gymnosperms and angiosperms. The spores-pollen referable to the following genera, viz., *Polypodium*, *Schizea*, *Lygodium*, *Pteris*, *Podocarpus*, *Abies*, *Picea*, *Pinus* and *Tsuga* have been reported. The angiosperms are represented by the pollen grains of Myricaceae, Juglandaceae, Magnoliaceae, Mimosae and Moraceae. The Ramshahr Well 1 and Raxaul assemblages are comparable in having common occurrence of some pteridophytic and gymnospermous pollen grains; however, the former lacks the presence of Myricaceae, Juglandaceae and Moraceae, etc.

Bengal — A comparative study of the present assemblage and Bengal Basin palynological zones V and VI (Baksi, 1975) reveals general development of some similar trends such as the abundance of small tricolpate, tricolporate pollen grains and the presence of few dinoflagellates and hystrichosphaerids. The index elements of conifer pollen and Parkeriaceae spore association which begin to appear in palynological zone V (Bengal Basin) are also found in palynological zones A and C of the present assemblage. Thus the Ramshahr Well 1 palynofloral assemblage representing palynological zones A and C compares very much with the Bengal palynological zones VI (Baksi, 1971) in the dominance of coniferous pollen grain — Parkeriaceous spore assemblage along with tricolpate and tricolporate pollen grains and may be dated as Middle-Upper Miocene in age.

Palynological zone B of the Ramshahr Well 1 is mostly comparable to the Bengal palynological zone V mainly by the dominance of coniferous pollen and parkeriaceous spores. This part of the sequence belongs to Miocene age. As such it can perhaps be suspected to be of Lower Miocene age as well. This palynological observation needs to be corroborated by the geological evidence which is not available for consideration.

Assam — The Ramshahr Well 1 assemblage is comparable to the Simsang palynological zone IV of Simsang River section (Baksi, 1962) which is considered to be of Miocene age. The spore pollen assemblage of this zone is characterized by the abundant occurrence of two winged pollen of conifers, frequent occurrence of ribbed spores which are related to Parkeriaceae and Schizeaceae and pollen grains of Polygonaceae. Small bordered spores ***Densexinosporites minuta*** and remains of microthyriaceous fungus, tricolpate and tricolporate pollen grains are also found in this zone.

The Ramshahr Well 1 assemblage is distinct in the absence of ***Densexinosporites*** and polygonaceous type of pollen grains. The common features between these two assemblages are the dominance of bisaccate pollen grains and costate spores, presence of tricolpate and tricolporate type of pollen grains, and occurrence of few dinoflagellates and hystrichosphaerids (thought to be reworked by Baksi, 1962).

Tamil Nadu — The miofloral assemblage of Neyveli lignite is considered to be of Miocene in age. Palynofloral assemblage reported by Dev (1972) does not resemble the Ramshahr Well 1 assemblage excepting by the presence of tricolporate pollen grains.

Kerala — The Cannanore lignite palynoflora (Potonié & Sah, 1958) represented by the pteridophytes and angiosperms have the following constituents, viz., *Lycopodiumsporites*, *Cyathidites*, *Polypodiites*, *Inaperturopollenites*, *Monoporopollenites*, *Monosulcites*, *Cupuliferoidaepollenites* and *Polyadopollenites*. Most of these forms are common between the Ramshahr and Cannanore assemblages. The only distinctive feature of the present assemblage is the presence of bisaccate and other coniferous pollen grains. The Warkali Lignite mioflora (Ramanujam, 1960, 1962) which is believed to be Miocene age differs from the Ramshahr Well 1 assemblage in the absence of bisaccate coniferous pollen grains.

CONCLUSIONS

1. Palynological contents of the Ramshahr Well 1, Himachal Pradesh, though not very rich quantitatively as well as qualitatively, have been utilized for the identification of its various depth levels. Consequently, three palynological zones A, B and C have been established.

2. On the basis of the comparative study of Ramshahr Well 1 assemblage along with others known from the possibly equivalent geological horizons in India it seems possible to assign Middle-Upper Miocene age to the sequence encompassed by palynological zones A (1400-1845 m) and C (2335-2650 m).

Palynological zone B (1845-2295 m) is very distinct by the preponderant occurrence of coniferous pollen grains particularly represented by the members of Abietineae indicating definite Neogene affinity with the assemblage. However, it seems difficult to date this part of the sequence with precision even though the comparative study of this assemblage points out that it may perhaps belong to Lower Miocene age. If this contention is true then it is an anomalous position which may possibly be explained by involving some complex geological event. Alternatively, if this sequence is presumed to be regular and the change in the composition of the assemblage is due to climate, even then there are no palynological taxa which indicate other than Neogene affinity. Hence the exact status of palynological zone B remains an open question.

3. The sediments seem to have been deposited under fresh water conditions. The recovery of reworked microplanktons in palynological zones A and C indicative of brackish environment seems to have been derived from the Subathu sediments.

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EXPLANATION OF PLATES

(All photographs are Ca. × 500. The coordinates of specimens in slides refer to the stage of Olympus microscope no. 2051).

PLATE 1

1. *Psilatricolpites* sp.; slide no. 6883, coordinates 18 × 114.
2, 3. *Malvacearumpollis nagii* Kar; slide no. 6871, coordinates 3.9 × 90.5, coordinates 12 × 77.
4. *Malvacearumpollis* sp., slide no. 6873, coordinates 5.6 × 93.9.
5, 6. *Retitricolpites* sp.; slide no. 6880, coordinates 16 × 77.8, slide no. 6875, coordinates 7 × 95.
7. *Polypodiisporites* sp., slide no. 6875, coordinates 13.9 × 96.8.
8. *Lycopodiumsporites palaeocenicus* Dutta & Sah; slide no. 6881, coordinates 3.9 × 107.5.
9. Pollen type-3, slide no. 6882, coordinates 3.8 × 113.5.
10-12. *Tricolporopollenites* sp., slide no. 6884, coordinates 11 × 83.9, coordinates 10.5 × 84; coordinates 7 × 111.9.
13. *Polyadopollenites* sp.; slide no. 6894, coordinates 5 × 76.4.
14, 15. *Striatriletes susannae* (van der Hammen) Kar; slide nos. 6871, coordinates 11 × 112.2, 6893, coordinates 7 × 76.8.
16. *Leiotriletes* sp.; slide no. 6874, coordinates 11 × 92.2.
17. *Palaeosantalaceaepites ellipticus*, slide no. 6871, coordinates 10.6 × 96.6.
18. *Tricolpites* sp.; slide no. 6874, coordinates 7 × 112.2.
19. Pollen type-1, slide no. 6882, coordinates 97 × 17.5.
20. Microplankton type-1; slide no. 6871, coordinates 16.6 × 91.9.

PLATE 2

21. *Monoporopollenites gramineoides* Meyer; slide no. 6881, coordinates 17 × 89.5.
22, 23. *Lycopodiumsporites* sp.; slide nos. 6876, coordinates 15 × 88.2, 6877, coordinates 3.9 × 90.8.
24. *Polypodiaceaesporites* sp.; slide no. 6890, coordinates 18 × 100.
25. *Pinuspollenites* sp., slide no. 6879, coordinates 2 × 82.5.
26. *Podocarpidites* sp., slide no. 6880, coordinates 15.5 × 95.
27. *Podocarpidites ellipticus* Cookson; slide no. 6890, coordinates 11.2 × 86.9.
28. *Cyathidites* sp., slide no. 6875, coordinates 8.4 × 87.8.
29. *Aplanosporites* sp.; slide no. 6890, coordinates 15 × 98.2.
30. *Phragmothyrites eocaenicus* Edwards; slide no. 6878, coordinates 7.6 × 116.8.
31. *Callimothallus pertusus* Dilcher, slide no. 6882, coordinates 17.5 × 97.
32. *Pediastrum diffusus* Singh & Khanna, slide no. 6872, coordinates 8.2 × 78.5.
33. *Pediastrum compactum* Singh & Khanna; slide no. 6884, coordinates 11.2 × 108.9.
34. Pollen type 2; slide no. 6890, coordinates 15 × 66.
35. *Monoporopollenites* sp.; slide no. 6877, coordinates 1.9 × 85.5.
36. *Inapertisporites kedvesii* Elsik; slide no. 6871, coordinates 3 × 98.
37. *Tetraploa* sp., slide no. 6874, coordinates 16 × 80.

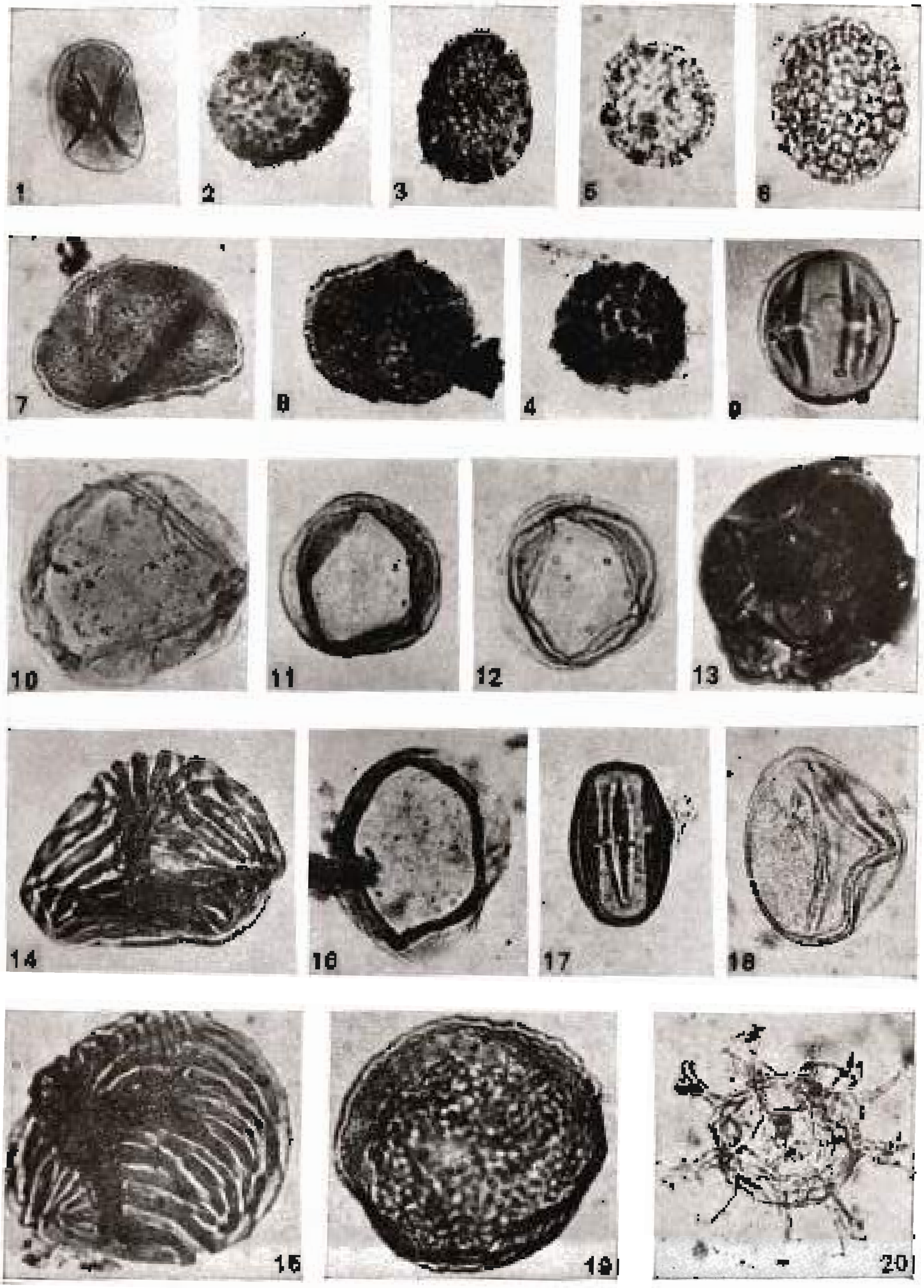

PLATE 1

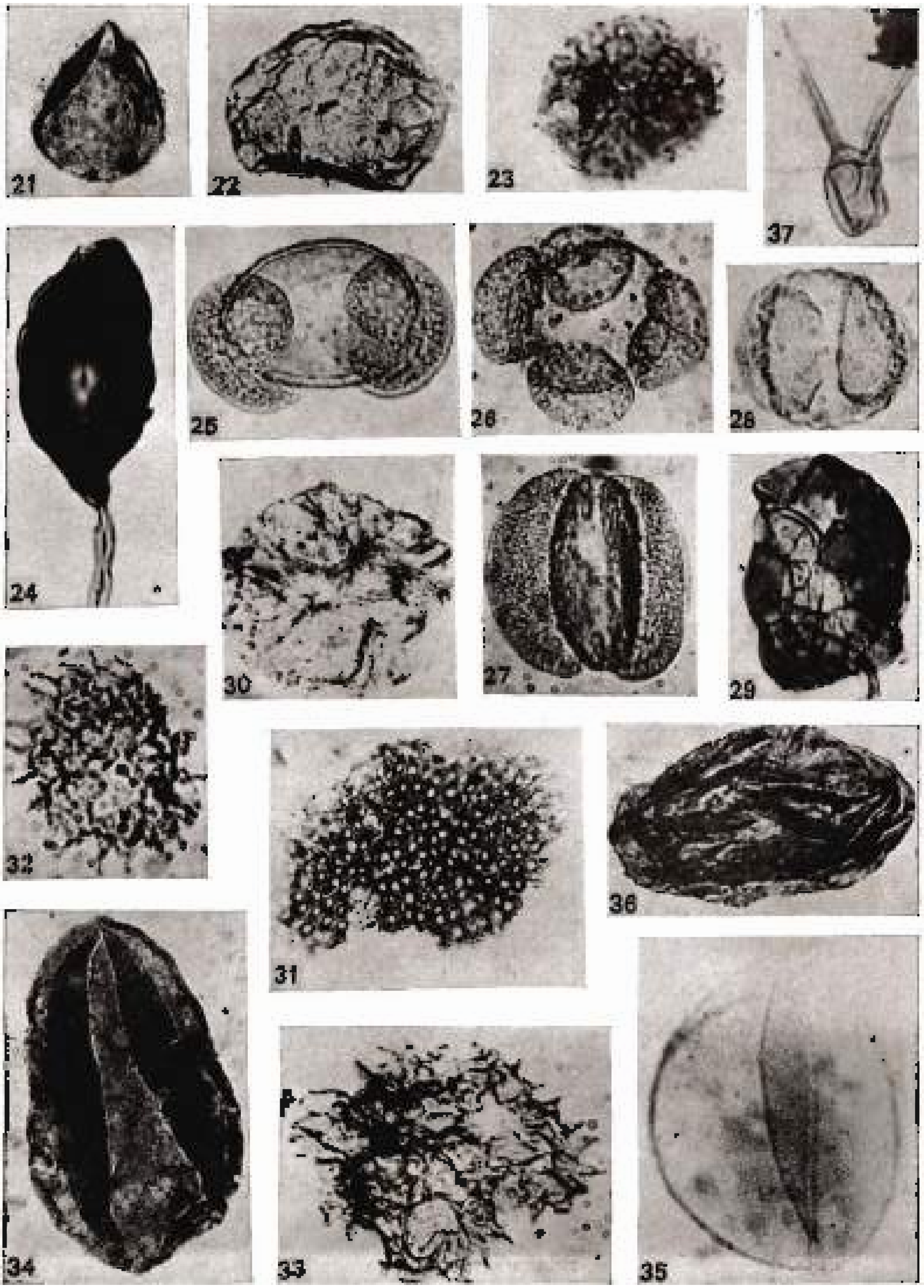

PLATE 2

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NONIASPORITES, A NEW MEGASPORE GENUS FROM THE UPPER PERMIAN OF RANIGANJ COALFIELD

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ABSTRACT

The new type of megaspore recovered from a shale of Kumarpur Sandstone Member of the Raniganj Formation is characterized by the presence of a large number of rill-like exoexinal folds in the inter-ray areas. The rill-like folds mask the rays of the trilete mark. Another characteristic feature is the apparent absence of a mesosporium.

Key-words — Palynology, Megaspore, *Noniasporites*, Raniganj Formation, Upper Permian (India).

साराँश

रानीगंज कोयला-क्षेत्र के उपरि परमी कल्प से एक नवीन गुरुबीजाणु वंश : नोनियास्पोराइटिस – हरिकृष्ण माहेश्वरी एवं ऊषा बाजपेयी

रानीगंज शैल-समूह के कुमारपुर बालुकाश्म सदस्य की शैल से उपलब्ध यह नवीन प्रकार का गुरुबीजाणु मध्य-अरीय क्षेत्र में धारा-सदृश बाह्यतम्चोल के घुमावों से अभिलक्षणित हैं। ये धारा-सदृश घुमाव त्रिअरीय चिन्ह के अरों को ढके रहते हैं। बीजाणु-मध्यचोल की स्पष्ट अनुपस्थिति इस गुरुबीजाणु के अन्य विशिष्ट लक्षण की द्योतक है।

INTRODUCTION

AFTER the initial record of megaspores by Sitholey (1943), from the Salt Range Triassic, there have been occasional reports of megaspores from many other formations of the Indian Gondwana. These records have been summarized among others by Pant and Srivastava (1961), Bharadwaj and Tiwari (1970), Maheshwari and Banerji (1975) and Banerji, Kumaran and Maheshwari (1978). It has been observed that though certain megaspore taxa are long ranging in the stratigraphical sequence, yet there are few forms that are restricted to individual formations. Further, the megaspore types known so far, particularly the ones from the Lower Gondwana formations, have a mesosporium or inner body (Bharadwaj & Tiwari, 1970, p. 61) and its nature and organisation have usually been considered to be diagnostic features in megaspore taxonomy (Høeg, Bose & Manum, 1955; Bharadwaj & Tiwari, 1970; Lele & Chandra, 1974) or atleast relevant to the correct interpretation of megaspore morphology (Pettitt, 1966, p. 254).

While investigating megaspores from the Lower Gondwana formations of India, we found that one of the megaspore types from the Raniganj Formation did not reveal the presence of a mesosporium though a large number of specimens were subjected to differential maceration. To further confirm the absence of the mesosporium, ultra-thin sections were prepared and examined both under the light as well as the transmission electron microscopes. A mesosporium could not be deciphered by either method.

Being an interesting observation, we are reporting this particular type of megaspore in the present paper. However, we still do not rule out the presence of a mesosporium because of the possibility that these megaspores were preserved at an ontogenetic stage when the separation of nexine from the sexine had not yet started.

Bharadwaj and Tiwari (1970) recorded following megaspore taxa from the Toposi Kenda (VI) Seam of the Raniganj Formation: *Talchirella raniganjensis* Bharadwaj & Tiwari, 1970; *T. densicorpa* Bharadwaj & Tiwari, 1970; *Jhariatriletes baculosus* Bharadwaj & Tiwari, 1970; *Surangaesporites raniganjensis* Bharadwaj & Tiwari, 1970 and *Biharisporites spinosus* (Singh) Potonié, 1956. Our samples come from a shale sequence, slightly above the Upper Kajora (IX) Seam, exposed near the Burnpur Crossing-Technical College road bridge on the Nonia Nala near Asansol. The Lower Triassic Maitur Formation shales exposed in the same section have also yielded a variety of megaspores (Maheshwari & Banerji, 1975). The genera *Srivastavaesporites* (*Banksisporites*), *Biharisporites*, *Jhariatriletes* and *Talchirella* continue from the Raniganj Formation while the genera *Pantiella*, *Maiturisporites* and *Nathorstisporites* become introduced at this level.

METHOD

More than 300 megaspores of this type were recovered by dissolving the shale in hydrofluoric acid. After routine cleaning and washing in water, individual megaspores were dried at room temperature and studied in incident light. Selected specimens were then subjected to routine differential maceration (cf. Maheshwari & Banerji, 1975, p. 151) and rephotographed.

More than a dozen specimens of this type were micrographed on the scanning electron microscope for topographical features. For this purpose completely dry megaspores were stuck on a small piece of conductive silver tape which was placed on an Aluminium stub. The megaspores were coated with Gold and Palladium alloy in a Sputter Coater. The sample was then scanned in Cambridge Stereoscan 180 microscope. Micrographs were taken on an ORWO NP 22, 120 roll film.

The megaspores for transmission electron microscopy were prepared according to the technique given by Taylor and Rothwell (1982). After embedding in Spurr's low viscosity resin, ultrathin sections were cut with glass knives on LKB ultratome III. Sections (700-800 Å) were picked upon Formvar coated 400 mesh copper grids and stained with 1% aqueous uranyl acetate for 15 minutes (Watson, 1957). The sections were examined under Hitachi Electron Microscope (H.U.-11E) at an accelerating voltage of 75 KV and selected areas were photographed on Fuji Orthochromatic sheet film.

SYSTEMATIC DESCRIPTION

Anteturma — *Sporites* H. Potonié, 1893
Turma — *Barbates* Mädler, 1954

Genus — *Noniasporites* gen. nov.

Type Species — *Noniasporites harrisii* sp. nov.

Diagnosis — Megaspores acavate, apparently trilete, circular to sub-circular in shape. Triradiate ridges raised, wavy, usually indistinguishable from radially oriented, exoexinal, simple or branched, rill-like structures occurring on contact faces. Contact areas not clearly demarcated by curvaturae. Exine laevigate, homogenous in sections, comprising discrete sporo-pollenin units.

Description — The megaspores which have been assigned to this genus occur in all possible views ranging from proximo-distal to oblique to lateral. While in proximo-distal view the megaspores are more or less circular, in lateral view the spore outline is broadly oval. Because of this the spores generally show an exinal fold near the equator. It has not been possible to clearly demonstrate, even under the scanning electron microscope, if the megaspores have a trilete mark. Most of the megaspores show a distorted, M- or W-shaped structure at the place where a tetrad mark is expected (Pl. 2, figs 8, 10). It is apparent that the tetrad mark is a trilete whose rays are thick and much raised. The trilete laesurae are often masked by a large number of rill-like exoexinal structures which occur in a radial orientation in the inter-ray areas. These rill-like structures are either simple or branched towards outside. Under the optical microscope the exine looks to be laevigate but under the scanning electron microscope (Pl. 2, figs 12, 13) it gives a corroded appearance. The acavate nature of the spore is clearly demonstrated in thin sections (Pl. 1, fig. 5). Ultrathin sections (Pl. 1, fig. 6) show that the exine is homogeneous and composed of discrete units of sporo-pollenin.

Comparison — The most characteristic features of the megaspores included here under the new genus *Noniasporites* is the exine ornamentation in the inter-ray areas. Mädler (1954, p. 147) established the Turma *Barbates* to include those spore taxa which had a strongly developed exine ornamentation in the inter-ray areas. This ornamentation could comprise, capilli, fimbriae, bacula, spinae, etc. Of the megaspore genera falling in the Turma *Barbates* the genus *Hughesisporites* Potonié, 1956 resembles somewhat the new genus. The genus *Hughesisporites*, which is so far known to range from Upper Triassic to Lower Cretaceous in age (Banerji, Kumaran & Maheshwari, 1978; Marcinkiewicz, 1962, 1976; Dettmann, 1961; Hughes, 1955; Dijkstra, 1951; Harris, 1935, etc.), is characterized by the presence of verrucae or spinae in the inter-ray areas (Potonié, 1956, p. 70). *Noniasporites*, however, is clearly distinguishable (i) in having rill-like features in the inter-ray areas, (ii) by triradiate laesurae marked by inter-ray ornamentation, and (iii) in the apparent absence of a mesosporium.

Noniasporites harrisii sp. nov.

Pl. 1, figs 1-6; Pl. 2, figs 8-13; Text-fig. 1

Holotype — Pl. 1, figs 1, 2; slide no. BSIP 6998 (megaspore mounted after differential maceration).

Type Locality — Nonia *nala* (stream), adjacent to Technical College Bridge near Asansol-Burnpur Crossing, Burdwan District, West Bengal.

Derivation of name — After the late Professor Thomas Maxwell Harris.

Diagnosis — As for the genus.

Description — Megaspores are circular to subcircular in outline and 275-337 μm in diameter. Even after differential maceration the megaspores generally retain the same outline though in water or KOH their size may show a marked increase (275-399 μm). The trilete mark which is not distinguishable in incident or transmitted light is, however, resolved under the scanning electron microscope due to its higher depth of focus and resolving power. The rays are much raised and highly wavy. The contact area is not well-marked but can be defined by the presence of a number (26-46) of fine rills. Under transmitted light as well in the SEM micrographs the rills appear to be simple or once branching away from the trijunction. These rills are probably formed as exoexinal extensions as is seen in thin sections of the megaspores (Pl. 1, fig. 5). The thin sections, as the partially macerated megaspores, show that the mesosporium is not present in this species. A transmission electron microscope study of the sporoderm layer indeed shows a homogeneous layer which is composed of discrete sporo-pollenin units. Usually the megaspores show a separation of nexine from sexine forming a mesosporium, both in fossil and living megaspores (cf. *Isoetes coromandelina* L.; Pl. 1, fig. 7). Due to poor preservation of the fossil megaspores the thickness of exine is not uniform all over. The SEM micrographs of both the proximal and the distal surfaces show a corroded topography.

TEXT-FIG. 1 — *Noniasporites harrisii* gen. et sp. nov. a free-hand sketch of the megaspore illustrated on plate 2, fig. 9.

CONCLUDING REMARKS

The megaspores so far known from the Gondwana of India all have two things in common, i.e. the presence of a distinct trilete tetrad mark and a mesosporium (inner body). *Noniasporites* is significant in that the presence of the trilete mark is not indubitably proved in the proximal-distal orientation of the megaspore. However, in oblique or lateral orientation, one can make out the tetrad mark which apparently is trilete with thick, much wavy and raised rays. As the inter-ray proximal area of the megaspores is studded with rill-like exinal modifications (? infolds) similar in extent to the tetrad rays, the latter are mostly masked. The mesosporium is also not seen, both in transmitted light or in thin sections. A similar situation regarding mesosporium has also been observed in *Tasmanitriletes* (*Triletes*) *pedinacron* (Harris, 1935) Jux & Kempf, 1971.

In most other megaspores, both extant and extinct, however, there is a clear indication of the separation of an inner layer of the sporoderm from an outer layer. Usually these two layers in megaspores were equated with nexine and sexine respectively. However, Kempf (1970, 1971a, 1971b, etc.) is of the opinion that the outer thick layer is a perine and the inner thin layer represents the exine. He further regards the separation of the 'exine' from the 'perine' to be either due to laboratory treatment or as an artefact of preservation and thus of no consequence as a taxonomic character. However, it is difficult to agree with Kempf's either conclusion at least with regards to fossil megaspores. The perine has always been regarded as an 'extra-exinous' wall layer deposited presumably by the activity of a periplasmodium (Bower, 1923) and as such could not be correctly identified without reference to ontogeny of the megaspore (Harris, 1955). Pokrovskaya *et al.* (1950) and Potonié and Kremp (1955, p. 17) have found that the perine is rather easily lost in fossil condition along natural separation surfaces. However, a perispore is not unknown in fossil megaspores (cf. Dijkstra, 1946, etc.) but it is not clear if the 'perispore' of Dijkstra is the same as the 'perine' of Jackson. In the extant species of the genera *Isoetes* and *Selaginella*, the 'perispore' is thick and silicified (Pettitt, 1966, pp. 227, 232). We have found that this layer often dissolves even in very dilute alkali, leaving two clear layers, an outer sexine and an inner nexine.

Similarly the constant occurrence of a mesosporium in almost all the fossil megaspores could not be a preservation artefact. Furthermore, mesosporia are almost universally present in megaspores of extant species, too. The occurrence of certain characteristic elements, e.g. 'cushions' on the mesosporium of the genus *Duosporites* is certainly not a preservation artefact. The mesosporia are quite often different in shape or smaller in size than the spore cavity. At ultrastructural level the arrangement of sporo-pollenin units in the mesosporia is also different from that in the sexine or ektexine or perine. Therefore, we regard the absence or presence, and in the latter case the nature and organisation, of the mesosporium to be a very important taxonomic character.

ACKNOWLEDGEMENTS

We are thankful to Drs A. C. Shipstone and V. K. Bajpai for advice on SEM microscopy. We are also thankful to Miss Abha Tamta for assistance with electron microscopy work.

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EXPLANATION OF PLATES

(All figures × 200, unless mentioned otherwise)

Nidiasporites harrisii gen. et sp. nov.

PLATE 1

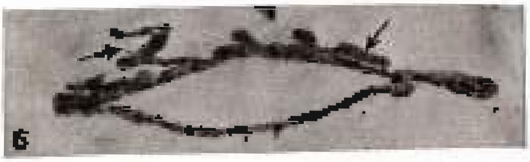
1. The holotype in dry condition, as seen under transmitted light.
2. The holotype after differential maceration. BSIP slide no. 6998.
3. Proximal view of another differentially macerated megaspore showing an incipient trilete tetrad mark and a number of rill-like features in the inter-ray areas. BSIP slide no. 6999.
4. Lateral view of a differentially macerated megaspore. Note that the distal surface of the megaspore is free of rill-like structures. BSIP slide no. 6970.
5. A thin section of a megaspore showing acavate nature. The rays of the trilete mark are pointed by arrows. BSIP slide no. 6971.
6. TEM micrograph of the megaspore sporoderm showing its homogeneous nature.
7. Thin section of a megaspore of *Isoetes coromandelina* L. showing distinct separation of nexine from sexine. BSIP slide no. 6972.

PLATE 2

8-11. SEM micrographs of megaspores in different views. The arrows in fig. 9 point out the triradiate ridges.

12. SEM micrograph showing surface topography of inter-ray area of the megaspore illustrated in fig. 10, × 1000.

13. SEM micrograph showing surface ornamentation of megaspore illustrated in fig. 11, × 2,700.



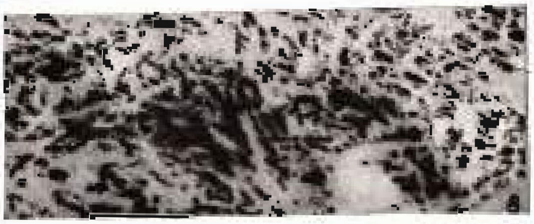
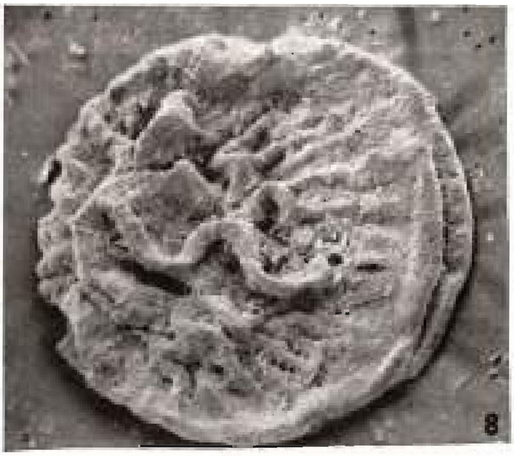


PLATE 1



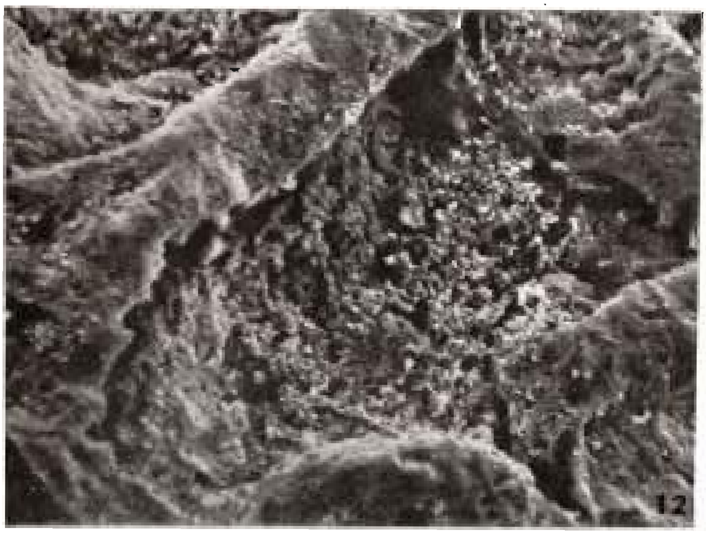


PLATE 2

The Palaeobotanist, **32**(2): 120-125, 1984.

OCCURRENCE OF CYANOPHYCEAN REMAINS FROM THE DECCAN INTERTRAPPEAN BEDS, MADHYA PRADESH

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ABSTRACT

Cyanophycean remains, viz., *Huronispora* cf. *microreticulata* Barghoorn, *Microcystiopsis mohgaonkalaensis* gen. et sp. nov., *Palaeohydrococcus raoi* gen. et sp. nov. and *Neophormidium indicum* gen. et sp. nov. have been reported from Mohgaonkalan, Madhya Pradesh.

Key-words — Cyanophyceae, *Huronispora*, *Microcystiopsis*, *Palaeohydrococcus*, *Neophormidium*, Deccan Intertraps, Eocene (India).

सारांश

मध्य प्रदेश की दक्खिन अन्तर्ट्रैपी संस्तरों से सियॅनोफ़ाइसीय अवशेष – प्रदीप कुमार मिश्रा एवं प्रभात कुमार माइती

मध्य प्रदेश में मोह्गाँव कलाँ से ह्यूरोनिस्पोरा सजातीय माइक्रोरेटिकुलाटा बारघूर्न, माइक्रोसिस्टिऑप्सिस मोह्गाँवकलाँयेन्सिस नव वंश व नव जाति, पेलियोहाइड्रोकोक्कस रावई नव वंश व नव जाति तथा निऑफ़ोर्मिडियम् इन्डिकम् नव वंश व नव जाति नामक सियॅनोफ़ाइसीय शैवाल-अवशेषों का वर्णन किया गया है।

INTRODUCTION

OCCURRENCE of fossil algae belonging to Cyanophyceae in Deccan Intertrappean beds was reported by Biradar (1977) and the specimens were described under the extant genus *Westiellopsis* Jannet (1941). Later Bande, Prakash and Bonde (1981) have compiled the earlier reports on the fossil algae of this area and described two rhodophycean forms namely *Peyssonnelia antiqua* Johnson and *Distichoplax raoi* Varma from the Mohgaonkalan in Chhindwara traps, Madhya Pradesh. However, while re-examining this slide (B.S.I.P. slide no. 6556) of the fossiliferous cherts, four types of Cyanophycean remains were observed and are being described here.

SYSTEMATIC DESCRIPTION

FAMILY — CHROOCOCCACEAE

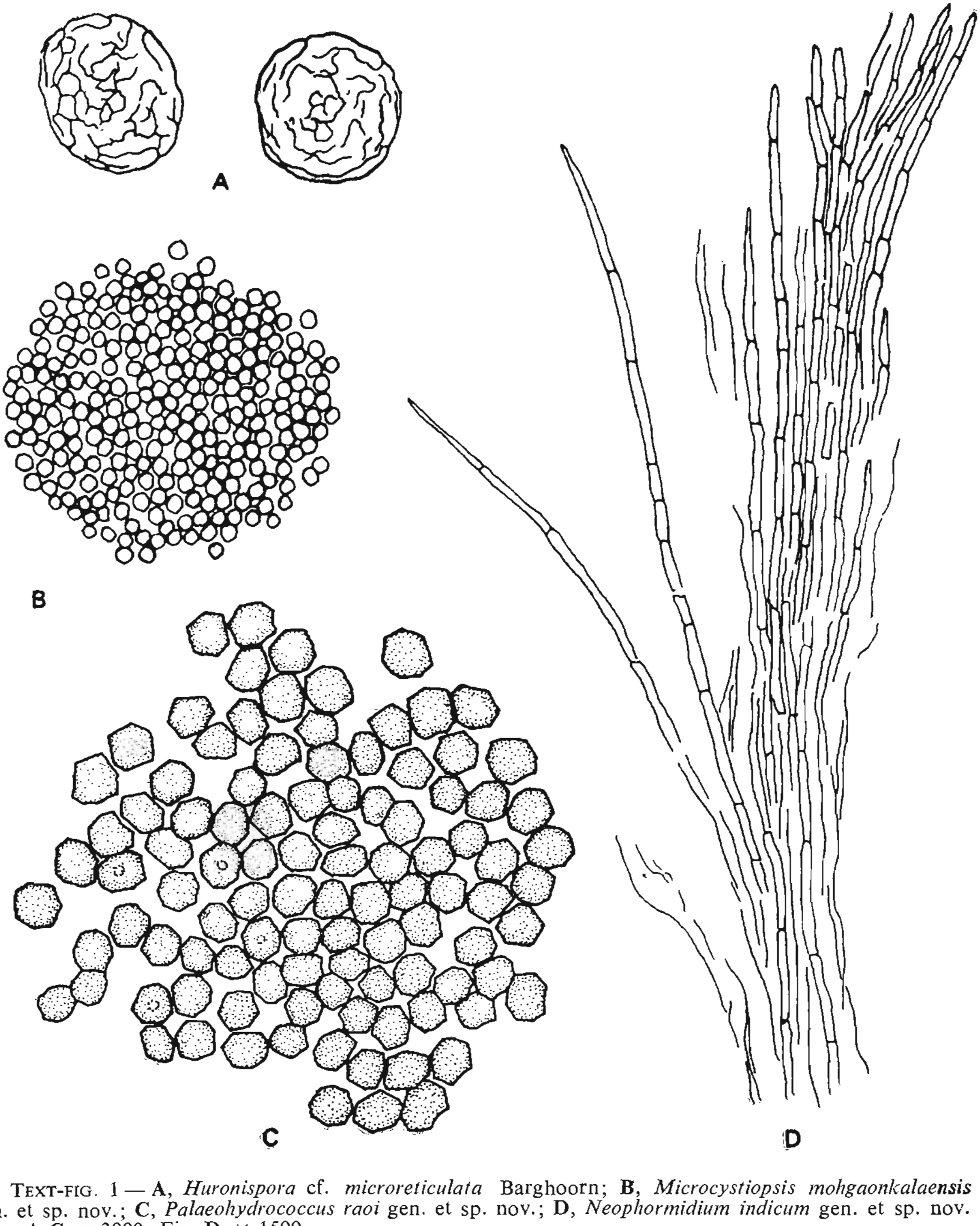
Genus — *Huronispora* Barghoorn, 1965

Huronispora cf. *microreticulata* Barghoorn, 1965

Pl. 1, figs 1, 8; Text-fig. 1A

Description — Cells rather large, more or less spherical, solitary or occurring in dyads, not surrounded by a mucilaginous sheath, cell wall thin and apparently reticulate, cells 6 μm in diameter.

Figured specimen — B.S.I.P. slide no. 6556. Stage coordinate 105×43 on Leitz-dialux microscope.



TEXT-FIG. 1 — **A**, *Huronispora* cf. *microreticulata* Barghoorn; **B**, *Microcystiopsis mohgaonkalaensis* gen. et sp. nov.; **C**, *Palaeohydrococcus raoi* gen. et sp. nov.; **D**, *Neophormidium indicum* gen. et sp. nov. Figs. **A-C**, × 3000; Fig. **D**, × 1500.

Remarks — Barghoorn (in, Barghoorn & Tyler, 1965) and Muir (1976, p. 147) have not mentioned the occurrence of solitary cells in this species as observed in the present specimen.

Genus — *Microcystiopsis* gen. nov.

Diagnosis — Cells very small, 0.5-1.25 μm in diameter, without individual sheath, outline spherical to more or less polyhedral, cells closely arranged into somewhat globular colonies, colonial mucilaginous sheath thin and indistinct.

Type species — *M. mohgaonkalaensis* sp. nov.

Microcystiopsis mohgaonkalaensis sp. nov.

Pl. 1, figs 2, 3; Text-fig. 1B

Diagnosis — As per the genus.

Holotype — B.S.I.P. slide no. 6556. Stage coordinate 104.8×43.5 on Leitz-dialux microscope.

Locality — Mohgaonkalan, Madhya Pradesh.

Horizon — Deccan Intertrappean beds (Eocene).

Comparison — In the presence of indistinct or diffluent colonial envelope and absence of sheath around individual cells, the present taxon is comparable with the modern blue-green alga *Microcystis* Kuetzing and is closest to a freshwater species *M. stagnalis* Lemm. (Desikachary, 1959, p. 95). Maithy (1975, p. 138) has described a fossil genus named *Palaeomicrocystis* from the Precambrians of Zaire, but the colonies in *Palaeomicrocystis* exhibit a filamentous habit with relatively much larger and overlapping cells, while in the present form the colonies are globular in outline. Moreover, the cells in the *Microcystiopsis* are smaller in size than the cells of *Palaeomicrocystis*. *Microcystiopsis* also shows resemblance with *Palaeoanacystis* Schopf (1968) and *Myxococcoides* Schopf (1968) in the globular shape of colonies, but both of them differ from the present form in having well defined organic matrix around colonies and larger dimensions of cells.

FAMILY — HYELLACEAE

Genus — *Palaeohydrococcus* gen. nov.

Diagnosis — Cells 1.7-3.5 μm in size, outline slightly to sharply polygonal with acute angles, cells loosely aggregated in formless colonial assemblage with indistinct mucilaginous sheath, some cells exhibit morphologically asymmetrical and more or less spherical inclusions, at places 3-6 peripheral cells of colony show linear arrangement.

Type species — *Palaeohydrococcus raoi* sp. nov.

Palaeohydrococcus raoi sp. nov.

Pl. 1, figs 4-7; Text-fig. 1C

Diagnosis — As per the genus.

Holotype — B.S.I.P. slide no. 6556; Stage coordinate 105×43·25 on Leitz dialux microscope.

Locality — Mohgaonkalan, Madhya Pradesh.

Horizon — Deccan Intertrappean beds (Eocene).

Etymology — The specific name has been derived after Prof. S. R. Narayan Rao for his contributions to the Indian fossil algae.

Comparison — In its shape, size and arrangement of cells within the colony and assumption of linear shape by peripheral cells the present taxon is comparable with the modern genus *Hydrococcus* Kuetz. and is nearest to *H. vulgaris* Kuetz. (Desikachary, 1959, p. 180). This living alga in older stages exhibits development of erect filaments from the colonial assemblage, though a faculty to form filamentous organisation is evident, well defined filaments are not exhibited by *Palaeohydrococcus raoi*. Oehler (1978, p. 340) has described a new cyanophycean fossil, *Nanococcus vulgaris*, in which the cells are loosely arranged in formless matrix but his specimen exhibits spheroidal to ellipsoidal cells which are much larger than that of present taxon. The present specimen resembles *Corymbococcus* Awramik & Barghoorn (Awramik & Barghoorn, 1977, p. 132) in the absence of sheath around individual cell and unlamellated colonial sheath but the Canadian form exhibits relatively large and spheroidal to ellipsoidal cells with thick walls and coarse surface texture.

FAMILY — OSCILLATORIACEAE

Genus — *Neophormidium* gen. nov.

Diagnosis — Plant body consisting of several filaments forming tough gelatinous bundles with torn margins, lower portion of thallus apparently attached and comprises rather closely packed and more or less parallel filaments, upper portion of thallus free and shows closely arranged filaments with somewhat diverging apices, sheath thin and firm; filaments unbranched, narrow multicellular, slightly or not at all constricted at septa, apices straight, attenuated and noncapitate; cells long and cylindrical throughout the filament, 1-1.5 µm broad, 2.25-7 µm long.

Type species — *N. indicum* sp. nov.

Neophormidium indicum sp. nov.

Pl. 1, figs 9-12; Text-fig. 1D

Diagnosis — As per the genus.

Holotype — B.S.I.P. slide no. 6556; Stage coordinate 101 × 46 on Leitz dialux microscope.

Locality — Mohgaonkalan, Madhya Pradesh.

Horizon — Deccan Intertrappean beds (Eocene).

Comparison — In general habit this plant compares with the modern alga *Schizothrix* Kuetz. (Desikachary, 1959, p. 321) but the margins of the thallus in the present form which might be mistaken as common sheath around trichomes are in fact distorted filaments, which is evident by the presence of sheath in the individual filaments at few places. Schopf (1968, p. 665) has described two new fossil taxa *Palaeolyngbya* and *Oscillatoriopsis* where uniseriate filaments comprise individual sheath but the former differs from *Neophormidium* in exhibiting thick mucilaginous sheath and rounded terminal cells showing somewhat granulate cross walls. Schopf and Blacic (1971, p. 950) have reported *Obconicophycus*, a member of Oscillatoriaceae showing uniseriate, unbranched filaments with attenuated apices but in this case median cells of the filaments are short and discoidal while in *Neophormidium* the cell morphology is uniform throughout the filament except at apices. The present specimen differs from all previously known cyanophycean remains belonging to family Oscillatoriaceae in its general habit, i.e. the filaments form a tough gelatinous assemblage in the form of compact bundles. The filaments are narrow with attenuated apices and also have a firm sheath. These characters suggest its close similarity with the modern blue green alga *Phormidium tenue* (Menegh.) Gomont (Desikachary, 1959, p. 259). This living form has been reported from both freshwater and marine habitats.

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EXPLANATION OF PLATE

(Figured specimens 1-8 are in 1000 magnifications and 9-12 are in 500 magnifications. The negatives are preserved in Birbal Sahni Institute of Palaeobotany Museum, Lucknow)

1. *Huroniospora* cf. *microreticulata* Barghoorn (shown with arrow) and colonies of *Palaeohydrococcus raoi* gen. et sp. nov.
2. *Microcystopsis malgaonkaliensis* gen. et sp. nov. — Globular colonies with closely aggregated cells.
3. *Microcystopsis malgaonkaliensis* gen. et sp. nov. — Showing arrangement of cells within the colony.

4-6. *Palaeohydrococcus raoi* gen. et sp. nov. — Showing general arrangement of cells, some peripheral cells arranged in somewhat linear fashion (marked with arrow).

7. *P. raoi* gen. et sp. nov. — Few cells with asymmetrical inclusions (marked with arrow).
8. *Huroniospora* cf. *microreticulata* Barghoorn.

9-12. *[illegible] indicum* gen. et sp. nov.

9. Habit of the plant showing several filaments forming tough gelatinous bundles.

10, 11. Showing filaments slightly or without constrictions at septa with attenuated apices.

12. Thalli apparently attached on lower side and free on upper half.

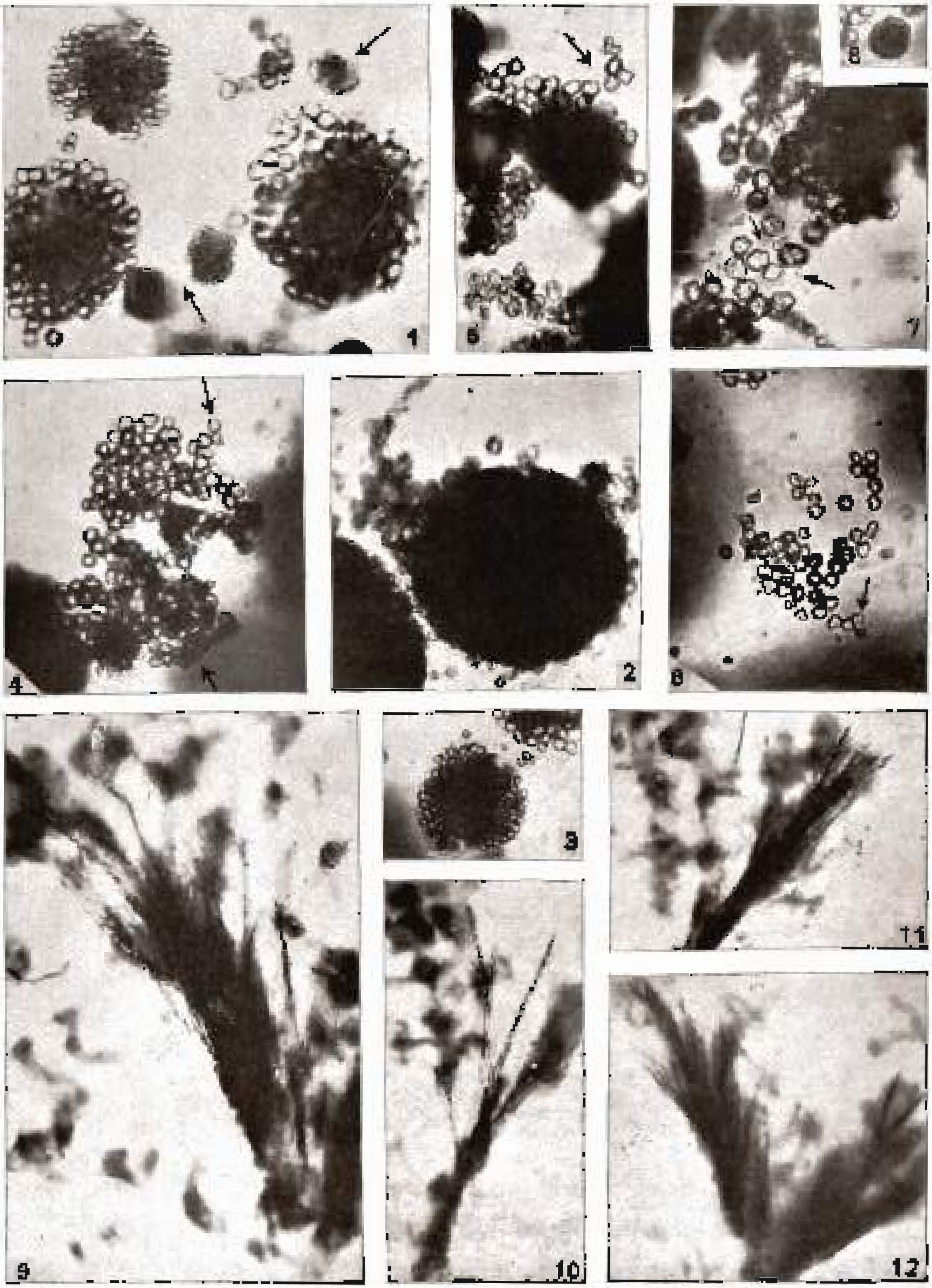

PLATE 1

The Palaeobotanist, **32**(2): 126-129, 1984.

FRAGMENTARY PLANT REMAINS FROM THE HARTALA HILL, SOUTH REWA GONDWANA BASIN, INDIA

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ABSTRACT

A few fragmentary plant remains, belonging to *Pagiophyllum*, *Brachyphyllum* and *Desmiophyllum* from the hillock south-east of Hartala Village, Shahdol District, Madhya Pradesh have been described. On the basis of megafloral contents, Hartala Hill beds seem to be of Rhaetic-Liassic age.

Key-words — Megafossils, *Pagiophyllum*, *Brachyphyllum*, *Desmiophyllum*, Hartala Hill, Gondwana, Rhaetic-Liassic (India).

साराँश

दक्षिण रीवा गोंडवाना द्रोणी (भारत) में स्थित हरतला पहाड़ी से आँशिक पादप-अवशेष – पंकज कुमार पाल

मध्य प्रदेश में शहदोल जनपद के हरतला गाँव से दक्षिण-पूर्व में स्थित एक पहाड़ी से प्राप्त पेजियोफ़िल्लम्, ब्रेकिफ़िल्लम् एवं डेस्मिओफ़िल्लम् के आँशिक पादप-अवशेषों का वर्णन किया गया है। गुरुवनस्पतिजातों के आधार पर हरतला पहाड़ी की संस्तर रिहॅटिक-लिऐँसिक आयु की प्रतीत होती है।

INTRODUCTION

THE hillock, lying SE of Hartala Village (23°49′29″N: 81°15′11″E; Survey of India Toposheet no. 64E/5) in Shahdol District, Madhya Pradesh consists of hard compact sandstone, dark-red ferruginous shales and white or pinkish-white fine-grained clays and shales. Rao (in Krishnan, 1958) reported the occurrence of *Pagiophyllum peregrinum* from this hillock. However, he did not describe or figure any of his specimens. A few fragmentary plant impressions described here were collected from the white or pinkish-white shales exposed at the top of the hillock.

DESCRIPTION

CONIFERALES

Genus — *Pagiophyllum* Heer, 1881

Pagiophyllum sp.

Pl. 1, figs 1-4; Text-fig. 1A-C

Description — Leafy twigs, 6 mm wide, largest available specimen about 2 cm long, incomplete at both ends. Leaves spirally disposed, linear-lanceolate, typically 2 mm long and 1 mm wide near middle region; decurrent at base; free-part distinctly keeled, spreading at an angle of 30°-50°, often slightly curving upwards; margin entire; apex acuminate.

Remarks — The specimens resemble *Pagiophyllum peregrinum* (Lindley & Hutton) Schenk described by Sahni (1928) from the Jabalpur Group (Jurassic-Cretaceous) of India, in gross features but their detail comparison is not possible due to the fragmentary nature and lack of cuticle.

Genus — *Brachyphyllum* Brongniart, 1828

Brachyphyllum sp.

Pl. 1, figs 5, 6; Text-fig. 1D

Description — Leafy twig, broken at both ends, available length 6.8 cm, about 5 mm wide. Leaves spirally borne, appressed to the stem, keeled, rhomboidal in shape, typically measuring 4×3 mm, base concealed by leaves lying immediately below, margin entire, apex subacute.

Remarks — In available gross features the present specimen resembles the specimens of *Brachyphyllum mamillare* Brongniart described from the Rajmahal Formation (Sahni, 1928, pl. 2, figs 19, 20) and *B. rhombicum* described from the Jabalpur Formation (Sahni, 1928, pl. 2, figs 23, 24). But both, *B. rhombicum* and *B. mamillare*, are known to be branched, whereas branching is not known in the present specimen.

INCERTAE SEDIS

Genus — *Desmiophyllum* Lesquereux, 1878

Desmiophyllum sp.

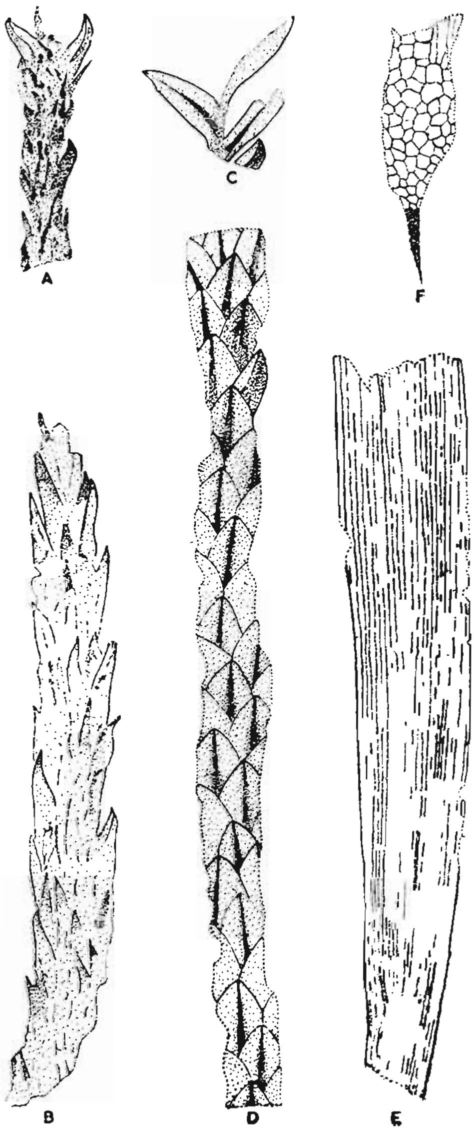
Pl. 1, fig. 7; Text-fig. 1E

Description — Leaves incomplete both near base and apex, ribbon-shaped, largest specimen about 10 cm long and 2 cm wide at one end, gradually tapering to 1 cm at the other end, slightly curved. Veins parallel, about 18 per cm.

Remarks — The specimens have been referred to *Desmiophyllum* because in none of them apex is preserved, therefore it cannot be said whether the veins are converging towards apex or ending at different levels towards margin. Moreover, such strap-shaped leaf-fragments may also be the portions of large-sized cycadophytic fronds.

DISCUSSION

About two dozen fragmentary specimens belonging to *Pagiophyllum*, *Brachyphyllum* and *Desmiophyllum* were collected from the Hartala Hill. Out of these *Pagiophyllum* is most common in occurrence. There is also a specimen of cone-like organ, an ovate body bearing crowdedly arranged tubercles on its surface, represented by both part and counterpart (Pl. 1, figs 8-10; Text-fig. 1F). In this collection there is not a single piece of frond comparable to *Lepidopteris* or *Dicroidium*. The Hartala Hill beds overlie the rocks of Tiki Formation which is known to be of Upper Triassic age (Roy-Chowdhury *et al.*, 1975; Maheshwari *et al.*, 1978). The complete absence of characteristic Triassic forms like *Lepidopteris* and *Dicroidium* which are abundant in the Tiki Formation and the frequent occurrence of *Pagiophyllum* which is more prevalent in the Indian Jurassic also suggest that the beds exposed at the top of hillock are younger in age than that of the Tiki Formation. As such the Hartala Hill beds appear to be of Rhaetic-Liassic age.



TEXT-FIG. 1 — **A-C**, *Pagiophyllum* sp. **A**, B.S.I.P. specimen no. 35521, × 2; **B**, B.S.I.P. specimen no. 35449, ×2; **C**, B.S.I.P. specimen no. 35519, ×3; **D**, *Brachyphyllum* sp., B.S.I.P. specimen no. 35450, × 2; **E**, *Desmiophyllum* sp., B.S.I.P. specimen no. 35523, × 1; **F**, cone-like organ, B.S.I.P. specimen no. 35451, × 2.

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EXPLANATION OF PLATE

1-4. *Pagiophyllum* sp.
1. B.S.I.P. specimen no. 35521.× 1.
2. B.S.I.P. specimen no. 35449.× 1.
3. Same as fig. 1.× 4.
4. B.S.I.P. specimen no. 35522, counterpart of specimen in text-fig. 1C.× 2.

5, 6. *Brachyphyllum* sp.
5. B.S.I.P. specimen no. 35450.× 1.
6. Same as fig. 5.× 2.
7. *Desmiophyllum* sp. B.S.I.P. specimen no. 35523.× 1.

8-10. Cone-like organ.
8. B.S.I.P. specimen no. 35451.× 1.
9. B.S.I.P. specimen no. 35540, counterpart of specimen in fig. 8.× 1.
10. Same as fig. 8.× 4.


1


2

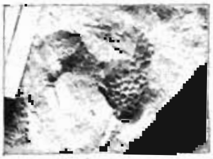

3


4


5


6


8


9


10


11

PLATE 1

The Palaeobotanist, **32**(2): 130-133, 1984.

A NEW CYANOPHYCEAN REMAIN FROM THE KARHARBARI FORMATION, GIRIDIH COALFIELD, BIHAR

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ABSTRACT

The present paper reviews the earlier work done on the Indian Permian algae and records a new Cyanophycean alga, *Palaeowestiellopsis karharbariensis* gen. et sp. nov., studied in cellular pulls taken from the stem surface of *Phyllotheca indica* Bunbury collected from the Karharbari Formation in Bengal-Nagpur Open Quarry. This new fossil alga is characterized by true branching, coiling of few branches and lack of sharp demarcation between the main filament and branches.

Key-words — Cyanophyceae, Algae, *Palaeowestiellopsis*, *Phyllotheca*, Karharbari Formation, Lower Permian (India).

सारांश

गिरीडीह कोयला-क्षेत्र (बिहार) में करहरबारी शैल-समूह से प्राप्त एक नवीन सियॅनोफ़ाइसीय अवशेष –
प्रभात कुमार माइती एवं प्रंदीप कुमार मिश्रा

इस शोध-पत्र में फ़िल्लोथीका इन्डिका बनबरी के तनाश्म की सतह से उपलब्ध कोशिकीय छापाँशों से पेलियो-वैंस्टियॅल्लॉप्सिस करहरबारीयेन्सिस नव वंश व नव जाति नामक एक नवीन सियॅनोफ़ाइसीय शैवालाश्म वर्णित किया गया है। यह फ़िल्लोथीका का तनाश्म बंगाल नागपुर ओपॅन-क्वेरी में स्थित करहरबारी शैल-समूह से एकत्रित किया गया था। इसी शोध-पत्र में भारतीय परमी युगीन शैवालों पर किये गये शोध-कार्य की समीक्षा भी की गई है। यह नवीन शैवालाश्म वास्तविक शाखाओं, कुछ कुण्डलित शाखाओं तथा मुख्य तंतु एवं शाखाओं के बीच स्पष्ट सीमांकन की अनुपस्थिति से अभिलक्षणित है।

INTRODUCTION

A PERUSAL of available literature on the Indian fossil algae reveals that only a few reports on the Permian algae have been published so far. In 1850, McClelland for the first time recorded *Fucoides* from the Permian of West Bengal (in Sastri & Gururaja, 1980). Oakley (1941) has mentioned the occurrence of *Solenopora* in the Upper Permian rocks of Sikkim. Rao (1948) and Rao and Varma (1953) described some taxa of *Gymnocodium* from Punjab Salt Range (now in Pakistan). Mehta (1954) described two taxa comparable with the species of *Aphanocapsa* from South Rewa Basin of the Lower Gondwanas. A fossil resembling *Pediastrum* was reported from the Barren Measure Sequence of the Jharia Coalfield, Bihar by Kar (1968). While describing microfossils from the Barakar Stage of the Lower Gondwanas in Madhya Pradesh, Sinha (1969) reported *Botryococcus* spp. a and b from the Middle Permian. Kalia (1974) and Mehrotra *et al.* (1976) have given a good account of the Permian algae from oolitic shell bearing limestone in Garhwal, Uttar Pradesh.

The material for the present communication was studied in cellular pulls taken from the carbonised compressions preserved on the stem of *Phyllotheca indica* Bunbury, collected by one of us (Maithy) from the Bengal-Nagpur Open Quarry in the Giridih Coalfield belonging to the Karharbari Formation.

SYSTEMATIC DESCRIPTION

FAMILY — STIGONEMATACEAE

Genus — *Palaeowestiellopsis* gen. nov.

Diagnosis — Filamentous with true branching, branches more or less thinner than main filament, sheath lacking, filaments constricted at septa; cells somewhat barrel-shaped to rectangular or polygonal, 4.0-7.5 μm long and 4.5-6.0 μm broad, usually terminal or sometimes intercalary portion of filaments with a group of closely arranged, overlapping, more or less spherical or slightly polygonal structures comparable with pseudohormocysts, at places branch filaments show coiling; heterocysts not seen.

Genotype — *P. karharbariensis* sp. nov.

Palaeowestiellopsis karharbariensis sp. nov.

Pl. 1, figs 1-10

Diagnosis — As per the genus.

Holotype — B.S.I.P. slide no. 6937.

Locality — Bengal-Nagpur Open Quarry, Giridih Coalfield.

Horizon — Karharbari Formation (Lower Permian).

Remarks — In general shape and size this alga is comparable with the modern genus *Westiellopsis* Janet (Janet, 1941, p. 167; Desikachary, 1959, p. 596), the only member of the family Stigonemataceae lacking sheath, but in the fossil specimen, though at certain places the branches are significantly thinner than main filament, the general demarcation is not as sharp as found in the modern alga. Besides, the coiling in few branches of the present fossil taxon is not known as in the modern genus *Westiellopsis* Janet. The branches in our specimen arise in several planes and directions but the distinction between primary and secondary filaments has not been observed clearly since the material is in the form of carbonised compressions.

Biradar (1977, p. 204) has described *Westiellopsis mahabalei* sp. nov. from Mohgaonkalan in the Deccan Intertrappean Series. His species is almost similar to the living type and differs only in the filaments being faintly or not at all constricted at septa and in very close arrangement of pseudohormocysts. However, our Permian specimen differs from Biradar's Eocene alga in exhibiting relatively broader filaments, marked constriction at cross walls and coiling of branches at few places.

In general morphology the present taxon approaches the genus *Hyella* Born. et Flah. but in this Pleurocapsalean alga the filaments form nemato- or pseudoparenchymatous thallus showing thick mucilaginous sheath. But our specimen lacks such features. Moreover, the plant *Hyella* has been reported from the aquatic (marine) habitats, while the present fossil alga found on the stem of *Phyllotheca indica* reveals its terrestrial habitat as of the modern plant.

Those morphological comparisons with the modern alga *Westiellopsis* Janet and it's known fossil representative *W. mahabalei* Birader (1977) distinguish our specimen in the presence of coiling of few branches, lack of sharp demarcation in the width of main filament and branches and the marked constrictions at cross walls. Hence, a new genus *Palaeowestiellopsis* with it's type species *P. karharbariensis* has been created. The specific name is after the locality from where it was collected.

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EXPLANATION OF PLATE

Palaeowestiellopsis karharbariensis gen. et sp. nov.

All figured specimens are magnified. × 1000. The figured slides and negatives are preserved at the Birbal Sahni Institute of Palaeobotany Museum.

1, 3. Showing true branching (B) of the filaments.

2, 5, 9. Pseudohormocysts-like structures (P) at the terminal position.

4, 8. Pseudohormocysts-like structure (P) in intercalary position.

6. A branch filament showing coiling (C).

7. A single terminal pseudohormocysts-like body.

10. Showing intercalary pseudohormccysts (P) and a branch filament (B) probably secondary in origin.

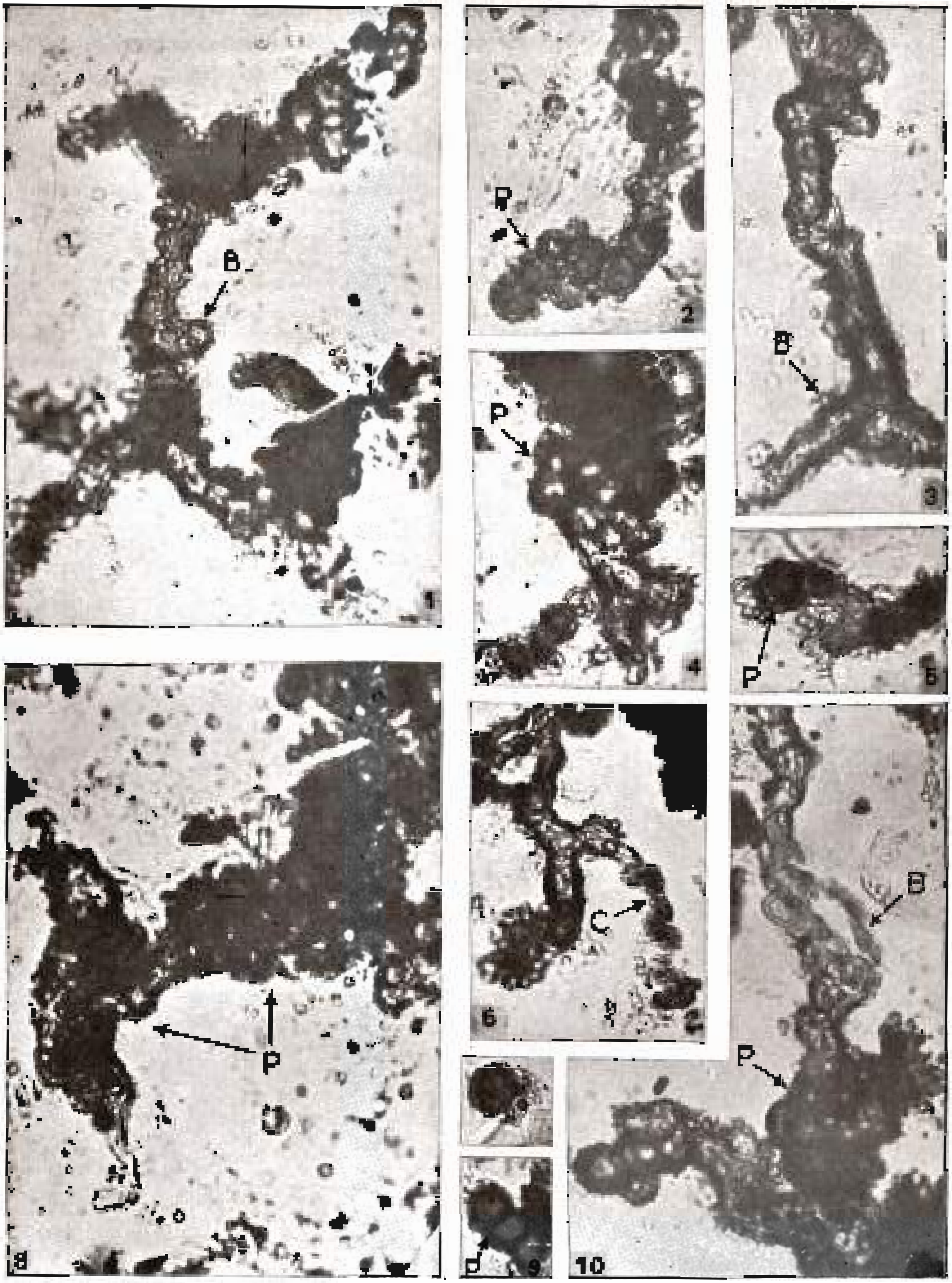

PLATE 1

PALMOSTROBOXYLON ARENGOIDUM SP. NOV.: A FOSSIL PALM PEDUNCLE RESEMBLING *ARENGA* FROM THE DECCAN INTERTRAPPEAN BEDS OF SHAHPURA, MADHYA PRADESH

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ABSTRACT

A fossil palm peduncle, *Palmostroboxylon*, recovered from the Deccan Intertrappean beds of the village Ghugua in Shahpura, Madhya Pradesh, has been described. The fossil specimen closely compares with the peduncle of the extant genus *Arenga*, a member of Caryotoidae. It is characterised by the presence of fibrovascular bundles with Lunaria-type of sclerenchymatous dorsal sheath, two metaxylem vessels associated with 2-4 protoxylem vessels and fused fibrovascular bundles.

Key-words — Xylotomy, Palm peduncle, *Palmostroboxylon*, Intertrappean beds, Early Eocene (India).

साराँश

मध्य प्रदेश में शाहपुरा के दक्खिन अन्तर्ट्रैपी संस्तरों से ऍरेन्गा के अनुरूप एक ताड़-पुष्पावलि-वृन्त, पाल्मॉस्ट्रॉबॉक्सीलॉन अरेन्गॉयडम् नव जाति – कृष्ण अम्बवानी

मध्य प्रदेश में शाहपुरा जनपद के घुगुआ गाँव की दक्खिन अन्तर्ट्रैपी संस्तरों से उपलब्ध पाल्मॉस्ट्रॉबॉक्सीलॉन नामक एक ताड़-पुष्पावलि-वृन्त का वर्णन किया गया है। यह प्रादर्श कैंरियोटॉयडी के एक विलुप्त सदस्य ऍरेन्गा से घनिष्ठ तुलनीय है। यह पुष्पावलि-वृन्ताश्म अर्ध-चन्द्राकार दृढ़ोतकीय पृष्ठ आच्छद युक्त वाहिनी बंडलों, 2-4 आदिदारु वाहिनियों से सहयुक्त दो अनुदारु वाहिनीयों तथा संयुक्त वाहिनी बंडलों की उपस्थिति से अभिलक्षणित है।

INTRODUCTION

So far the fossil palms, viz., *Palmoxylon ghuguensis* sp. nov. Ambwani & Prakash (1983), *Palmoxylon shahpuraensis* sp. nov. Ambwani (1983) resembling *Chrysalidocarpus* and *Licuala* respectively as well as *Palmoxylon siltherensis* sp. nov. Ambwani (1984) and a fossil palm fruit *Hyphaeneocarpon indicum* gen. et sp. nov. (Bande, Prakash & Ambwani, 1982) showing the affinities with modern *Hyphaene* fruit, have been described from these beds. Besides, a few dicotyledonous woods have also been described from the same beds by Ingle (1972, 1973), Bande (1973, 1974), Lakhanpal, Prakash and Bande (1978), Bande and Khatri (1980), and Bande and Prakash (1981). Recently, Mehrotra, Prakash and Bande (1983) reported *Euphorbiocarpon drypteoides* for the first time from this area.

The present fossil specimen is well-preserved to reveal all the anatomical details, and differentiated into outer and inner zones. Further, its cylindrical shape and size, vascular system differentiated into outer and inner zones, compact arrangement of fibrovascular bundles in outer and gradually becoming sparse in the inner zone as well as larger number of trace, fusion and diminutive bundles collectively suggest that the present specimen belongs to a palm peduncle.

SYSTEMATIC DESCRIPTION

MONOCOTYLEDONAE

FAMILY — PALMAE

Genus — *Palmostroboxylon* Biradar & Bonde, 1979

Palmostroboxylon arengoidum sp. nov.

Pl. 1, figs 1, 2, 4, 6, 9, 10

Material — The fossil palm peduncle about 8 cm long and 4 cm in diameter is almost cylindrical in shape and complete in cross section consisting of an outer and inner vascular zones. The outermost cortical zone is not preserved (Pl. 1, fig. 1).

Outer Zone — It is a narrow zone about 4 mm wide. The fibrovascular bundles are more or less regularly oriented, round to oval, 200 × 400-300 × 400 μm. Their frequency varies from 200-250 per cm.^{2} The f/v ratio is usually 1 : 1. The dorsal sclerenchymatous sheath is well-developed and Lunaria-type. The median sinus is concave and the auricular lobes are pointed. Generally two metaxylem vessels are seen in each fibrovascular bundle, rarely three or more may also be present (Pl. 1, fig. 4). Tabular parenchyma, stegmata as well as radiating parenchyma are absent. Phloem is represented by a wide semicircular lacuna (Pl. 1, fig. 4). The diminutive fibrovascular bundles may be seen frequently in this zone whereas the fusion bundles are sometimes seen (Pl. 1, fig. 9). Trace bundles are present while the fibrous bundles are absent.

Inner Zone — It covers a wider portion of the axis and is about 2 cm in thickness. The fibrovascular bundles in this zone are 150-200 per cm^2 and their size ranges from 400 × 400-400 × 600 μm. The shape of the fibrovascular bundles varies from round to oval but sometimes elongated bundles may also be seen. The f/v ratio is 1:1 or less. Dorsal sclerenchymatous sheath is prominently developed and is generally of Lunaria-type (Pl. 1, fig. 6). The median sinus is concave and the auricular lobes are pointed. Usually two rarely three metaxylem vessels alongwith a few smaller protoxylem elements are present in each fibrovascular bundle (Pl. 1, fig. 6). Tabular as well as radiating parenchyma are absent. Stegmata are also not seen. Phloem is represented by a semicircular lacuna (Pl. 1, fig. 6). The diminutive fibrovascular bundles are sometimes seen dispersed in the ground mass. Trace bundles are present while the fibrous bundles are absent (Pl. 1, fig. 6). Metaxylem element shows scalariform thickening while the protoxylem element has spiral to annular thickenings. The perforation plates of metaxylem vessels have 6-8 bars (Pl. 1, fig. 10).

Ground Tissue — The ground tissue is compact throughout and composed of isodiametric parenchymatous cells. Cells of outer zone are generally isodiametric and the amount of parenchymatous cells is lesser as compared to the fibrovascular bundles (Pl. 1, fig. 4), while in the inner part the ground parenchymatous cells are also isodiametric, but slightly larger in size.

Diminutive Fibrovascular Bundles — The diminutive fibrovascular bundles are present throughout the peduncle and are distinguished by their smaller size and absence of protoxylem elements. They show irregular orientation. Each diminutive fibrovascular bundle reveals similar structure to that of normal fibrovascular bundle but possesses only one metaxylem vessel and measures 200 × 200 μm in size (Pl. 1, figs 4, 6).

Fusion Bundles — A few fusion bundles may be seen dispersed among the normal fibrovascular bundles in the fossil specimen. The fusion of the fibrovascular bundles is only by their fibrous part while the vascular part remains free (Pl. 1, fig. 9). Their size ranges from 800 × 800-800 × 1000 μm.

Trace Bundles — The trace bundles are scattered throughout the peduncle but are more frequently seen in the outer zone (Pl. 1, fig. 4). They are easily recognised by their enlarged vascular portion revealing similar structure to that of a normal fibrovascular bundle and range up to 800 × 600 μm in size.

SPECIFIC DIAGNOSIS

A small portion of the axis, complete in cross section, measuring 8 × 4 cm in size; vascular region demarcated by outer and inner zones. *Outer zone* narrow, 4 mm wide; fibrovascular bundles more or less regularly oriented; frequency 200-250 per cm^2; size 200 × 200 to 300 × 400 μm, shape round to oval. F/v ratio usually 1:1;

dorsal sclerenchymatous sheath well-developed, Lunaria-type. Median sinus concave; auricular lobes pointed. Two metaxylem vessels in each fibrovascular bundle, rarely three to four; stegmata, tabular and radiating parenchyma absent; phloem represented by semicircular lacuna. Fusion, trace and diminutive bundles present. Metaxylem scalariform, perforation plates with 6-8 bars, protoxylem spiral to annular. Fibrous bundles absent. *Inner zone* wider, 2 cm thick; fibrovascular bundles irregularly oriented, frequency 150-200 per cm², size 400 × 400-400 × 600 μm, shape round to oval sometimes elongated, f/v ratio 1 : 1 or less. Dorsal sclerenchymatous sheath prominent, Lunaria-type. Median sinus concave, auricular sinus absent, auricular lobes pointed; generally two rarely three metaxylem vessels in a fibrovascular bundle associated with a few smaller protoxylem vessels; stegmata, tabular and radiating parenchyma absent; phloem represented by semicircular lacuna, diminutive fibrovascular bundles, trace and fusion bundles present, fibrous bundles absent; metaxylem scalariform, perforation plates with 6-8 bars, protoxylem spiral to annular. *Ground tissue* compact throughout, cells isodiametric, slightly larger in inner zone.

Holotype — B.S.I.P. Museum no. 35474.

Locality — Ghugua near Shahpura, Mandla District, Madhya Pradesh.

Horizon — Deccan Intertrappean Series.

Age — Early Eocene.

AFFINITIES

The present palm peduncle differs from *Palmoxylon indicum* Biradar & Bonde, 1979 in having dorsal sclerenchymatous sheath Lunaria-type, fibrovascular bundles of the inner zone usually bigger in size, f/v ratio almost constant (1 : 1) throughout. The frequency of the fibrovascular bundles is usually much more whereas the end wall perforation plate of the vessel bears 6-8 bars. The general ground tissue cells are compactly arranged.

The characteristic anatomical features of the present fossil palm peduncle with Lunaria-type of dorsal sclerenchymatous sheath and undivided semicircular patch of phloem as well as absence of fibrous bundles and stegmata, are the characters met with the caryotoid palms, especially the peduncle of *Arenga* Labill. Caryotoid palms are represented by the genera like *Arenga* Labill., *Caryota* L., *Didymosperma* Wendl. et Drude and *Wallichia* Roxb. (Tomlinson, 1961). However, from the living material as well as available related literature, it has been observed that the present fossil palm peduncle differs from *Caryota*, *Didymosperma* as well as *Wallichia*, as they possess reniform as well as segetate, rarely lunaria type of dorsal sclerenchymatous sheath. The number of the fibrovascular bundles per unit area is greater, usually more than 300 per cm² whereas the f/v ratio is always less than one throughout these peduncles. The fibrous bundles are present in all these genera. Median sinus is usually triangular to mucronate in shape, usually one rarely two metaxylem vessels are present in each fibrovascular bundle of *Caryota*, *Didymosperma* and *Wallichia*, whereas there are generally two metaxylem vessels in each fibrovascular bundle of the present fossil specimen. The diminutive fibrovascular bundles are profusely present in the above living specimens and the presence of raphide sacs is also observed in the ground tissue.

On the basis of anatomical features, the present fossil specimen can closely be compared with the peduncle of *Arenga (saccharifera) pinnata* Labil. as both show demarcation of an outer and inner zones. The fibrovascular bundles in the outer zone of the fossil as well as living specimens are closely placed and usually regularly oriented. They have Lunaria-type of dorsal sclerenchymatous sheath. The size of the fibrovascular bundles is almost similar in both, ranging from 200 × 400-300 × 400 μm in fossil and 200 × 300-300 × 500 μm in *Arenga (saccharifera) pinnata* Labil. The frequency of the fibrovascular bundles in the outer zone of fossil and living specimens varies from 200-250 and 200-270 per cm² respectively. The f/v ratio is generally 1 :1 or less and the number of metaxylem vessels is usually two, both in the fossil and living specimens. Median sinus is concave and the auricular sinus is absent whereas the auricular lobes are pointed in both. Tabular as well as radiating parenchyma are absent whereas diminutive fibrovascular bundles, trace bundles and fusion bundles are also present in the fossil and living specimens (Pl. 1, figs 8, 9).

Similarly, the inner zone of the fossil is also comparable with that of *Arenga* (*saccharifera*) *pinnata* Labil. It is a wider zone in both; the fibrovascular bundles are irregularly oriented and sparsely placed. The dorsal sclerenchymatous sheath is Lunaria-type in both. The shape and size of the fibrovascular bundles is almost similar, they are round to oval in shape; the size ranges from 400×400-600×480 µm in the fossil and 400×400-640×500 µm in the living specimen. The frequency of the fibrovascular bundles in the fossil and living specimens is nearly same ranging from 150-200 per cm^2 and 150-180 per cm^2 respectively. The f/v ratio is generally 1:1 or less in both. The number of metaxylem vessels is usually two in the fossil as well as living specimens which are associated with a few smaller protoxylem vessels. Median sinus is concave and the auricular sinus is absent. Auricular lobes are pointed both in the fossil and living specimens. The diminutive fibrovascular bundles, trace bundles as well as fusion bundles are also present in the fossil and living specimens.

Ground Tissue — Apart from the above mentioned facts the ground tissue both in the fossil and living species can also be compared. It shows similar features in outer and inner zones, being compact throughout in the fossil as well as in the living specimen. The cells are isodiametric in shape and slightly larger in size in the inner zone as compared to the cells of the outer zone.

Presently, the genus *Arenga* Labil. is represented by 11 species growing in tropical Asia and Australia (Blatter, 1926; Brandis, 1971; Tomlinson, 1961; Willis, 1973). *Arenga* (*saccharifera*) *pinnata* Labill. grows in Burma, Assam, Martban and Tenasserim, occasionally on the Pegu Yoma while *Arenga wightii* Griff. grows in North Kanara, evergreen forests of the Western Ghats and very common near the falls of Gairsoppah, Nilgiris and Travancore. The genus extends to an altitude of about 500-3000 ft.

The resemblance of the fossil specimen with the peduncle of modern *Arenga* which is also indigenous to India, indicates that similar plants must have also been growing in the Deccan Trap country during the Early Eocene time.

It may be mentioned here that the pollen grains assignable to *Arenga* have also been recovered by Dr R. K. Kar (Personal communication) from the Panandhro lignite field (Lower Eocene) of Kachchh, Gujarat. Thus it becomes apparent that during the Lower Tertiary *Arenga* was quite wide spread in central and western parts of India enjoying a warm, humid climate with much rainfall. From this it may be surmised that with the advent of drier climate, *Arenga* migrated towards east in Assam in farther east as well as Western Ghats in Nilgiris.

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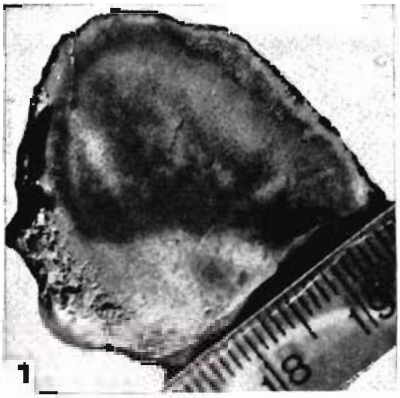
EXPLANATION OF PLATE

Palmostroboxylon arengoidum sp. nov.

1. Transectional view of the fossil specimen. × 1.5; specimen no. 35474.
2. Transverse section of the fossil to show general distributional pattern of fibrovascular bundles in outer and inner zones. × 6; slide no. 6273.
3. Transverse section of *Arenga (saccharifera) pinnata* Labill. peduncle to show the general pattern of distribution of fibrovascular bundles in outer and inner zones. × 6; B.S.I.P. Herbarium slide no. 3644.
4. Transverse section of fossil to show the arrangement of fibrovascular bundles in the outer zone. Note the regular orientation of the bundles with Lunaria-type of dorsal sclerenchymatous sheath. × 25; slide no. 6723.
5. Transverse section of *Arenga (saccharifera) pinnata* peduncle to show regular arrangement of fibrovascular bundles in the outer zone with Lunaria-type of dorsal sclerenchymatous sheath. Also note the number of metaxylem vessels in each fibrovascular bundle. × 25; B.S.I.P. Herbarium slide no. 2644.
6. Transverse section of fossil to show the irregular arrangement of the fibrovascular bundles in the inner zone with Lunaria-type of dorsal sclerenchymatous sheath. Note the number of metaxylem vessels in each fibrovascular bundle. × 25; slide no. 6723.
7. Transverse section of *Arenga (saccharifera) pinnata* peduncle to show the irregular orientation of the fibrovascular bundles in the inner zone with Lunaria-type of dorsal sclerenchymatous sheath. Also note number of metaxylem vessels in each fibrovascular bundle and a semicircular patch of phloem in each fibrovascular bundle. × 25; B.S.I.P. Herbarium slide no. 2644.
8. A single enlarged fusion bundle of the fossil. × 60; slide no. 6723.
9. A single enlarged fusion bundle of *Arenga (saccharifera) pinnata* peduncle. × 60; B.S.I.P. Herbarium slide no. 2644.
10. A portion of longitudinal section of fossil showing lateral wall pitting and nature of end plate of the metaxylem elements. × 60; slide no. 6724.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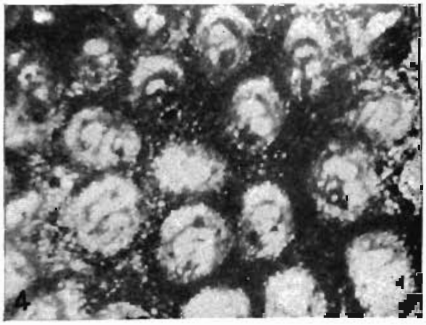
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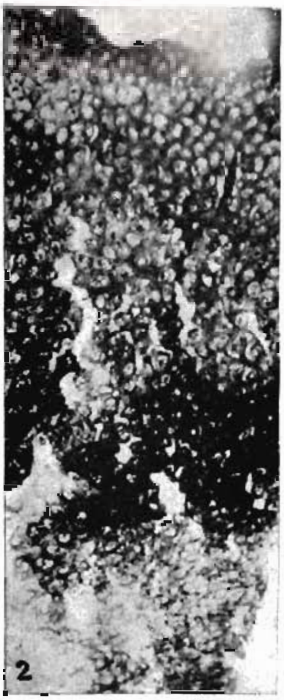
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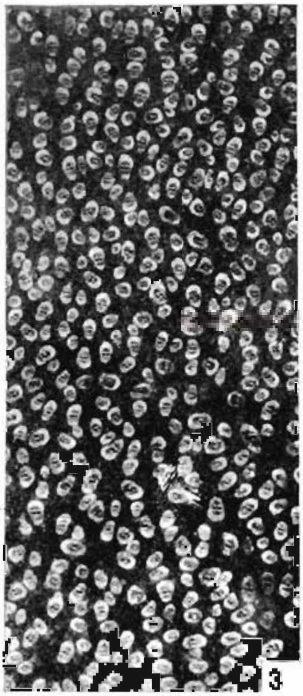
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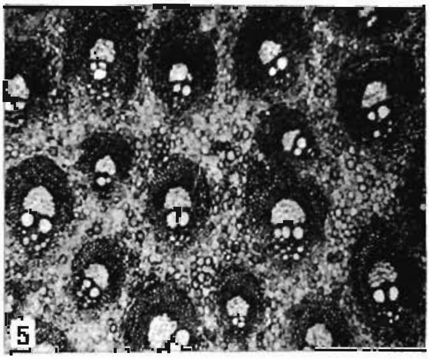
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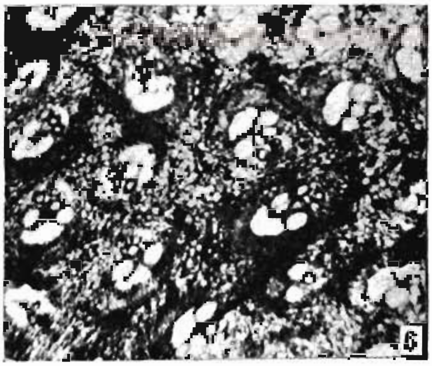
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PLATE 1

The Palaeobotanist, **32**(2): 140-145, 1984.

WOOD OF *BAUHINIA* FROM THE SIWALIK BEDS OF UTTAR PRADESH, INDIA

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ABSTRACT

A fossil wood of *Bauhinia*, *Bauhinium palaeomalabaricum* sp. nov., is being described from the Lower Siwalik beds of Kalagarh in Pauri Garhwal District. It resembles the modern taxon, *Bauhinia malabarica* Roxb. which is widely distributed in the deciduous forests of almost all the states of India and Burma. It also grows in the forests of the Siwalik Range.

Key-words — Xylotomy, *Bauhinium*, Lower Siwalik beds, Miocene (India).

सारांश

उत्तर प्रदेश (भारत) के शिवालिक संस्तरों से उपलब्ध बॉहीनिआ का काष्ठाश्म – उत्तम प्रकाश एवं महेश प्रसाद

पौढ़ी-गढ़वाल जनपद में कालागढ़ के अधरि शिवालिक संस्तरों से बॉहीनियम् मालाबारिकम् नामक काष्ठाश्म का वर्णन किया गया है। यह काष्ठाश्म बॉहीनिआ मालाबारिका रॉक्सबर्ग नामक वर्तमान वर्गक से समानता प्रदर्शित करता है जो कि बर्मा एवं भारत के प्रायः सभी प्रदेशों के पर्णपाती वनों में दूर-दूर तक पाया जाता है। इसके साथ-साथ यह शिवालिक श्रेणी के वनों में भी पाया जाता है।

INTRODUCTION

THE previous studies on the fossil flora of the Siwalik beds of Kalagarh in Pauri Garhwal District of Uttar Pradesh have revealed that there was a rich assemblage of plant taxa in this region during the Mio-Pliocene times. This consists of fossil woods of Leguminosae, Dipterocarpaceae, Anonaceae, Sterculiaceae, Anacardiaceae, Rosaceae, Combretaceae, Meliaceae and Ebenaceae (Trivedi & Misra, 1977, 1978, 1979; Trivedi & Ahuja, 1978a, 1978b, 1978c, 1979a, 1979b; Prakash, 1978, 1981; Awasthi, 1982). Further studies in this area have shown some more new fossil woods, one of which belongs to *Bauhinia* and is being described here. The fossil wood was collected from Nungarh Nala about 1.5 km ahead of a temple and is of black colour.

SYSTEMATIC DESCRIPTION

FAMILY — LEGUMINOSAE

Genus — *Bauhinium* Trivedi & Panjwani, 1983

Bauhinium palaeomalabaricum sp. nov.

Pl. 1, figs 1, 3; Pl. 2, figs 5-8

Material — The present species is based on a piece of decorticated secondary wood measuring about 10 cm in length and 8 cm in diameter. The preservation of anatomical structures is quite satisfactory.

Topography — *Wood* diffuse-porous. *Growth rings* indistinct. *Vessels* small to large, solitary as well as in radial rows of 2-7 (mostly 2-3) (Pl. 1, fig. 1) and 6-10 per sq mm, usually with rays contiguous on one or both the sides; tyloses absent, but vessels sometimes filled with brownish-black contents. *Parenchyma* paratracheal, confluent forming slightly sinuate, ragged, mostly continuous, concentric bands which alternate with somewhat broader bands of fibres (Pl. 1, fig. 1; Pl. 2, fig. 5); parenchyma bands 3-4 per mm and 3-9 (usually 4-6) cells thick; *xylem rays* fine, 1-2 (mostly 1) seriate, 18-52 μm in width, 4-32 cells or 132-720 μm in height and storied (Pl. 1, fig. 3; Pl. 2, fig. 6); ray tissue heterogeneous, consisting of homo- to heterocellular rays composed either of procumbent cells only or both upright and procumbent cells (Pl. 2, figs 6, 7); upright cells 1-2 (usually 1) rows at the ends (Pl. 2, fig. 7) or sometimes in the middle part of rays. *Fibres* not aligned in radial rows.

Elements — Vessels round to oval in shape when solitary, usually tangentially compressed due to pressure during fossilization (Pl. 1, fig. 1; Pl. 2, fig. 5); those in radial multiples flattened at the places of contact, t.d. 80-220 μm, r.d. 102-300 μm; vessel segments 152-750 μm in length with truncate ends and are irregularly storied; perforations simple; intervessel pit-pairs (Pl. 2, fig. 8) alternate, vestured, round to oval in shape, 6-8 μm in diameter with linear to lenticular apertures. *Parenchyma cells* thin-walled, 12-30 μm in diameter and 40-100 μm in length; parenchyma strands irregularly storied. *Ray cells* thin-walled, tangential height of procumbent cells 13-22 μm, radial length 30-65 μm; upright cells 24-40 μm in tangential height and 12-18 μm in radial length. *Fibres* libriform to semilibriform, usually moderately thick-walled (Pl. 2, figs 5-7), nonseptate, polygonal in cross section, 8-17 μm in diameter and 440-1364 μm in length; interfibre pits could not be seen. *Ripple marks* present due to storied arrangement of vessel members, parenchyma strands and xylem rays.

Affinities — Among dicotyledonous woods such anatomical features as small to large vessels, banded parenchyma, 1-2 seriate, storied xylem rays alongwith irregularly storied vessel segments and the parenchyma strands are found in the woods of the family Leguminosae (Chowdhury & Ghosh, 1946) where these features are known to occur in *Bauhinia*, *Millettia*, *Pterocarpus*, *Dialium*, *Swartzia*, *Dalbergia* and *Crabia*. Of these, *Pterocarpus*, *Dialium* and *Dalbergia* can easily be differentiated from the present fossil wood in having predominantly narrow bands of parenchyma and homogeneous to almost homogeneous xylem rays (Pearson & Brown, 1932, pp. 362, 363, 382, 383; Prakash, 1975, pp. 203, 204) in contrast to broader bands of parenchyma and heterogeneous xylem rays seen in the present fossil wood. Besides, the xylem rays are comparatively short in *Pterocarpus* and *Dalbergia*. The woods of *Millettia* also differ from this fossil wood in possessing mostly solitary vessels, broader xylem rays and almost straight and continuous bands of apotracheal parenchyma, whereas the vessels are commonly in multiples, the xylem rays are fine and the parenchyma bands are sinuate and paratracheal in the present fossil. Further, *Swartzia* and *Crabia* can be distinguished in having predominantly narrow bands of parenchyma and regularly arranged storied parenchyma strands and the vessel segments. However, the vessel segments and the parenchyma strands are somewhat irregularly storied in this Siwalik fossil wood, thus, it is with the modern wood of *Bauhinia* Linn. that the fossil wood shows a nearest affinity. After a critical examination of thin sections of extant woods of a large number of species of *Bauhinia*, it has been found that the present fossil exhibits a closest resemblance with the modern woods of *Bauhinia malabarica* Roxb. (F.R.I. Slide no. 6343). Our examination included the study of thin sections of the woods of *Bauhinia foveolata* Dalz., *B. malabarica* Roxb., *B. mirandina* Pittier, *B. purpurea* Linn., *B. racemosa* Lam., *B. reticulata* DC., *B. retusa* Ham. and *B. variegata* Linn. Besides, the published anatomical descriptions and photographs of *Bauhinia anguina* Roxb., *B. malabarica* Roxb., *B. purpurea* Linn., *B. racemosa* Lam., *B. retusa* Ham., *B. vahlii* W. & A., and *B. variegata* Linn. were also consulted (Moll & Janssonius, 1914, pp. 112-119, fig. 158; Pearson & Brown, 1932, pp. 417-425, figs 144-146; Metcalfe & Chalk, 1950, pp. 493-501; Gamble, 1972, pp. 280-284; Ramesh Rao & Purkayastha, 1972, pp. 64-68, pl. 72, figs 428-432; pl. 73, fig. 433).

Both the present fossil wood and *Bauhinia malabarica* Roxb. possess mostly medium to large vessels with similar distribution pattern, vestured intervessel pits, simple perforations, almost similar banded parenchyma, 1-2 (mostly 1) seriate, homo- to heterocellular xylem rays with storied arrangement, libriform to semilibriform and nonseptate fibres and ripple marks due to storied rays, vessel segments and the parenchyma strands.

In 1964-65 Rawat recorded a fossil wood of *Bauhinia* from the Siwalik beds of Mohand, District Saharanpur, Uttar Pradesh and named it as *Bauhinioxylon indicum* gen. et sp. nov. But because no description and figures have been given by the author, it has become an invalid publication vide Article 38 of the International Code of Botanical Nomenclature. Later, another fossil wood comparable to *Bauhinia* is also known from the Cuddalore Series of South India but no generic name was assigned to this fossil wood (Ramanujam & Rao, 1966). Recently, Trivedi and Panjwani (1983) instituted an organ genus *Bauhinium* to include the fossil woods of *Bauhinia* and described *Bauhinium miocenicum* from the Siwalik beds of Kalagarh. However, it can be differentiated from the present fossil in having medium-sized vessels (t.d. 132-176 µm), somewhat narrow parenchyma bands (2-6 seriate) and 1-3 (mostly 2) seriate xylem rays with 1-3 marginal rows of upright cells in contrast to small to large vessels (t.d. 80-220 µm), thick parenchyma bands (3-9 seriate) and 1-2 (usually 1) seriate rays with 1 or rarely 2 rows of upright cells present in our fossil wood. Further, the fossil wood described by Ramanujam and Rao (1966) as *Bauhinia* differs from this fossil in possessing predominantly medium-sized (t.d. 125-175 µm), solitary to sometimes paired vessels and short, 10-20 cells high rays as against small to large (t.d. 80-220 µm) and solitary as well as radial multiples of 2-7 (usually 2-4) vessels. However, from the anatomical description and figures given by the authors (Ramanujam & Rao, 1966, p. 376, figs 1-3) it appears that this Cuddalore fossil wood might belong to *Millettia*. Because the present fossil is quite different from so far known fossil woods of *Bauhinia* it is therefore being described here as a new species of *Bauhinium* Trivedi & Panjwani (1983) and named as *Bauhinium palaeomalabaricum* sp. nov., the specific name indicating a precursor of *Bauhinium malabarica* Roxb. with which it shows a close resemblance in wood structure.

Bauhinia Linn. consists of 300 species of shrubs and trees, widely distributed throughout the tropics of the world (Ramesh Rao & Purkayastha, 1972, p. 64; Willis, 1973, p. 127) and about 30 species occur in India and Burma (Brandis, 1971). *Bauhinia malabarica* Roxb. with which the present fossil wood resembles closely is a moderate sized tree occurring from Ravi eastward to Assam through the Himalaya. It also grows in Bengal, the Central Provinces, Gujarat, Bihar, Orissa and west coast down to South India, and in mixed forests of Pegu Yomas and South Burma (Pearson & Brown, 1932).

SPECIFIC DIAGNOSIS

Bauhinium palaeomalabaricum sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* mostly medium to large, solitary as well as in radial multiples of 2-7 (mostly 2-3), t.d. 80-220 µm, r.d. 102-300 µm, 6-10 per sq mm, sometimes plugged with dark to brown gummy deposits; vessel members 152-750 µm in length with truncate ends, irregularly storied; perforations simple; intervessel pit-pairs alternate, vestured, 6-8 µm in diameter with linear to lenticular apertures. *Parenchyma* confluent, banded, bands slightly sinuate, ragged, 3-9 (usually 4-6) cells thick, running in concentric arrangement, 3-4 per mm, alternating with somewhat broader bands of fibres; parenchyma strands irregularly storied. *Xylem rays* 1-2 (mostly 1 seriate), 18-52 µm in width, 4-32 cells or 132-720 µm in height and storied; ray tissue heterogeneous consisting of homo- to heterocellular rays composed either of procumbent cells only or both upright and procumbent cells; upright cells usually in one row at the ends or sometimes in the middle part of the rays. *Fibres* libriform to semilibriform, moderately thick-walled, polygonal in cross section, nonseptate, 8-17 µm in diameter and 440-1364 µm in length; interfibre pits not seen. *Ripple marks* present due to storied arrangement of xylem rays, vessel segments and parenchyma strands.

Holotype — Birbal Sahni Institute of Palaeobotany Museum specimen no. 35534.

Locality — Kalagarh, District Pauri Garhwal, Uttar Pradesh.

Age — Lower Siwalik (Middle Miocene).

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATES

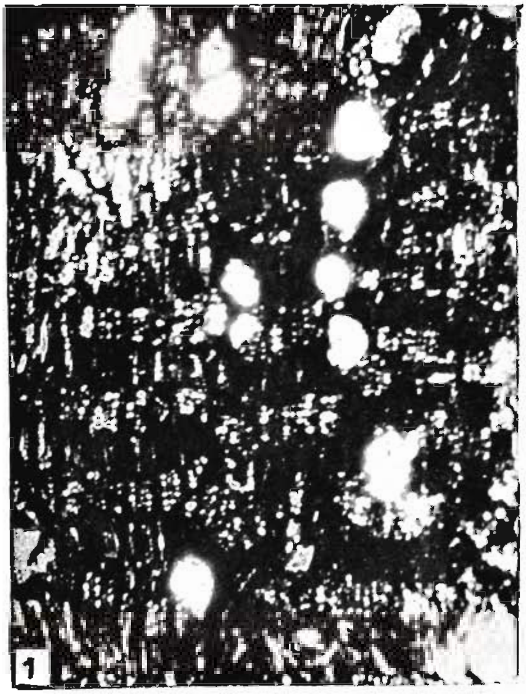
Bauhinium palaeomalabaricum sp. nov.

PLATE 1

1. *Bauhinium palaeomalabaricum* sp. nov. — Cross section in low power showing vessel distribution and banded parenchyma. × 35; B.S.I.P. slide no. 7037.
2. *Bauhinia malabarica* — Cross section of the modern wood showing similar shape, size and distribution of vessels and the parenchyma pattern. × 35.
3. *Bauhinium palaeomalabaricum* sp. nov. — Tangential longitudinal section showing storied xylem rays. × 50; B.S.I.P. slide no. 7038.
4. *Bauhinia malabarica* — Tangential longitudinal section of the modern wood showing similar xylem rays. × 50.

PLATE 2

5. *Bauhinium palaeomalabaricum* sp. nov. — Cross section magnified to show the nature and distribution of vessels and parenchyma. × 45; B.S.I.P. slide no. 7039.
6. *B. palaeomalabaricum* sp. nov. — Tangential longitudinal section magnified to show the nature of xylem rays. × 100; B.S.I.P. slide no. 7040.
7. *B. palaeomalabaricum* sp. nov. — Radial longitudinal section showing heterocellular xylem rays. × 100; B.S.I.P. slide no. 7041.
8. *B. palaeomalabaricum* sp. nov. — Magnified intervessel pit-pairs. × 530; B.S.I.P. slide no. 7042.
9. *Bauhinia malabarica* — Magnified intervessel pit-pairs showing similar pits and apertures as in the fossil (fig. 8). × 530.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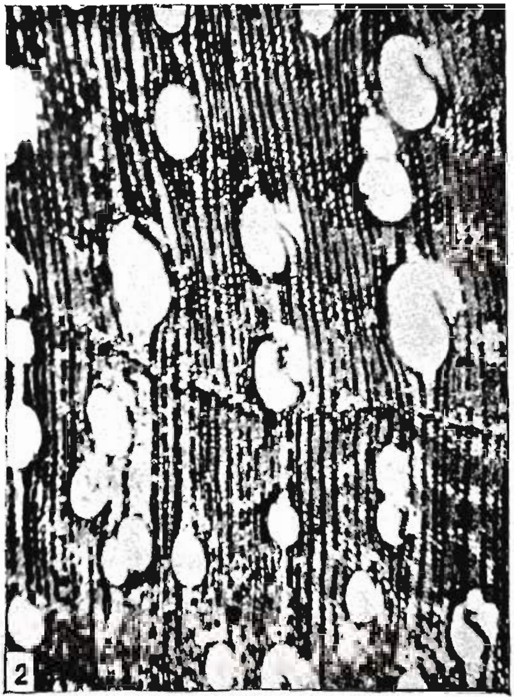
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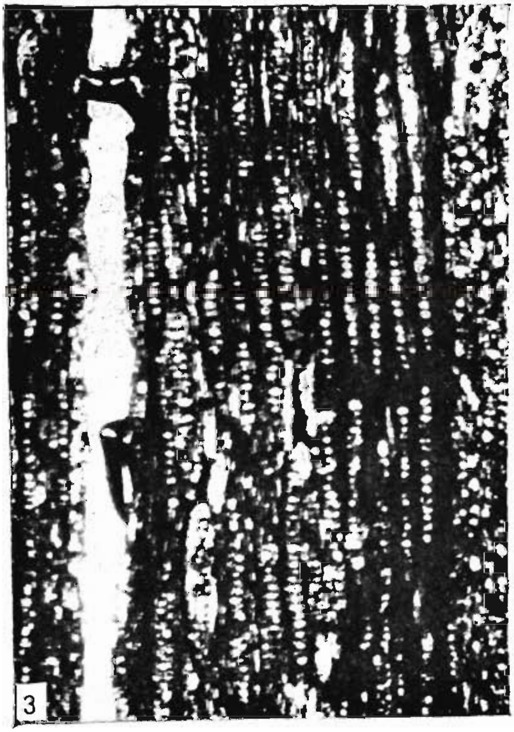
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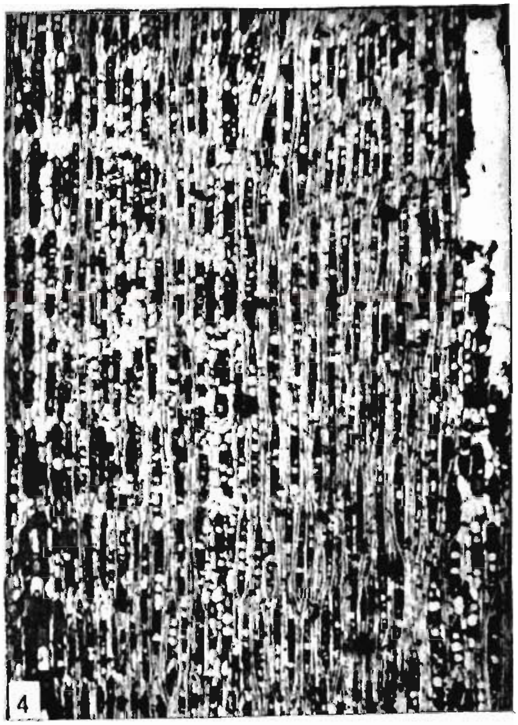
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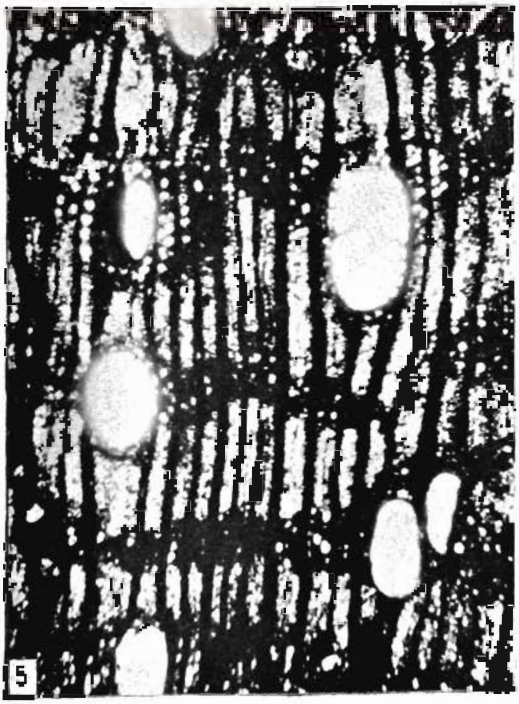
Plate 1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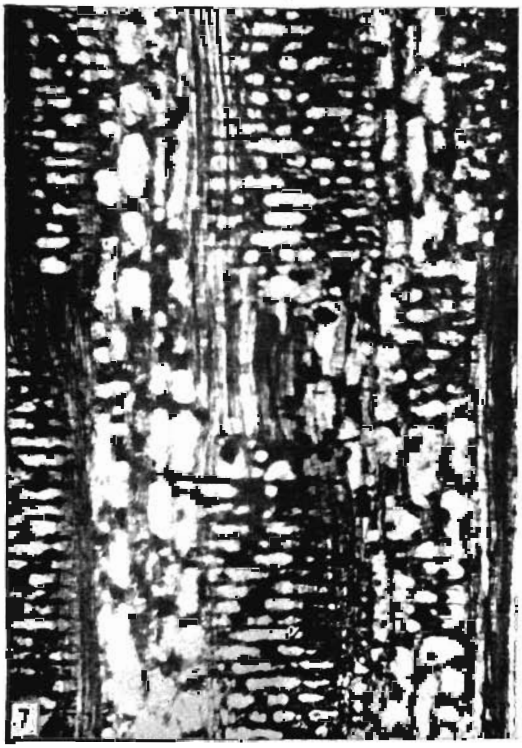
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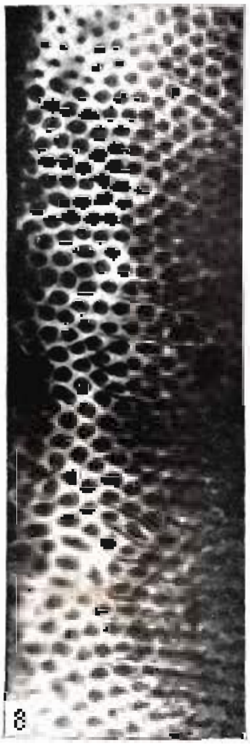
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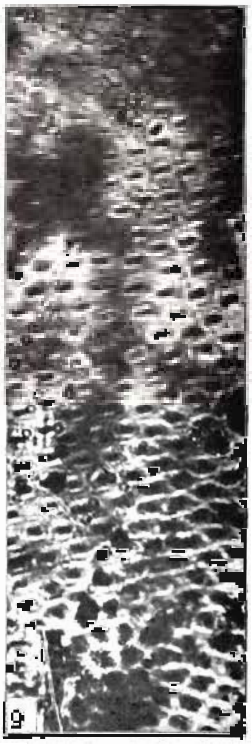
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PLATE 2

The Palaeobotanist, **32**(2): 146-152, 1984.

REAPPRAISAL OF *FERMORIA* AND ALLIED REMAINS FROM THE SUKET SHALE FORMATION, RAMAPURA

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ABSTRACT

Fermoria and other allied remains described earlier have been restudied critically. The observations suggest that all the Indian forms, viz., *Fermoria*, *Krishnania acuminata*, *Tawuia* and *Vindhyania* are morphologically alike and similar to the genus *Chuaria* Walcott, but they are distinct at specific level.

Key-words — *Fermoria*, *Chuaria*, Suket Shale Formation, Precambrian (India).

साराँश

सुकेत शैल से उपलब्ध फ़र्मोरिया एवं समवंशी अवशेषों का पुन: आकलन – प्रभात कुमार माइती एवं मनोज शुक्ला

फ़र्मोरिया एवं अन्य समवंशीयों के पूर्व वर्णित अवशेषों का पुन: अध्ययन किया गया है जिससे यह इंगित होता है कि फ़र्मोरिया, कृष्णानिआ ऍक्यूमिनेटा, तवुइया एवं विन्ध्यानिया नामक सभी भारतीय प्रारूप बाह्य-आकारिकीय दृष्टि से एक-सदृश हैं तथा चुआरिआ वाल्कोट से मिलते-जुलते हैं। परन्तु जातीय स्तर पर ये एक दूसरे से भिन्न हैं।

INTRODUCTION

JONES in 1909 (in Holland, 1910) first recorded small carbonised horny concentrically wrinkled discs in the Suket Shale near Ramapura. Examination of the collections made by several workers, viz., Chapman (1935), Sahni (1935), Ghare and Badve (1978) have led considerable divergence of opinion whether they are organic or inorganic, and if organic then whether they are animal or plant remains comparable to *Chuaria* Walcott. The present study has been carried out especially to assess the different shapes of discs and their possible biological affinities.

The present observation is based on the material collected by Bharadwaj and Verma in 1956 from the Suket Shale Formation, Ramapura, Madhya Pradesh. The collection comprises carbonised compressions and impressions of discs showing different shapes and wide size range. Carbonised specimens were first studied on the rock surface in incident light and then they were encircled by wax for isolation from rock. To isolate the discs from rocks hydrofluoric acid was poured in the enclosed area. The discs after becoming loosend from the rock matrix were picked up, subsequently cleared and mounted in glycerine jelly. About 100 discs have been measured at random for size variation. Measurements of discs were also taken to understand the size frequency distribution both from the yellow and black shales separately. All the figured specimens are preserved in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION

Genus — *Chuaria* Walcott, 1899

Genotype — *Chuaria circularis* Walcott, 1899.

Chuaria minima Chapman, 1935 emend.

Pl. 1, figs 1-10

Synonymy:

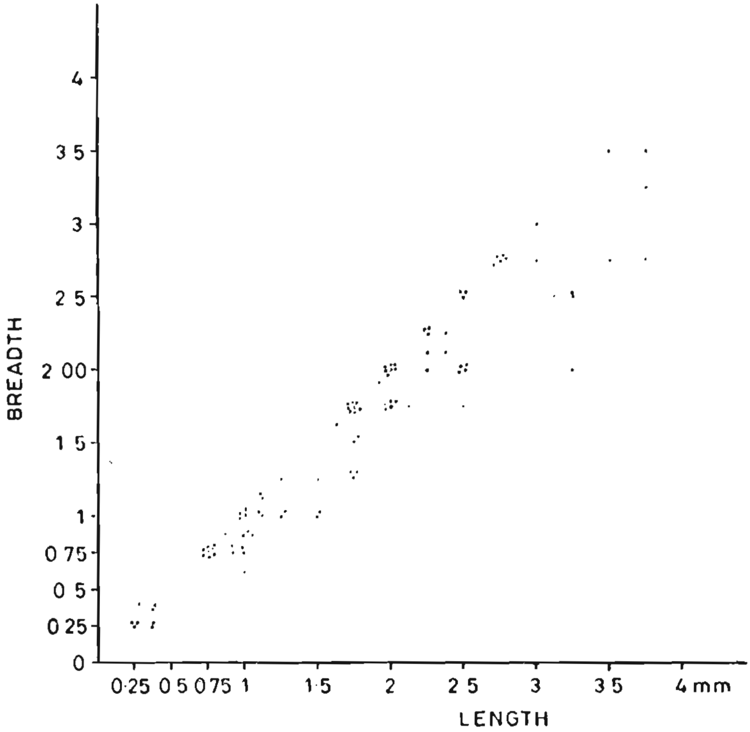
1909 Discinoid discs Jones.
1935 *Fermoria minima* Chapman, p. 115, pl. 1, figs 1, 3.

1935 *Fermoria granulosa* Chapman, p. 116, pl. 1, figs 2, 4; pl. 2, fig. 5.
1935 *Fermoria capsella* Chapman, p. 117, pl. 2, figs 3, 4.
1935 *Protobolella jonesi* Chapman, p. 117, pl. 1, figs 5, 6; pl. 2, fig. 1.
1936 *Fermoria minima* Chapman: Sahni, p. 466, pl. 43, figs 1-4.
1936 *Vindhyanella jonesi* Sahni, p. 467.
1952 Broadly ovoid form: Misra & Dube, p. 48, fig. 2.
1952 Egg-shaped form: Misra & Dube, p. 48, fig. 3.
1952 Semi-ovoid, tapering towards one end: Misra & Dube, p. 48, fig. 4.
1952 Kidney-shaped form: Misra & Dube, p. 48, fig. 5.
1952 Cluster of discs: Misra & Dube, p. 48, fig. 6.
1952 Almond-shaped form: Misra & Dube, p. 48, fig. 7.
1952 Circular form: Misra & Dube, fig. 1.
1954 *Krishnania acuminata* Sahni & Srivastava, p. 40, fig. 4.
1957 Circular form (*Fermoria* spp. Chapman): Misra, p. 56, pl. 7, fig. 1.
1957 Broadly ovoid form: Misra, pl. 7, fig. 2.
1957 Almond-shaped form: Misra, pl. 7, fig. 3.
1957 Semi-ovoid form tapering towards one end (*Krishnania acuminata* Sahni & Srivastava): Misra, pl. 7, fig. 4.
1957 Kidney-shaped form: Misra, pl. 7, fig. 5.
1962 *Fermoria* Chapman: Hantzschel, p.W. 240, figs 148, 4.
1962 *Krishnania* Sahni & Srivastava: Hantzschel, p.W. 241.
1973 *Chuaria circularis* Walcott: Ford & Breed (Indian specimen), pp. 539-540.
1975 *Krishnania* Sahni & Shrivastava (*K. acuminata*): Hantzschel, p.W. 185.
1975 *Protobolella* Chapman: Hantzschel, p.W. 187, figs 108, 4; 107, 5.
1977 *Chuaria circularis* Walcott (Indian forms): Hofmann, p. 7.
1977 Disc-like remains — Type-1, Maithy & Shukla, p. 183, pl. 5, fig. 37.
1977 Disc-like remains — Type-2, Maithy & Shukla, p. 183, pl. 5, fig. 35.
1977 Disc-like remains — Type-3, Maithy & Shukla, p. 183, pl. 5, fig. 36.
1977 Disc-like remains — Type-4, Maithy & Shukla, p. 183, pl. 5, fig. 38.
1977 Disc-like remains — Type-5, Maithy & Shukla, p. 183, pl. 5, fig. 39.
1977 Disc-like remains — Type-6, Maithy & Shukla, p. 183, pl. 5, fig. 40.
1977 *Fermoria minima* Chapman: Sahni, pl. 1, figs 1-6; pl. 2, figs 1-4; pl. 3, figs 1, 2.
1977 *Krishnania acuminata* Sahni & Srivastava: Sahni, pl. 3, fig. 3.
1978 *Chuaria circularis* Walcott: Ghare & Badve, p. 34, pl. 1, figs 1-4, text-figs 1-6.
1979 *Chuaria circularis* Walcott: Ghare & Badve, p. 91, pl. 7, figs 1, 2; pl. 8, figs 3,4.
1982 *Chuaria circularis*: Mathur, p. 128, fig. 3A.
1982 *Chuaria fermorei* Mathur, p. 128.
1982 *Morania antiqua*: Mathur, p. 128.
1982 *Tawuia suketensis* Mathur, p. 128, fig. 3B.
1982 *Tawuia rampurensis* Mathur, p. 128.
1982 *Vindhyania jonesii* Mathur, p. 129, fig. 3C.

Emended Diagnosis — Platyspermic discs, when solitary circular or oval in shape; when in groups almond or elongate oval shape, disc diameter 0.25-3.5 mm; surface smooth or with thickenings; thickenings either in the form of concentric rings on margin or irregular folds of varying patterns. Isolated discs confirm the compression outline; exine structure smooth to finely intrapunctate (comparable to cryptarch genus *Orygmatosphaeridium* Timofeev).

Holotype — K. 21/360 Geological Survey of India.

Description — Discs are either preserved in the form of impressions on yellow colour shales or carbonised compressions on greyish-black colour shales. At times discs with different shapes, i.e. circular, oval and elongate-oval are found closely packed together at one place on the rock (Pl. 1, fig. 1). The size of discs vary from 0.25 to 3.5 mm. At random measurements of 100 discs show that there is a distinct relationship between the shape of discs and increase in size. The smaller forms are circular in outline whereas the oval forms are bigger in size (see Text-fig. 1). The different type of surface thickenings preserved on the specimens can be observed in impressions (Pl. 1, figs 3, 4) and also on isolation of specimens from rock. Isolated specimens show several fine microfolds or concentric thickenings on the margin. Specimens are also with irregular folds or with two to three thick vertical



TEXT-FIG. 1 — Showing size variations of discs to show their circular to oval tendencies.

folds (Pl. 1, fig. 5). These different shapes and fold patterns of discs may have formed either due to drying of specimens by the loss of aqueous media before fossilization or may be due to pressure of sediments during fossilization.

Often 4 or more discs are preserved together in a linear row to form a single oval mass, measuring 4-6 mm in length (Pl. 1, fig. 6). Similar specimens have also been described by Hoffmann (1977, p. 10, fig. 2a) from Red Pine Shale. In view of their linear alignment and nearly equal size, Hofmann (1977) considered it to be a case of consangunity, i.e. the original uncompressed spheroids were the part of single colonial strand of bead-like cells which remained intact even after burial.

All the discs of different shapes and size on isolation from rock show identical exine structure. Exine in well-preserved specimens is thin, laevigate with intrapunctate structure (Pl. 1, figs 7, 19, 10) comparable to cryptarch genus *Orygmatosphaeridium* Timofeev.

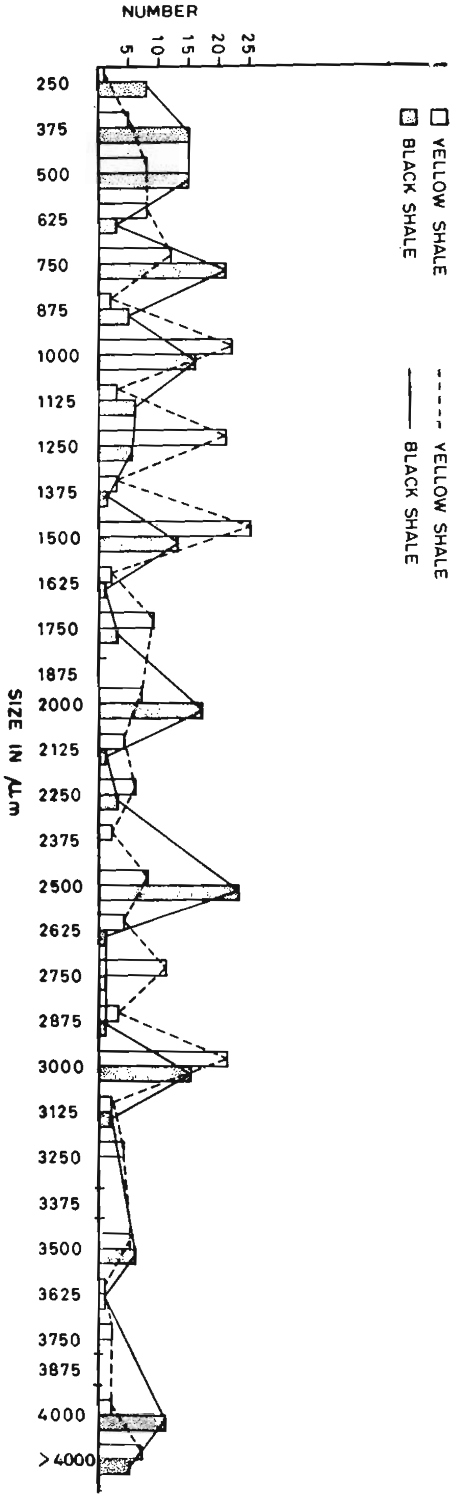
The distorted specimens show secondary thickenings on the surface, as a result the original exine pattern of specimens gets distorted. This distortion may even give rough appearance to surface or irregular reticulate ornamentation (Pl. 1, fig. 8).

Size frequency distribution — In all, 200 samples each from the yellow and black shales were measured at random for size frequency distribution. Their variations in size with number of specimens have been plotted (Text-fig. 2). The present study supports the observations made by Ghare and Badve (1978) that the large size specimens dominate in black shale while the smaller size ones are common in yellow shales. Furthermore, no morphologic distinction could be marked in the specimens belonging to different lithologies.

Comparison and Discussion — Much controversy remained eversince the discovery of these discs from the Suket shales, Ramapura. In 1909, Jones (in Holland, 1910) first reported the discinoid discs and suggested that they may agree with the genus *Obolella* or *Chuaria circularis* described by Walcott from the Pre-Cambrian rocks of Arizona or possibly the operculum of *Hyoloithellus*. Walcott and Resser (1927) opined that the markings represent true fossils closely comparable with brachiopod genus *Acrothele* from the Cambrian. Howell (1926) (in Heron, 1936) suggested them to be the plant remains, considering the fact that the shiny film of fossil which is evidently the only part of organism now remains glowing and burns to grey ash on heating. Chapman (1935) postulated them to be equivalent to protegulum stage of atrematous and neotrematous brachiopods somewhat allied to primitive genera like *Mickwitca*, *Micromitra*, *Obolus* and *Acrothele*. Considering this he created two new genera *Fermoria* and *Protobolella*. Sahni (1936) completely re-examined Chapman's collection and observed "Although the circular outline vaguely reminds one of the primitive obolillids or related forms, this evidence is unsupported by any other, which places beyond dispute the brachiopod affinities of these fossils" (p. 464). He considered all of them to be only one species of *Fermoria*, i.e. *F. minima* and suggested that the genus *Fermoria* be placed in a family by itself for which the name 'Fermoriidae' was proposed. The affinities of this new family were left undetermined till further evidences could be available.

Misra and Dube (1952) heated thin slices of shale bearing the discs as well as isolated discs on a platinum foil in an electric muffle furnace at a temperature of 900°C. The discs remained as such except the change in colour, i.e. they became red as if only oxidized. The chemical examination of discs showed the absence of phosphate and presence of iron and manganese in small amounts. On the basis of these observations they concluded that the discs are inorganic in nature, i.e. an example of colloidal precipitation of mineral matter. This has been further supported by Misra (1957).

In 1954, Sahni and Shrivastava recorded circular discs intimately associated with broad filaments and considered them to be



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TEXT-FIG. 2 — Showing the size variations in discs both from black and yellow shales.

algal in nature, possibly the spore sacs. In the same paper they instituted a new genus *Krishnania*. The figured specimen (fig. 4) is incomplete and broken on one side. It is oval in outline, roundly acute apex with two distinct vertical folds comparable to the figured specimen in Pl. 1, fig. 5; while describing this form the authors remarked on p. 39 " a new genus which we propose to name *Krishnania* probably related to *Fermoria* ". The present study demonstrates that the oval shape of the specimen is only a preservational feature. Therefore *Krishnania* as such is considered to be the junior synonymn to *Chuaria minima*.

Pascoe (1959, p. 498) commented that *Fermoria* left a white ash when incinerated and was therefore a plant, but at the same time he felt that *Fermoria* could be an archaic form of brachiopod though with ' no reliable feature definitely attributable to this class. Glaessner (1966, p. 41) was non-committal and placed both *Fermoria* and *Chuaria* under some other algae. Two years later Cloud (1968) also listed *Fermoria* as possible alga. Thereafter, Ford and Breed (1973, p. 540) considered *Fermoria* to be synonymous to *Chuaria* Walcott. Furthermore, on the basis of isolated specimens, they considered them to be acritarch belonging to subgroup ' Sphaeromorphitae '. On the other hand, Hoffmann (1977) opined that the form genus *Chuaria* most likely comprises a variety of biological groups including planktonic algae and possibly medusoids. On the basis of their studies on the Suket Shale Formation Maithy and Shukla (1977) opined that the disc-like bodies are either impressions of acritarcha or the algal colonies. Sahni (1977) also considered that the placement of *Fermoria* under *Chuaria* is an erroneous assignation. Ghare and Badve (1978) on the basis of their observations on discs from the Suket Formation, Ramapura, considered them to be identical to *Chuaria circularis* Walcott.

Recently, Mathur (1982) reported *Chuaria circularis*, *C. fermorei* sp. nov., *Morania antiqua*, *Tawuia suketensis* sp. nov., *T. rampurensis* sp. nov. and *Vindhyania jonessi* gen. et sp. nov. from the Suket Shale, Ramapura. This paper gives poor photographs showing *Chuaria circularis* (3A), *Tawuia suketensis* sp. nov. (3B) and *Vindhyania jonesii* sp. nov. (3C) without any details and diagnosis. *V. jonesii* is an ill-preserved form and in the absence of diagnosis and other details it is nomen nudum. *Tawuia suketensis* is an oval form with 3-4 circular discs arranged closely in a linear fashion as figured in Pl. 1, fig. 6. Hence, it is a synonym to *Chuaria minima* emend.

Thus on the basis of present study it can be summarized that (i) *Fermoria* and other allied Indian forms agree morphologically to the genus *Chuaria* Walcott, but the Indian forms are distinct at specific level; (ii) they are biogenic in origin and resemble morphologically to cryptarch genus *Orygmatosphaeridium* Timofeev on isolation from rock; and (iii) the different shapes of discs from Ramapura belong to a single genus and a single species as evident from their exine pattern and size frequency distribution. The fold patterns and different shapes are the preservational features.

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EXPLANATION OF PLATE

Chuaria minima (Chapman) emend.

1. Several specimens of circular to oval discs on rocks. B.S.I.P. specimen no. 27252/273. × 6.

2-4. Circular discs showing variation in the width of marginal thickenings. B.S.I.P. specimen nos. 25265/274. × 12; 25198A/273. × 16; 26175/273. × 12.

5. Oval impression with two vertical thickenings. B.S.I.P. specimen no. 25230/273. × 12.

6. Elongate-oval form composed of 4-6 discs preserved adjacent to each other. B.S.I.P. slide no. 6971/27052. × 15.

7. An isolated specimen showing folds on margin and intrapunctate exine. B.S.I.P. slide no. 6972/27502. × 70.

8. Poorly preserved specimen; exine showing coarse reticulare pattern. B.S.I.P. slide no. 6973/26280. × 30.

9 & 10. Portion of isolated discs enlarged to show intrapunctate structure and varying fold pattern. B.S.I.P. slide nos. 6974/26527, 6975/27806. × 150.

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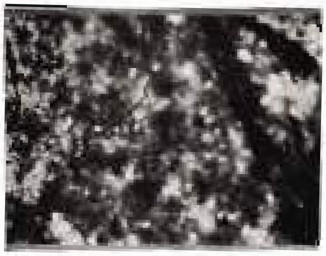

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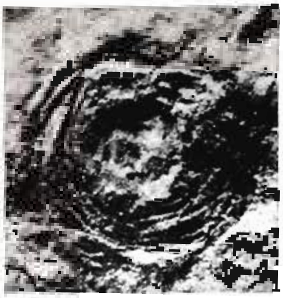

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PLATE 1

The Palaeobotanist, **32**(2): 153-157, 1984.

TWO NEW POLLEN GENERA FROM THE LOWER TERTIARY SEDIMENTS OF MEGHALAYA, INDIA

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ABSTRACT

Two new pollen genera, viz., *Collospermumpollis* and *Densiverrupollenites* have been established. The genus *Collospermumpollis* has been recovered from the Palaeocene sediments of Therria Formation, Jaintia Hills, Meghalaya and seems to have liliaceous affinity. The genus *Densiverrupollenites* has been described from the Upper Eocene sediments of the Kopili Formation, Jaintia Hills, Meghalaya. Its botanical affinity is uncertain.

Key-words — Palynology, *Collospermumpollis*, *Densiverrupollenites*, Lower Tertiary, India.

सारांश

मेघालय (भारत) के अधरि तृतीयक युगीन अवसादों से प्राप्त दो नवीन परागकण वंश – सूर्यकान्त मणि त्रिपाठी
एवं हरीपाल सिंह

इस शोध-पत्र में कोलोस्पर्मम्पॉलिस एवं डेन्सीवेरुपॉलिनाइटिस नामक दो नवीन परागकण वंश बनाये गये हैं। कोलोस्पर्मम्पॉलिस वंश मेघालय की जयन्तिया पहाड़ियों के थैरिया शैल-समूह के पुरानूतन कालीन अवसादों से उपलब्ध हुआ है तथा लिलिएसी कुल से सजातीयता व्यक्त करता है। डेन्सीवेरुपॉलिनाइटिस वंश जयन्तिया पहाड़ियों के कोपिली शैल-समूह के उपरि आदिनूतन अवसादों से वर्णित किया गया है तथा इसकी वनस्पतिक सजातीयता अभी सुनिश्चित नहीं हो पाई है।

INTRODUCTION

A DETAILED palynostratigraphical work on the Palaeocene-Eocene sediments of Meghalaya revealed the presence of two new pollen genera, viz., *Collospermumpollis* and *Densiverrupollenites*. Both these genera have been studied morphologically, illustrated and compared with the other comparable fossil pollen genera. The pollen grains of *Collospermumpollis* occur in the lower part of the Therria Formation (Palaeocene). This formation is exposed along the road cuttings near Jowai in the south-east of Shillong. Morphologically pollen grains of *C. laevigatus* are closely comparable to those of the extant form *Collospermum microspermum* (Cranwell, 1953).

The genus *Densiverrupollenites* has been recovered from upper part of the Kopili Formation (Upper Eocene). The sediments of this formation are also exposed along the Jowai-Badarpur road between Jowai and Sonapur, Jaintia Hills, Meghalaya. It has been difficult to surmise any exact botanical affinity to the pollen grains of *Densiverrupollenites*.

SYSTEMATIC DESCRIPTION

Anteturma — *Pollenites* Potonié, 1931
Turma — *Plicates* (Naumova) Potonié, 1960
Infraturma — *Monoptyches* (Naumova) Potonié, 1958

Genus — *Collospermumpollis* gen. nov.

Type species — *Collospermumpollis laevigatus* sp. nov.

Diagnosis — Pollen grains semicircular to semiovoidal; monocolpate, colpus widely open, long; sexine as thick as nexine, sexine smooth, nexine indistinctly structured to punctate.

Comparison — *Liliacidites* Couper (1953) is distinctly different from the present genus in having reticulate ornamentation. *Liliapollis* Krutzsch (1970) possesses crotonoid to columellate sculpture of the exine and is non-tectate. *Palmidites* Couper (1953) is elliptical to oval in shape and possesses narrower colpus. *Monosulcites* Cookson (1947) is smaller in size, oval in shape and generally has smooth exine. *Arecipites* Wodehouse (1933) is elliptical to elongate-oval in shape, smaller in size and possesses a reticulate exine without having clavae or baculae in optical section. *Pinjoriapollis* Saxena & Singh (1981) is elliptical to lanceolate in shape, heteropolar and bigger in size.

Collospermumpollis laevigatus sp. nov.

Pl. 1, figs 7-10; Text-fig. 1

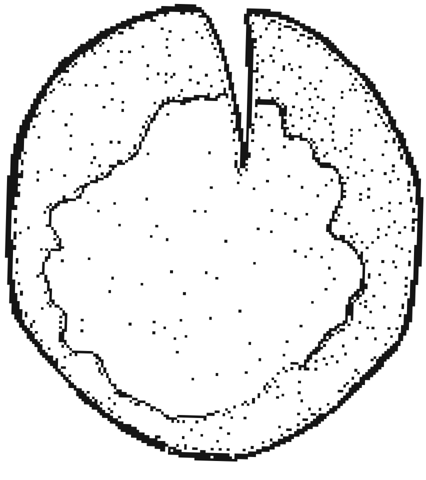
Holotype — Pl. 1, fig. 8, slide no. 6948.

Type Horizon — Therria Formation.

Type Locality — At 79.5 km from Shillong on Shillong-Badarpur Road, Meghalaya.

Diagnosis — Pollen grains semicircular to semioval; monocolpate, colpus distinct, widely open, sexine as thick as nexine, sexine laevigate, nexine indistinctly structured, often appearing punctate.

Description — Pollen grains semicircular to semioval in shape, some specimens exhibiting unequally broad lateral ends, size 86-79-140 × 110 µm (holotype 120 × 110 µm). Monocolpate. Colpus distinct, wide, ± parallel to the margin of pollen. Exine 1.5-3 µm thick, sexine and nexine almost equally thick, sexine apparently laevigate, nexine indistinctly structured, sometimes punctate.



Text-fig. 1 — *Collospermumpollis laevigatus* gen. et sp. nov.

Occurrence — Lower-Middle part of Therria Formation (Palaeocene), Meghalaya.

Affinity — Monosulcate pollen grains are mostly met within the families Amaryllidaceae, Iridaceae, Liliaceae and Palmae, where the colpus is generally not very wide. However, *Collospermumpollis laevigatus* gen. et sp. nov. can be compared with the pollen grains of extant plant *Collospermum microspermum* (Liliaceae). Pollen grains of this plant measure up to 48 µm in size, and have a widely open colpus with distinctly smooth exine (Cranwell, 1953, fig. 51).

Collospermumpollis (Venkatachala & Kar, 1969) *ellipticus* comb. nov.

1969 *Liliacidites ellipticus* Venkatachala & Kar, pl. 1, fig. 13.

Holotype — Venkatachala & Kar, 1969, Pl. 1, fig. 13.

Diagnosis — As published by Venkatachala & Kar, 1969.

Remarks — Venkatachala and Kar (1969) reported *Liliacidites ellipticus* with the following diagnosis: "Pollen grains oval-elliptical in shape, 30-43 × 25-38 µ. Sulcus broad and ± boat-shaped, exine finely intra-microreticulate". Thus it is clear from the diagnosis of *L. ellipticus* that its sexine is smooth, whereas the nexine is micro-reticulate. Hence it has been transferred to *Collospermumpollis*.

Infraturma — *Prolati* Erdtman, 1943

Genus — *Densiverrapollenites* gen. nov.

Type Species — *Densiverrapollenites emenisis* sp. nov.

Diagnosis — Pollen grains spheroidal to subspheroidal in polar view; tricolporate, apertures subequatorially placed, brevicolpate, ora circular to slightly lalongate; exine ornamentation verrucae beset with gemmae.

Comparison — *Foveospollenites* Raatz (1937) is spherical and tricolporate, but the pores in it are rounded and equatorially placed. It has intragranulose to intrabaculate exine ornamentation. *Nyssapollenites* Thiergart (1937) is tricolporate but has intrapunctate exine and subtriangular shape. *Vitipites* (Wodehouse) Potonié (1960) and *Rhamnacidites* (Chitaley) Potonié (1960) possess long and narrow colpi. *Hippocrateaceaedites* Ramanujam (1966) is subtriangular, trizonicolporate and the sexine bears knob-like processes on both the sides of the colpus. *Trilatiporites* Ramanujam (1966) exhibits subequatorial pores but lacks colpi. *Psilatricolporites* v.d. Hammen (1956) is trizonicolporate, but in the present genus the colpi are very long and exine is psilate. *Lakiapollis* Venkatachala & Kar (1969) is tribrevicolporate and possesses laevigate to indistinct exine. *Tricolporopollis* Dutta & Sah (1970) is also tribrevicolporate but it exhibits reticulate to foveolate exine ornamentation. *Verrucolporites* Sah & Kar (1970) is tricolporate but possesses smaller size range and longer colpi. *Pellicieroipollis* Sah & Kar (1970) is smaller in size, triangular to subtriangular in shape (polar view), tegillate and possesses baculate ornamentation.

Densiverrupollenites eocenicus sp. nov.

Pl. 1, figs 1-6; Text-fig. 2

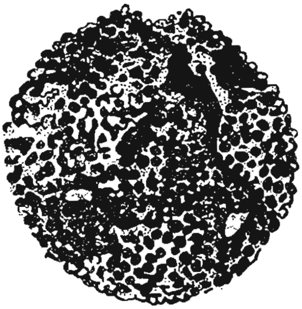
Holotype — Pl. 1, fig. 3; slide no. 6958.

Type Horizon — Kopili Formation.

Type Locality — At 133 km from Shillong on Shillong-Badarpur Road, Meghalaya.

Diagnosis — Pollen grains spheroidal to subspheroidal; tricolporate, brevicolpate; apertures subequatorially placed; exine 1.5-2.5 μm thick, sexine as thick as nexine, verrucate to gemmate, verrucae and gemmae very closely placed.

Description — Pollen grains spheroidal to subspheroidal in shape. Size 75-95 μm (holotype 78 μm). Tricolporate, brevicolpate, apertures subequatorially placed. Colpi lalongate, 8-10 μm long, mostly distinct. Ora distinct, circular to slightly lalongate, margin of ora thickened. Exine 1.5-2.5 μm thick, sexine as thick as nexine, ornamented with gemmae or verrucae. Gemmae 1-2 μm high, rounded and 2-3 μm wide. Verrucae and gemmae may be present on the same specimen. The verrucae or gemmae very closely placed giving an appearance of a negative reticulum in surface view.



TEXT-FIG. 2 — *Densiverrupollenites eocenicus* gen. et sp. nov.

Occurrence — Upper part of Kopili Formation (Upper Eocene), Meghalaya.

Affinity — Uncertain.

DISCUSSION

Both the genera, *Collospermumpollis* and *Densiverrupollenites*, besides being distinct morphologically are of stratigraphical importance as well. The former is associated with the Palaeocene sediments whereas the latter is identified with the Upper Eocene sediments. Some of the other important Palaeocene marker genera like *Couperipollis*, *Assamialetes*, *Liliacidites*, *Proxapertites*, *Palmidites* and *Dandotiaspora* have also been found in the *Collospermum* assemblage. Likewise, the occurrence of Upper Eocene genera, viz., *Striatriletes*, *Lakiapollis* and *Homotryblium* in association with *Densiverrupollenites* supports its stratigraphical importance.

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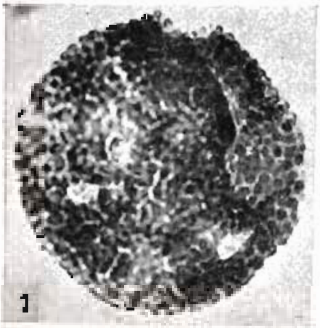
EXPLANATION OF PLATE

(All photomicrographs are enlarged ca. × 500)

1-6. *Densiverrupollenites eocenicus* gen. et sp. nov.; slide nos. 6943, 6944, 6958 (Holotype), 6944, 6945 and 6946; coordinates: 106.8 × 9.4, 99.8 × 12.4, 80.1 × 18.10 (Holotype), 86.9 × 21.5, 111.10 × 20.0 and 79.5 × 17.9 respectively.

7-10. *Collospermumpollis laevigatus* gen. et sp. nov.; slide nos. 6947, 6948 (Holotype), 6949 and 6948; Coordinates: 104.3 × 14.3, 100.5 × 6.2 (Holotype), 71.2 × 25.9 and 103.5 × 24.6 respectively.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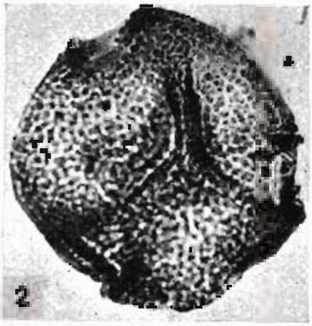
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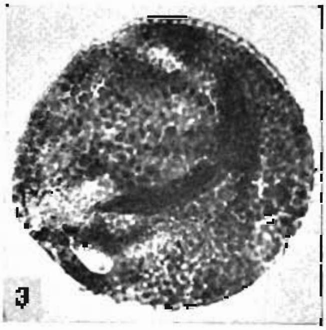
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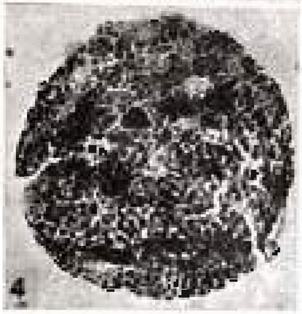
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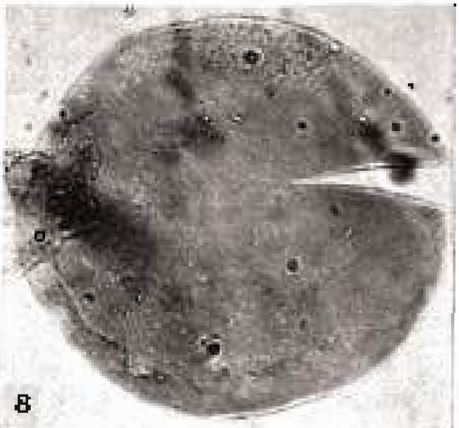
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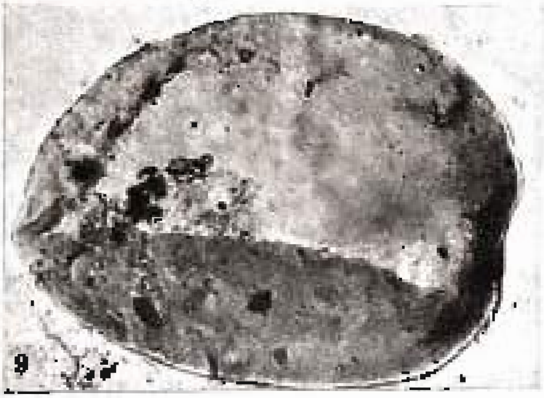
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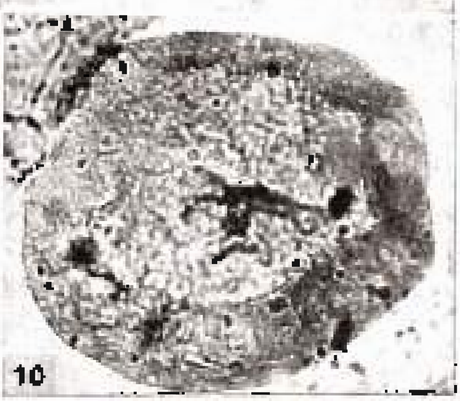
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PLATE 1

The Palaeobotanist, **32**(2): 158-187, 1984.

QUATERNARY PALAEOBOTANY/PALYNOLOGY IN THE HIMALAYA: AN OVERVIEW

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ABSTRACT

The overview appraises critically the work on Quaternary palaeobotany/palynology carried out in the Himalaya during last over hundred years. The fluctuations in cool and temperate vegetation and climate during the early Quaternary (Lower Karewas), aspects of vegetational development during the last glaciation and during present interglacial period impart a glimpse of the changing patterns of vegetation through the Quaternary period. Further, it urges the construction of more pollen diagrams, intensification of researches on the comparative data base together with increased indigenous ecological insight and the sophistication in methodology to bring out invaluable information of biogeographical, geological and archaeological interests. The history of lake basins and fluctuations in hydrochemistry should be built up through the studies of diatoms in conjunction with pollen and spores.

The studies of the evolution of Quaternary floristics should not overlook the historical perspective, i.e. its evolution from the Miocene/Pliocene flora. The recognition of transitional stage in the evolution of flora is highly imperative to demarcate the Neogene/Quaternary boundary on botanical grounds. A few names for various stages (vegetational/climatic phases) during the Quaternary have been proposed after the type sites in keeping with the Code of Stratigraphical Nomenclature for their use in bio- and chronostratigraphy. Besides, it emphasises the importance of indigenous ecological insight in solving the ecological problems and biogeographical riddles in the diversity of floristics in the Himalaya, and to determine the rate and extent at which the forests in the Himalaya have been adversely affected by the progressive increase in land use and by the progressive and selective exploitation of the forest constituents.

Key-words—Palaeobotany, Palynology, Palaeoecology, Quaternary, Himalaya (India).

साराँश

हिमालय का चतुर्थक युगीन पुरावनस्पतिक/परागाणविक अध्ययन : एक विशेष समालोचना – विष्णु-मित्र

पिछले लगभग सौ वर्षों में हिमालय पर किये गये चतुर्थक युगीन पुरावनस्पतिक/परागाणविक अध्ययन की विस्तृत समीक्षा की गई है। प्रारम्भिक चतुर्थक युग (अधरि करेवा) में ठंडी व शीतोष्ण वनस्पति एवं जलवायु के उतार-चढ़ावों तथा अन्तिम हिमानी व वर्तमान अन्तरहिमानी काल में हुए वनस्पतिक विकास से चतुर्थक युग में वनस्पति के बदलते स्वरूपों की झलक मिलती है। इसके अतिरिक्त और अधिक परागकण-चित्र बनाने, ठोस तुलनीय आँकड़ों के आधार पर अनुसंधान में गति लाने तथा जैवभौगोलिक, भूवैज्ञानिक एवं पुरातात्विक जानकारी प्राप्त करने के लिए नवीनतम् विधियों के प्रयोग हेतु आग्रह किया गया है। इसके साथ-साथ यह प्रस्तावित किया गया है कि परागकणों व बीजाणुओं के सहयोग से डाऍटमों के अध्ययन द्वारा जलरसायन की अस्थिरताओं तथा झील द्रोणीयों के इतिहास का अन्वेषण किया जाना चाहिये।

मध्यनूतन/अतिनूतन वनस्पतिजात के द्वारा चतुर्थक वनस्पतिजात के विकास का अध्ययन करते समय ऐतिहासिक स्वरूप को भी विशेष महत्व देना आवश्यक है। वनस्पतिक आँकड़ों के आधार पर पश्च-तृतीयक/चतुर्थक युग का सीमाँकन करने के लिए वनस्पतिजातीय विकास की अन्तरवर्ती अवस्था पर बल देना अत्यावश्यक है। चतुर्थक युग में विद्यमान विभिन्न चरणों (वनस्पतिक/जलवायवी अवस्थायें) के लिए स्तरिकीय नामपद्धति संहिता के अनुसार कुछ नये नाम भी प्रस्तावित किये गये हैं जिनका जैवस्तरिकी एवं कालस्तरिकी में उपयोग किया जा सकता है। इसके अतिरिक्त हिमालय में पाई जाने वाली वनस्पतिक विविधता की पारिस्थितिक समस्याओं और जैवभौगोलिक रहस्यपूर्ण गुत्थियों को सुलझाने के लिए स्वविकसित पारिस्थितिक अन्तरदृष्टि तथा हिमालय की भूमि के तेजी से बढ़ते उपयोग एवं यहाँ पाये जाने वाले विशेष वन्य तत्वों के विनष्टीकरण की सीमा एवं दर सुनिश्चित करने पर भी विशेष बल दिया गया है।

INTRODUCTION

THE information on Quaternary Palaeobotany of the Himalaya commenced accumulating in the middle decades of the nineteenth century when the occurrence of leaf impressions in the Lower Karewa deposits of Kashmir Valley was brought to light by the early geologists (Godwin-Austen, 1864). To this, Middlemiss (1910) added several taxa identified from leaf impressions. A comprehensive list of plant remains from the Lower Karewas, identified by Prof. R. R. Stewart, together with climatic and geographical aspects of this flora, was published in 1939 by de Terra and Paterson. Puri in a series of papers described and figured a bulk of Lower Karewa leaf impressions, synthesized the data and discussed their phytogeography (Puri, 1945, 1948a, 1948b, 1957). In 1965, all the taxa identified from leaf impressions and discovered from the Lower Karewas in Kashmir Valley were reconsidered ecologically and in relation to stratigraphy (Vishnu-Mittre, 1965a). Robert's (1967) re-examination indicated the occurrence in them of some elements matching with the leaves of eastern Himalayan extant taxa. Awasthi and Guleria (1982a, 1982b) have recently added fresh information on leaf impressions and carbonized woods from the Lower Karewas.

It was in 1935 when the first results of pollen analysis of Upper and Lower Karewa sediments were published by Wodehouse and de Terra. Two years later Deevey (1937) described fossil pollen spectra from second interglacial sediments of Panggong Lake. Puri (1948a) too had pollen-analysed some samples. Diatoms and algae have been reported by Conger (1939) and Iyengar and Subramanyam (1943).

The pollen analytical work resumed in the mid fifties in the Himalaya (Nair, 1960) has been continued comprehensively at the Birbal Sahni Institute and elsewhere ever since (Dodia *et al.*, 1982a, 1982b, 1982c; Gupta, 1971, 1973, 1977; Gupta & Khandelwal, 1982a; Gupta *et al.*, 1982a, 1982b, 1982c; Gupta & Sharma, 1982; Mehrotra, Pal & Srivastava, 1979; Rawat, 1982; Robert, 1967; Sharma, 1972, 1973, 1976; Sharma & Singh, 1974; Sharma, B. D. & Vishnu-Mittre, 1969; Singh, 1963; Singh & Agarwal, 1976; Tewari, Swain & Sharma, 1979; Tewari, Swain & Awasthi, 1979; Vishnu-Mittre, 1963, 1964, 1965a, 1965b, 1966a, 1966b, 1972a, 1972b, 1973a, 1973b, 1974a, 1974b, 1974c, 1974d, 1979, 1980a, 1984; Vishnu-Mittre, Singh & Saxena, 1962; Vishnu-Mittre & Sharma, B. D., 1966; Vishnu-Mittre, Gupta & Robert, 1967; Vishnu-Mittre & Robert, 1971; 1973, Vishnu-Mittre & Gupta, 1971; Vishnu-Mittre & Sharma, C., 1984; Vishnu-Mittre & Bhattacharyya, 1980, 1983).

Studies on fossil algae since 1960 have been carried out by Goswami (1955), Rao and Awasthi (1962), Roy (1970, 1971, 1972, 1975, 1979), Gupta and Khandelwal (1982b), Mohan *et al.* (1982a, 1982b) and Swain (1982) and on fossil fungi by Purekar (1962). Studies on plant remains from the archaeological sites in the Himalaya have been carried out by Buth, Bisht and Gaur (1982), Ghosh and Lal (1961), Savithri (1976), Sharma, A. K. (1979-80) and Vishnu-Mittre (1966b, cf. 1974).

In the Upper Siwaliks in the sub-Himalayan region, where the Pinjor and the overlying conglomerates are believed to date from the Quaternary period the pollen analytic work has been carried out by Saxena and Singh (1980, 1982a, 1982b), Singh and Saxena (1981) and Singh *et al.* (1973), cf. Singh (1982).

The concise historical account outlined above reveals rapid progress, during the last two decades, in our knowledge of the Quaternary palaeobotany/palynology in the Himalaya. The growth of this knowledge has been lopsided; most efforts have been confined to the Jammu and Kashmir State, particularly to the Kashmir Valley. During the last two decades not only the efforts have been intensified in this region but the investigations have also been extended to the adjoining states of Himachal Pradesh, Kumaon and Nepal with the eastern Himalaya receiving scant attention.

A broad and a general glimpse into the evolution of Quaternary flora of the Himalaya has indeed emerged from these studies. The chief objective of this overview is not only to appraise critically the work hitherto accomplished bringing out areas requiring intensified research but also to draw attention toward the adoption of the new and current approaches.

EVOLUTION OF EARLY QUATERNARY VEGETATION AND CLIMATE

KASHMIR VALLEY

The early Quaternary Flora known from its remains from the Kashmir Valley was of a varied nature comprising angiosperms, gymnosperms, pteridophytes and algae, particularly diatoms.

Comprising over 100 species and belonging to 65 genera of 36 natural orders, the macrofossils, mostly foliar impressions, have shown rarity of gymnosperms and ferns against the abundance of angiosperms. From their over-all quantitative estimates and cumulative considerations, the oak conifer mixed woods have been reconstructed (de Terra & Paterson, 1939; Vishnu-Mittre, 1965a, 1966a). The data have allowed reconstruction of the submerged, free floating and the reedswamp communities of the Karewa Lake, besides various storeys including the climbers and riverain vegetation that constituted these forests (Vishnu-Mittre, 1965a, 1966a). It was a predominently temperate flora with a small proportion of tropical/subtropical elements such as *Ficus cunia*, *Mallotus philipensis*, *Pittosporum eriocarpum*, *Wendlandia exserta*, *Odina wodier*, *Woodfordia floribunda* and species of *Berchemia* and *Myrsine*. The modern maximum altitudinal limit of these tropical and subtropical elements approaches 1,700 m above mean sea level. The climate was temperate and not tropical as inferred by Puri (1957).

Considered sitewise, the Ningle Nullah flora on account of the absence of oaks appears distinct from the Liddarmarg, the Laredura and the Dangarpur floras. The abundance of *Quercus incana* and *Q. glauca*, the only oaks, together with the species of *Litsea*, *Cinnamomum*, *Machilus* and *Phoebe* distinguishes Liddarmarg flora where not only the species of *Quercus* (*Q. semecarpifolia*, *Q. ilex*, *Q. dilatata*) are different but members of Lauraceae are absent. The Dangarpur Flora has the same kind of *Quercus* spp. as at Laredura but it has a member of Lauraceae (*Litsea elongata*) too. Is this apparent distinction in these floras real and finally established ? Extensive collections from these sites may provide the answer. Unaware of de Terra and Paterson's statement that these floras were contemporary and belonged to a part (Lithozone 4) of the Lower Karewas, Puri (1957) constructed the evolution of the entire Quaternary vegetation from these floras (cf. Vishnu-Mittre, 1965a).

Pollen analysis of the random leaf impression bearing sediments from these sites by Vishnu-Mittre and Robert (1973) has revealed that these floras are not really distinctive as they apparently seem to be. Pollen grains of oaks occur predominantly in the sediments of Ningle Nullah against their absence in macrofossils. The abundance of leaf impressions of oaks at Laredura is represented by under 20% of *Quercus* pollen and at Liddarmarg by 15-20%. At Botapathri where only leaf impressions of *Quercus incana* and *Q. glauca* have been recovered, the pollen evidence shows spruce-oak-deodar woods with pollen of oaks being 20-30%. The pollen analysis of the leaf impression bearing sites reveals that the conifer mixed oak woods had occurred as the regional vegetation during Lithozone 4 to which these sites belong. The apparent floristic differences in the macrofloras of these sites may be attributed among other causes to former varying consocies within this regional vegetation.

Judging from the present day climatic requirements of the taxa identified, the occurrence of *Betula utilis* with *Alnus nepalensis* at Ningle Nullah; of *Quercus semecarpifolia* and *Litsea elongata* at Dangarpur; of *Q. semecarpifolia*, *Q. ilex* and *Q. dilatata* at Laredura and Dangarpur; of *Q. incana* and *Q. glauca* with *Betula utilis* and of *Acer pentapomicum* and *Acer oblongum* with subtropical element at Liddarmarg may cast doubt on the validity of identifications. Considering the identifications unquestionable, one may be compelled to believe that the climatic requirements of these taxa during the early Quaternary were different and their present day climatic requirements have evolved in course of time.

The identity of macrofossils to specific level provides the unequivocal evidence for the former occurrence of the species in local or adjacent environs. It has distinct advantage in this regard over pollen and spores which with rare exceptions can not be run down to specific level. This shortcoming in pollen/spores is accompanied by their ubiquitous nature so that they allow reconstruction of regional vegetation against the local or adjacent from macrofossils. Both are thus complementary to each other in particular regard to the reconstruction of vegetation and environment. Most herbs are unrepresented and the conifers under-represented in the macrofossils. At the same time there are several common taxa in both which enhance the complementary status of both the micro- and macrofossil evidences.

Further, pollen evidence can allow reconstruction of fluctuations in the past vegetation and the relative percentages of pollen grains can be matched with the relative proportions of their mother plants in the forest communities. Pollen evidence thus has additional advantages over macrofossils. For a fuller reconstruction of past vegetation and climate they ought to be considered together. In the event of either of the evidences available, the local or adjacent significance of macrofossils against the regional of the microfossils should not be overlooked in drawing inferences of past vegetation and environment.

The early pioneering attempts on pollen analysis of stray Quaternary sediments from Jammu and Kashmir State (Wodehouse & de Terra, 1935; Deevey, 1937; Puri, 1948a; Nair, 1960) are significantly important in suggesting that the sediments are polliniferous besides providing a glimpse of the kinds of plants that had existed when these sediments were deposited. However, Nair (1960) alone endeavoured to build up fluctuations in the past vegetation even though measurements of the sections and the intervals between samples analysed were not given in his paper. Also no mention was made of the lithostratigraphy adopted. However, he confirmed palynologically the former occurrence (in the Lower Karewas) of *Alnus*, *Carpinus* and *Quercus* already known from macrofossils, though *Larix* and *Pinus roxburghii* were not recorded in macrofossils. The latter two have not been found in subsequent macrofossil studies (Awasthi & Guleria, 1982a, 1982b).

The pollen analysis of five type sites — Sedau, Laredura, Nichahom, Raithan and Botapathri (Text-figs 1-5) in the fine lithostratigraphy of de Terra and Paterson (1939), enabled Vishnu-Mittre (1973a) to infer fluctuations in temperate vegetation interspersed by cool oscillations. The entire reconstructed sequence was referred to the early Pleistocene the commencement of which was indicated at its base. The first forestless condition designated as the First Cool Oscillation after the decline of the oak-alder phase was equated with First Glaciation. The commencement of Glacial Epoch was suggested to be not coeval with that of Pleistocene. In the absence of any physical evidence of a glaciation, cryoturbation, permafrost, etc. within the Lower Karewas, the first and the subsequent cool oscillations should not be equated with glacial events, for the unequivocal botanical evidence indicating that is still lacking. The forestless conditions may be attributed to intensely dry summers and very cool winters. The only undisputed physical evidence of a glaciation occurs on top of the Lower Karewa deposits. And this on the present evidence is in fact the first glaciation which was referred to second by de Terra and Paterson. The evidence for the first glaciation advanced by de Terra and Paterson has not been confirmed by Wadia (1951), Vishnu-Mittre (1964) and Bhatt (1976).

The immigrating and expanding blue pine (*Pinus wallichiana*) subsequent to the First Cool Oscillation constituted first the open blue pine forests changing into the dense blue pine mixed forests. Subsequent to the Second Cool Oscillation which destroyed pine woods, the pattern of vegetation changed into spruce-oak-deodar woods. Indications of the Third Cool Oscillation are inferred in the opening out of these forests. It has also been suggested that during the temperate phases the average annual precipitation was of the order of 1,000-1,300 mm (Vishnu-Mittre, 1979).

A reconsideration of the nature of climates from the following three major plant communities reconstructed becomes necessary from whatever data are available for the corresponding communities in the western Himalaya (Champion & Seth, 1968). The reconstructed plant communities allow comparisons with the following corresponding forests in the western Himalaya only:

1. Oak mixed woods comprising thermophilous elements.
2. Mixed conifer forests comprising *Picea*, *Abies*, *Pinus* or *Cedrus* with or without some deciduous and evergreen broad leaved elements.
3. The steppe comprising chenopod-grass-sedge-*Artemisia*.

The oak-mixed woods with some *Cedrus* are found at Sedau only where no evidence of macrofossils was found. Precipitation from 1,100-1,200 mm can indeed be inferred (Champion & Seth, 1968, p. 293). Presuming that the oaks identified from macrofossils from Lithozone 4 also occurred in the vicinity at Sedau during Lithozone 1, the oak woods may be presumed to have been *Q. dilatata* forests in which *Q. incana* and *Q. semecarpifolia* occurred freely as they do today. Should this presumption be correct ? If so, then winter was pronouncedly cold with a warm summer and with snow lying for several weeks as in modern *Q. dilatata* forest. Temperatures in such a forest would range from 5.5-15°C with high soil moisture and the precipitation at its lower limit would range between 1,500 and 1,900 mm.

The mixed conifer forests occur today under temperatures cooler than in *Q. dilatata* forest, with normal and good snowfall lying for several weeks with the precipitation being 1,100-1,300 mm. This kind of forest is inferred from pollen evidence of Lithozone 4. However, the macrofossil evidence suggests a mixture of temperate and subtropical species. At Liddarmarg, for instance, *Q. incana* and *Q. glauca* are accompanied by several members of Lauraceae which occur in moist temperate forests (Champion & Seth, 1968) along with temperate species of *Acer*, *Buxus*, *Parrotia*, *Ulmus* and others of subtropical nature. At other sites, *Q. semecarpifolia*, *Q. dilatata* and *Q. ilex* are found associated with many temperate elements and a small proportion of subtropical element. Pollen evidence shows that *Picea* and *Cedrus* were the important conifers along with oaks. Both the evidences together indicate moist temperate conifer-mixed-oak woods, and the estimates of temperature and precipitation given above is based upon modern comparable forests in the Himalaya.

The climatic conditions during the Steppe periods (the Cool Oscillations) can be estimated from the present day distribution of *Artemisia* and chenopods in the Pishin Valley (1,375-1,600 m) in Quetta or above tree limit and below glacier at 2,800 m at Tilel or below snowmelt alpine region in Baluchistan and elsewhere in Himalaya (Stewart, 1982). And this suggests that the climate was cooler and much drier with severe winters. Total precipitation may have been under 1,000 mm.

Against the wet or moist climate inferred from macrofossils of which additional support was derived from geology for the much lower altitude of the Pir Panjal (de Terra & Paterson, 1939), pollen evidence suggests fluctuations between moist temperate and cool but dry climates during the time the Lower Karewa deposits were laid even when the Pir Panjal mountain, the present barrier to monsoon, was of a lesser height. There were fluctuations in the annual precipitation regime from 1,500-1,900 mm, 1,100-1,300 mm to under 1,000 mm.

There is indeed additional botanical evidence to support the earlier one (Sahni, 1936; Puri, 1946) that the Pir Panjal was of a lesser height. The modern comparable forests for the reconstructed plant communities from the Lower Karewas occur between 2,000 and 3,000 m above sea level. In spite of the occurrence of fossil leaves referred to alpine/subalpine taxa (*Betula utilis & Quercus semecarpifolia*), the pollen evidence has not brought out alpine birch-blue pine, birch-fir, fir-oak forests which extend today from above 2,500 m to tree limit. Not only these occur today at much higher altitudes but they are also indicative of cooler periglacial, protocratic or telocratic stages in vegetational development. The steppe stages referred to cool oscillations still lack elements distinctive of full glacial vegetation.

Early Quaternary *Betula utilis* and *Quercus semecarpifolia* from their associated majority of temperate taxa and with some subtropical elements must have had climatic requirements different from what they have today as argued elsewhere in the text or else their identifications be looked into again.

The evolution of the present day alpine communities and the Full Glacial Alpine steppe must be traced to the Glacial epoch which commenced after the Lower Karewa sediments had been deposited. Their absence during the Lower Karewa, as the present evidence suggests, is supported by the absence of physical evidence of glaciation within the Lower Karewas.

Palaeobotanical and palynological data in the background of fine lithostratigraphy of de Terra and Paterson (1939) has brought out interesting patterns of change in the vegetation comprising migration, expansion and decline of some taxa in response to the cool oscillations prior to the First Glaciation (the II by de Terra & Paterson, 1939). *Cedrus* was present in small proportions in Lithozone 1 (Text-fig. 1). The blue pine (*Pinus wallichiana*) immigrated during the First Cool Oscillation in Lithozone 2 (Text-fig. 2), expanded in Lithozone 3 (Text-fig. 3), and declined subsequent to the Second Cool Oscillation (Text-fig. 4) in Lithozone 4 (Text-fig. 5) when the spruce-deodar-oak woods were constituted which changed into *Juglans*-elm open woods possibly in response to the Third Cool Oscillation. Small pollen frequencies of *Abies*, *Picea*, accompanying those of blue pine perhaps suggest that these too immigrated along with blue pine. Among these *Picea* alone eventually became an important constituent of temperate forests. Traces of *Engelhardtia* and *Rhus* in the pollen-diagrams and minor subtropical constituents in the macrofossils during Lithozone 4 are indicative of the trailing subtropical element along with overwhelming temperate elements. The transition between tropical and temperate vegetation has not been brought out which could help to demarcate the beginning of the Quaternary on botanical grounds. That this boundary should be drawn at the base of the Lower Karewas investigated palynologically was suggested by Vishnu-Mittre (1964) and Lithozone 1 was equated with Pinjor deposits in the Siwaliks suggesting the boundary at the transition between Tatrot/Pinjore stages (Vishnu-Mittre, 1964, 1965b, 1972a).

The latest information on past vegetation and climate from the Lower Karewas in Hirpur region (Dodia *et al.*, 1982a) indeed reveals a clumsy and careless work: the samples are stated 30-50 cm apart at p. 23 and the same several meters apart in pp. 24-25; sand samples are also pollen analysed and pollen spectra of all the six samples from Hirpur are not considered in sequential order.

A prominent grass-chenopod-*Artemisia* pollen assemblage from a single lignite sample from Wapzan (Gupta *et al.*, 1982a), believed to be the top of the Lower Karewas, is considered to indicate alpine scrub the like of which occurs in the trans-Himalayan region in Ladakh suggesting cold dry climate even though modern pollen spectra from this region are not known.

The two pollen spectra from sandy samples from Hirpur Locality III show 80-85% pollen of *Pinus roxburghii*. The four lignitic mud samples at this site reveal gradual increase in grasses whereas *Quercus* remains consistently low (10-15%). *Larix* shows high values in one sample (H-68) only and *Carya* in another (H-36) whereas *Juglans* is 3-5% in two samples. Even though all these tree genera do not dominate in samples H-36 and H-68 (wrongly quoted as H-38 by the authors), a warm temperate and humid climate with more precipitation is inferred from them. Increasing high values of grasses and much reduced values of *Larix* and *Careya* in top samples is attributed to deterioration of climate. In complete disregard of the present climatic requirements and associates of *Larix* in the Himalaya, the migration of *Larix* to more congenial environments is believed to have been due to dry cold spell, strong-winds, decreasing precipitation and physiographic change without realizing if the pollen evidence really provides all that information.

Arranged in sequential order and utilizing the climatic inference by Dodia *et al.* (1982a), the six widely separated pollen spectra from Hirpur Locality III indicate that the warm temperate humid climate as indicated by *Carya*-*Quercus*-Poaceae or *Larix*-*Quercus*-*Engelhardtia*-Poaceae (samples 36, 38) was preceded and followed by warm dry outer Himalayan slope climate (subtropical) as inferred from the dominance of *Pinus*-*roxburghii* (in samples 10 and 70) and thereafter deteriorated as evidenced from Poaceae-cheno-ams-*Quercus*-*Alnus* and Poaceae-*Quercus*-*Engelhardtia* respectively (S-164 & S-230). On the whole pre-glacial conditions are inferred in these sediments which on provisional palaeomagnetic evidence are referred to Gauss Normal Epoch (3.41-2.47 million years).

The tropical, subtropical, temperate and alpine climates in the Himalaya are the result of varying altitudes. Did the Kashmir Valley swing like a spring board during 3.41-2.47 million years ago, rising up and down until towards the later part of this time period it had attained altitude as high as in Ladakh. When did it attain the present altitude of 1,800 m is not considered ?

Was *Larix* really forced out of the valley during the Lower Karewa times as is held by Dodia *et al.* (1982a)? Tentatively identified *Larix* pollen has been reported from the Toshmaidan site (Sharma & Singh, 1974) now dated from 15,000 radiocarbon years. Does the pollen evidence support this or does it support any of all the causes for this biogeographical change ? The authors fail to make a distinction between cool and cold oscillation as understood in the Quaternary. Had the climatic conditions that exist today in Ladakh ever occurred in the Kashmir Valley during the Lower Karewa times ? A careful ecological and biogeographical understanding of the data published by Dodia *et al.* (1982a) is highly necessary.

The indication in paper by Dodia *et al.* (1982a) that the three lithotypes, viz., sand, mud and lignite, which occur repeatedly in Hirpur Locality III section and characterized each by ± similar pollen assemblage, is confirmed in brief report by Gupta *et al.* (1982b). Thus, the sand layers are characterized by *Pinus roxburghii*, *Juglans* and *Viburnum*; the mud layers by *Pinus wallichiana*, *Abies*, *Picea*, *Cedrus*, *Betula*, and the lignite layer by *Larix*, *Cedrus*, *Cupressus*, *Juglans*, *Engelhardtia*, etc. Nevertheless, Gupta *et al.* (1982b) infer as many as 15 climatic oscillations (four tropical dry, one tropical wet, one subtropical, four warm and wet temperate, and five cold and dry temperate). These briefly reported pollen assemblages do not suggest the evidence for tropical vegetation complex. The inference of this and the other climatic types requires exercise of much care in the perspective of each lithotype being characteristic of the same pollen assemblage irrespective of its position in the section.

No pollen is observed in sands at the Dubjan site believed to represent the lowermost Lower Karewa (Gupta *et al.*, 1982c). Both the Upper and Lower Lignite bands at this site have ±similar pollen assemblage (high grasses, *Picea*, *Cedrus*, *Cupressus* & *Betula*) whereas the intervening mud layer is characterized by *Pinus roxburghii*, *Alnus*, *Juglans* and *Quercus*. The sequence here is interpreted to indicate warm temperate climate interrupted by a moist subtropical phase.

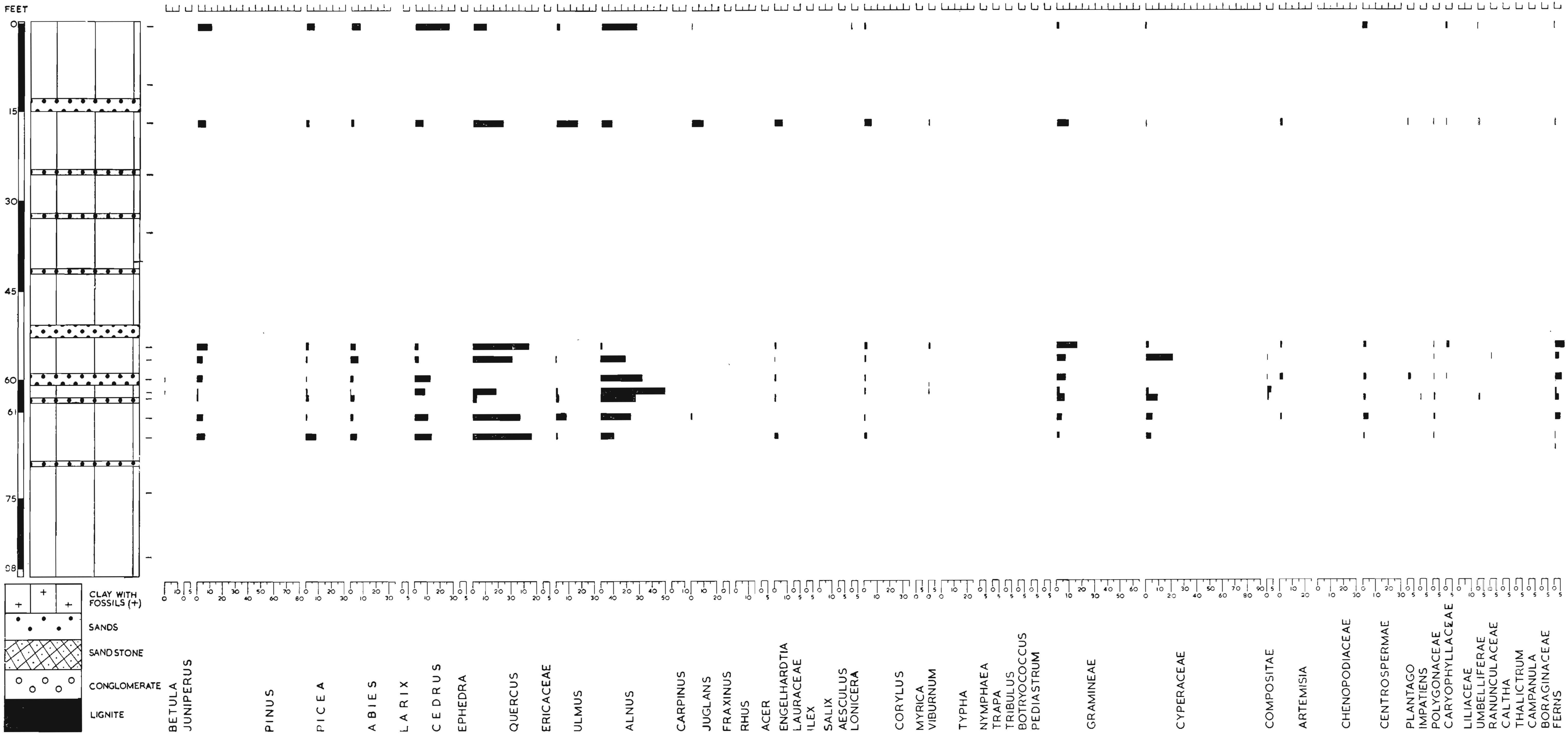
The recent work by Dodia *et al.* (1982a) and Gupta *et al.* (1982b) at the present seems to be a palynological mess and highly confusing. Which way the trend of floristic development is proceeding can not be made out ? The factors which seem to be responsible for this mess in interpretation are overlooked.

A large part of the Hirpur Locality III Section dates from mid- to Upper Pliocene with the top represented by early Pleistocene. More than a dozen climatic oscillations as inferred seem as unusual as the three repeated lithotypes each characterized by the same pollen assemblage irrespective of their position in the section. The latter seems intriguing and its significance not understood properly. It must be pointed out that 2-3 climatic oscillations during the entire Pliocene have been reported from other parts of the world through application of palynology, micropalaeontology and oxygen and carbon isotope studies to both terrestrial and oceanic sediments (cf. Proc. First Int. Conf. on Palaeooceanography held at Zurich, 1983). The Himalayan region by no means could be an exception. If the careful evaluation of the recent palynological data establishes it to be an exception, it would be a very great discovery.

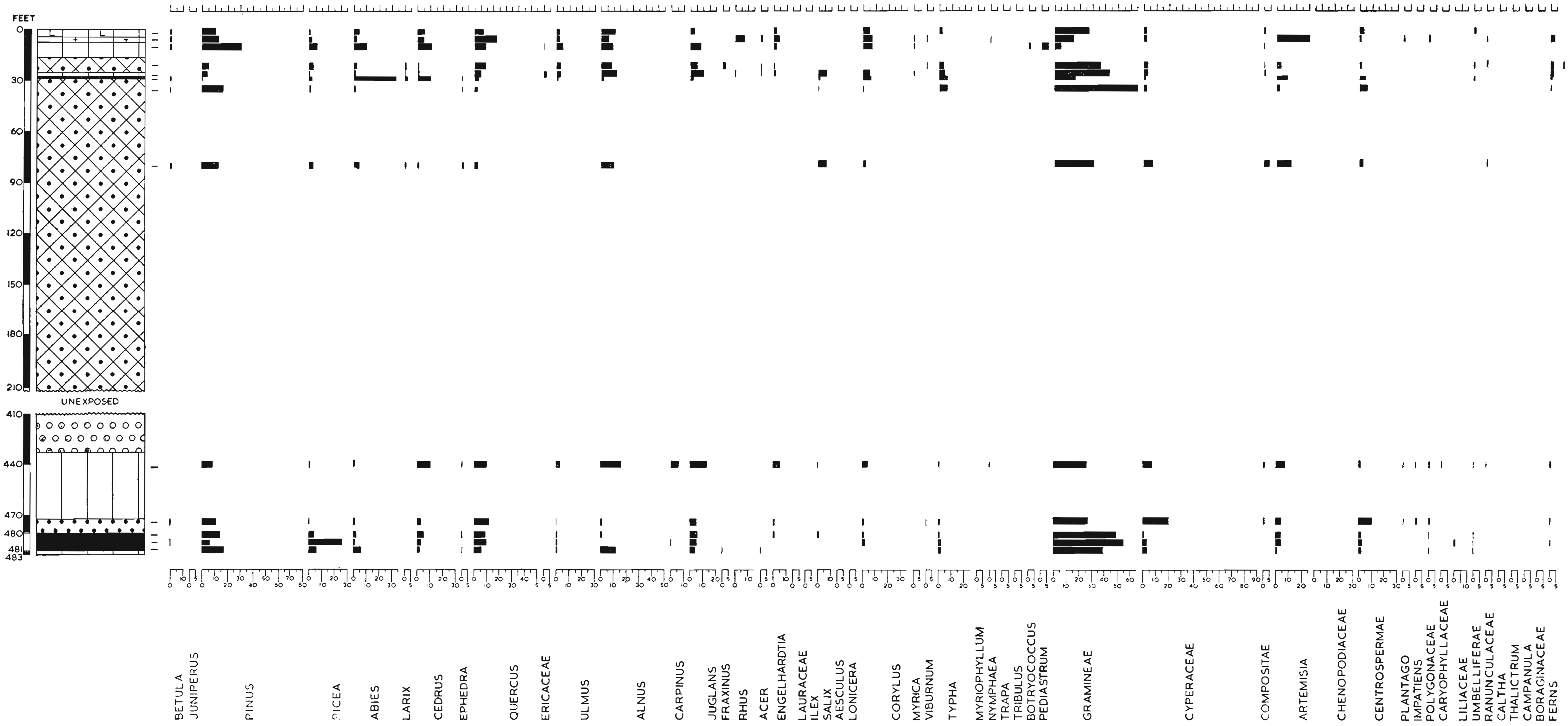
Alongside the recent palynological evidence discussed above there is the macrofossil evidence comprising several taxa reported recently (Awasthi & Guleria, 1982a, 1982b) from the exposures in the Hirpur Formation at Dubjan, Hirpur, Hirpur-Dechhom and Krachipathra in the Upper Rimbiara Valley and from near Raithan in the Shaliganga Valley. The leaf impressions discovered between conglomerates I and II (believed to be within the Gauss Normal Epoch, i.e. 3.41-2.47 m years) are referred to the taxa — *Acer villosum*, *A.* sp., *Aesculus indica*, *Nelumbo* sp., *Populus euphratica*, *Potamogeton* sp., *Ulmus wallichianus*, *Quercus semecarpifolia*, *Rosa macrophylla*, *Salix wallichiana*, *Viburnum cottinifolium*, *Trapa* sp. and *Pteridium aqualinum*.

The fossil woods from sandy layers between conglomerates II and III (believed to be within the Matuyama-Gauss Epoch, i.e. 2.8-1.5 m years: Dodia *et al.*, 1982a, p. 22) are referred to the following taxa — *Abies* sp. cf. *A. pindrow*, *Cupressus* sp. cf. *C. torulosa*, *Fraxinus excelsior*, *Juglans regia*, *Pinus wallichiana*, *Populus* sp. cf. *P. euphratica*.

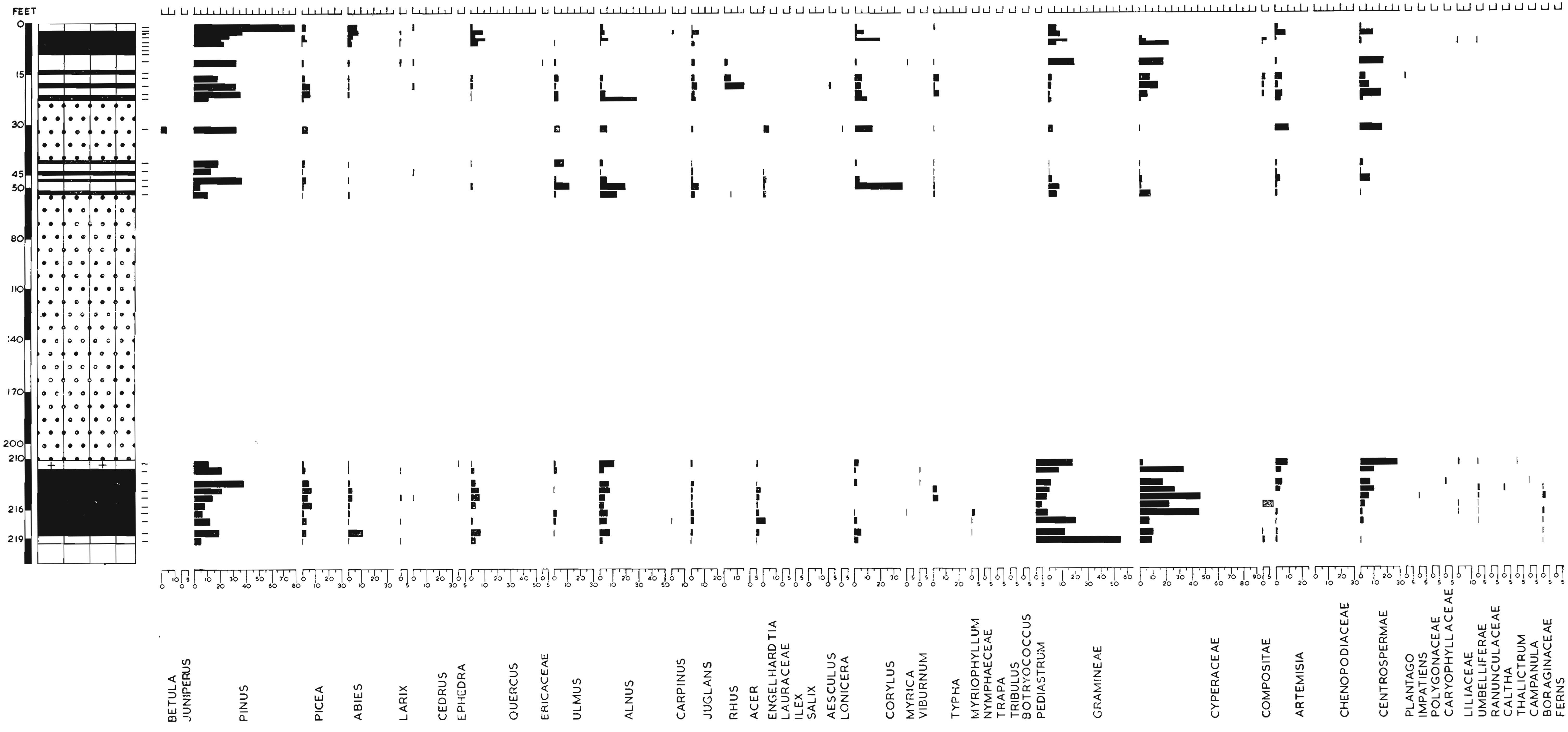
These macrofossils suggest temperate climate from 3.41-1.5 million years supporting the inference of temperate climate from macrofossils from the other Lower Karewa exposures discussed above.



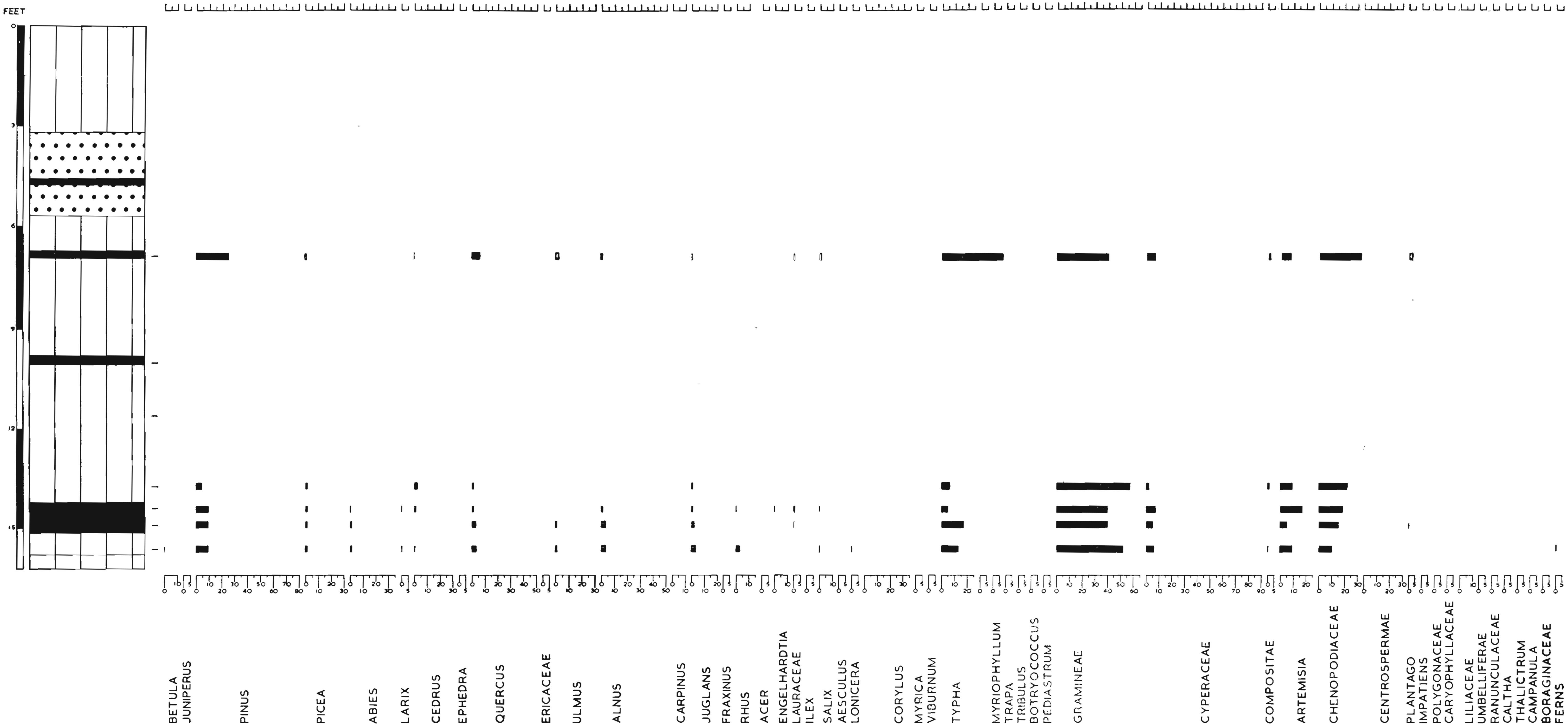
TEXT-FIG. 1 — Pollen diagram from Sedau showing fluctuations in dense oka-alder woods with some deodar and with slight opening of the forest. The extreme top pollen spectra show indications of the formation of deodar-alder-oak-woods.



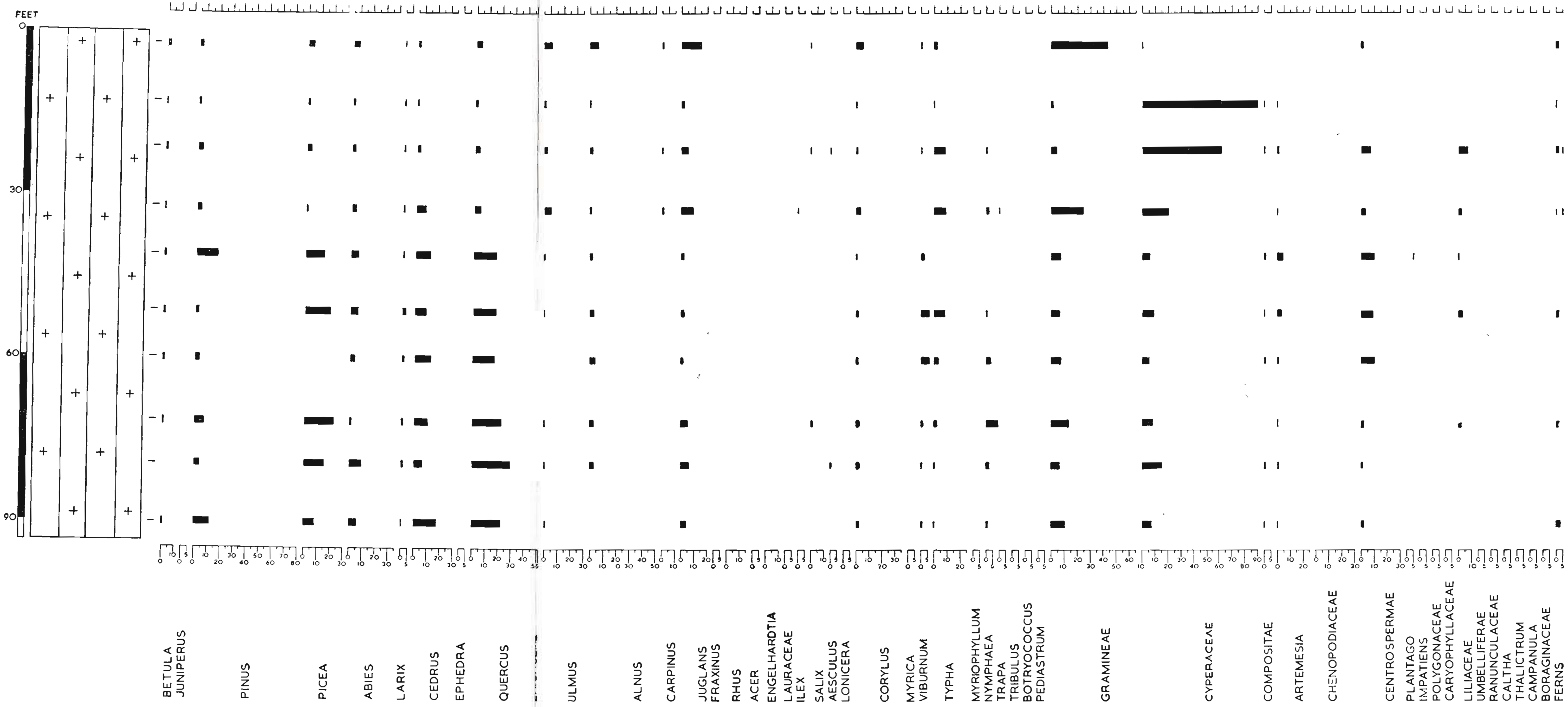
TEXT-FIG. 2 — Pollen diagram from Laredura: The pollen spectra from both the lower and upper lignitic horizons show open conditions with small frequencies of pollen of trees or shrubs. The latter show decreasing trend except *Juglans* and *Alnus* in the lower and rising trend excepting of *Juglans* in the pollen spectra from the upper lignitic horizon. Frequencies of *Pinus*, *Abies*, *Ulmus*, *Salix*, *Corylus*, etc. are much better represented in the lower lignitic horizon. The impact of cool oscillation of climate is apparent in both the horizons of lignite.



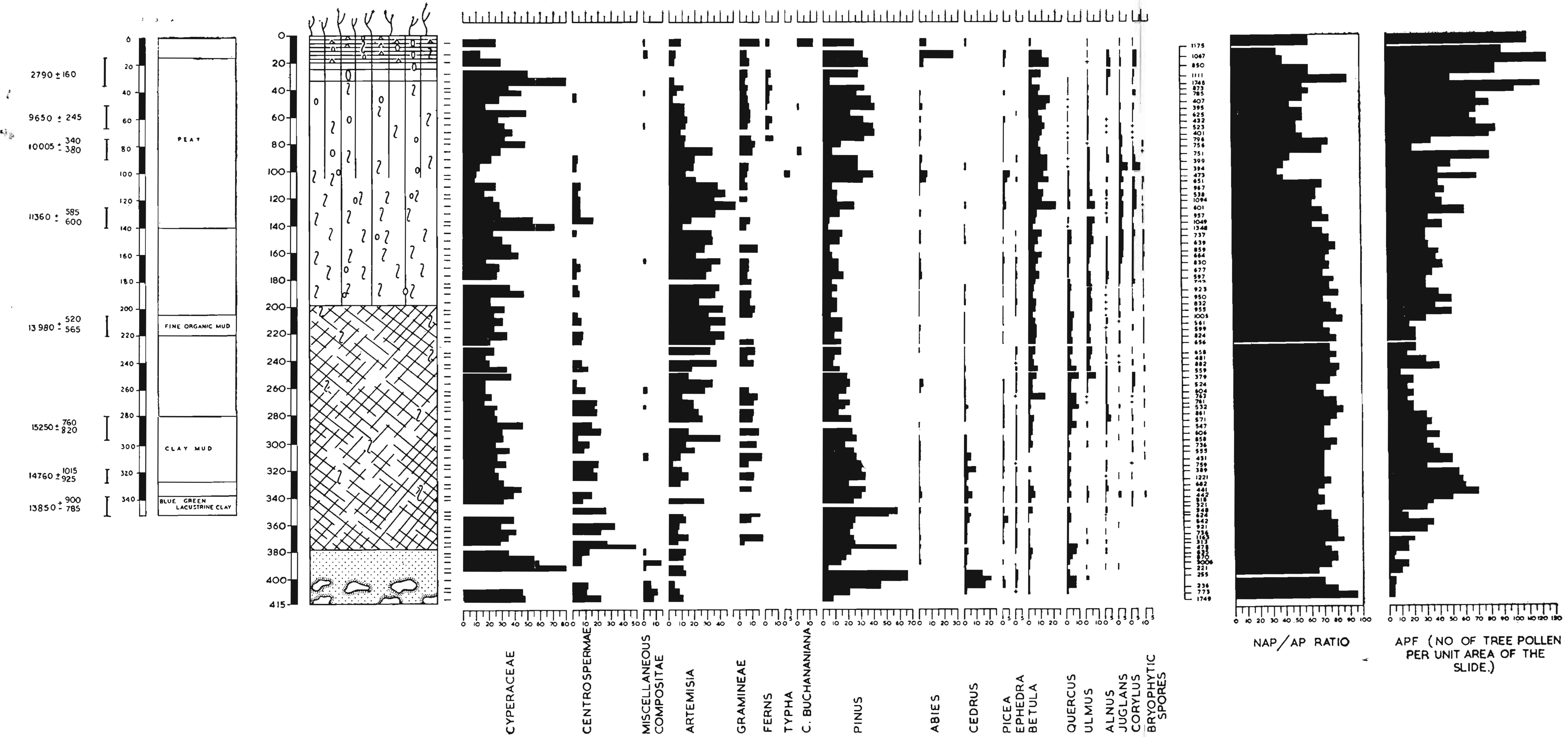
TEXT-FIG. 3 — Pollen diagram from Nichahom: The lower lignitic horizon is characterized largely by steppe which is less represented in the upper lignitic horizon. The upper one is further characterized by much higher values of *Pinus*, *Ulmus.*, *Alnus*, *Rhus* and *Corylus* indicating pine-mixed broad-leaved forest. In the lower horizon, the grass-sedge steppe, the open pine mixed woods and the chenopod-grass-*Artemisia* steppe (Cool steppe-cool temperate-cool steppe) and in the upper, pine-mixed-alder woods increase in steppe vegetation followed by pine mixed oak woods (Warm temperate-cool steppe-warm temperate) are the trends in vegetational and climatic fluctuations.



TEXT-FIG. 4 — Pollen diagram from Raithan: The pollen spectra reveal grass-chenopod-*Artemisia* steppe — The Cool Oscillation.



TEXT-FIG. 5 — Pollen diagram from Botapathri: The deodar-oak woods are succeeded by spruce-oadeodar woods showing cool temperate climatic conditions. The increase of grasses and sedges and the decline of forest in the top pollen spectra suggest the onset of the Third Cool Oscillation.



TEXT-FIG. 6 — The Toshmaidan pollen diagram reconstructed by the author from the sum of all land plants pollen, from pollen statistics after Singh (1963). On the extreme left is shown the meadow prof with a sequence of radiocarbon dates after Singh and Agrawal (1976).

These macrofossils from below Conglomerate III and provisionally dated through palaeomagnetism provide important palaeobotanical evidence which must be considered along with pollen evidence to reconstruct and interpret alterations in past vegetation and climate. It is interesting to observe that no macrofossil evidence has been found of former occurrence of *Pinus roxburghii* from sand samples, and none of *Larix*. A careful consideration of both the macro- and microfossil evidences may help to clear the mess created by the recent work discussed above.

The mass of botanical information from the Lower Karewas, now dated from the Pliocene to Early Pleistocene, reveals hardly any difference in the Pliocene and Early Pleistocene floristics. Even pollen analysis has not brought out the transition of floristics from the Pliocene into the Early Pleistocene. The species identified with modern taxa tend to suggest that the modern species had emerged during the Pliocene and there was practically no evolution as a result of successive climatic and edaphic alterations which characterized Pliocene and early Quaternary. This would lead us to believe that the modern species have survived, without any change, the ferocity of cooler oscillations intervening the warmer oscillations of climate during this period when the pedogenic processes were equally active. Further, this would indicate that the endemization of several immigrant plant species must have occurred prior to Pliocene. The information on Miocene floristics from the Himalaya does not bear it out (Vishnu-Mittre, 1984). The discovery of ecologically incompatible species in the Lower Karewa floristics shows vis-a-vis their climatic requirements today that the climatic requirements of these species had indeed altered but strangely these were not accompanied by morphographic changes. The identifications need revision to confirm the situation as brought out from this potential time period in the history of Indian floristics, which should in fact provide substantial information on the immigration, expansion and endemisation or extinction of several phytogeographic units which had entered the Himalaya from the surrounding and distant regions and comprise today an enormous bulk of the Himalayan floristics.

Seen in the perspective of the Miocene tropical forests, the denizens of the western Himalaya, the temperate vegetation in the Pliocene shows a sudden change. And there are no known geologic, geomorphologic or climatic events at this transition that can account for this change. It is this serious anomaly which needs a concerted effort for its solution.

It is encouraging that information has brought out several fluctuations in climate during the Pliocene and Early Pleistocene. This overview finds that some of these are not supported by the floristic evidence.

THE UPPER SIWALIKS

Recent palaeomagnetic dating by Opydke *et al.* (1979) suggests that the Upper Siwaliks in the Outer Himalaya date from before 5.44 million years (close of Epoch 5). The deposits referred to the lowermost stage, the Tatrot, were laid during the Gilbert and Gauss epochs. About 2.40-2.50 million years ago, towards the close of the Gauss Epoch, the sediments referred to the Pinjor Stage were deposited and these had continued until beyond 0.72 m years ago. The Olduvai event (1.8-1.6 million years) has been found in the lower half of the Pinjor Stage. However in the Chandigarh region, Yokoyama (1981) has discovered Olduvai event on top of the Tatrot Stage. Palaeomagnetic and Fission Track dating of the Lower Karewas by Burbank and Johnson (1982) reveal that the Upper Siwaliks and the Lower Karewas were contemporary. The Neogene/Quaternary boundary in both remains undecided. In the Siwaliks, however, it is largely believed to be at the transition between the Tatrot and the Pinjor stages or at the base of Pinjor.

Very meagre palaeobotanical information is available from the Upper Siwaliks as compared with that from the Lower Karewas: *Boraginocarpus lakhanpalii*, *Litsea bhatiai* and *Neolitsea pallens* from the Tatrot Stage (Mathur, 1974) and of palms (*Palmoxylon wadiai* & *P. jamuense*) and grasses from the boulder conglomerate (Sahni, 1964; Mathur, 1978).

Pollen grains believed to be comparable with those of *Pinus*, *Podocarpus*, *Alnus*, grasses, *Alsophila* and Cyathaeaceae have been discovered from the transition between the Middle and Upper Siwaliks (Nandi, 1975), whereas of *Pinus*, *Larix*-type (abundant), Araucariaceae, *Magnolia*, grasses and comparatively less of Cyathaeaceae, Schizaeaceae and Parkeriaceae from middle part of the Pinjor Stage near Chandigarh and more or less similar assemblage from the middle part of Pinjor Stage in the Gagret-Bharwain road section in district Una in Himachal Pradesh have been reported. However, the latter differs from Chandigarh pollen assemblage in the absence of pteridophytes and *Magnolia*, *Larix* type is not predominant and angiosperm pollen is 7% in contrast to 23% in Chandigarh Section (Singh & Saxena, 1980, 1981; Saxena & Singh, 1982). From another section extending from Chaksadu in Hoshiarpur to Una in Himachal Pradesh, the lower composite Pollen Assemblage I (made up from the pollen content of 1-25 samples owing to poverty of pollen) shows abundance of *Larix*-like pollen (43%) over bisaccates (9%) in contrast to abundance of bisaccates (77%) and poor *Larix* type (11%) in the upper composite Pollen Assemblage II with pollen of Schizaeaceae, Polypodiaceae, etc. (Saxena & Singh, 1982).

It must be mentioned that the pollen analytical work in the Upper Siwaliks has been carried out from palynostratigraphic viewpoint and the fossil pollen referred to non-commital taxa. The identification of fossil pollen with those of extant himalayan plant species and the climatic inference therefrom have been done very loosely. Besides the evidence of reworking, the remains of fungi (9-14% of total pollen/spore count) have also been found. Except in a few samples, most samples have been found unproductive and the others have extremely poor pollen content.

The sediments in the Upper Siwaliks comprising sandstones, mud-stones and conglomerates are largely fluvial in nature and these were deposited in well-developed meandre regimes which migrated laterally more than once, striking a balance between basin subsidence and fluvial aggradation. The conglomerate deposits were formed owing to decreased sinuosity in stream development and to increase in gradient possibly related to the events of uplift suggesting individual responses to ancient distributary systems in response to local changes in hydrological regimes. The estimated sedimentation rate ranged from 0.33 m/10^3 years to 0.5 m/10^3 years in Pakistan side and this may be the order in the Indian Siwaliks also (Opydke *et al.*, 1979). In the light of these any reconstruction of floristics and climates from the Upper Siwaliks pollen assemblages may be highly misleading.

The overall information available at the present may be taken to suggest that the Pinjor plant remains show a gradual change from the Lower Middle Siwalik floristics in reduction of Cyathaeaceae, Schizaeaceae, Parkeriaceae, *Podocarpus*, and relative increase in *Larix* type pollen and *Pinus* and there is an indication of *Magnolia* also. The section extending from Chaksadu to Una appears to indicate substantial increase of bisaccates towards the top of the section which in lower part of the section were poor with the *Larix* type predominant. There is nothing of this kind of floristic change observed in the contemporary Lower Karewas.

Whether the above floristic change observed in the Pinjor Stage is real or a function of poverty of pollen, inadequate identification, a variable rate of sedimentation and differential destruction of pollen due to oxidation, or effect of fungi needs to be determined. Further, from the biogeographical viewpoint, it ought to be determined if the fossil pollen belong to the extant species or they represent their precursors. Proper identifications will reveal to what extent the east himalayan tropical floristics had continued into the western Himalaya and to what extent the floristics from the surrounding regions had invaded the western Himalaya, expanded and endemized later replacing the tropical floristics prevalent here prior to its advent. The Pinjor Stage in particular is the potential time period which through intensive palaeobotanical/palynological research can yield very valuable information to the above mentioned important aspects of the history of plant geography of the western Himalaya.

FOSSIL DIATOMS

The earliest report on diatoms in Karewas is by Lundquist (1936). Three years later, Conger (1939) published the qualitative and quantitative dominance of Pennales over Centrales in three samples of the Lower Karewas from Handawar and Shaliganga Valley and inferred a rather sizeable, moderately shallow somewhat alkaline or hard water lake at the peak of its productivity.

However, he did not find diatoms in the Upper Karewa sediments. Conger's work enhanced our knowledge of the diatom flora in the Lower Karewas by a dozen taxa not reported by Lundquist (1936).

Later, Iyengar and Subramanyam (1943) from the Ningle Valley and Rao and Awasthi (1962) from Laredura added more taxa to the diatom flora of the Lower Karewas, particularly some endemic taxa. They also reported some taxa in these fresh water deposits which elsewhere occurred in marine and brackish waters. Strangely enough, Rao and Awasthi mentioned marine sediments at Laredura (1962, table 1, p. 89).

Nearly two decades later, Roy (1970, 1971, 1972, 1975, 1979) added 14 genera hitherto unknown from the Lower Karewas. Like Conger (1939) he did not recover diatoms in the Upper Karewas. He also established (Roy, 1972) the Diatom Biozones I and II in the Upper Ningle Valley-Botapathri region, at Baramula and Raithan and Biozone I at Liddarmarg and the other sites and Biozone II at Handawar, Nichahom, Laredura, etc. He also created subzones named after a single taxon.

Roy neither reconstructed palaeoenvironment nor brought out alterations or fluctuations in diatom populations at the sites examined. A large majority among the 30 species identified (Roy, 1972), indeed is of fresh, slightly brackish and euhaline habitat, but *Synedra crystallina*, *Coscinodiscus marginatus* and *C. morensis* are known from ancient to recent marine sediments. Their occurrence in the majority of fresh to slightly brackish water diatoms may either be due to insecure identifications, their habitat plasticity or due to transport of pre-Karewa marine sediments into the fresh water deposits of the Lower Karewas.

The more or less exclusive occurrence of Centrales (90-98%) in Biozone I and that of Pennales in Biozone II may not be that real as it appears. Evidence for differential destruction or dissolution and diagenesis of silicious tests of Pennales in Biozone I and of Centrales in Biozone II has not been looked into. It is hoped that the future diatom researchers would undertake such studies.

The abundance of Centrales in the Diatom Biozone I and the first appearance of *Navicula* in Biozone II led Roy to assign Mio-Pliocene age to the Lower Karewas. Indeed from historical and phylogenetic viewpoints, the Centrales are the oldest group of diatoms as far best they are genuinely known from the marine sediments from Cretaceous (Albian) onwards, it is during the Miocene (marine) as known from elsewhere that the Pennales, erstwhile quantitatively poor, begin to overtake the Centrales. Among several other pennalean taxa, *Navicula* also appeared in the Upper Miocene (marine) while several centric forms disappeared and others declined.

Should the first appearance of *Navicula* in marine sediments be synchronous with its appearance in fresh water sediments too? Or should a single taxon in place of floral composition be considered adequate for age determination? How far the diatom telecorrelations in disjunct and unconnected basins as Mexico and South Asia and even between Alps and the Himalaya are justifiable? The answers to several such questions would need due consideration of the time involved in evolution and migration of taxa in the background of the plaleogeographical evolution of the basins.

Predominance of Pennales without *Navicula* was reported by Conger, 1939 (cf. de Terra & Paterson, 1939, p. 261) in the Tatrot Stage now dated to Pliocene in the Naushera Salt Range and recently their predominance has been reported in the Pliocene deposits at Hirpur Locality III in the Lower Karewas (Gupta & Khandelwal 1982a). This evidence provides basis for age correlation even between Siwaliks and the Kashmir Valley, the two basins in close proximity.

Roy's work (1972, 1975, 1979) further, and for that matter of his predecessors and the recently reported work (Gupta & Khandelwal, 1982a; Mohan *et al.*, 1982a, 1982b), falls short of the statistical evaluation of diatoms to elucidate the evolutionary and biographic trends such as the extent of the long-living continuous species, the extent of those dying out, the emergence of progressive taxa, their expansion and continuity to the present.

There is practically no work conducted towards the understanding of ecology and development of the Karewa Lake through recognition of planktonic, epiphytic and benthic taxa among the recovered diatoms, through the relative alterations between them and through the overall quantitative evaluation of diatoms per gram of the sediment vis-a-vis the chemistry of sediments to determine alterations in water levels in Karewa Lake and its changing trophic status.

Immature conclusions on past climates have been arrived at (Mohan *et al.*, 1982b) without fresh data-base on the distribution of extant diatoms in various climatic regimes in the Himalaya or without recourse to concerning information published during the last hundred years (Vishnu-Mittre, 1983).

Changes in water level of a lake or fluctuations in its trophic status are responses to climatic and tectonic-geomorphic effects. Total increase in evaporation owing to increase in evaporation rate together with decrease in output by decrease in rainfall is a climatic effect. On the other hand total increase in evaporation resulting from increase in lake surface and further decrease in input by decrease in drainage area (stream capture) is a tectonic-geomorphic effect. Similarly, increase in diatoms of subaerial habitat during a stage when herbs such as *Artemisia*, cheno-ams, caryophylls, etc. predominated indicating severe nature of climate on the mainland is due to erosional phenomena. The diatom distribution is primarily dependent upon edaphic factor rather than climatic factor. The edaphic factor in this concern means the extent of organic matter present, fluctuations between carbon and phosphorous, the clastogenic materials and also the rate of sedimentation, etc.

BIOSTRATIGRAPHY

Vegetational history should always be based upon good lithostratigraphy. De Terra and Paterson's (1939) lithostratigraphical scheme for the Lower Karewa adopted for pollen analysis stood the test of time for some decades. Whereas their evidence for the First Glaciation in the underlying massive conglomerate was disputed as early as 1951 (Wadia, 1951) and subsequently (Vishnu-Mittre, 1965b), their utilization in their scheme of the occurrence of two bands of lignite within the Lower Karewas after Middlemiss (1924) was confirmed in 1958 through detailed mapping and measuring of sections (Mehta & Srivastava, 1958). The mapping and measuring sections led Roy (1972) to recognize four lithozones equivalent to I-IV of de Terra and Paterson, who also built up the diatom stratigraphy of the Lower Karewas.

Without consulting and commenting upon the work of Mehta and Srivastava (1958) on the occurrence of two bands of lignite in the Lower Karewa deposits, Bhatt (1979 cf. Bhatt, 1981, 1982) considered that de Terra and Paterson's fine stratigraphy of the Lower Karewas was based upon presumed correlatability of different lignitic occurrences. Further, he considered that the Lower Karewa outcrops are uncorrelatable owing to unequal folding, erosion and the frequent changes in lithostratigraphy (extreme lateral change in lithofacies). Bhatt (1979) therefore chose conglomerate molasse as a very convenient and handy marker horizon for a field geologist to build stratigraphy, for it occurs in several sections of the Lower Karewas even though it varies in thickness from 6 to 200 m in different outcrops. The three-fold stratigraphy of the Lower Karewas proposed by Bhatt (1979, cf. 1981, 1982) comprises a pre-Conglomerate Zone (Zone 1), a Conglomerate Zone (Zone 2) and a post Conglomerate Zone (Zone 3) as observed in the Type section at Hirpur.

Agrawal *et al.* (1981) reported thin horizons of conglomerate within the post-Conglomerate Zone (Zone 3) at Bhatt's type site, the lower was dated to Gauss normal Epoch (2.47-3.41 m years) and the Upper to Matuyama Reversal Epoch (1.70-1.91 million years). These overly the 200 million thick bottom conglomerate molasse dated to Gilbert Reversal Epoch (3.41-5.44 million years). Attributing these minor conglomerates to minor tectonicity, Bhatt (1982) does not consider these significant for correlation purposes. Their dating to different palaeomagnetic epochs reveals that their significance is perhaps being overlooked and these are certainly not time equivalent with Bhatt's convenient and handy marker, the cemented conglomerate, underlying them. It needs to be proven by isotopic dates that the cemented conglomerate exposed in several sections is time equivalent as believed by Bhatt (1982).

The conglomerate deposits within the Upper Siwaliks in Pakistan have been found to be of varying dates: 5.44 and 4.42 million years respectively at Bhaun at Totrot; 1.9-2.1 million years in Rohtas anticline in Jhelum District; later than 1.9-2.1 million at Mangla-

Samoval anticline (Jhel Khas Section, SW of Kashmir) and to 7,00,000 years at Camphellpur (Opdyke *et al.*, 1979). Yokoyama (1981) dates the upper part of Tatrot, east of Chandigarh to about 1.9-2.1 million years. A more or less similar situation observed in the Lower Karewas, howsoever preliminarily determined at the present trends to reveal contemporaneity of the Lower Karewas with the Upper Siwaliks.

The continuing pollen analytic work has yet to establish the validity of Bhatt's three-fold stratigraphy of Lower Karewas. Utilizing the earlier palynological data (Vishnu-Mittre, 1973a) in this context, the deposits below conglomerate at Laredura (Text-fig. 2) and Raithan (Text-fig. 4) do not reveal similar vegetational pattern. Likewise the exposures at Ningle Nala, Nichahom (Text-fig. 3) Laredura (Text-fig. 2) and Sedau (Text-fig. 1) above conglomerate are also dissimilar palynologically.

Testing the validity of de Terra and Paterson's fine stratigraphy from palynology reveals that the Basal Clay Zone at Sedau (Lithozone 1, Text-fig. 1) and the Upper Clay Zone at Botapathri (Lithozone 4, Text-fig. 5) are distinctly different. So are the Lower and the Upper Lignite Zones (Lithozone 2 & 3, Text-figs 2, 3) at Laredura and Nichahom. The bottom horizon of lignite at Nichahom (Text-fig. 3) portrays continuation of vegetational development with immigrating blue pine into steppe as observed in the Lower Lignite Zone at Laredura (Text-fig. 2). The Raithan Section (Text-fig. 4) correlated with the middle of Laredura Section by de Terra and Paterson (1939) brings out the continuation of the decline of pine forests. The pollen analyses of exposures at Laredura, Raithan and Nichahom above the cemented conglomerate therefore portray the immigration, expansion and decline of blue pine commencing with the First Cool Oscillation and ending with the Second, and this important aspect of vegetational development seems to support the lithological correlation attempted by de Terra and Paterson.

The random pollen analyses of leaf-bearing sediments at Laredura and Liddarmarg justify de Terra's referring these exposures to Lithozone 4 but Dangarpur depicting Deodar mixed conifer woods differs from the other sites in Lithozone 4 (Vishnu-Mittre & Robert, 1973). Systematic pollen analysis of sediments at Botapathri (Lithozone 4) brings out spruce-deodar oak woods leading into the *Juglans-Ulmus* open woods. Detailed and systematic analyses of these sites randomly pollen-analysed and of others may throw adequate light on their correlation with one another.

Recently Pal *et al.* (1980) have reported the evidence of II Glaciation in the cemented conglomerate underlying the Lower Karewas. Earlier de Terra and Paterson (1939) had reported hesitatingly I Glacial evidence in it. Should Pal *et al.* (1980) be correct, then II Glaciation as believed by Pal *et al.* would be as old as 3.41-5.44 million years to which cemented conglomerate in the Lower Karewa is dated now.

In keeping with the Code of Stratigraphical Nomenclature of India, the Lower and Upper Karewas have recently been named after the type sites (Pakharpura & Shopian formations by Farooqi & Desai, 1974; Hirpur & Nagum formations by Bhatt, 1976). Following this, Vishnu-Mittre (1980a) has recently suggested that the distinct vegetational stages in the Lower Karewas should be named after the type sites such as Sedauian for the oak-alder wood stage at Sadau; Nichahomian for the pine mixed woods at Nichahom; Botapathrian for the spruce-deodar-oak wood stage at Botapathri. It is also suggested that the cool oscillation in the Upper Lignitic Horizon at Laredura which is the extension of the one observed at Raithan should be named de Terran; the cool oscillation in the Lower Lignite of Laredura and within the base of Nichahom be named Wadian and the one towards the top of Botapathri as Patersonian to commemorate the names of H. de Terra, D. N. Wadia and T. T. Paterson. The five pollen diagrams accompanying this paper are so constructed that they can be easily superimposed in any of the floating lithostratigraphies to which the sites investigated may be accorded stratigraphical position different from that in de Terra and Paterson's scheme of lithostratigraphy for the Lower Karewas.

LATE QUATERNARY VEGETATION AND CLIMATE AND LAND USE

VEGETATION AND CLIMATE

The results of pollen analysis of bore-cores dating from 40,000-10,000 radiocarbon years from above tree limit in Ladakh at 34° Lat. and above 4572 m a.s.l. and reported briefly by Vishnu-Mittre and Bhattacharyya (1980, 1983) reveal alterations between the chenopod-grass steppe and expansion of juniper, the latter interpreted to indicate amelioration of climate, i.e. interstadial. It is claimed (Vishnu-Mittre & Bhattacharyya, 1980, 1983) that more than five periods of amelioration of climate had occurred during the last glaciation. There was one before 40,000 years ago. The one between 28,000- and 34,000 years ago is also supported by a biogenic deposit in the profile. It seems to be a distinct interstadial comparable with Denekamp in Europe. The interstadial between 21,000 and 18,000 years ago indicates deglaciation at this time or slightly after. Among the others recognized are between 17,000 and 16,000 radiocarbon years and at 10,000 radiocarbon years. Between 15,800 and 10,000 years the climate reverted to cold again. Interestingly, close correspondence is observed between these interstadials and some dated palaeosols in the Kashmir Valley (Vishnu-Mittre, 1984; Vishnu-Mittre *et al.*, 1984).

A profile (Text-fig. 6) about 4 km from the subalpine meadow at Toshmaidan has on radiocarbon dating (Singh & Agrawal, 1976) shown that the bottom 3 m were deposited before 15,000 years ago and the top one meter during the Holocene times commencing from 10,000 years ago. An erosional break has been observed in the extreme top above 50 cm as the topmost sample at 15-35 cm is dated to 2,790 ± 160 radiocarbon years. Unfortunately this profile has not been pollen analysed in detail. The pollen spectra of the dated samples are related with the pollen stages in pollen diagram from Toshmaidan earlier published and referred to post-glacial (Singh, 1963). Both the stratigraphy and pollen stage correlation in the two profiles leave much to be desired.

The substantial part of the reconstructed Toshmaidan pollen diagram (Text-fig. 6) is dominated by the sedge-chenopod-Compositae steppe, chenopod-*Artemisia*-grass steppe and subsequently by *Artemisia*-grass steppe, and finally sedges predominating above 60 cm to the top. Within this predominant steppe environment there were events of immigration and expansion of trees constituting forest communities. The extrapolation of the radiocarbon dates from the unpollenized profile to this pollen profile would suggest the occurrence of blue pine-deodar community with temporary rise of oaks prior to 15,000 years which seems to indicate a warm oscillation as inferred at slightly before 15,800 years in the Tsokar Lake profile. Within the steppe conditions, the immigration of birch followed by its expansion indicates the commencement and increase in amelioration of climate. Its subsequent expansion and eventual formation of alpine fir-birch forest is seen towards the extreme top of the diagram. The present belt of this forest occurs slightly higher up.

The Haigam pollen diagram from the valley proper (Vishnu-Mittre & Sharma, 1966) reflects ± similar pattern of change but the alpine constituents are present in extremely poor frequencies. The two radiocarbon dates are much younger (Vishnu-Mittre, 1979). A well-dated sequence needs to be prepared again. However, here too the *Artemisia* steppe conditions dominate nearly three-fourth of the pollen diagram. The abrupt decline of oak mixed wood towards the top is observed in both the Toshmaidan and the Haigam pollen profiles.

Both the pollen diagrams show the occurrence of *Quercus* and *Alnus* in fair to good frequencies declining towards the extreme top. These two genera have long been known to be absent from the valley except the subsequent discovery of stray occurrence of *Quercus dilatata* and *Q. semecarpifolia* (Vishnu-Mittre, 1963). They would, on pollen evidence, appear to be relics of early Quaternary oaks. The occurrence of oaks with *Artemisia* makes a better case for the former occurrence of the dry *Quercus ilex* steppe forest (Champion & Seth, 1968, p. 325), because the precipitation had already become much reduced by the lofty Pir Panjal (Vishnu-Mittre, 1966a, 1974a, 1974b).

At a still lower latitude (about 27° lat.) 7° lower than that of Tsokar, Haigam and Toshmaidan in the western Himalaya and discussed above, the vegetational sequence during the last glaciation in the subtropical Kathmandu Valley, Nepal in the Central Himalaya (Vishnu-Mittre & Sharma, 1984) shows fluctuations between steppe and oak or oak-pine woods. Three interstadials recognized by expansion of oak woods within steppe are dated pre-40,000, 25,000 and 17,000 radiocarbon years more or less corresponding with those in Ladakh. Between 15,000 and 11,000 radiocarbon years open oak or open pine-oak woods had occurred. Both natural pine and oak woods are nonexistent in the valley today. However, they occur in the surrounding mountains under much higher precipitation.

In keeping with the Code of Stratigraphical Nomenclature of India, the last Glaciation in the Himalaya should be named as Tsokarian after the Tsokar Lake profile. The interstadials can be named subsequently after more information is gathered.

About 5 m deep marginal profile from Naukuchiya Tal not far from Nainital in the Kumaon Himalaya (Vishnu-Mittre *et al.*, 1967; Gupta, 1977) has an undated pollen profile where the chirpine woods were gradually invaded by oak mixed woods and these eventually dominated the remaining pollen diagram to its extreme top. The sequence seems to cover a large part of the postglacial, here commencing most likely from about or before 8,000 years ago. Recent brief report reveals it to be before 8,000 radiocarbon years (Khandelwal & Gupta, 1983). The Sat Tal pollen sequence in the same region is much later and shows predominance of pine over oaks until 1,400 radiocarbon years when oaks predominated over pines and the re-expansion of oaks took place again in the late 19th century (Gupta & Khandelwal, 1982b).

The pollen sequences from Himachal Pradesh show dense oak woods dominating the region since about 4,000 years ago. They were replaced by *Cedrus* (Deodar) woods in Khajiar by about 1,250 years ago whereas at Rewalsar their replacement by chirpine commenced about 1,400 years ago and completed by about 500 years ago (Sharma & Singh, 1974). The floating islands in these lakes began forming by about 700 A.D. (Sharma, 1972). It is not certain if this change may be attributed to a change in climate or to anthropogenous influence destroying the oak woods thus allowing the light demander chirpine or deodar to replace them. The stumps of oaks in these forests are still reminiscent of not only their former occurrence but dominance also.

The pattern of vegetational change in the immediate past in the Kashmir Valley (Singh, 1963) is observed in two shallow and undated profiles. The shallow profile (70 cm) from Braman Mire-B shows predominance of blue pine with high frequencies of grasses and other herbs and *Abies* showing rising trend. The large-sized grass pollen grains are identified as of *Zea*. The deeper (120 cm) profile from Walanwar shows consistently high frequencies of grasses and other herbs and those of *Zea* consistently rising. The pollen of *Zea*, if correctly identified, would date the diagram from about 1,500 years A.D. Against the high values of non-arboreals those of pine pollen may be misleading. The modern pollen spectra do, however, show high pine values but with poor grass pollen frequency. At present the population of blue pine in the valley is extremely poor except along the surrounding slopes of Pir Panjal or Himalayan mountain, and there is intense grazing pressure on the ground vegetation besides cultivation in the valley. The decline of oaks in the valley, as the pollen evidence suggests, took place within the last about 500 years.

From within the mid-altitude about 2,500-2,700 m in the Kashmir Valley, the two shallow profiles namely the Yus Maidan profile from the famous meadow surrounded by pine-fir forest (Pine 70%, Fir 20%, Spruce 5%) and the Baba Rishi profile from within fir-pine forest with stands of *Taxus baccata* show the history of these forests in the immediate past (Sharma & Vishnu-Mittre, 1969). The Yus Maidan formerly extended over much vaster area and the forests now surrounding it and comprising blue pine-fir and spruce had gradually encroached upon the Maidan. Birch was a conspicuous member leading eventually to the blue pine-fir-spruce forest whereas at Baba Rishi the blue pine-fir forest has continued to exist here with gradually increasing proportion of *Abies* and spruce. A feature of great interest is observed in the lower two-third of both these pollen diagrams where fir pollen curve shows decline and then rise at both the sites about 48 km apart. This has been attributed to exploitation of fir for timber in the recent past. This selective extraction of fir seems to induce rise in blue pine in the Baba Rishi profile, and of birch followed by blue pine in the Yus Maidan profile. Fir is largely used for matches, wood pulp, timber and for firewood.

In addition to the above, the recent brief reports (Dodia *et al.*, **1982b**, 1982c) show the continued dominance of *Pinus wallichiana* since 15,000 years ago in the vicinity of Botapathri, since 4,000 years ago in the vicinity of Anchar Lake and since 1,000 years ago in the vicinity of Hokar Sar in the Kashmir Valley. However, the detailed results must be awaited on these unusual features, and any comments are reserved till then.

The small sequence from Bhim Tal (Gupta, 1977) likewise portrays recent developments of vegetation in the vicinity of this lake in Kumaon Himalaya.

The predominance of Chirpine pollen in a clay sample from Kalidhang, District Sirmur, Himachal Pradesh has led Tewari *et al.* (1979a) to infer the former occurrence of *Pinus roxburghii* forest. Pine pollen grains are capable of misleading for their former occurrence and this fact is well known in most parts of the world and in the Himalaya. From the same deposit Tewari *et al.* (1979b) have described some leaf impressions — a mixture of temperate and subtropical species (*Prunus* sp., *Mallotus philippensis* and *Celtis* sp.). Diatoms such as *Melosira granulata*, *Rhoicosphenia curvata* and *Pinnularia gibba* are also reported from here (Swain, 1982).

The only information from Assam comprises two pollen spectra from near Tockalai Experimental Station, Cinnamara indicating fluctuations in the open *Ardisia-Eurya-Dillenia*-oak forest unsupported by modern pollen/vegetation relationships (Gupta, 1971).

Information on macrofossils has also been brought out by pollen analyses. The seeds and fruits from the postglacial deposits from Kumaon (Gupta, 1973) remain to be properly identified and evaluated from the climatic and phytogeographical viewpoints (Vishnu-Mittre, 1974a, p. 24), but the evidence of the former occurrence of mosses more particularly of sphagna in the subtropical belt and some hitherto unreported from the western Himalaya is an invaluable contribution to Indian phytogeography (Singh, 1963; Vishnu-Mittre & Gupta, 1971; Sharma, 1976).

LAND USE

The impact of early man and his grazing animals upon vegetation in the Himalaya has also been inferred from the pollen diagrams. The selective use of fir at Baba Rishi and Yus Maidan (Sharma & Vishnu-Mittre, 1969); of *Celtis* in Kumaon (Vishnu-Mittre, Gupta & Robert, 1967; Gupta, 1977); overall change of oak woods into pine or deodar woods in Himachal Pradesh (Sharma & Singh, 1974); the extinction of oaks and alders in the Kashmir Valley and the poor values of grasses in Kashmir pollen diagrams attributed to intensive activity of grazing animals (Vishnu-Mittre, 1966; Vishnu-Mittre & Sharma, 1966) are some of the examples. Besides the exploitation of wild plant life, the event of commencement and progressive increase in land use by man through recognition of cereal pollen and weeds of cultivation and through fluctuations in pollen curves indicating decline and recovery of forest in response to clearance, farming and abandonment of the sites has been inferred in specially computed pollen diagrams (Vishnu-Mittre & Sharma, 1966; Gupta, 1977). In one instance evidence of charcoal has also been found, whether it is natural or man-made remains to be known (Vishnu-Mittre, *et al.*, 1967; Gupta, 1977).

The recent radiocarbon assay dates some events of land use much beyond the known estimates for the Neolithic period in the Himalaya. The discovery that very large grass pollen comparable with that of any known cereal is also produced by wild grasses in India, and some of these are also distributed in the Himalaya (Vishnu-Mittre, 1973b) suggests that the inference of land use from pollen diagrams based upon this criterion requires more dependable and indisputable evidence. Further, it is important that the significance of the alterations in vegetational development inferred to suggest that the past land use must be carefully understood. That these might have been caused by factors other than human influence must not be overlooked (Vishnu-Mittre, 1980).

The undisputed evidence for the past land use indeed can be provided by the remains of cultivars discovered from well-dated archaeological sites. And this parameter has shown recently that the land use in the Indian subcontinent had commenced some thousands of years before the hitherto dated Neolithic, that is at the beginning or soon after the Holocene period (Vishnu-Mittre, 1976; Jarrige, 1982). The dependable support for the same from pollen evidence may await till the distinction between the fossil and the extant cereal and grass pollen has been demonstrated by the sophisticated methods known today.

Against the pollen evidence for land use by man and exploitation of wild plant life by man and his grazing animals may be mentioned the macrofossil evidence discovered from the archaeological sites in the Himalaya. The evidence of seeds of wild plants and forage crops (*Lithospermum arvense*, species of *Ipomoea*, and of several wild legumes: Vishnu-Mittre, 1966b) from the Neolithic site Burzahom about 6 km north-east of Srinagar in the Kashmir Valley and dating from 4,300 radiocarbon years (Agrawal & Kusumgar, 1965) shows that the Neolithic Burzahomians were possibly food gatherers. These weeds and forage crops also occur in the wheat and barley fields. That these two crops were grown in the valley becomes evident nearly 300 radiocarbon years later at the site Gufkral about 41 km south-east of Srinagar (Sharma, A. K., 1979-80). Besides, wheat (*Triticum*) economy at this site had also included lentil (*Lens culinaris*) and *Pisum arvense*. This food economy at this site had continued until towards the end of the Megalithic period, when rice (*Oryza sativa*) and Ragi (*Eleusine coracana*) were introduced in the valley.

From 1,500 B.C. to 2nd cent. B.C., the food economy at yet another site Semthan in the Kashmir Valley comprised wheat (*Triticum compactum & T. sphaerococcum*), barley (*Hordeum vulgare*) and rice (*Oryza sativa*). Together with these were found seeds of forage crops *Vicia sativa*, species of *Trifolium* and *Medicago* and *Avena fatua* (Buth *et al.*, 1982).

The continuation of more or less the same weeds and forage crops from 4,300 radiocarbon years till early historical times and the introduction of farming nearly 300 years later seems to suggest the continuation of food gathering even after the introduction of farming. What for these weeds and forage crops were gathered and used remains unknown. A very significant feature brought out by these discoveries is that rice, the present staple crop in the valley, was introduced in wheat-barley based economy about 900 years later. That Ragi was introduced later to rice is also interesting as it is grown in the Himalaya today and perhaps not in the Kashmir Valley.

The evidence of rice cultivation from other parts of western Himalaya (site Kalsi in Dehradun and from sites in Assam: Vishnu-Mittre, unpublished) is much later than records in the Kashmir Valley. With considerable diversity in progenitors of rice in Assam, it is hoped that this potential region in the Himalaya may yield the oldest records of rice cultivation in the Himalaya.

The exploitation of forest trees by the Neolithic peoples at Burzahom and Gufkral nearly 47 km apart from one another shows a progressive and selective use of the forest trees but the kinds of trees used at these two sites were not the same. Whereas timber of *Cedrus deodara*, *Parrotia jacquimontiana* and species of *Celtis*, *Ulmus* and *Pinus* (Savithri, 1976) was used by the Neolithic Burzahomians; the Neolithic Gufkralians had used timber of *Pinus* sp. during the Aceramic period, of *Juglans regia*, *Aesculus indica* and species of *Pinus* and *Prunus* during the Early Neolithic and of *Ulmus wallichiana*, *Buxus wallichiana* and species of *Picea* and *Pinus* during the late Neolithic (Vishnu-Mittre & Chanchala, 1983).

Around the Christian era timber of *Shorea robusta*, *Mangifera indica* and species of *Terminalia* and *Cinnamomum* were exploited by the people at the site Kalsi in Dehradun (Ghosh & Lal, 1961; cf. Vishnu-Mittre, 1974a, 1974b). No information is available from the central and eastern Himalaya of the exploitation of forest wealth.

CONCLUSION

Overviewing the entire available mass of palaeobotanical/palynological information from the Himalaya, it would be admitted that this botanical parameter hardly shares any iota of credit for delimitation of the Neogene/Quaternary boundary and likewise the Pleistocene/Holocene boundary. On the other hand the entire credit in the potential area of the Lower Karewas in the Kashmir Valley goes to preliminary palaeomagnetic studies and to, howsoever insufficient, fission track dating (Burbank & Johnson, 1982). The palaeobotanical/palynological evidence would have us believe that the Pliocene floristics were much like the early Pleistocene floristics, and there is hardly anything like the transition from the one into the other. The boundary could have been recognized at this botanical transition.

An overview of the Miocene-Pliocene floristics in the Siwaliks (Vishnu-Mittre, 1984) reveals that a remarkable change is discernible from wet tropical evergreen forests in the Miocene to floristics indicating moist conditions in the Pliocene and comprising members of Cyathaeaceae, Parkeriaceae, Schizaeaceae along with species of *Podocarpus*, *Pinus*, *Cedrus*, *Magnolia* with an inaperturate pollen type referred to the form genus *Laricoidites* (believed to be comparable with the pollen of *Larix*) predominating on which tropical to temperate, temperate to subtemperate climatic conditions have been inferred (Singh, 1982; Saxena & Singh, 1982). However, the temperate climate did exist in the Miocene period at altitude higher than that of the then Siwaliks as inferred from the recent discovery of palms of Chinese-Russian taxa in the Liyan Formation of Ladakh (Lakhanpal *et al.*, 1983; Vishnu-Mittre, 1984).

The utter absence of the Siwalik Pliocene flora complex referred to above in the corresponding Lower Karewa exposures in the Kashmir Valley but for pollen grains of *Cedrus*, *Pinus* and *Larix* type deserves serious consideration from biogeographical viewpoint. Nevertheless as many as 15 climatic oscillations, tropical, subtropical, temperate and cold (alpine), are briefly reported by Gupta *et al.* (1982b) which in fact are not borne out by the reported pollen assemblages. Further, each lithotype without regard to its position in the section has been found to be characterized by the same pollen assemblage and the alterations between temperate and subtropical floristics makes the entire information highly confounding. However, the publication of full information is eagerly awaited. At the present state it would seem that this confusion may be attributed to insecure identifications, utter disregard of sedimentation/preservation phenomena and ignorance of the ecological and distributional perspectives of the taxa identified.

Besides a sound knowledge of the ecology and distribution pattern of the extant taxa in the Himalaya, well-established determinations of their remains, a good conversance with the role of dispersal, sedimentation and preservation and the rate of sedimentation are imperative in achieving the objectives through the application of pollen analysis. The identification of plant remains with published figures and photographs from other parts of the world (Gupta, 1973), the interpretation of composition of the present forest communities from modern pollen spectra from within them (Gupta, 1977), and describing occupation phase in lower part of a pollen diagram and the Landnam phase in the upper part of the same (Gupta & Khandelwal, 1982) without realising that they mean the same, and inferring from *Artemisia*-cheno-ams-grass-sedge assemblage from Lower Karewas vegetation of the type that exists today in Ladakh 5,000 m above sea level (Dodia *et al.*, 1982a) suggest utter lack of understanding the methodology of Quaternary palynology, of ecology and distribution of plant life in the Himalaya, and the tendency to jump to conclusion.

The *Artemisia* - cheno - ams - grass-sedge assemblage could indicate an environment approximating the one in the Pishin Valley (1,375-1,600 m) near Queta for the same altitude as of the Lower Karewas at present or the environment above tree limit and below the glacier at 2,800 m at Tilel or below the snowmelt alpine region in Baluchistan (Stewart, 1982) if believed that the Lower Karewa deposits were laid at altitude higher than that at present.

The abominable mystery of *Laricoid*, *Larix*-like or *Larix* pollen from the Pliocene to recent requires special attention towards the solution of this mystery, more particularly in the light of its restricted distribution in the central and eastern Himalaya where it occurs in the fringe near the timberline in the upper part of high level conifer forest with *Abies spectabilis* and *Betula utilis* with shrubs of the species — *Rosa macrophylla*, *Berberis aristata*, *Cotoneaster rotundifolia* and *Rhododendron campanulatum* between 3,000 and 3,500 m a.s.l. in the Buri Gandak Basin in Nepal (Kitamura, 1955). More or less at the same altitude and ascending slightly higher, it occurs along with *Picea morinda* and *Tsuga brunoniana* in the humid mountains of the Lachung Valley in Sikkim (Gammie, 1894) and in the Zemu Valley at about, 3,000 m alongwith *Picea*, *Tsuga*, *Abies*, *Juniperus* associated with species of *Berberis*, *Ilex*, *Euonymus*, *Acer*, *Rubus*, *Rosa*, *Rhododendron*, *Betula*, *Alnus* (Smith & Cave, 1911) and again above 3,000 m in the Mishmi hills in North-East Frontier Agency associated with mixed conifer forests (Bor, 1938). Believed to be edaphic or pioneer, *Larix* occurs in an environment which may be described subalpine though Champion and Seth (1968) mention the Larch forest among the temperate forest types. It is nowhere associated with *Pinus roxburghii*, as observed in Holocene pollen diagrams from the subtropical regions of Kumaon and Himachal Pradesh along with pollen of subtropical pines and oaks (Gupta & Khandelwal, 1982b; Sharma & Singh, 1974). In the light of its environment discussed above *Larix* should not be considered to have been a member of subtropical forests during the postglacial times. The continuous recovery of its pollen from Pliocene until recent times in the Himalaya may suggest that it was either widely distributed in the past or it is a high pollen producer with a capability of wide dispersal. Has its pollen been distinguished beyond doubt is another question that needs a definite answer ? Likewise there is a case of definite distinction of pollen grains of *Pinus roxburghii* from those of *P. wallichiana*. It is therefore all the more important that fresh and copious materials of pollen grains of himalayan conifers collected from the length and breadth of the Himalaya are examined again to solve the abominable mystery of *Larix*-like pollen and similar problems concerning other conifers.

The present day Himalayan flora is made up of taxa of diverse geographical origins: Irano-Turanian, Saharo-Sindhian, Sino-Japanese, Mediterranean and tropical to name some important geographical units. Barring a small percentage, many species are endemic. When and underwhat circumstances (climatic, edaphic or biotic) these diverse plant geographic units entered the Himalaya ? What were the floristics which were replaced by them ? When and under what circumstances the immigrating foreign species reaclimatized and endemized ? What were the indigenous tropical taxa that have continued and escaped the repeated and drastic changes in climate and how many were decimated ? It is a huge task for the Quaternary pollen analyst to find answers to these questions. This overview finds that hardly any attempt has been made to answer any of these questions. This is a very rich area of biogeographical enquiry and pollen analysis can alone provide a factual history through mapping the distribution in time and space of the Himalayan taxa.

There can be no denying that the plant species subjected to successive climatic and edaphic alterations during the Quaternary period must have been compelled to acquire climatic requirements different from those when they had entered the Himalaya, otherwise they could not have survived. The instances of ecologically incompatible taxa among those identified Lower Karewa plant remains discussed elsewhere in the text is a testimony to the concept that the past is the key to the present but the present cannot be ignored because this provides the comparable floristic complex in the Himalaya comprising considerable phytogeographical diversity and therefore it deserves a serious attention.

The occurrence of some himalayan plant species in the hills of Madhya Pradesh (Pachmarhi), Bihar (Parasnath) and Rajasthan (Mt. Abu) where the peaks are about 1,200-1,350 m a.s.l. and in the south Indian mountains (Nilgiris, Pulneys) where the peaks are over 2,000 m has remained an abominable mystery in Indian phytogeography. Even though constituting a small percentage, this himalayan floristic element in the hills of central and south India has long been attributed to the impact of glaciation in the Himalaya which forced these species to migrate southwards.

The climatic fluctuations during the last glaciation in the trans-himalayan to subtropical regions of western and central Himalaya as discussed elsewhere in this paper were not strong enough to cause migration of the trans-himalayan floristics into the subtropical region of the Himalaya. What were the conditions during the previous glaciations are still unknown.

Interestingly, the climatic oscillations during the last glaciation in the Himalaya and those during this period in the Nilgiris have been found to be largely synchronous (Vishnu-Mittre, 1983; Vishnu-Mittre *et al.*, 1984). Thus, the theory that the himalayan floristic elements migrated southwardsduring glaciation is not borne out by the present state of knowledge.

There are on record recently discovered instances of occurrence of plants of one region into the other. The west himalayan *Oxybaphus himalaicus* has been recorded recently at the foot-hills of Chamundi Hills in Mysore (Rao & Razi, 1975); *Solanum khasianum* Clarke var. *Chatterjeeanum* of Assam, Burma, Bengal, Orissa, Madras has been recently reported in Dehradun in western Himalaya (Bahadur & Dayal, 1968); the east Himalayan orchid *Tropidia curculigoides* has also been reported in Dehradun (Deva & Arora, 1971); *Helminthostachys zeylanica* of South India, Assam and Bengal has been recently recorded from Lakshmipur forests in Gorakhpur (Dikshit & Tripathi, 1966). To which climatic oscillations in the recent times the migration of these and such other examples reported from the peninsular south to Himalaya and from the east to the west of the Himalaya and vice-versa may be attributed?

The parameters other than climate for the dispersal and distribution of plant species from one climatic regime to another must be considered. Among these the role of avefauna (Ali, 1981) deserves special mention in this context. There are quite a few himalayan relicts in the avefauna in the Western Ghats complex, for instance, the Laughing Thrushes (*Garulax*) of Indo-chinese origin, the Great Hornbill (*Buceros bicornis*), the Frogmouths (*Batra chostomus*) and species of *Irena*, *Aviceda* and several others. The subspecies of these relicts are now recognized in the Nilgiris and these are considered to be endemic. The species of *Garulax* particularly are closely associated with species of *Rubus* both in the Himalaya and Nilgiris and they occur at the same altitudinal range about 1,000 m or above (Ali, 1981).

Even some birds endemic in Himalaya fly nonstop 1,500-2,000 km each way to hills in South India such as the Woodcock (*Scolopax masticola*), the Pied Ground Thrush (*Zoothera wardii*), the Blue Chat (*Erithacus brunneus*), etc. Their halts in between hills are seldom observed. From the normal flight of 60-80 km per hour, they reach the Nilgiri and Pulney mountains in about 25 hours. The seeds of many plant species retain the viability during this interval of time.

It appears that the solution to the abominable mystery in Indian phytogeography referred to above lies in the role of avifauna rather in the impact of himalayan glaciation(s).

The importance of the immediate antecedents of present forest communities from pollen analysis of shallow profiles in the understanding of events in the immediate past particularly for a larger understanding of the factors which governed distribution of past plant life does not need emphasis. It is encouraging that some work as discussed elsewhere in the text has already been done. It is this area of research which needs more attention but it must be accompanied by ecological studies of present day communities surrounding the shallow swamps and marshes. The Muthronwala swamp about 15 km south-east of Dehradun in the western Himalaya is a typical example where both pollen analytic and ecological work has been done. The great botanical potential of the forest in this swamp was reported by Kanjilal in 1901 recording *Quercus incana*, *Olea glandulifera*, *Acer oblongum*, etc. at this swamp at 600 m, much below their normal occurrence between 1,000 and 2,500 m. The ecological studies at this swamp by Deva and Aswal (1974) have revealed the absence here today of *Pittosporum rawalpindiense*, *Pterospermum acerifolium*, *Itea nutans*, *Hedera nepalense*, *Symplocos crataegoides*, *Linociera intermedia*, *Holostemma annulare*, *Persea duthiei*, *Neolitsea cuipala*, *Helixanthera ligustrina*, *Celtis australis*, *Ficus glaberrima*, *Albizia chinensis* which were recorded by Kanjilal (1901) about 73 years before. The stumps of *Acronychia pedunculata*, *Acer oblongum*, *Sabia paniculata*, *Olea glandulifera*, *Persea gamblii*, *Elaegnus conferta*, *Drypetes assamica* and *Quercus incana* in the swamp forest reveal their former occurrence as reported by Kanjilal (1901).

The pollen analysis of a 1.65 m profile from the swamp (Rawat, 1982) shows a well-developed forest complex which declined subsequently after 500 years ago. No evidence of change in climate has been observed in the pollen sequence. The pollen analysis brings out the evidence for the occurrence of *Pterospermum*, *Acronychia*, *Acer*, *Itea*, *Symplocos*, *Albizia*, *Ficus*, *Elaegnus*, *Olea*, *Quercus* and members of Lauraceae. The stumps of some of them occur in this swamp forest.

It is indeed interesting that the floristic development in the Himalaya, as the pollen analytical studies have revealed, has exhibited broadly more or less similar pattern as has been observed during the Quaternary period in temperate and alpine regions in other parts of the world. It is further interesting that some of the climatic fluctuations inferred from the patterns of vegetational development more particularly during the last glaciation to recent synchronize those elsewhere supporting their secular nature. There is need to construct several more pollen diagrams supported by well-determined isotopic dates to establish the global and local climates in the past. The indigenous ecological perspective, and a good understanding of the phenomena of production, dissemination and preservation of pollen/spores is highly important in achieving this objective. Any disregard of these is certain to result in misleading and confusing interpretations, examples of which have been pointed out elsewhere in the text.

tropical, temperate, alpine, and in the trans-himalayan regions of the Himalaya differ today from one another so these must have in the past. The climatic inferences would be more secure if this fact is realized pollen analytically also. The same may be said of the patterns of forest development in these latitudinal belts. From the present day distribution of forest types within these latitudes schemes for probable forest development in response to climatic fluctuations can be constructed which should help in translating the pollen sequences in terms of vegetation and climate.

An example of such a scheme for the temperate belt in western Himalaya is given below which gives development of vegetation between two cold oscillations (glaciations).

Cold	Steppe	Cryocratic
Post temperate	*Abies*, *Betula*, *Pinus* with or without *Sorbus*, *Larix* and *Quercus*	Telocratic
Late temperate	Mixed conifer-oak mixed forest with *Alnus*, *Corylus* and *Acer*	Oligocratic
Early temperate	Mixed oak forest with *Ulmus*, *Juglans*, *Fraxinus* and *Corylus*	Mesocratic
Pretemperate	*Abies*, *Betula*, *Pinus* with or without *Sorbus*, *Larix* and *Quercus*	Protocratic
Cold	Steppe	Cryocratic

There is no denying that information on development of forest communities at the same latitude in the Himalaya in response to climatic alterations and edaphic changes is not available. However, climatic gradients are discernible from the forest belts distributed altitudinally. These belts must have ascended or descended in the past in response to climatic oscillations. Extensive work is needed to bring out this important aspect of biogeography.

The mass of pollen analytical data has indeed given some indications of the kinds of plant life that had characterized the Glacial and Interglacial periods, and the stadials and interstadials. Extensive work is needed to establish this — the botanical criteria for recognition of these stages and to distinguish the warmer and cooler fluctuations in latitudinal belts. They may not be similar in all latitudes in the Himalaya. The steppe vegetation types in the subtropical, temperate, alpine, and in the trans-himalayan regions of the Himalaya differ today from one another so these must have in the past.

A similar postulated scheme workable for the eastern Himalaya should include *Tsuga*, *Eurya*, *Pittosporum*, *Magnolia*, *Acer*, etc. in the temperate stages.

An interstadial (temporary warm fluctuation within a glacial) may be recognized by Juniper scrub, *Betula-Salix*, *Betula-Sorbus-Quercus semecarpifolia-Lonicera* or *Rhododendron*.

Similar schemes can be drawn up for the subtropical and alpine belts to serve as guide lines and to see if the factual patterns of floristic development from pollen analytic work confirm or modify these. It is through such schemes that not only the interpretation of pollen profiles is fascilitated, correlations can be securely established and the behaviour of the immigrating taxa can also be made out.

It is highly important that glacial/interglacial, stadial/interstadial stages in the Himalaya are named after type sites in keeping with international practice. Some names are suggested in the text. Detailed work is needed to achieve this objective.

Encouraging results have been obtained concerning the origin and progressive expansion of land use, and progressive and selective exploitation of the himalayan forests. This important area needs further research to bring out the manner and the rate at which some himalayan ranges have been denuded of forests, and where the forests exist they have been physiognomically altered through selective exploitation. May be the studies suggest measures for the reclamation and conservation of the remnant forest wealth in the Himalaya. Likewise the work on past climates should be understood to predict the climatic trends in the future.

Finally to sophisticate the pollen analytical technology in achieving these objectives in the Himalaya and elsewhere in the country, this overview urges the Indian pollen analysts to adopt the current approaches such as total influx of pollen and rate of sedimentation, numerical methods, etc. to impart a new dimension to the techniques hitherto followed so that the results obtained become more dependable for flora history and for inference of past climates. Attention to these has been drawn earlier (Vishnu-Mittre, 1978).

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RAJMAHALISPORA, A NEW CINGULATE SPORE GENUS FROM THE TRIASSIC OF RAJMAHAL BASIN, INDIA

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ABSTRACT

A new trilete-bearing cingulate miospore genus with rugulate ornamentation from the Triassic sediments of Rajmahal Hills, India is described.

Key-words — Palynology, *Rajmahalispora*, Rajmahal Basin, Triassic (India).

सारांश

राजमहल द्रोणी (भारत) के त्रिसंघी कल्प से एक नवीन मेखलित बीजाणु वंश : राजमहलिस्पोरा – राम शंकर तिवारी, अर्चना त्रिपाठी एवं प्रमोद कुमार

भारत में राजमहल पहाड़ियों के त्रिसंघी अवसादों से उपलब्ध रूगीय अलंकरण से युक्त एक नवीन त्रिअरीय मेखलित बीजाणु वंश का इस शोध-पत्र में वर्णन किया गया है।

INTRODUCTION

PALYNOLOGICAL record known from the Upper Gondwana horizons of Rajmahal Basin, India is meagre. Rao (1953) and Vishnu-Mittre (1954) described few spore-types from thin sections of Nipania Chert. Sah and Jain (1965) studied the *sporae dispersae* from Basko and Sakrigali Ghat assigning the micflora a Jurassic age, but no record of the Triassic palynomorphs is yet available from this area. As regards the trilete, cingulate miospore genera from the Triassic sediments in other basins, a few on record are: *Lundbladispora* Balme, 1963 : emend. Playford, 1965; *Densoisporites* Weyland & Krieger, 1953 emend. Bharadwaj & Kumar, 1976; *Cingulizonates* Dybova & Jachowicz, 1957 emend. Butterworth, Jansonius, Smith & Staplin, 1964; *Densosporites* Berry, 1937 emend. Butterworth, Jansonius, Smith & Staplin, 1964 and *Discisporites* Leschik, 1955 emend. de Jersey, 1964. The presently described taxon is an addition to the above mentioned group of cingulate sporomorphs.

The present communication is based on the study of material from a bore-hole from the north-eastern part of Rajmahal Basin. This bore-hole (No. RJR-2) was drilled by the Coal Division, Geological Survey of India. The samples were processed by usual maceration method using hydrofluoric acid and nitric acid followed by suitable alkali, as and when required. The excess of silica of the shale samples was removed by the heavy-liquid (Iodide solution) separation method.

SYSTEMATIC DESCRIPTION

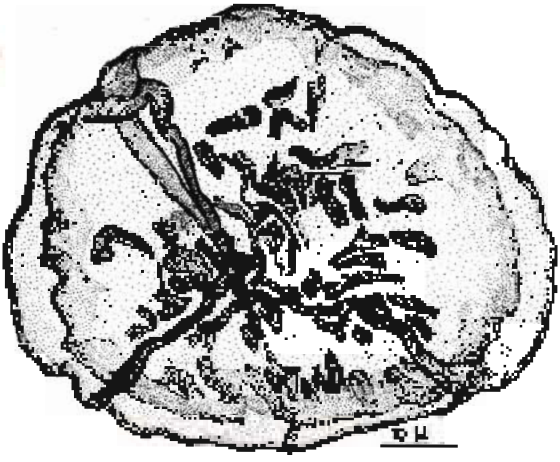
Anteturma — *Proximegerminantes* Potonié, 1975
Turma — *Zonales* Bennie & Kidston, 1886 emend. Potonié, 1956
Subturma — *Zonotriletes* Waltz, 1935
Infraturma — *Cingulati* Potonié & Klaus, 1954 emend. Dettmann, 1963

Genus — *Rajmahalispora* gen. nov.

Type species — *Rajmahalispora rugulata* sp. nov.

Generic Diagnosis — Cingulate, trilete miospores with rugulate exine, rugulae sometimes anastomose to form reticulation. Central body distinct. Cingulum smooth, unstructured, not massive in construction, usually denser towards the peripheral region. Inner body not seen.

Description — Cingulate miospores, triangular to subtriangular, mostly the latter shape prevailing. Trilete mark usually distinct, in some cases may be less distinct; rays usually with thin lips, may be slightly elevated, sometimes associated with fold or parallel ridge, sinuous, reaching up to the equatorial margin of the spore (Pl. 1, figs 2, 6; Text-fig. 1). In some cases the trilete rays appearing to bifurcate at their ends forming a curvature-like structure; in others the contact area being not well-defined. Central body distinct, conforming to the overall shape of the specimen, equatorially thickened. Cingulum distinct, well developed equatorial in position (Text-fig. 2A, B), never massive in nature, its outer-half being thicker than the inner one. Exine generally plain on the proximal side but bearing rugulae of different shapes and sizes on the distal surface of the body as well as the cingulum; proximally rare and low ridges seen, rugulae may be straight, curved or wavy, simple, bifurcated (Pl. 2, figs 10-12) or forming reticuloid pattern (Pl. 1, figs 8, 9) densely or sparsely disposed. Under SEM the rugulae appearing to be uneven in thickness and showing low coni-like projections (Pl. 4, figs 30, 31). Exine of the body and cingulum in most of the specimens unstructured; some indeterminate faint structures seen in a few specimens (Pl. 1, fig. 2); *extrema lineamenta* smooth.



TEXT-FIG. 1 — *Rajmahalispora rugulata* gen. et sp. nov. showing the nature of trilete mark and rugulae.

Comparison — It is, thus, evident from the above observations that this genus is characterized by the rugulate-reticuloid pattern of ornamentation, equatorial cingulum of simple nature and unstructured exine.

From amongst the comparable forms, the genus *Aldasporites* erected by Scott, in 1971, although resembles the genus *Rajmahalispora* gen. nov. in having rugulate-verrucate pattern of muri, differs in having a massive cingulum and complex trilete ridges bearing small, isolated or joined verrucae. However, this group of spores was latter described under the genus *Interulobites* Paden Phillips *in* Paden Philips & Felix, 1971) by Scott himself. *Interulobites* too differs from the present genus in having massive distal ornament elements which more or less fuse with each other, more so at the equator, heavy trilete rays with very broad lips and wide thickend, undemarcated cingulum (see Type specimen — Brenner, 1963; pl. 17, fig. 3).

The genus *Densoisporites* Weyland & Krieger, 1953 emend. Dettmann, 1963 is not comparable with the present genus because the former includes un-ornamented spores. However, Scott (1976) illustrated few specimens under two species of this genus, viz., *Densoisporites perinatus* Couper 1958 and *D. corrugatus* Archangelsky & Gamerro, 1956 which apparently are comparable with the present genus, but a critical assessment of the photomicrographs and the description reveal that these two species differ in having spongy structured exine, massive cingulum and an inner body and hence they differ.

The genus *Callialasporites* Sukh Dev, 1961 emend. Bharadwaj & Kumar, 1976 apparently resembles *Rajmahalispora* in shape, size and general appearance. However, *Callialasporites* is a monosaccate pollen, with trinotched tendency (Pl. 4, fig. 33), with microsculptured exine (Pl. 4, fig. 34) and subequatorially attached frilled saccus with generally radial folds indicating its vesiculate nature. On the contrary, the new genus described here is a cingulate trilete spore with rugulate, unstructured exine (Pl. 2, figs 10-13) having distinct equatorial development of the cingulum. Thus, we are dealing with separate organization. Only apparent resemblance is due to a tendency in *Rajmahalispora* gen. nov.

in which the cingulum becomes slightly narrower at the angles, that too in the quasi-laterally flattened specimens (Pl. 1, fig. 1, Pl. 3, figs 20, 25); this gives a tri-notched look to the outline seemingly comparable with some species of *Callialasporites*. But the differences are well-defined as enumerated above.

Rajmahalispora rugulata sp. nov.

Pl. 1, figs 1-5, Pl. 2, figs 10-13, Pl. 3, figs 16, 17-25; Text-fig. 1

Holotype — Pl. 1, figs 1-3; slide no. BSIP 8089.

Isotype — Pl. 1, figs 4, 5, slide no. BSIP 8089.

Locus Typicus — Bore-hole RJR-2, sample no. 108, depth 836-842 m, Rajmahal Basin, India.

Age & Horizon — Triassic, Dubrajpur Formation.

Diagnosis — Triangular to subtriangular miospores, Y-mark distinct, rays with thin lips 1 to 2 µm wide, slightly elevated, sinuous, reaching up to outer margin of cingulum, sometimes associated with narrow folds. In semilaterally preserved specimens, Y-rays appearing to exhibit area contagionis at their ends, hence at times a notched condition simulated. Central body distinct conforming to the overall shape, thickened equatorially. Exine proximally as well as distally rugulate, rugulae dense, of various shapes and sizes, straight, curved or wavy, simple or bifurcated, 3 to 7 µm in length and 2 to 3 µm in width. Scanning electron micrographs showing uneven thickening of rugulae with coni-like small projections sparsely disposed on rugulae. Cingulum well-defined, 2.5 to 8 µm wide, never massive, outer-half along periphery thicker than inner one, equatorial thickening limbus-like in appearance, less than 1 µm wide. Exine of central body and cingulum unstructured. Inner body not seen.

Dimensions — Overall spore 62-70 µm, holotype 69.5 µm; central body 50.5-60 µm.

Rajmahalispora triassicus sp. nov.

Pl. 1, fig. 6; Pl. 3, figs 14, 26; Pl. 4, fig. 32; Text-fig. 3A

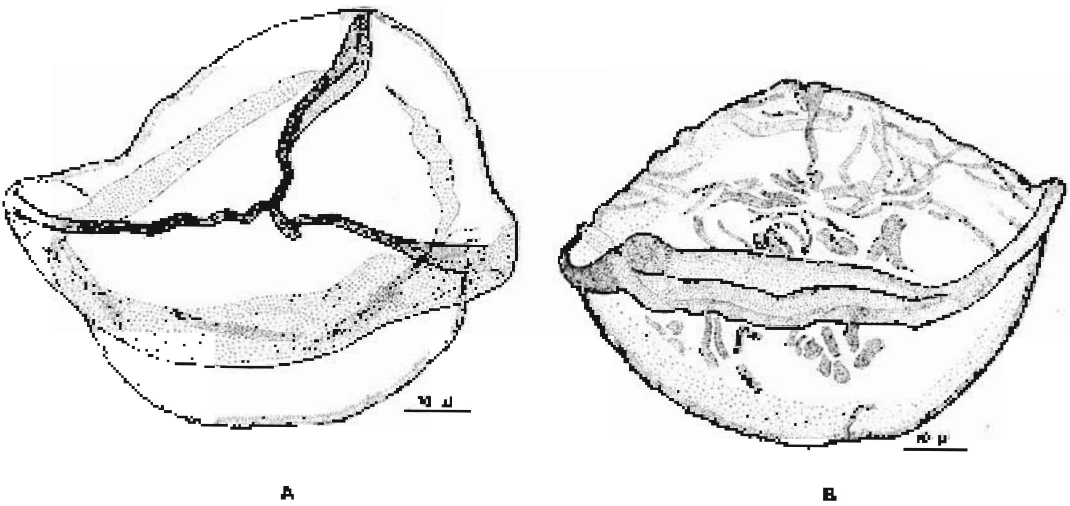
Holotype — Pl. 1, fig. 6, slide no. BSIP 8088.

Isotype — Pl. 3, fig. 26; slide no. BSIP 8089.

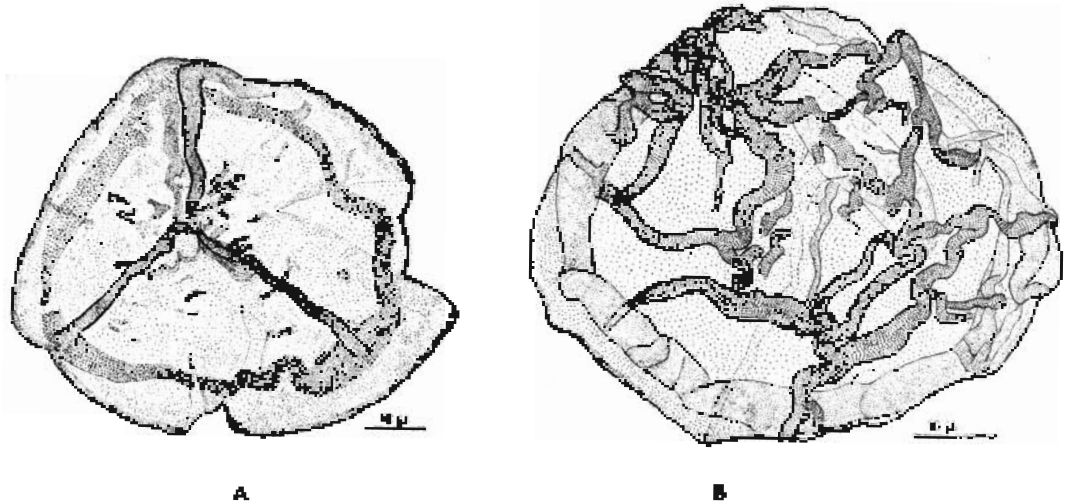
Locus Typicus — Bore-hole RJR-2, sample no. 108, depth 836-842 m, Rajmahal Basin, India.

Age & Horizon — Triassic, Dubrajpur Formation.

Diagnosis — Miospores triangular with convex sides and broadly rounded angles. Y-mark distinct, rays with thin lips, 0.4 to 3 µm wide, slightly elevated, sinuous,



TEXT-FIG. 3 — A, Showing the equatorial nature of cingulum in semilaterally flattened grain, and B, laterally flattened grain.



TEXT-FIG. 3 — A, *Rajmahalispora triassica* sp. nov. showing the nature of trilete mark, central body and few rugulae; B, *Rajmahalispora reticulata* sp. nov. showing the nature of rugulae, some of which are anastomosed.

reaching cingulum, rays sometimes associated with folds. Central body distinct, conforming with overall shape of the specimens distinctly thickened equatorially. Exine proximally and distally rugulate. Rugulae sparse, very few in number may be straight, curved or wavy, simple or bifurcated, 3 to 6 µm in length and 1 to 3 µm in width, cingulum well-defined, 3 to 12.5 µm wide, never massive, outer half thicker than inner one; equatorial thickening 1.25 µm wide. Exine of central body and cingulum unstructured. Inner body not seen.

Dimensions — Overall spore 62-77 µm, holotype 68 µm; central body 54-58.50 µm.

Comparison — The present species differs from the type species, *R. rugulata* sp. nov., in rarity and less developed nature of the rugulae.

Rajmahalispora reticulata sp. nov.

Pl. 1, figs 7-9; Pl. 3, figs 16, 27-29; Text-fig. 3B

Holotype — Pl. 1, figs 8, 9; slide no. BSIP 5087.

Isotype — Pl. 1, fig. 7; slide no. BSIP 5087.

Locus Typicus — Bore-hole RJR-2, sample no. 108, depth 836-842 m., Rajmahal Basin, India.

Age & Horizon — Triassic, Dubrajpur Formation.

Diagnosis — Subtriangular to subcircular miospores. Y-mark not very distinct. Central body conforming to overall shape, thickened equatorially. Exine proximally and distally rugulate, some rugulae anastomose to form incomplete to complete reticulum, rugulae 0.6 to 4 µm wide and 1 to 3 µm high. Cingulum well-defined, 2.5 to 4.5 µm wide, never massive, peripheral half being thicker than inner half, limbus-like equatorial thickening less than 1 µm thick. Exine of central body and cingulum unstructured, inner body not seen.

Dimensions — Overall size 59-67 µm, holotype 59 µm. Central body size 56-59 µm.

Comparison — *Rajmahalispora reticulata* sp. nov. differs from the other two species in the nature of rugulae, some of which anastomose to form incomplete to complete reticulum.

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EXPLANATION OF PLATES

(All the slides are deposited in the BSIP Museum)

Plate 1

1-5. *Rajmahalispora rugulata* gen. et sp. nov.
1. Holotype — Distal face, rugulae in focus, slide no. 8089. × 750.
2. Holotype — Proximal face showing the nature of trilete mark. × 750.
3. Holotype in Differential Phase Contrast (DIPC) showing the rugulae on the distal face. × 750.
4, 5. Isotype — Showing the trilete mark and rugulae, slide no. 8089. × 500.
6. *Rajmahalispora* [illegible] sp. nov., Holotype, slide no. 8088. × 750.
7-9. *Rajmahalispora reticulata* sp. nov., slide no. 8087.
7. Isotype — Slide no. 8087. × 750.
8, 9. Holotype — Showing the anastomosing rugulae, slide no. 8087. × 750.

Plate 2

10-13. *Rajmahalispora rugulata* sp. nov. — Distal face showing the nature of rugulae. × 1500, slide nos. 8088 and 8089. Fig. 13 in DIPC, slide no. 8088.

Plate 3

14. Tetrad of spores of *Rajmahalispora*, slide no. 8089. × 500.
15, 16. Semi-laterally and laterally flattened grain showing the equatorial nature of the cingulum and rugulae (fig. 16) on proximal and distal face, slide no. 8088. × 500.
17-25. *Rajmahalispora rugulata* gen. et sp. nov. × 500.
21. Showing folds along trilete rays. Fig. 20 in slide no. 8089, figs 18, 24 in slide no. 8090, figs 17, 19, 21, 22, 23, 25 in slide no. 8088.
26. *Rajmahalispora* [illegible] sp. nov. showing the central body (Holotype), slide no. 8089. × 500.
27-29. *Rajmahalispora reticulata* sp. nov., slide nos. 8089 and 8088. × 500.

Plate 4

30-32. Scanning Electron Micrographs of *Rajmahalispora*.
30. Nature of trilete mark and rugulae on proximal face. × 1550.
31. Portion of fig. 30 enlarged to show cone-like projections on the rugulae. × 3100.
32. Distal face of another specimen having small and big rugulae and the smooth cingulum.
33. *Callialasporites* showing the triradiate ridge and the saccate nature of the spore. × 750.
34. Portion of specimen in fig. 33 in DIPC to show the granulose ornamentation, slide no. 8091, × 1500.

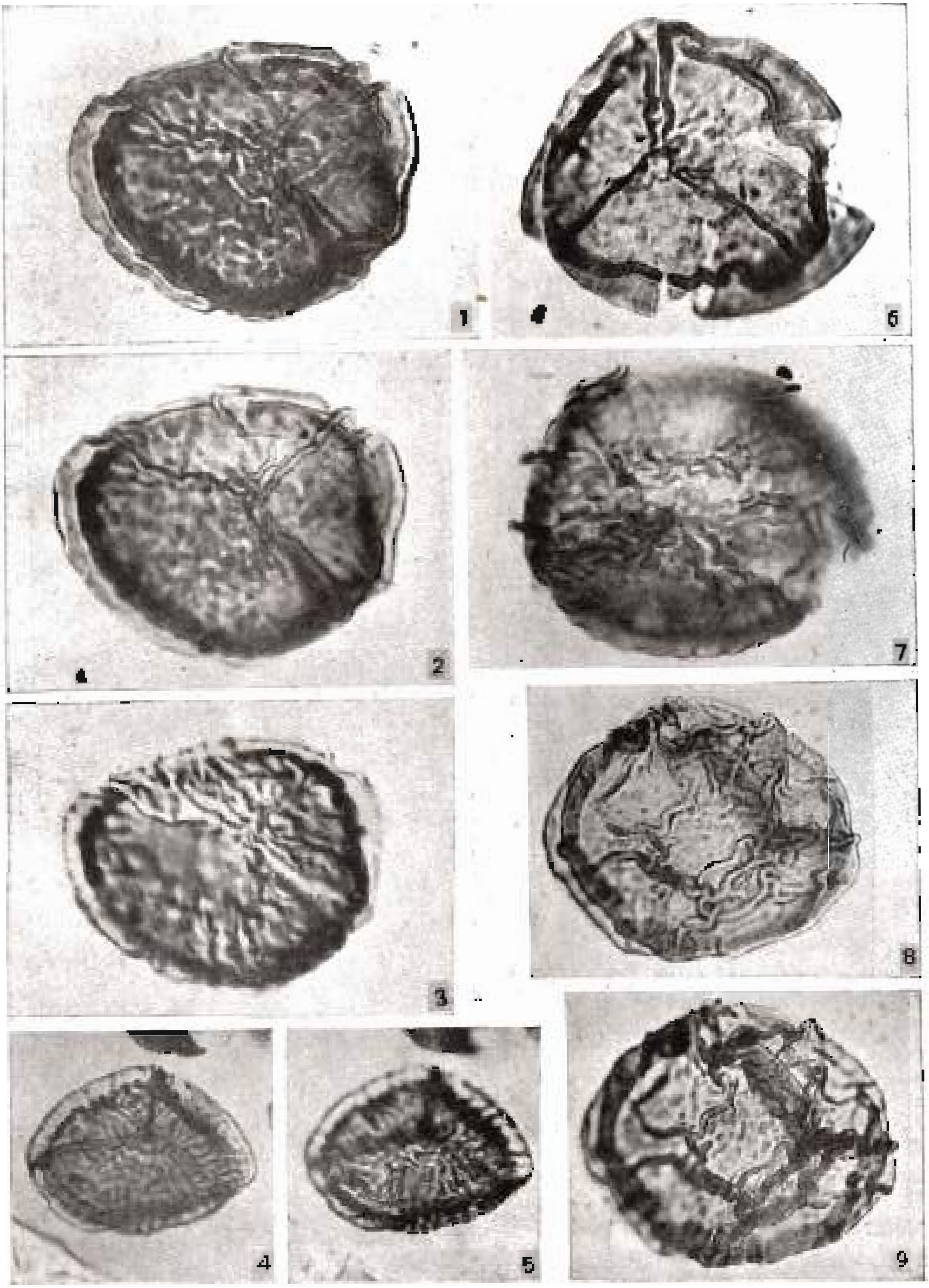
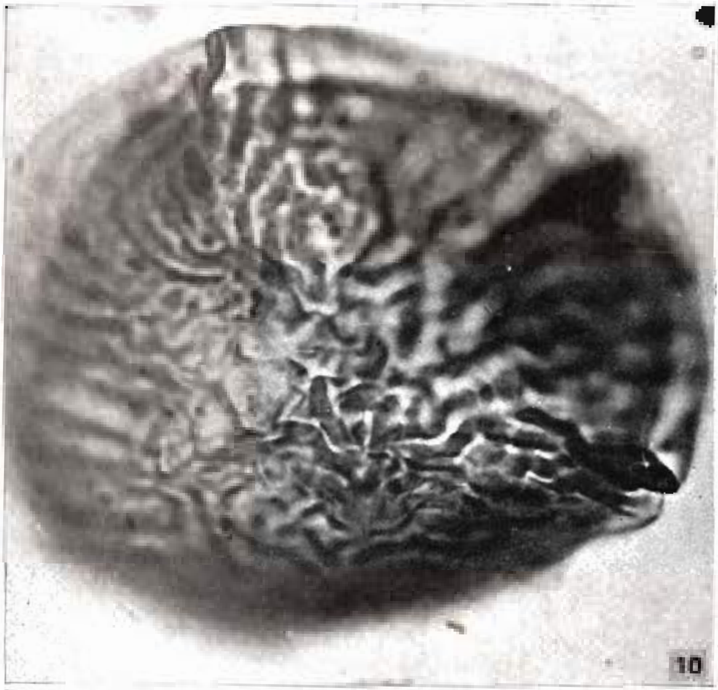


PLATE 1



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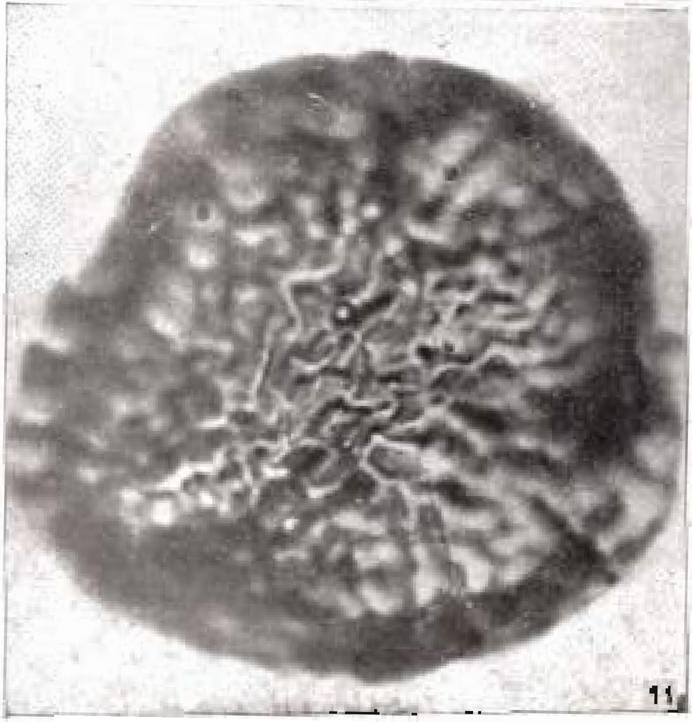

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PLATE 2

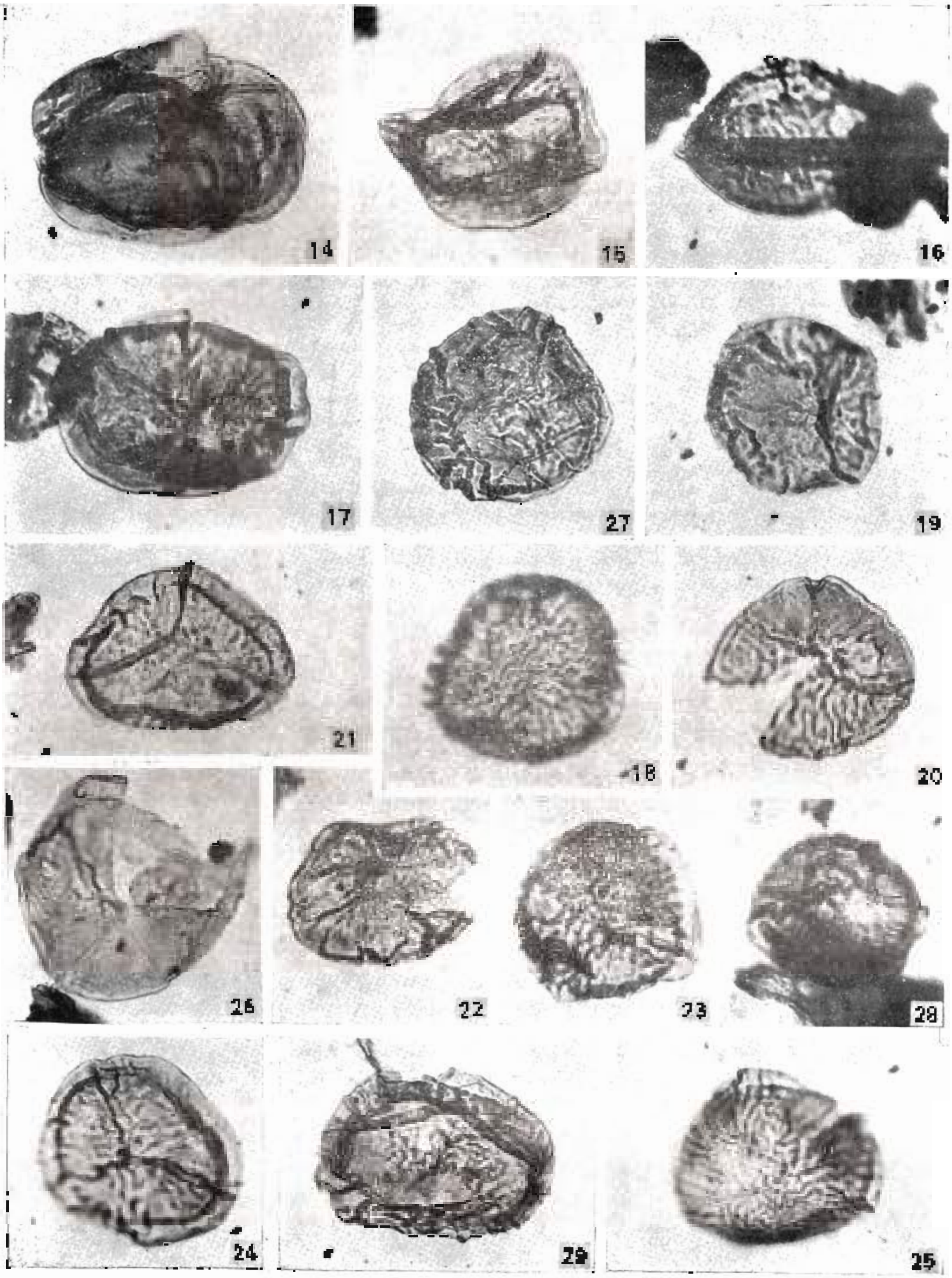
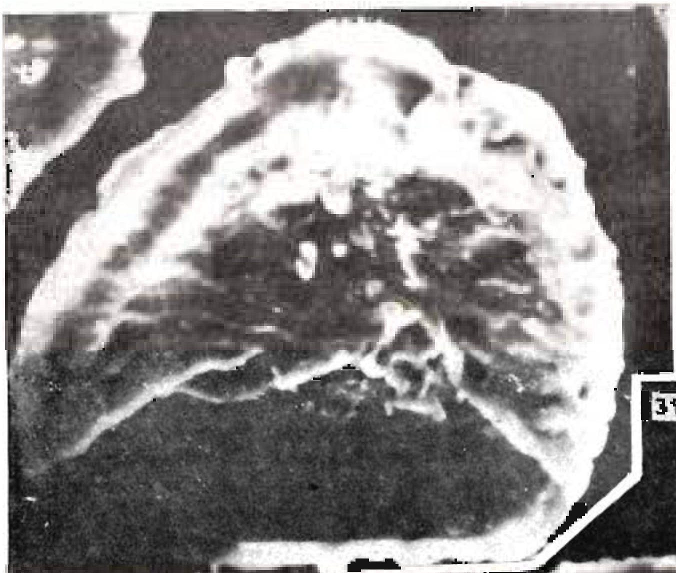


PLATE 3



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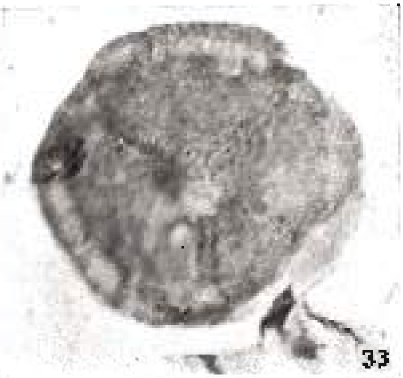

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PLATE 4

The Palaeobotanist, **32**(2): 197-202, 1984.

THIRTEENTH BIRBAL SAHNI MEMORIAL LECTURE

PLANTS, ANIMALS AND TIME

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I regard it as a great privilege to present the Sahni Memorial Lecture in this splendid new auditorium, which has only just been completed. It is a particular pleasure for me, but also a very humbling one, to reflect that the two men under whom I have studied palaeobotany, Professor Tom Harris of Reading and Professor Chester Arnold of Michigan, both in their time gave this Memorial Lecture.

I suppose that most people would say that the proper role of the palaeobotanist is to seek to reconstruct the plant life of time past in all its aspects. Over some 150 years in the development of our science, this has resulted in the accumulation of a vast body of information. Some of it is detailed, and well founded; some of it is of less secure quality. The very size of the palaeobotanical systematic "data store" has perhaps encouraged some to seek evidence of other aspects of past life, rather than simply adding to the store. One such line of research which has proved most rewarding in the last decade has been the study of palaeoecology. A particularly challenging aspect of this field is the extent of the interaction between plants and animals through time. What, if any, direct evidence do we have in the fossil record for their co-evolution ? I want to briefly to explore this question.

In the entire fossil record of life, one thing is very clear. We have evidence of the existence of plants — or at least of aquatic autotrophic organisms long pre-dating by at least 1,000 million years any evidence of recognizable animal life (Barghoorn & Tyler, 1965). Perhaps the greatest evolutionary leap in the whole history of life was the migration from the aquatic into the terrestrial environment. Plants, which apparently arose in the aquatic setting, pioneered the colonization of the land. It is in the earliest records of plant life on land that we see the first hints of the interaction of plant and animal life. In the Rhynie chert, a silicified peat deposit of Early Devonian age from Scotland, we have one of the first pictures of a terrestrial ecosystem (Tasch, 1957; Kevan *et al.*, 1975). Associated with structurally preserved remains of the vascular plants *Rhynia*, *Horneophyton* and *Asteroxylon* we have fragments of arthropods. Some, such as the freshwater "shrimp" *Lepidocaris*, were apparently aquatic. Others, such as the collembolan *Rhyniella*, the mite *Protacarus* and the trigonotarbid arachnids, were adapted for life on land. A number of reviews of this fossil ecosystem have been published in the last few years (Scott, 1980; Chaloner & MacDonald, 1980).

Two features of the Rhynie community are suggestive of plant-animal interaction. Firstly, empty sporangia of *Rhynia* have been found, containing several bodies of trigonotarbid arachnids (Kevan *et al.*, 1975). This may be simply a fortuitous association; or perhaps, more probably, the arachnids had entered the sporangia as a moist, protected microhabitat. The prey of this (probably zoophagous) arachnid, in the form of collembolans, might well have been inhabiting such sites within the bog surface litter, and the empty sporangia were a profitable feeding ground. Equally, the arachnids may have been spore eating. We have much more positive evidence of spore-eating in the Carboniferous (Scott, 1977; Scott *et al.*, in press). It seems that spore-eating may have been one of the earliest manifestations of phytophagy among land-adapted arthropods; perhaps the high protein and lipid content of spores made them a worthwhile food source for basically zoophagous organisms, when animal prey was unavailable. As Southwood (1973), discussing the evolution of insect feeding habits, says of the origin of plant-eating in that group: "The evolutionary path of the phytophagous insect has not been an easy one: pollen feeding often seems to represent 'the first step' and feeding in or on foliage 'full success'." It is interesting that he makes this suggestion apparently solely on the basis of extant groups: for it is a proposition which is certainly consistent with the fossil evidence of spore eating appearing early in the fossil history of terrestrial arthropods.

A more direct hint of phytophagy in the Rhynie early Devonian community is the occurrence of lesions in the plant axes which evidently occurred in life, and show a "wound reaction" in the adjoining tissue (Kevan *et al.*, 1975). This indicates that the lesions were formed during the life of the plant, and that the plant survived the injury. These lesions characteristically extend to the phloem, and may represent the results of sap feeding by contemporaneous arthropods — possibly the arachnids.

When we come to the Carboniferous, there is much more extensive evidence of plant-eating by arthropods. Most notably, we have droppings (coprolites), attributed to arthropods, containing a diversity of spore exines (Scott & Taylor, 1983). Lepidodendrid spores actually extracted from the gut of the Carboniferous insect *Eucaenus* (Scott *et al.*, in press) are perhaps the most direct possible evidence of Carboniferous spore-eating by insects.

Before leaving the topic of spore-eating, one particular aspect of it may be noted, since it bears on its role in subsequent plant/animal co-evolution. It may easily be shown (Chaloner, 1976) that spore-eating need not destroy the viability of all the spores: locusts, used in one experiment, only reduced the viability of spores fed to them by about 50 per cent. Such a relationship between plants and spore-eating insects would probably have had compensations for both parties. Even if the insect only digested the contents of say a half (or even three-quarters) of the spores consumed, their high nutritive value compared to, say, leaf tissue would have been very adequate compensation to the insect. The plant would at the same time have benefited by having at least the surviving spores transported well away from the parent plant and deposited (in a faecal pellet) in a moist, nutrient-rich site for germination. Such a site would be particularly suitable for the growth of subterranean (mycorrhizal) gametophytes such as characterize many extant primitive spore-bearing plants (e.g. some *Lycopodium* spp., *Psilotum*).

A further feature of plant-animal co-evolution of mutual benefit is the development of fleshy seeds (and, in the angiosperms fruit), as a means of encouraging biotic seed-dispersal. The role of animals in the process is well documented for at least some of the few living gymnosperms (e.g. *Taxus*) which adopted this strategy. It is less clear, although eminently plausible, that even Palaeozoic gymnosperm seeds with this same "drupe syndrome" of a stony, inner structure surrounded by a soft fleshy one, may also have been showing an adaptation to biotic seed dispersal (Chaloner & Sheerin, 1981).

Scott and Taylor (1983) give very full documentation to the range of lesions seen in Carboniferous plant organs, which may reasonably be ascribed to some animal causal agent. Despite the diversity of such occurrences, surprisingly few are actually recorded in the literature. As those authors suggest, this may well be because of the inclination of palaeobotanists to avoid or ignore damaged specimens in their collecting, so that plant material damaged by phytophagous animals is seriously under-represented in our collections.

Evidence as to the role of different plant groups (and indeed different plant organs) as primary food sources through the rise of the terrestrial fauna of tetrapods — amphibians, reptiles and eventually mammals — is very inadequate. Swain (1978) has suggested the doubtless important role of various plant constituents either distasteful or toxic, in discouraging predators. Inevitably our picture of the evolution of such symptoms of plant-animal interaction — the so-called chemical warfare in the plant-animal struggle — is based almost solely on our knowledge of the biochemistry of living plants. The fossil record can contribute little in this direction, beyond evidence of the time of appearance of various plant and animal groups, and of such biochemically suggestive structures as glandular hairs (Scott & Taylor, 1983) and nectaries (Friis & Skarby, 1982).

The possible role of changing vegetation in the biology of (terrestrial) dinosaurs has probably had more than its fair share of attention, compared with other aspects of plant-animal interactions. The displacement of gymnosperms by angiosperms, which is obviously a feature of the Late Cretaceous scene, has been implicated in dinosaur extinction in diverse ways by different authors. Swain (1978), says succinctly, "one fact stands out; the extinction of the dinosaurs (but not other mainly carnivorous small reptiles; crocodiles and snakes) is inversely related to the rise of the flowering plants". On the hand, Bakker (1978) turns the evidence the other way round, and suggests that a change in feeding strategy of herbivorous dinosaurs opened up ecological opportunities which triggered the diversification of the angiosperms. This particular field of plant-animal interaction seems to be strewn with conflicting interpretations of the evidence, and a corresponding multiplication of diverse working hypotheses !

The Cretaceous rise of the angiosperms must represent the major plant evolutionary event in which plant-animal co-evolution of the pollination process is most securely implicated. In the extant angiosperms, insects (and in a more limited way, birds and a few mammals) are deeply involved in their biotic pollination. Our knowledge of the extent of co-adaptation of angiosperms with animal pollinators (see e.g. Faegri & van der Pijl, 1979) is inevitably based largely on studies of living flowers. None the less, some progress has been made in linking fossil evidence of flower evolution with the appearance of relevant insect groups (Crepet, 1979).

Much less attention has been paid, at least by palaeobotanists, to the equally extensive involvement of mammals and birds, in particular, in the dispersal of angiosperms. The role of selection by fruit-feeding animals in the evolution of fleshy-fruited angiosperms is inescapable. The occurrence of many living angiosperm fruits and seeds with hooking devices to effect adhesion to mammals' hair is another obvious instance of such co-adaptation. But our supposition of the co-evolution involved in such plant adaptations is again based almost entirely on living plants, and direct fossil evidence of that type of plant-animal interaction is negligible.

The evidence for early insect spore-eating encourages the view that this must have been antecedent to gymnosperm pollen-feeding by insects. Scott and Taylor (1983) renew the suggestion made by earlier authors that biotic pollination may have occurred in some Carboniferous pteridosperms. The evidence that the hermaphrodite Bennettitalean fructifications may have arisen in response to an insect pollination relationship has also recently gained ground.

The sequence of events leading to entomophily seems likely to have been:

1. Spore-eating by insects and ensuing spore dispersal in pteridophytes, which apparently occurred early in land plant evolution.

2. Since this probably pre-dated the evolution of the seed, pollen-eating is likely to have accompanied the rise of seed plants at least in some groups (see, for example, evidence of pollen-eating in the Mesozoic plant *Caytonia*, Harris, 1946).

3. An obvious step towards insect pollination would be effected by bringing the pollen and seed-bearing structures into juxtaposition. Only in this way would pollen-feeding (and scattering) predators, foraging for pollen, bring the compensation of "out-breeding" pollen into proximity with the ovule, in return for removal of "self" pollen. The assumption of a strong co-evolutionary link between a hermaphrodite flower and insect pollination is supported by the fact that among living wind-pollinated gymnosperms, pollen and seed-bearing structures are separate, either on the same plant (monoecy) or on separate plants (dioecy). The sole exception appears to be in some *Gnetum* species (Sporne, 1965).

4. The development of the hermaphrodite flower has made protection of the ovules (produced in limited numbers) an essential accompaniment to accessibility of the anthers to insect visitors, attracted by the opportunity for pollen feeding.

5. The evolution of zygomorphy, nectar secreting and storage structures, and the numerous complex behavioural relationships between insects and flowers must then have followed these early steps.

6. The fact that the many angiosperms which have reverted to wind pollination have frequently also reverted to separate male and female flowers (as in the sedges and in the wide range of catkin-bearing trees) is consistent with the suggestion made in (3) above.

Our picture of early flower structure has recently received a boost from the work of Dr E. M. Friis on charcoalified flower buds of late Cretaceous age from Sweden (Friis & Skarby, 1982). Two interesting features in her work have relevance to the present theme. Her Saxifragalean flower, *Scandianthus*, shows in addition to all the essential flower parts, clear evidence of nectaries. This is perhaps the earliest occurrence in the fossil record of this particular tangible adaptation of the angiosperm flower to zoophily (presumably, entomophily). The other feature which emerges from the work of Friis (1983) on these Cretaceous fossils is that there were contemporaneous flowers, evidently of Juglandaceous affinity, with a reduced perianth, representing the early reversion to wind pollination which was eventually to culminate in the wind-pollinated amentiferous trees.

Crepet (1981) has reviewed the evidence for the early (Eocene and possibly Paleocene) adoption of wind pollination in the several catkin-bearing angiosperm families. It seems rather surprising that the angiosperms, having evolved the ingenious outbreeding potential represented by entomophily then abandoned it in certain groups relatively early in their evolutionary history. The grasses developed a parallel reversion to wind pollination, although in the context of a very different reproductive strategy from the Amentiferae. Pollen evidence suggests that, as in the dicots, this was an early feature of monocot evolution with grass-type pollen appearing in the Eocene (Muller, 1970).

The grasses seem to have combined this disengagement from insect pollination with the adoption of a different co-evolutionary relationship, involving grazing mammals. The grass vegetative strategy of keeping its growing point at or in the soil surface, coupled with leaf growth by basal (intercalary) meristems gave many members of that family a remarkable capacity to survive heavy grazing, seasonal aridity and even frequently recurring fire. By late Tertiary time, at least, the grasslands of the prairies and savana evidently supported extensive mammal populations. These, as a food source for early hunters may have helped to tempt them away from the forest environment.

The great American anthropologist and " human palaeontologist " Loren Eiseley, has argued cogently for the close relationship between the rise of the angiosperms and that of the mammals. He expressed this idea in his characteristically graphic prose (Eiseley, 1958): " Flowers changed the face of the planet. Without them the world we know — even man himself — would never have existed. Francis Thompson, the English poet, once wrote that one could not pluck a flower without troubling a star. Intuitively he had sensed like a naturalist the enormous interlinked complexity of life. To-day we know that the appearance of the flowers contained also the equally mystifying emergence of man".

The early interaction of man and vegetation is very well documented, most particularly in the form of palynological evidence of forest clearance (by use of fire and axe), the spread of weeds favoured by arable and pastoral land use, and of the gradual appearance of the larger grass pollen characteristic of the cereals (for a readable general review, see Cole, 1967.) It is interesting that man's history came to be closely intertwined not so much with those " mainstream ", entomophilous angiosperms, committed to their own co-evolution with the insects, but with the one group, the grasses, which had made such a success of reverting to wind pollination. The conventional picture of man's relationship with the cereals is one of control and manipulation by man. This has resulted in what is usually seen as the exploitation and modification of originally wild species to produce the high-yielding maize, wheat, barley, millets and rice on which such a large proportion of mankind now depends.

A less anthropocentric assessment of man's relationship with the cereals gives a very different picture. This might be best presented as a " fairy story ", in which a grass plant, early in Pleistocene time, was confronted by a Fairy Godmother. (This is a figure dear to English children's folklore — she is, you will remember, able to grant three wishes.) The grass, competing with only limited success in the environment of expanding open habitats might have presented its plight to the Fairy Godmother as follows: " Firstly, when we produce our seed, much of it falls on compacted or dry ground, or in the shade of the forest. Our first wish is for something which would clear away the forests, and prepare and irrigate the ground, so that our seedlings can develop successfully. Then, our young plants have to compete with other aggressive colonizers of open communities. So our second wish would be for something which would remove those competing herbs, and leave our seedlings to grow unimpeded. Finally, we would like to colonize new territory. Even our small wind-borne seed cannot cross oceans. Our third and final wish then, to achieve world-wide success, would be to have some mechanism which could gather up our seed and take it across the seas to other parts of the world".

The Fairy Godmother might have replied: "You see that group of apes over there, chasing a mammoth? They are capable of fulfilling all three wishes for you. Their meat supply will run out eventually — they are destroying it pretty quickly. They will then find a substitute for it in your grain. They will get addicted to eating your seeds, and will clear forests, plant huge areas of nothing but grass, which they will tend carefully, and will gather the seed and transport it all over the world for you. You will come to dominate huge areas of the world by thus enslaving these apes. Of course they will think that they have done it all — that they are manipulating you grasses, and exploiting you. As you well realize it is the other way round, and you will have tamed and harnessed this omnivorous ape, to achieve your own ecological success."

Well, of course, all this came about. The end of this particular thread of the complex intertwining of the evolution of plants and animals has been that the grasses domesticated man. But we, with our usual egocentricity, prefer to see it the other way round.

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ON PLANT MEGAFOSSILS FROM THE LATE TRIASSIC SEDIMENTS OF THE EASTERN PART OF SICHUAN BASIN, CHINA

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ABSTRACT

The paper deals with the plant remains collected from the Late Triassic sediments in the eastern part of Sichuan Basin, China. These remains include *Lobatannularia kaixianensis* sp. nov., *L. hechuanensis* sp. nov., *Pseudoctenis hechuanensis* sp. nov., *Ctenis kaixianensis* sp. nov., *Lobatannularia chuandianensis* (Wang) comb. nov. and *Acthephyllum kaixianensis* gen. et sp. nov.

Key-words — Megafossil, *Lobatannularia*, *Pseudoctenis*, *Ctenis*, *Acthephyllum*, Sichuan Basin, Triassic (China).

सारांश

चीन में सिचुआन द्रोणी के पूर्वी भाग के अनंतिम त्रिसंधी युगीन अवसादों से गुरुपादपाश्म – दुआन शुइंग एवं चेन ये

चीन में सिचुआन द्रोणी के पूर्वी भाग में स्थित अनंतिम त्रिसंधी युगीन अवसादों से एकत्रित किये गये गुरुपादपाश्म अवशेषों का वर्णन किया गया है। ये लोबेटॅन्नुलेरिया केक्सिआँनेन्सिस नव जाति, लो० हैचुआनेन्सिस नव जाति, स्यूडोटीनिस हैचुआनेन्सिस नव जाति, टीनिस कैक्सिआँनेन्सिस नव जाति, लोबेटॅन्नुलेरिया चुआन्डियानेन्सिस (वाँग) नव संयोजन एवं ऍक्थीफ़िल्लम् कैक्सिआँनेन्सिस नव वंश व नव जाति नामक गुरुपादपाश्म हैं।

INTRODUCTION

MANY fossil plants were collected from the Mesozoic Coal Formation in eastern Sichuan Province in 1977-78. This coal formation was formerly called as Xiangxi (Hsiangchi) Coal Formation and an Early Jurassic age has been assigned to it by the late Prof. Sze. Thereafter the study of these fossil plants revealed that this formation does not have totally the Early Jurassic deposits. It almost wholly refers to the Late Triassic in west of Daxian County, partly to Early Jurassic and partly to Late Triassic in Daxian County and to east of the County. We call the Early Jurassic Coal Formation as Zhenghuchong Formation to distinguish it from the old Xiangxi Formation. The late Triassic Formation is called Hsuchiahe Formation.

The Hsuchiahe flora consists of 72 species belonging to 37 genera. The important taxa are: *Annulariopsis* sp., *Equisetum sarrani* Zeil., *Neocalamites carrerei* (Zeil.) Halle, *Lobatannularia kaixianensis* sp. nov., *L. hechuanensis* sp. nov., *Taeniocradopsis rhizomoides* Szé, *Danaeopsis fecunda* Halle, *Clathropteris meniscioides* Brongn., *C. platyphylla* (Goep.) Nathorst, *Dictyophyllum nathorsti* Zeil., *D. gracile* (Tur-Ket.) Chu, *Hausmannia* sp., *Phlebopteris xiangyunensis* Li et Tsao, *Todites denticulata* (Brongn.) Krasser, *T. princeps* (Presl) Gothan, *Cladophlebis asiatica* Chow et Yeh, *C. haiburnensis* (L. et H.) Brongn., *C. ingens* Harris, *C. kwangyüanensis* Lee, *C. raciborskii* Zeil., *C. scariosa* Harris, *C. shansiensis* Sze, *C. williamsoni* (Brongn.) Seward, *Sphenopteris chowkiawanensis* Sze, *Ptilozamites chinensis* Hsü, *P. nilssoni* Nathorst, *Anomozamites* cf. *hartzi* Harris, *A.* sp., *Pterophyllum aequale* (Brongn.) Nathorst *P. angustum* (Braun) Gothan, *P. exhibens* Lee, *P. jaegeri* Brongn., *P. multilineatum* Schirley, *P. ptilum* Harris, *P.* cf. *pinnatifidum* Harris, *P. subaequale* Hartz, *P.* sp., *Nilssoniopteris* cf. *tenuinervis* (Braun) Nathorst, *Ctenis kaixianensis* sp. nov., *Pseudoctenis hechuanensis* sp. nov., *Anthrophyopsis leeiana* (Sze) Florin, *Sinoctenis calophylla* Wu et Lih, *Sphenozamites* sp., *Baiera multipartita* Sze et Lee, *Ginkgoites* cf. *sibiricus* (Heer) Seward, *Glossophyllum shensiensis* Sze, *Podozamites distans* (Presl) Braun, *P. lanceolatus* (L. et H.) Braun, *P. schenki* Heer, *P.* sp., *Cycadocarpidium erdtmanni* Nathorst, *Ferganiella podozamioides* Lih, *F.* sp., *Elatocladus* sp., *Pityophyllum* sp., *Taeniopteris* cf. *sterophylla* Kryshtofovich, *T. richthofeni* (Schenk) Sze, *T.* sp., *Strobilites* sp., *Carpolithus* sp., *Schizolepis gracilis* Sze, *Stenorachis lepida* (Heer) Seward, *Swedenborgia* sp. and *Acthephyllum kaixianensis* gen. et sp. nov. Most of these species and genera are typical in the Late Triassic flora and have also been reported from many other places of southern China, for example, in Ipinglang flora of Yunnan Province and Anyuan flora of Jiangxi Province. The coal formation has been compared with the Hsuchiahe Formation of Kwangyüan in northern Sichuan Province. It is also comparable with the Tonkin flora of Vietnam and the Nariwa flora of Japan. It has been thought to be the Middle-Late Stage of the Late Triassic. The climate at that time was subtropical or tropical, hot and humid.

Zhenghuchong flora consists of 44 species belonging to 25 genera. The main species are: *Annulariopsis inopinata* Zeil., *Equisetum* sp., *Neocalamites* sp., *Marattia asiatica* (Kaw.) Harris, *M. hoerensis* (Schimper) Harris, *Coniopteris hymenophylloides* (Brongn.) Seward, *C. murrayana* (Brongn.) Brongn., *C.* sp., *Clathropteris meniscioides* Brongn., *C. obovata* Ôishi, *C.* sp., *Thaumatopteris* sp., *Hausmannia* sp., *Todites denticulata* (Brongn.) Krasser, *T. princeps* (Presl) Gothan, *Cladophlebis asiatica* Chow et Yeh, *C. kwangyunensis* Lee, *C. raciborskii* Zeil., *C. scoresbyensis* Harris, *Pterophyllum decurrens* Sze, *P. macrodecurrens* Duan, *P.* sp., *Tyrmia nathorsti* (Schenk) Ye, *Anomozamites* sp., *Nilssonia* spp., *Ctenis* sp., *Ptilophyllum contiguum* Sze, *P. pecten* (Phillips) Morris, *Baiera minuta* Yabe et Ôishi, *B. pseudogracilis* Hsü, *B.* spp., *Czekanowskia rigida* Heer, *C.* sp., *Ginkgoites* cf. *marginatus* (Nathorst) Florin, *G.* sp., *Sphenobaiera hungi* (Sze) Hsü, *S.* sp., *Podozamites lanceolatus* (L. et H.) Braun, *P.* sp., *Elatocladus* sp., *Pityophyllum* sp., *Schizolepis gracilis* Sze, *Williamsonia* sp., *Taeniopteris* sp. and *Carpolithus* sp. The Zhenghuchong Coal Formation is similar to Baitianba Coal Formation of Kwangyüan in northern Sichuan and Xiangxi Coal Formation in west Hubei Province. It is probably Early Jurassic in age. No distinct discontinuity has been found between Zhenghuchong Formation and Hsuchiahe Formation in this area.

DESCRIPTION

Lobatannularia kaixianensis sp. nov.

Pl. 1, figs 2-6

Diagnosis — Stem about 1 mm with 12-17 mm long (usually 15 mm) internodes; whorls divided symmetrically into two leaves, each half usually consisting of 12-16 leaves, toothed, slightly split into leaves; leaf oblanceolate to spatulate, 8-25 mm long and 2 mm wide at the widest part, mostly slightly curved upwards but the uppermost ones curved downwards, unequal in length, with the lowest one the shortest, successively getting longer upwards but getting shorter again after the middle one, each with a median vein; vein extending from the base to top. The distal whorl not divided into two leaves, fan-shaped.

Comparison & discussion — The characters of this species mostly resemble the other species of the genus *Lobatannularia*. Some authors consider *Lobatannularia* synonymous with the genus *Annulariopsis* which was established in 1903, but this is not accepted by most authors because the latter has only the distal whorl whose leaves are free to near base. Our specimens also differ from the genera *Neocalamites* and *Schizoneura*. The whorls in *Neocalamites* are not divided into two leaves, instead have radiate and entirely separate leaves; the whorls in *Schizoneura*, though divided into two leaves, they are equal in length. The species described here is closest to *Lobatannularia heianensis* and *L. multifolia*, but differs from them in fewer and shorter leaves in a whorl. The genus *Lobatannularia* is usually considered to be restricted to Palaeozoic but several species of this genus are known from Mesozoic of Sichuan, Yunnan and Shanxi Provinces.

Holotype — Specimen no. 7154 (Pl. 1, fig. 3).

Locality & Age — Tongshuhe Ba of Kaixi County, Sichuan Province, People's Republic of China; Late Triassic.

Lobatannularia hechuanensis sp. nov.

Pl. 1, fig. 1

Description — Specimen having only the upper part of a thin stem with two nodes; internode 16-18 mm long. Whorls not perfectly preserved, apical part missing, relatively small, divided into two lobes, each lobe consisting of 8-12 leaves. Leaves uninerved, united for their most part. The distal whorl not divided into two lobes, fan-shaped.

Comparison — The leaves of the present specimen are smaller and narrower than those of *L. kaixianensis* and thus has been described as a new species.

Holotype — Specimen no. 7102.

Locality & Age — Tan Ba of Hechuan County, Sichuan Province, People's Republic of China; Late Triassic.

*Lobatannularia chuandianensis** (Wang) n. comb.

Pl. 1, figs 7, 8

1977 *Neoannularia chuandianensis* Wang, p. 187, pl. 1, fig. 10; text-fig. 1.
1978 *Lobatannulariopsis yunnanensis* Yang, p. 472, pl. 158, fig. 6.
1980 *Annulariopsis lobatannularioides* Huang et Zhou, p. 69, pl. 23, figs 8-10; pl. 24, fig. 1.

Emended diagnosis — Stem thin, about 1-1·5 mm wide with 12 mm long internodes. Whorls divided into two leaves, each one usually consisting of 6-10 leaves; leaf lanceolate or oblanceolate, 7-15 mm long and 1 mm wide, unequal in length, with the lowest one shortest, successively getting longer upwards but getting shorter again after the middle one, each with a median vein; the vein extending from the base to the top.

Comparison & discussion — The species differs from *L. kaixianensis* and *L. hechuanensis* in having whorls which divide into deeply splitted two leaves. It resembles *L. sinesis* collected from the Palaeozoic, but the leaves in the latter are larger and more and more oblanceolate.

The characters of *Neoannularia chuandianensis* (Wang, 1977, p. 187, pl. 1, fig. 10) from south-west of Sichuan Province, *Lobatannulariopsis yunnanensis* Yang (Yang, 1978, p. 472, pl. 158, fig. 6) from Yunnan Province and *Annulariopsis lobatannularioides* Huang et Zhou (Huang & Zhou, 1980, p. 69, pl. 23, figs 8-10; pl. 24, fig. 1) from the Yenchang Formation of northern Shenxi Province are very similar to this species. It is also similar to *Lobatannularia* than *Annularia* and *Annulariopsis*. Thus a new combination, viz., *L. chuandianensis* (Wang) n. comb., has been established.

Holotype—Specimen no. 7544 (Pl. 1, fig. 7).

Locality & Age — Qinghe Formation of south-west of Sichuan Province and Ipinglang Formation of Yunnan Province, People's Republic of China; Late Triassic.

Pseudoctenis hechuanensis Chen et Duan sp. nov.

Pl. 3, fig. 14

Diagnosis — Leaf pinnate, leaf substance thin, 22 cm in length and 15 cm in width (estimated length more than 40 cm). Rachis about 1 cm wide with longitudinal striations on its surface. Pinnae opposite or sub-opposite, arising at an angle of 70°-80° from the rachis, linear, entire, at the basal part the lower margin being slightly decurrent on its rachis, but on meeting the base of adjacent pinnae, apex of pinnae obtusely rounded to rounded. Veins slender and closely set, most of them unforked, a few branched once near the rachis, 7-8 veins per cm at the middle parts of pinnae.

Comparison & discussion — Although the leaf is incomplete both at the base and apex, the new species resembles *P. gigantea* (Hsü *et al.*, 1975, p. 73, pl. IV) from Baoding of Sichuan Province. The pinnae of *P. gigantea* are broader (about 2·8-3 cm wide) and veins very closely 30-36 per cm. In general shape of leaf, this new species closely resembles *P. spectabilis* (Harris, 1932, p. 20, pl. 2, figs 1, 4; pl. 3, fig. 6; text-figs 11, 12) and *P. depressa* (Harris, 1932, p. 25, pl. 2, figs 3, 5; text-fig. 14) from East Greenland, but the veins of *P. spectabilis* and *P. depressa* thinner than those of our new species *P. hechuanensis*.

Holotype — Specimen no. 7125.

Locality & Age — Tan Ba of Hechuan County, Sichuan Province, People's Republic of China; Late Triassic.

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*This species n. comb. is not from the Eastern part of Sichuan Province.

Ctenis kaixianensis sp. nov.

Pl. 1, fig. 9; Pl. 2, fig. 13

Diagnosis — Leaf pinnate, estimated at 30 cm in length and 18 cm in width, rachis slender, 2-5 mm wide, pinnae linear, subopposite, 6-9 cm long and 1-1.7 cm wide, apex of pinnae rounded, arising at an angle of 70°-90° from the rachis, base of pinnae extending but not contacting the adjacent pinnae. Veins slender and thinner, fairly conspicuous, about 10 veins arising from the rachis, simple or once forked, at variable distance and forming elongate meshes, 6-22 mm long, 12-15 veins per cm at the middle part of pinnae.

Comparison & discussion — Full shape of this new species unknown, but its shape and veination differ from other species of this genus. *C. pterophylloides* (Chen *et al.*, 1979, p. 270, pl. 3, fig. 2) and *C. reguloria* (Chen *et al.*, 1979, p. 187, pl. 1, fig. 3) from Yanbian County, South-west of Sichuan Province rather resemble our new species, but both of them differ in closer pinnae and closer and regular meshes.

Holotype — Specimen no. 7178 (Pl. 2, fig. 13).

Locality & Age — Tongshuhe Ba of Kaixi County, Sichuan Province, People's Republic of China; Late Triassic.

Genus — *Acthephyllum* gen. nov.

Diagnosis — More than 10 leaves look like foliage at the top of stem. Leaf taeniopteroid, tapered to the apex, gradually slendered to the base with a thin petiole, 12-22 mm wide at middle part (the widest part) several to more than 10 cm in length, entire. Midrib prominent, extending to the apex, 1-1.5 mm wide, lateral veins thin, arising nearly at an angle of 80° to the midrib, less at the base with about 16-17, more at the middle part with 21-23, simple or bifurcating once at any position, branch sometimes forward back and form a circle, sometimes crossing or meeting.

Comparison & discussion — This plant often preserves simple leaf, which looks like the leaf of genus *Taeniopteris*, but the different types of lateral veins and attachment of leaves distinguish it from *Taeniopteris*. It closely resembles *Mironeura dakengensis* Zhou (Zhou, 1978, p. 114, pl. 25, figs 1, 1a, 2; text-fig. 4), but the leaf of *M. dakengensis* is much bigger and leaf membrane attached on the top of the leaf, and the leaves of new genus look like foliage at the top of stem. Because there is not any cuticle preserved on specimens, we can't identify the natural family of the new genus.

Genotype — *Acthephyllum kaixianensis* sp. nov.

Acthephyllum kaixianensis sp. nov.

Pl. 2, figs 10-12

Diagnosis — See the diagnosis of the genus.

Holotype — Specimen no. 7221 (Pl. 2, fig. 10).

Locality & Age — Tongshuhe Ba of Kaixi County, Sichuan Province, People's Republic of China; Late Triassic.

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EXPLANATION OF PLATES

(All figures. × 1. All specimens are deposited in the Institute of Botany, Academia Sinica.)

PLATE 1

1. *Lobatannularia hechuanensis* sp. nov.
2-6. *Lobatannularia kaixianensis* sp. nov.
7-8. *Lobatannularia chuandianensis* (Wang.), n. comb.
9. *Ctenis kaixianensis* sp. nov.

PLATE 2

10-12. *Acthephyllum kaixianensis* gen. et sp. nov.
13. *Ctenis kaixianensis* sp. nov.

PLATE 3

14. *Pseudoctenis hechuanensis* sp. nov.


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PLATE 1


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PLATE 2

PLATE 3

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PALMOXYLON DILACUNOSUM SP. NOV. FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT, MADHYA PRADESH

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ABSTRACT

Palmoxylon dilacunosum sp. nov., collected from the Deccan Intertrappean beds of Shahpura near village Silther in Mandla District, Madhya Pradesh is described. It is characterized by the outer and inner distinct lacunar parts in the central vascular zone.

Key-words — Xylotomy, *Palmoxylon*, Palmae, Deccan Intertrappean beds, Probably Eocene (India).

साराँश

मध्य प्रदेश में मँडला जनपद के दक्खिन अन्तर्ट्रैपी संस्तरों से पाल्मॉक्सीलान डाइलाकुनोसम नव जाति – कृष्ण अम्बवानी

मँडला जनपद (मध्य प्रदेश) में सिलथर ग्राम के समीप शाहपुरा की दक्खिन अन्तर्ट्रैपी संस्तरों से एकत्रित पाल्मॉक्सीलॉन डाइलाकुनोसम् नव जाति का वर्णन किया गया है। इस ताड़-काष्ठाश्म में केन्द्रीय वाही मंडल सुस्पष्ट बाह्य एवं अन्तस्थ दो रिक्तिकीय भागों से अभिलक्षणित है।

INTRODUCTION

SO far only a few fossil dicotyledonous woods (Ingle, 1972, 1973; Bande, 1973, 1974; Lakhanpal, Prakash & Bande, 1978; Bande & Khatri, 1980; Bande & Prakash, 1981, 1983), a petrified palm fruit resembling *Hyphaene* (Bande, Prakash & Ambwani, 1982) and a few fossil palm woods (Lakhanpal, Prakash & Ambwani, 1980) have been recovered from this region. Besides, the fossil palm woods resembling *Chrysalidocarpus* (Ambwani & Prakash, 1983) and *Licuala* (Ambwani, 1983) have been described from the Deccan Intertrappean exposures of Mandla District. However, this paper deals with a new species of a fossil palm wood from the Intertrappean beds near Silther Village in Mandla District, Madhya Pradesh.

SYSTEMATIC DESCRIPTION

Palmoxylon Schenk, 1882

Palmoxylon dilacunosum sp. nov.

The palm wood sector is about 9.5 cm long and 6,5 cm in radius. It shows the presence of cortical, dermal, subdermal and central zones (Pl. 1, fig. 1).

Cortical zone — The cortical zone is very narrow, mainly composed of fibrous and irregularly oriented fibrovascular bundles. Fibrovascular bundles are composed of a large fibrous sheath and usually single small excluded metaxylem vessel. Fibrous bundles range from 40-80 μm in diameter. The fibrovascular bundles measure up to 400 × 200 μm. Leaf-traces are frequently seen and are slightly larger than the fibrovascular bundles. The ground tissue is parenchymatous.

Dermal zone — It is about 2.5 cm thick and the fibrovascular bundles are regularly orientated (Pl. 1, fig. 3). They are usually oval to elongated in shape, 800 × 400-1000 × 400 μm in size and 160-170 per cm^2. The f/v ratio is generally 4/1-6/1. The dorsal sclerenchymatous sheath is prominent, usually reniform, rarely cordate with thick-walled cells having narrow lumen. The median sinus is generally concave sometimes angular and the auricular lobes are present, while the auricular sinus is indistinct. Generally one rarely two excluded oval metaxylem vessels are present (Pl. 1, fig. 3). Tabular and radiating parenchyma are absent. Stegmata are present around the fibrous part of fibrovascular bundles. The diminutive fibrovascular bundles are sometimes seen. They are usually irregularly oriented. Leaf-trace bundles are present. Horizontal bands of elongated parenchyma are frequently present in the ground mass which sometimes run obliquely between fibrovascular bundles (Pl. 1, fig. 3).

Subdermal zone — This zone extends further to about 3.5 cm towards the centre of the stem and the fibrovascular bundles are irregularly orientated (Pl. 1, fig. 4). They range in size from 1000 × 800-1000 × 1000 μm and are comparatively bigger in size than the bundles in the dermal zone. Their frequency varies from 120-130 per cm^2 and the f/v ratio from 2/1-5/1. The dorsal sclerenchymatous sheath is prominent and usually reniform. Its cells are thick walled, the lumen of the cells of inner part of sheath is very narrow as compared to the cells of outer portion. Median sinus is generally concave and auricular lobes are rounded, while the auricular sinus is indistinct. Generally two sometimes three large, round, excluded metaxylem vessels are present (Pl. 1, fig. 4). Tabular parenchyma is mostly in a single layer around the fibrovascular bundles. Stegmata are present around the fibrous part of fibrovascular bundles. The diminutive fibrovascular bundles are occasional and show irregular orientation. Leaf-trace bundles are frequently present. The horizontal files of parenchymatous cells are absent. Phloem is usually represented by a lacuna.

Central zone — This zone can further be divided into two parts: the *outer* and an *inner* part. *Outer* part is highly lacunar and is about 0.5 cm in thickness, composed of very large air cavities. This portion is devoid of fibrous and fibrovascular bundles. The parenchymatous cells of this part are long, cylindrical and usually branched to form lacunae of very large size (Pl. 1, figs 2, 5, 6). The *inner* part is also lacunar but the lacunae are much smaller in size. It has profuse fibrous and fibrovascular bundles. The fibrovascular bundles are irregularly oriented (Pl. 1, figs 2, 7), 800 × 800-1000 × 1040 μm in size and round to oval in shape. The frequency ranges from 65-70 per cm^2 and the f/v ratio from 1/1-2/1. The dorsal sclerenchymatous sheath is quite prominent and reniform. Its cells are thick-walled with considerably larger lumen. Generally two, sometimes three excluded metaxylem vessels and an ill-developed ventral fibrous sheath is also seen (Pl. 1, fig. 7). Tabular and radiating parenchyma are absent. Stegmata are present in the fibrous part of the fibrovascular bundles (Pl. 1, fig. 8). Phloem is represented by a small cavity. Diminutive fibrovascular bundles are absent. Leaf-trace bundles are present. Fibrous bundles profusely occur (Pl. 1, fig. 7).

Diminutive Fibrovascular Bundles — The diminutive fibrovascular bundles, similar in structure to normal fibrovascular bundles, are present in the dermal, subdermal and central zones and measure up to 200 × 400 μm in size. They are irregularly orientated (Pl. 1, figs 3, 4).

Leaf-trace Bundles — These are present throughout the stem and can easily be distinguished by their extended vascular part with many smaller xylem vessels. They are slightly larger than the normal fibrovascular bundles (Pl. 1, figs 3, 4, 7).

Fibrous Bundles — These bundles are rarely found in the dermal zone. Their frequency increases in subdermal zone and profusely occur in the inner part of central zone (Pl. 1, fig. 7). Their size also gradually increases from dermal to central zone from 40 to 120 μm. Their absence in the outer part of the central zone is notable (Pl. 1, fig. 6).

Ground Tissue — The ground tissue in the dermal zone is parenchymatous, compact and scanty; parenchyma in the subdermal zone is slightly more while in the central zone it occupies a major portion of stem. Cells in the dermal zone are small, polygonal alongwith a large number of irregularly traversing horizontal files of cells (Pl. 1, fig. 3), absent from subdermal zone. The ground tissue consists only of polygonal parenchymatous cells (Pl. 1, fig. 4). The central zone is highly lacunar and the lacunarization starts abruptly (Pl. 1, figs 2, 6, 7). Based on the distribution pattern of lacunae, the central zone can be distinguished into two parts (i) the outer, about 5 mm wide, devoid of fibrous and fibrovascular bundles exclusively composed of large lacunae bordered by elongated parenchymatous cells forming mesh-like structure

(Pl. 1, fig. 6), and (ii) the inner portion with small lacunae accompanied by abundant fibrous and fibrovascular bundles (Pl. 1, fig. 7).

Vessel Elements — Metaxylem vessels of the fibrovascular bundles of dermal, subdermal and central zones are usually oval to round, sometimes laterally flattened (Pl. 1, figs 3, 4, 7), measuring 200×120 μm to 350×200 μm in cross section and 3 to 4 mm long. Their end plates are oblique with 2-4 perforation bars; side wall pitting is scalariform to reticulate. Annular and spirally thickened protoxylem vessels are sometimes seen associated with metaxylem vessels; measure 50-70 μm in cross section and are much longer than the metaxylem vessels (Pl. 1, fig. 8).

DIAGNOSIS

Fossil palm wood a triangular sector; cortical, dermal, subdermal and central zones present; 9.5 cm long, 6.5 cm radius; cortical fibrovascular bundles irregularly placed measuring 400×200 μm in size. Dermal zone bundles regularly oriented, 800×480 μm to 1000×400 μm in size, 160-170 per cm ; f/v ratio 4/1-6/1, dorsal sclerenchymatous sheath reniform, cell lumen very narrow; median sinus concave to angular; auricular sinus indistinct, lobes rounded; generally one rarely two metaxylem vessels in each fibrovascular bundle, tabular, radiating parenchyma absent; stegmata and diminutive fibrovascular bundles present; phloem represented by lacuna; fibrous bundles and parenchymatous bands present.

Subdermal fibrovascular bundles irregular in orientation, round to oval, 120-130 per cm^2, size 1000×800-1000×1000 μm, f/v ratio 2/3-3/1; dorsal sclerenchymatous sheath reniform; median sinus concave, auricular sinus indistinct, lobes rounded; stegmata, diminutive bundles, tabular parenchyma and fibrous bundles present; radiating parenchyma and parenchymatous bands absent.

Central fibrovascular bundles irregular in orientation; frequency 65-70 per cm^2, shape round to oval, 800×800-1400-1000 μm in size, f/v ratio 1/1-2/1; metaxylem vessels 2-3, excluded; dorsal sclerenchymatous sheath reniform; median sinus concave, auricular sinus indistinct, auricular lobes rounded; tabular and radiating parenchyma absent; stegmata present; fibrous bundles profuse; horizontal parenchymatous bands absent; phloem represented by lacuna; leaf-trace bundles present. Metaxylem vessels 200×120-350×200 μm in diameter, 3-4 mm long; perforation plates oblique with 2-4 bars, scalariform to reticulately thickened; protoxylem vessels 50-70 μm in diameter, annular and spirally thickened perforation plates usually with two bars. Central ground tissue distinguished into outer part devoid of fibrous and fibrovascular bundles; inner part with small lacunae, fibrous and fibrovascular bundles profuse.

Holotype — B.S.I.P. Museum no. 35541.

Locality — Silther, near Shahpura, Mandla District, Madhya Pradesh.

Horizon — Deccan Intertrappean beds.

Age — Probably Early Eocene.

DISCUSSION

The present palm wood possesses distinct lacunar ground tissue in the central zone which is further distinguishable into two parts, i.e. an outer highly lacunar part without any fibrous or fibrovascular bundles and an inner part with profuse fibrous and fibrovascular bundles (Pl. 1, figs 2, 6, 7). A large number of Indian fossil palm woods possessing lacunar ground tissue have been described. These are: *Palmoxylon hislopi* Rode (1933), *P. dakshinense* Prakash (1960), *P. chhindwarense* Prakash (1960), *P. eocenum* Prakash (1962), *P. deccanense* Sahni (1964), *P. wadiai* Sahni (1931, 1964), *P. kamalam* Rode (Rode, 1933; Shukla, 1939; Sahni, 1964; Mahabale & Kulkarni, 1973), *P. jammuense* Sahni (1931, 1964), *P. blanfordi* Schenk (Schenk, 1882; Sahni, 1931, 1964), *P. parthasarathyi* Rao & Menon (1964), *P. feistmanteli* Rao & Achutan (1969), *P. keriense* Trivedi & Verma, (1971a), *P. superbum* Trivedi & Verma (1971b), *P. parapaniensis* Lakhanpal *et al.* (1979) and *P. livistonoides* Prakash & Ambwani (1980). None of them possess the distinct pattern of distribution of lacunae in the central zone as seen in the present fossil and hence the fossil has been assigned to a new species, *Palmoxylon dilacunosum* sp. nov.

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EXPLANATION OF PLATES

Palmoxylon dilacunosum sp. nov.

1. Transverse section of stem in low power to show dermal, subdermal and central zones, × natural size. (D = dermal, SD = subdermal, C = central zones); B.S.I.P. specimen no. 35541.
2. Transverse section of stem through central zone to show its outer and inner parts. × 4; slide no. 8015.
3. Transverse section of stem to show dermal zone. Note the presence of horizontal files of parenchymatous cells. × 25; slide no. 8014.
4. Transverse section of the stem to show subdermal zone. Note the presence of diminutive fibrovascular and leaf-trace bundles. × 25; slide no. 8014.
5. Longitudinal view of the specimen showing outer and inner lacunar parts of the central zone of the specimen. × 3. B.S.I.P. specimen no. 35541 (O = outer, I = inner).
6. Transverse section of stem to show outer lacunar part of the central zone. Note the absence of

fibrovascular and fibrous bundles in this part. × 25; slide no. 8015.

7. Transverse section of stem to show inner part of the central zone. Note the presence of fibrous, fibrovascular bundles and smaller size of lacunae. × 25; slide no. 8015.
8. Longitudinal section of fibrovascular bundle to show stegmata and the nature of the xylem elements. × 60; slide no. 8016.

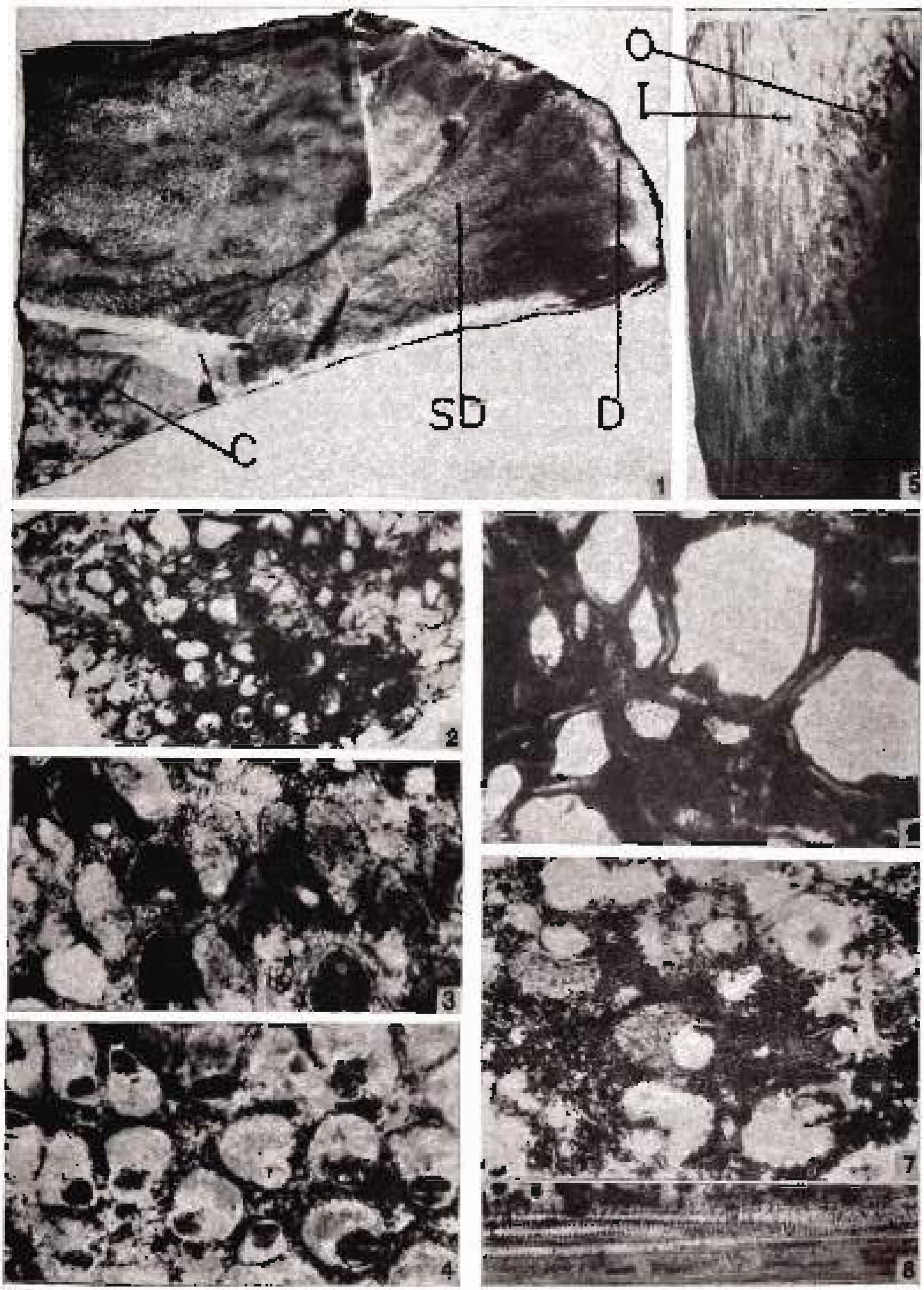

PLATE 1

The Palaeobotanist, **32**(3): 217-229, 1984.

AMARJOLIA DACTYLOTA (BOSE) COMB. NOV., A BENNETTITALEAN BISEXUAL FLOWER FROM THE RAJMAHAL HILLS, INDIA

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ABSTRACT

Amarjolia dactylota (Bose) comb. nov. comprises spirally arranged bracts enclosing a whorl of microsporophylls and the female receptacle with immature seminiferous and interseminal scales. Microsporophylls in gross features resemble the microsporophylls of *Weltrichia santalensis* (Sitholey & Bose) Bose described by Sitholey and Bose (1971). Flower being protandrous, the details of seminiferous and interseminal scales are not known.

Key-words — *Amarjolia*, Bennettitales, Bisexual flower, Rajmahal Hills, Upper Jurassic (India).

साराँश

भारत में राजमहल पहाड़ियों से एक बैन्नेटाइटेली उभयलिंगी पुष्पाश्म : अमरजोलिया डेक्टाइलोटा (बोस) नव संयोजन – महेन्द्र नाथ बोस, जयश्री बैनर्जी एवं पंकज कुमार पाल

अमरजोलिया डेक्टाइलोटा (बोस) नव संयोजन में लघुबीजाणुपर्णों के चक्र के चारों ओर सर्पिलाकार विन्यस्त सहपत्र तथा अपरिपक्व बीजधर शल्क एवं अन्तराबीजी शल्क विद्यमान हैं। लघुबीजाणुपर्ण सिथोले व बोस (1971) द्वारा वर्णित वैलट्राइकिया सॅन्तालेन्सिस (सिथोले व बोस) बोस से सभी लक्षणों में समानता प्रदर्शित करते हैं। यह पुष्प पुंपक्व है तथा इसके बीजधर एवं अन्तराबीजी शल्कों के विषय में विस्तृत जानकारी नहीं है।

INTRODUCTION

A BISEXUAL flower belonging to Bennettitales was described by Bose (1966) as *Cycadeoidea dactylota* from Amarjola (about 1.8 km NE of Amarapara Village), Rajmahal Hills, Bihar. His description was based on a well-preserved petrified specimen. Since then several visits were made to the same locality in search of new specimens, but without any success. However, a specimen having only the outer bracts enclosing an immature 'androecium' was collected by one of us (M.N.B.) from the same locality. The present paper describes the original specimen of Bose (1966) and the immature flower bud.

DESCRIPTION

Genus — *Amarjolia* n. gen.

Diagnosis — As for the only species *Amarjolia dactylota* (Bose) comb. nov.

Amarjolia dactylota (Bose) comb. nov.

Pl. 1, figs 1-4; Pl. 2, figs 7-10; Pl. 3, figs 13-15; Pl. 4, figs 16-19; Text-figs 1-4

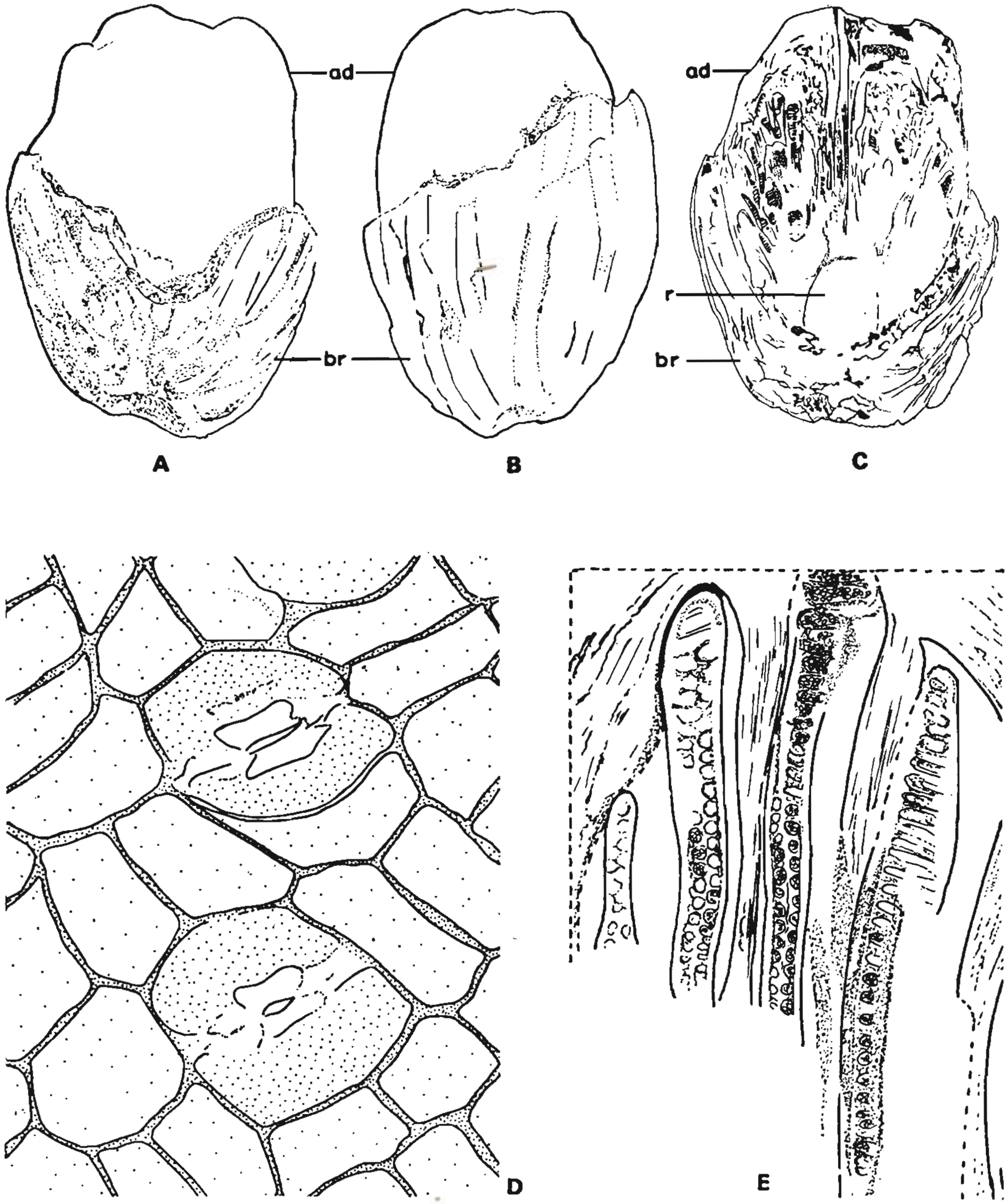
1966 *Cycadeoidea dactylota* Bose, p. 569, fig. 1 (description and text-figure of the holotype).

1971 *Cycadeoidea dactylota* Bose: Sitholey & Bose, pp. 153, 158, pl. 34, figs 19-21 (brief discussion and figures of microsporophylls).

1974 *Cycadeoidea dactylota* Bose: Bose, p. 194 (brief description and discussion).

Diagnosis — Bisexual flower consisting of an axis bearing bracts, 'androecium' and female receptacle with immature seminiferous and interseminal scales.

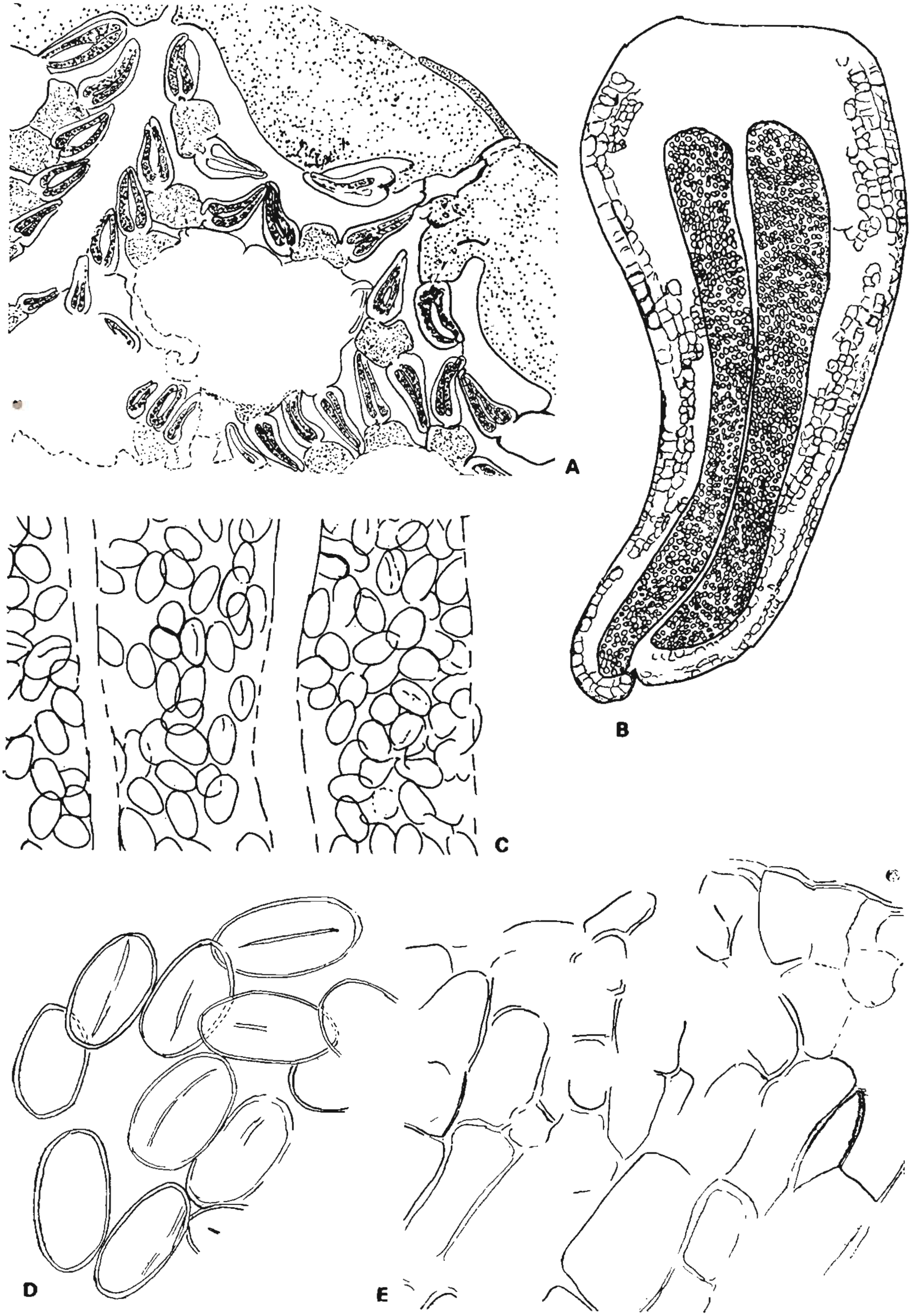
Flower as a whole oval in shape, 6 cm long and 4.5 cm wide. Bracts spirally arranged, forming a perianth of more than two turns, exact number in each turn not known, lateral sides showing prominent



TEXT-FIG. 1A-E — *Amarjolia dactylota* (Bose) comb. nov.— **A, B**, the flower as seen from two different sides, B.S.I.P. specimen no. 24133, × 1; **C**, median longitudinal section of the flower, B.S.I.P. slide no. 24133-1, × 1; **D**, showing two stomata and epidermal cells of a bract, B.S.I.P. slide no. 24133-12, × 500; **E**, longitudinal section of a few 'synangia', B.S.I.P. slide no. 24133-1, × 7 (ad = 'androecium', br = bracts and r = receptacle).

→

TEXT-FIG. 2A-E — *Amarjolia dactylota* (Bose) comb. nov.— **A**, a part of 'androecium' in transverse section showing parts of microsporophylls and a few 'synangia', B.S.I.P. slide no. 24133-8, × 6; **B**, a synangium showing two pollen masses, B.S.I.P. slide no. 24133-8, × 60; **C**, parts of 'synangia' showing pollen grains, B.S.I.P. slide no. 24133-1, × 200; **D**, a few pollen grains, B.S.I.P. slide no. 24133-1, × 500; **E**, showing a few cells of seminiferous and interseminal scales in longitudinal section, B.S.I.P. slide no. 24133-1, × 500.



TEXT-FIG. 2A-E

long hairs; hairs about 4-5 mm long. Surface cells of bracts on ventral side polygonal or rectangular; lateral- and end-walls straight or at places slightly wavy; surface-wall unspecialized. Cells on dorsal surface like those on ventral surface. Stomata confined to dorsal surface only, not so densely crowded, transversely orientated. Subsidiary cells smaller than ordinary epidermal cells, non-papillate. Guard cells crescent-shaped; aperture elliptical in shape.

Bracts in cross section showing a thick layer of cuticle followed by rectangular epidermal cells, an ill-defined zone of hypodermal cells and ground tissue of loosely connected isodiametric cells. Vascular bundles not well-marked, their number and arrangement not clear.

'Androecium' as a whole ovate in shape, entirely covering and concealing female receptacle, about 4.7 cm long and 3.5 cm wide near middle region; consisting of 12 microsporophylls in a whorl, microsporophylls compressed together but not fused with each other, externally showing 12 prominent ridges and grooves; each groove finely striated in longitudinal direction, at places somewhat rugose. Microsporophylls attached in a whorl just below base of female receptacle. In cross section microsporophylls showing a thick cuticle followed by a layer of rectangular epidermal cells and parenchymatous zone consisting of loosely connected isodiametric cells traversed by a large number of secretory canals. In some near centre a single vascular bundle is visible. In longitudinal section microsporophylls near apex showing a thick parenchymatous tissue, about 1.2 cm in height; lower down microsporophylls bending inwards and reaching close to the base of female receptacle and entirely encircling it from all sides so as to form a sort of "chamber" between walls of microsporophylls and receptacle. On adaxial side of microsporophylls a large number of finger-like 'synangia' are seen projecting out and almost filling the entire "chamber". 'Synangia' attached in two rows on adaxial sides of microsporophylls; about 1.7-2 cm long. Bases of 'synangia' swollen, gradually narrowing towards tip. Each 'synangium' in median longitudinal section showing two series of small chambers along its entire length; chambers of one series lying in contact with each other and alternating with those of the other series. Each chamber full of numerous pollen grains. In cross section 'synangium' showing a central parenchymatous zone bearing on either side ovate pollen-bearing organ, each consisting of an outer layer of cuticle followed by a layer of rectangular epidermal cells and a 3-cell wide zone, cells within this zone rectangular in shape, enclosing somewhat two oval chambers full of pollen grains. The layer separating the two pollen bearing chambers not well-preserved.

Pollen grains oval with symmetrical ends, sometimes with asymmetrical ends, 16-24 × 24-36 µm. Monosulcate, sulcus long, usually narrow, ends ± tapering. Exine thin, about 1 µm thick, laevigate and infra-structured.

Female receptacle dome-shaped, internal tissue not well-preserved. In cross section at places isodiametric cells visible, numerous secretory canals are also present, xylem extremely poorly preserved. Seminiferous and interseminal scales immature, visible only at places, represented by a few cells here and there.

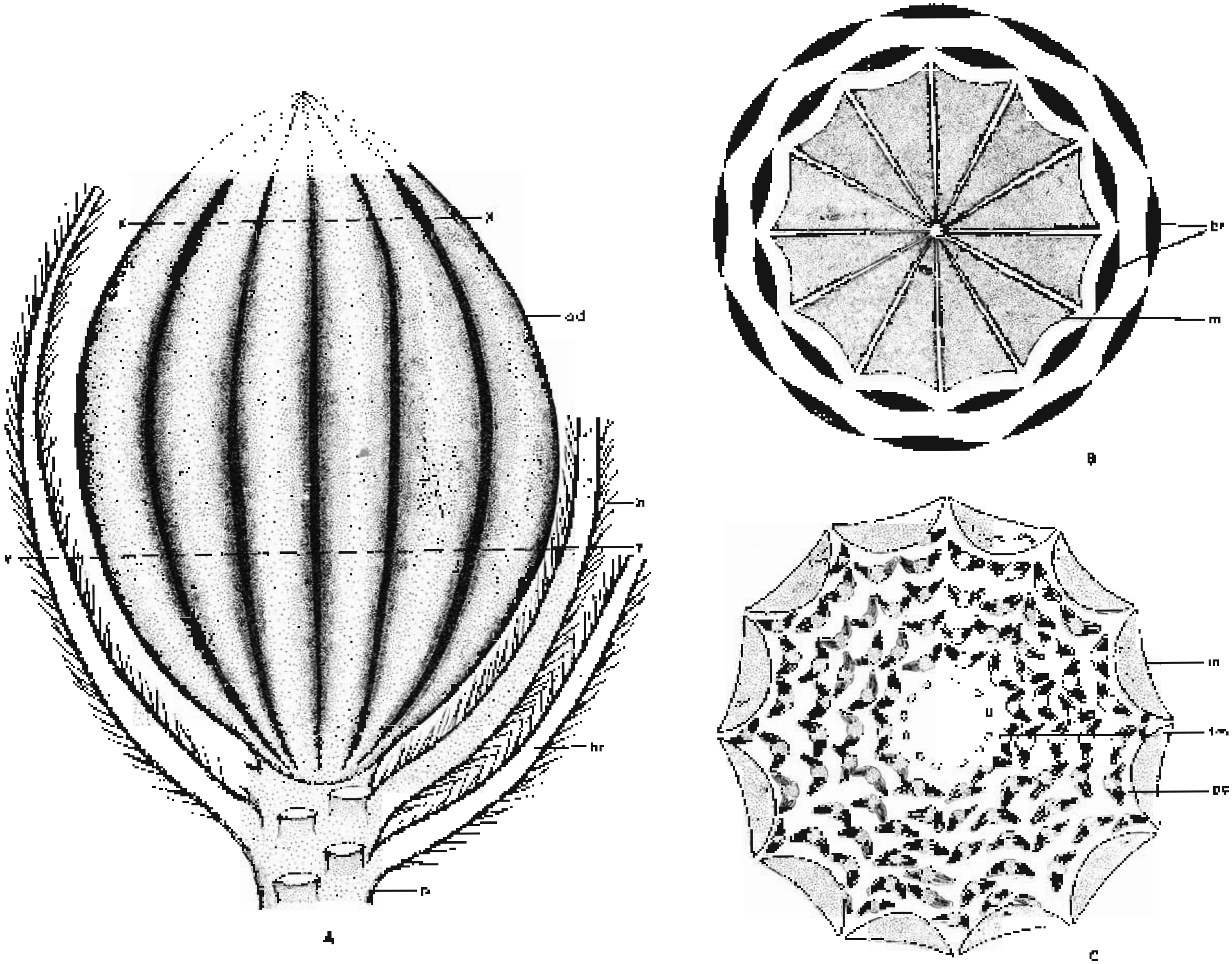
Holotype — Specimen no. 24133 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality—Amarjola, Rajmahal Hills, Bihar.

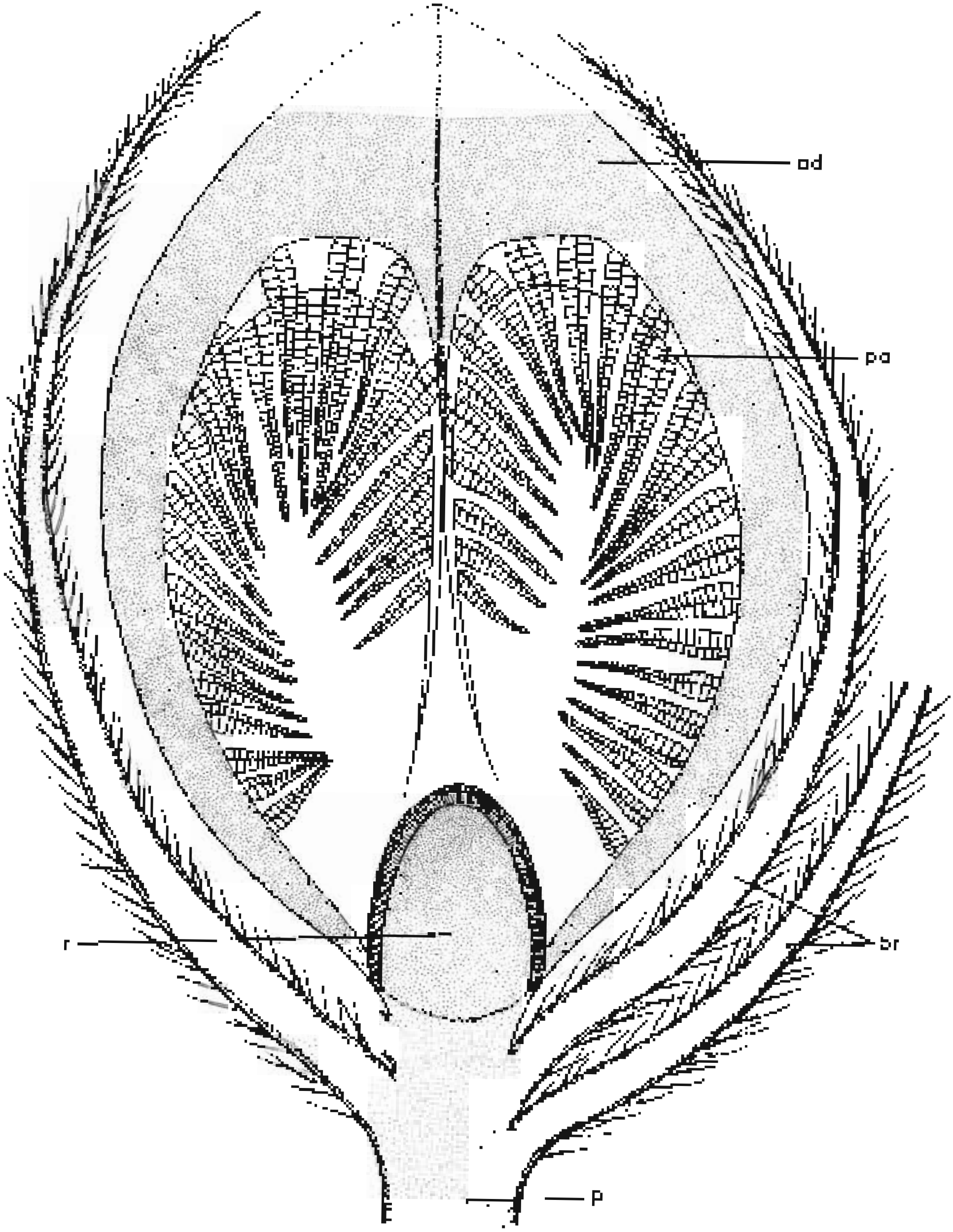
Horizon & age — Rajmahal Formation; Upper Jurassic.

Remarks & comparison — *Amarjolia dactylota* is the only Bennettitalean bisexual flower so far known from India. The above diagnosis is based on a petrified specimen whose bracts are incomplete towards distal end, exposing major part of 'androecium'. Unfortunately, except for the 'androecium' the anatomical details of the bracts, peduncle and the receptacle, together with seminiferous and interseminal scales, are not so well-preserved. In none of the microsporophylls vascular supply is visible. In some of the transverse sections of the microsporophylls, where the finger-like 'synangia' are attached, a single vascular bundle is visible in the centre. In median longitudinal section some of them show, at places, scalariform tracheids.

The seminiferous and the interseminal scales are in a very young stage of development. Except for a few cells their details are not clearly visible. From their stage of development it is clear that this flower was protrandrous. Perhaps the ovules matured after the pollen grains were shed



Text-fig. 36A-C, [illegible] [illegible] (Brsc) comb. nov. — A, Idealized restoration of the flower, the majority of bracts (br) not shown in order to show the 'androecium' with ridges and grooves, × ca 3. B, idealized restoration of the transverse section along the line X—X shown in fig. A (br, bracts and m, microsporophylls), × ca 2.5. C, Idealized restoration of transverse section of the flower along the line Y—Y shown in fig. A, showing proximal (outer) part of microsporophyll-[illegible], synangia attached to stalks (ps) and distal (inner) part of microsporophylls (tm) close to receptacle, × ca 2.5 (bracts not shown).



TEXT-FIG. 5 — The median longitudinal section of the flower — an idealized restoration showing spirally arranged bracts (br), 'androecium' (ad) bearing fertile finger-like 'synangia' (pa), female receptacle (r) bearing stalked ovules and interseminal scales and the peduncle (p).

It is of course difficult to say and demonstrate whether the ovules were in the pollen receptive stage at the time of shedding of the pollen grains.

The microsporophylls of *A. dactylota* resembles most, in gross features, the microsporophylls of *Weltrichia santalensis* (Sitholey & Bose) Bose described by Sitholey and Bose (1971). The details of pollen bearing organs of *W. santalensis* are not known. In general appearance *A. dactylota* somewhat resembles *Cycadeoidea dacotensis*

(Macbridge) Ward and *Cycadeoidea* sp. described by Delevoryas (1963) and Crepet (1974). The microsporophylls of *C. dacotensis* and *C.* sp. are quite different from those of *A. dactylota*. The microsporophylls of *C. dacotensis* are more like *Weltrichia spectabilis* (Nathorst) Harris (1969). In *Cycadeoidea* the flowers are partially embedded within leaf bases. Unlike species of *Cycadeoidea*, it seems that *A. dactylota* was exposed and was attached to stems like *Williamsonia* Carruthers, *Wielandiella* Nathorst and *Williamsoniella* Thomas. Both *Williamsonia* and *Wielandiella* differ from *A. dactylota* in having unisexual flowers. Only *Williamsoniella* is bisexual, but its ‘androecium’ is entirely different from *A. dactylota*. The microsporophylls of *Williamsoniella* are wedge-shaped and on its adaxial surface usually there are two or three pairs of short fertile branches and each branch has a two valved pollen capsule.

A YOUNG FLOWER BUD WITH ANDROECIUM LIKE *AMARJOLIA DACTYLOTA*

Pl. 1, figs 5, 6; Pl. 2, fig. 1; Pl. 3, fig. 12

The flower bud consists of an axis covered with spirally arranged bracts enclosing the ‘androecium’. The gynoecium is not preserved or perhaps was not formed when it was fossilized.

The bud measures 4.5 cm in length and 2 cm in width. The axis is about 1.7 cm in length and the details of its anatomy are not known. The bracts forming the perianth are in more than 2-3 turns, none of them are complete and their substance is fairly thick. At places fine lateral hairs of bracts are visible. In cross section, the bracts show an outer layer of cuticle followed by a layer of rectangular epidermal cells twice as long as broad. The epidermis is followed by a zone of hypodermis 5-6 cells thick. They are thick-walled and polygonal in shape. The cells of the hypodermis on the dorsal side are larger than those on the ventral side. The vascular bundles are collateral and mostly seven in number (two above and five forming an arc parallel to the lower surface). The ground tissue consists of loosely connected isodiametric cells.

‘Androecium’ is not well-preserved. In median longitudinal sections it seems to be like that of the ‘androecium’ of *Amarjolia dactylota*.

Because the specimen is imperfectly preserved so it has not been assigned to any species.

Collection — Specimen no. 32834 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Locality — Amarjola, Rajmahal Hills, Bihar.

Horizon & age — Rajmahal Formation; Upper Jurassic.

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EXPLANATION OF PLATES

PLATE 1

Amarjolia dactylota (Bose) comb. nov. (figs 1-4)

1, 2. Showing external features from two different directions; B.S.I.P. specimen no. 24133. × 1. (ad.=‘androecium’ and br.=bracts).

3. Longitudinal section of a few cells of seminiferous and interseminal scales; B.S.I.P. slide no. 24133-1. × 500.

4. Showing two stomata of a bract as seen under reflected light; B.S.I.P. slide no. 24133-12. × 500.

5. A young flower bud having 'androecium' like *A. dactylota*; B.S.I.P. specimen no. 32834. × 1.
6. Median longitudinal section of the above specimen; B.S.I.P. specimen no. 32834. × 2.5 (m=microsporophyll).

PLATE 2

Amarjolia dactylota (Bose) comb. nov. (figs 7-10)

7. A part of 'androecium' in transverse section showing a finger-like 'synangia'; B.S.I.P. slide no. 24133-8. × 6.
8. 'Synangia' in longitudinal section; B.S.I.P. slide no. 24133-1. × 7.
9. 'Synangia' showing two rows of contiguous chambers; B.S.I.P. slide no. 24133-1. × 40.
10. A part of figure 8 enlarged to show a portion of a 'synangium'. × 16.
11. Transverse section of a bract of the young flower bud shown in Pl. 1, fig. 5; B.S.I.P. slide no. 32834-2. × 15.

PLATE 3

Amarjolia dactylota (Bose) comb. nov. (figs 13-15)

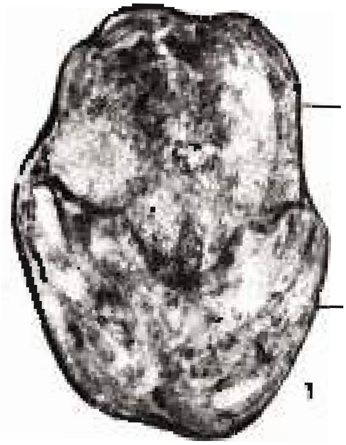
12. A portion of the 'androecium' in median longitudinal section of the young flower bud (Pl. 1, fig. 5) showing the finger-like 'synangia'; B.S.I.P. slide no. 32834-1. × 40. (m=microsporophyll).
13. *A. dactylota*, showing 'synangia' in cross section with numerous pollen grains; B.S.I.P. slide no. 24133-8. × 60.
14. *A. dactylota*, transverse section of 'androecium' showing 'synangia'. B.S.I.P. slide no. 24133-6. × 17.
15. *A. dactylota*, median longitudinal section showing a portion of 'androecium' and the female receptacle. B.S.I.P. slide no. 24133-1. × 17. (r=receptacle).

PLATE 4

Amarjolia dactylota (Bose) comb. nov.

16, 17. Showing pollen grains; B.S.I.P. slide no. 24133-1.16 × 200; 17 × 500.

18. Showing part of a receptacle with seminiferous and interseminal scales; B.S.I.P. slide no. 24133-1. × 50.
19. Median longitudinal section of the flower, B.S.I.P. slide no. 24133-1. × 2.5 (**ad**=androecium, **po**=pollen bearing 'synangia', and **r**=female receptacle).



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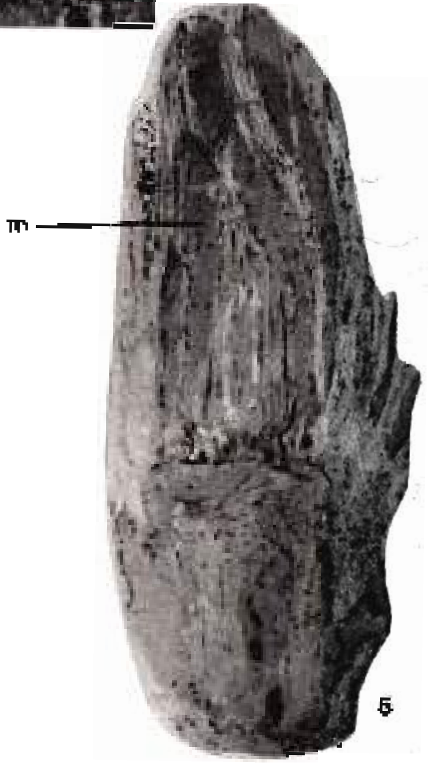

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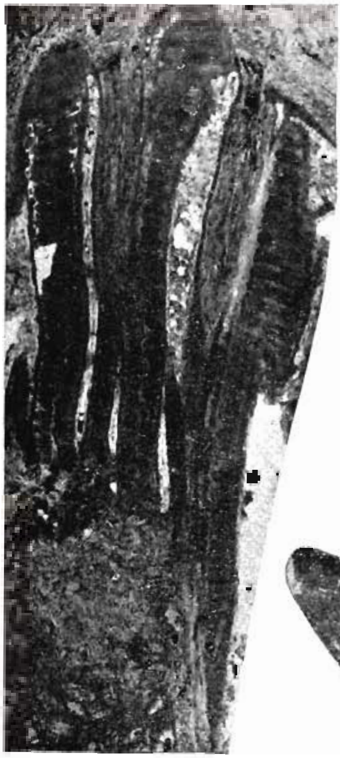
PLATE 1



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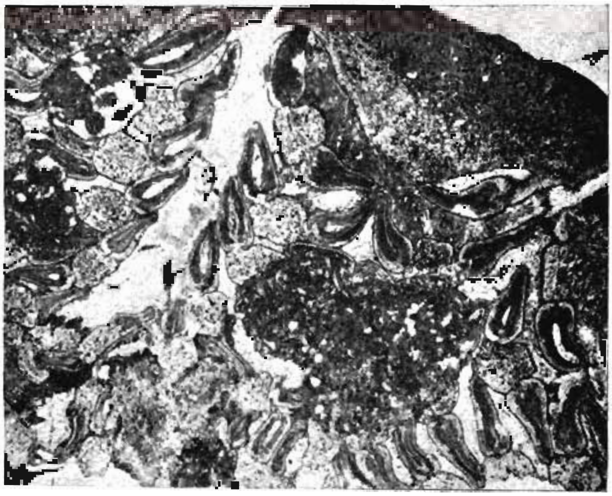

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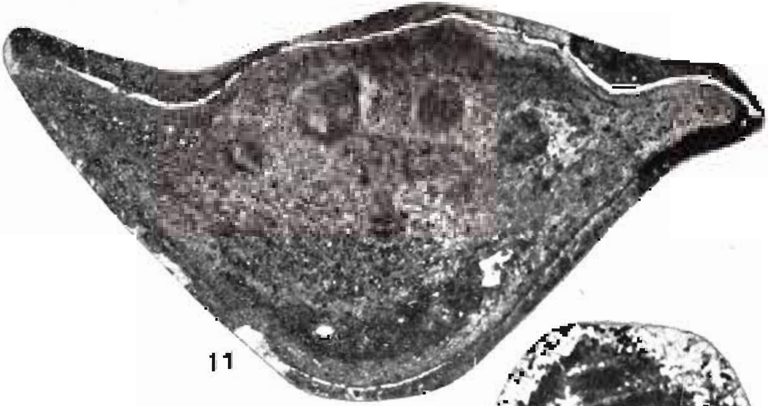

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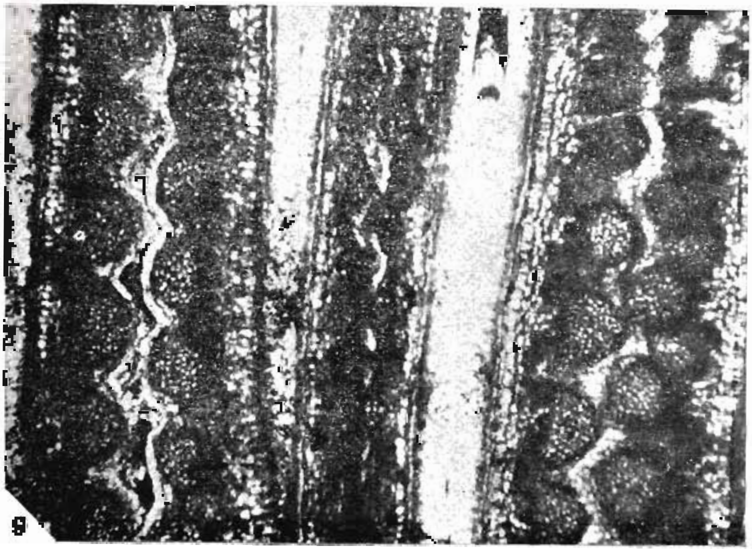

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PLATE 2

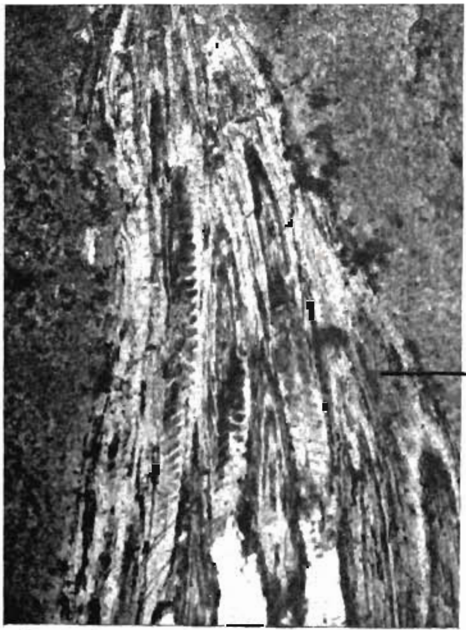

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PLATE 3

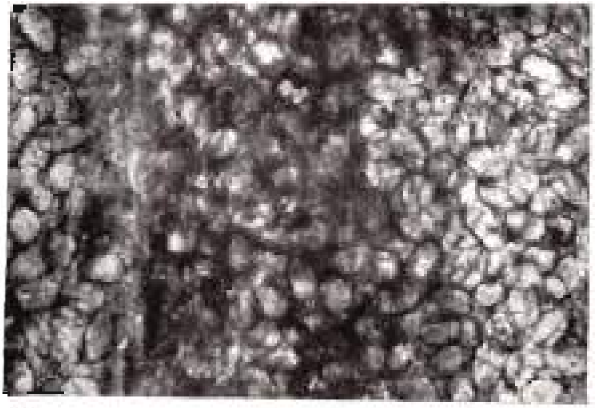
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PLATE 4

The Palaeobotanist, **32**(3): 230-235, 1984.

PALYNOLOGICAL CORRELATION OF COAL SEAMS IN KUSMUNDA BLOCK, KORBA COALFIELD, MADHYA PRADESH, INDIA

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ABSTRACT

Six bore-core samples from four bore holes in Kusmunda block of the Korba Coalfield, Madhya Pradesh have been studied palynologically. The distributional pattern of various palynotaxa suggests the occurrence of three palynological assemblages. Assemblage A is characterised by the dominance of *Horriditriletes* and sub-dominance of *Striatites* and *Faunipollenites*. Assemblage B is marked by the dominance of *Faunipollenites* while *Horriditriletes* is subdominant. Assemblage C is characterised by dominant *Scheuringipollenites* whereas *Faunipollenites* and *Horriditriletes* are subdominant. Assemblage A and B show a younger aspect of the Barakar Stage and are present in the two successive coal seams, Upper and Lower Kusmunda, of bore-hole nos. NCKK-7 and NCKK-11. Assemblage C is present in coals supposed to be Upper Kusmunda seam of bore-hole nos. NCKK-16 and NCKK-18 but shows an older aspect. Apparently the so-called Upper Kusmunda seam met with in these two bore-holes is not palynostratigraphically the same as its name sake occurring in bore-hole nos. NCKK-7 and NCKK-11 and could more reasonably be older, underlying the Lower Kusmunda seam.

Key-words — Palynostratigraphy, Seams correlation, Korba Coalfield, Lower Gondwana (India).

सारॉंश

मध्य प्रदेश (भारत) में कोरबा कोयला-क्षेत्र के कुसमुन्डा खंड में स्थित कोयला-सीमों के परागाणविक सहसम्बन्ध —
सुरेश चन्द्र श्रीवास्तव

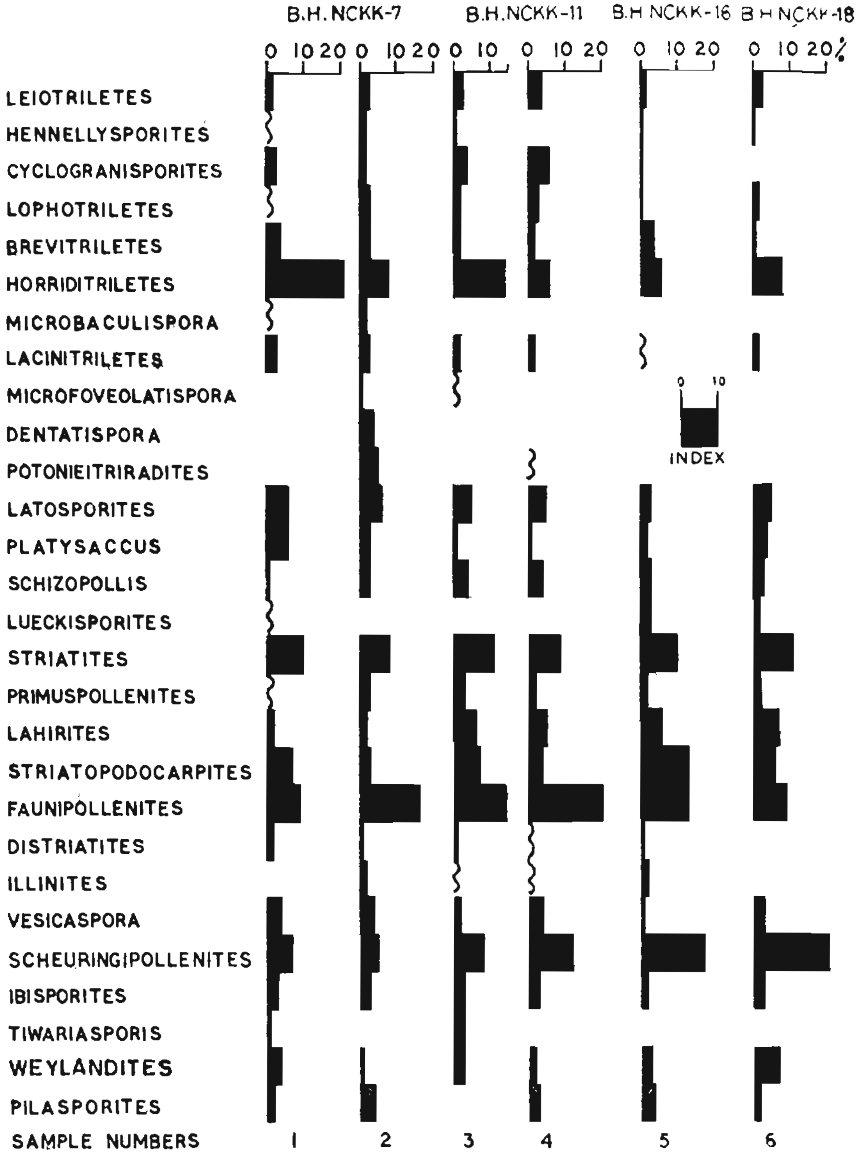
कोरबा कोयला-क्षेत्र (मध्य प्रदेश) के कुसमुन्डा खंड में चार वेध-छिद्रों से प्राप्त छः वेध-क्रोड़ों के नमूनों का परागाणविक अध्ययन किया गया है। इन नमूनों में विभिन्न वर्गकों के वितरण से तीन परागाणविक समुच्चयों की उपस्थिति इंगित होती है। समुच्चय अ होरिडीट्राइलिटीज़ की बाहुल्यता तथा फ़ॉनिपोलिनाइटिस एवं स्ट्रआटाइटिस से उपप्रभावी है। समुच्चय-ब में फ़ॉनिपोलिनाइटिस की बाहुल्यता है तथा यह होरिडीट्राइलिटीज़ से उपप्रभावी है। समुच्चय-स श्यौरिंपोगीलिनाइटिस की बाहुल्यता तथा फ़ॉनिपोलिनाइटिस एवं होरिडीट्राइलिटीज़ के उपप्रभाव से अभिलक्षणित है। समुच्चय-अ और ब प्रारम्भिक बराकार चरण को प्रदर्शित करते हैं तथा दो उत्तरोत्तर सीमों में ये दोनों समुच्चय विद्यमान हैं। समुच्चय-स वेध-छिद्र संख्या ऍन-सी-के-के० 16 एवं ऍन-सी-के-के० 18 की उपरि कुसमुन्डा सीम के कोयलों में मिलती है। अतएव इन दोनों वेध-छिद्रों में विद्यमान उपरि कुसमुन्डा सीम परागाणविक दृष्टि से वह सीम नहीं है जो कि वेध-छिद्र संख्या ऍन-सी-के-के० 7 एवं ऍन-सी-के-के० 11 में मिलती है और सम्भवतया अधरि कुसमुन्डा सीम के नीचे पाये जाने के कारण इससे अधिक आयु की है।

INTRODUCTION

THE Korba Coalfield, named after the village Korba in Bilaspur District of Madhya Pradesh, is nearly 4.8 km wide and 64 km long spread over an area of 520 sq km west of Mand-River Coalfield. The Geological Survey of India, the geologists of Madhya Pradesh Government and the Indian Bureau of Mines have made extensive drilling in the area and have established a number of coal seams in the Lower Barakar and Upper Barakar horizons. The sporae dispersae of the Korba Coalfield

TABLE 1 — SHOWING DETAILS OF THE COAL SAMPLES FROM KUSMUNDA BLOCK, KORBA COALFIELD, MADHYA PRADESH

Sample Nos.	Bore Hole Nos.	Overall Sample Nos.	Strata	Depth (in meter) from Surface		Thickness
				From	To	
	NCKK-7		Details above 50.93 m	Not known	—	—
			Grey carbonaceous shale	50.93	53.37	2.44
1.		CACI-BH/IA(C1-C40) bcs	Coal seam (Upper Kusmunda)	53.37	79.99	26.62
			Arenaceous shale	79.99	80.02	0.03
			Parting details	Not known		
			Shale	151.72	153.44	1.72
2.		CACI-BH/IB(C1-C98)bcs	Coal seam (Lower Kusmunda)	153.44	217.65	64.21
			Inferior coal	217.65	222.03	4.38
			Grey shale and Carbonaceous shale	222.03	226.63	4.60
			Details below this depth	Not known		
	NCKK-11	-	Details above 16.17 m	do		
3.		CACI-BH/5A(C1-C27)bcs	Coal seam (Upper Kusmunda)	16.17	34.72	18.55
			Carbonaceous shale	34.72	34.78	0.06
			Arenaceous shale	34.78	38.81	4.03
			Fine grained sandstone	34.81	34.90	0.09
			Parting details	Not known		
			Carbonaceous shale	102.18	102.38	0.20
			Shaly coal	102.38	103.20	0.82
4.		CACI-BH/5B(C3-C90)E	Coal seam (Lower Kusmunda)	103.20	167.34	64.14
			Inferior coal	167.34	168.10	0.76
			Carbonaceous shale	168.10	168.57	0.47
			Details below this depth	Not known		
	NCKK-16		Details above 15.25 m	Not known		
			Carbonaceous shale	15.25	15.35	0.10
			Inferior coal	15.35	16.86	1.51
5.		CACI-BH/24A(C4-C19)E	Coal seam (Upper Kusmunda)	16.86	32.32	15.46
			Carbonaceous shale	32.32	32.45	0.13
			Sandstone	32.45	33.84	1.39
			Details below this depth	Not known		
			Carbonaceous shale	103.36	103.69	0.33
			Coal	—	106.41	2.72
			Details below this depth	Not known		
	NCKK-18		Details above 13.29 m	Not known		
			Shale and carbonaceous shale	13.29	16.43	3.14
			Coal	16.43	18.21	1.78
			Arenaceous shale	18.21	18.24	0.03
			Sandstone	18.24	18.93	0.69
			Parting details	Not known		
			Shale and carbonaceous shale	88.63	90.63	2.00
			Shaly coal	90.63	91.81	1.18
6.		CACI-BH/26B(C4-C38)bcs	Coal seam (Upper Kusmunda)	91.81	117.13	25.32
			Shale	117.13	117.93	0.80
			Fine grained sandstone	117.93	119.13	1.20
			Details below this depth	Not known		



Histogram 1 — Showing percentage distribution of miospore in different coal seams of Kusmunda block, Korba Coalfield.

have earlier been studied by Bharadwaj and Tiwari (1964a) and Tiwari (1964, 1965) who have instituted a number of new genera and species. Bharadwaj and Tiwari (1964b) have also suggested the correlation of coal seams in the bore-hole samples of Rajgamar, Ghordewa and Korba sectors. The subsurface palynological succession of the Korba Coalfield has also been studied by Bharadwaj and Srivastava (1973) in a deep bore-hole No. NCKB-19. Srivastava (1973) has furthur studied the mioflora of the Talchir Formation in Dhengur Nala of the same coalfield. Thus, the succession of miofloras in the subsurface sediments of Korba Coalfield is fairly known from the Talchir

Formation to Barakar Formation from the above sectors. However, the mioflora from the Kusmunda block of the Korba Coalfield is being described for the first time which includes six coal samples from four different bore-holes of this area, the details of which are given in Table 1. These samples were made available through the kind courtesy of the authorities of Central Fuel Research Institute, Regional Coal Survey Station, Bilaspur, to whom the author is thankful.

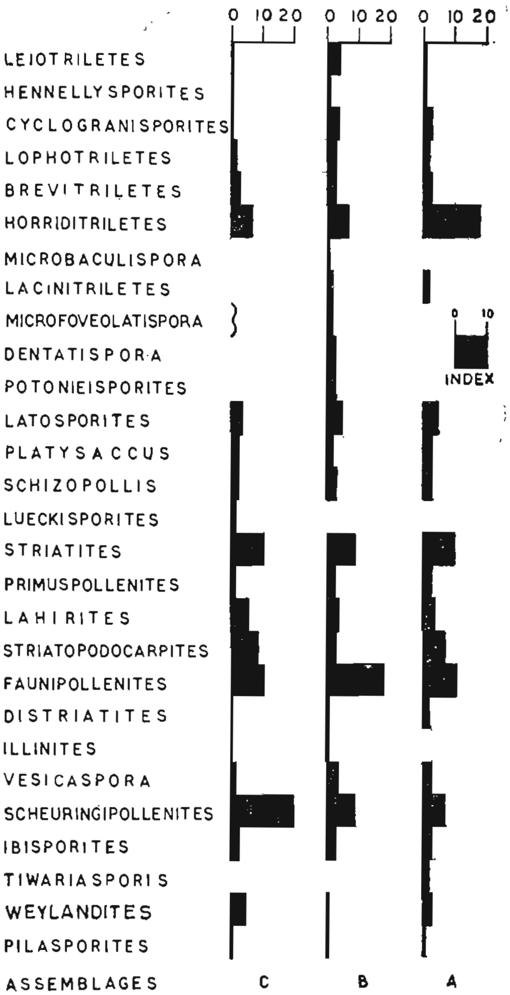
MIOFLORAS

The miofloral assemblage in the Kusmunda block of Korba Coalfield consists of 38 genera which are mentioned below:

Leiotriletes, *Callumispora*, *Hennellysporites*, *Cyclogranisporites*, *Lophotriletes*, *Brevitriletes*, *Horriditriletes*, *Microbaculispora*, *Lacinitriletes*, *Microfoveolatispora*, *Potonieitriradites*, *Dentatispora*, *Latosporites*, *Barakarites*, *Platysaccus*, *Schizopollis*, *Lueckisporites*, *Striatites*, *Circumstriatites*, *Primuspollenites*, *Rhizomaspora*, *Lahirites*, *Striatopodocarpites*, *Verticipollenites*, *Faunipollenites*, *Distriatites*, *Illinites*, *Vesicaspora*, *Scheuringipollenites*, *Ibisporites*, *Tiwariasporis*, *Weylandites*, *Ginkgocycadophytus*, *Pilasporites*, *Hemisphaerium*, *Hindisporis*, *Peltacystia* and *Leiosphaeridia*.

Amongst these, *Horriditriletes*, *Striatites*, *Faunipollenites* and *Scheuringipollenites* characterise the miofloral assemblage at various levels of the bore-core by their quantitative abundance. *Callumispora*, *Microbaculispora*, *Microfoveolatispora*, *Lueckisporites*, *Illinites* and *Tiwariasporis* occur rather inconsistently and rarely too. The zonate triletes are represented by *Potonieitriradites* and *Dentatispora* which are present in one sample only. The alete sporomorphs also show a great inconsistency in their occurrence and hence, all of them have been merged with the percentage of the genus *Pilasporites*.

Thus, the quantitative as well as the qualitative distribution of various palynotaxa (Histogram 1) permit segregation of the mioflora into three different assemblages (Histogram 2). The oldest association is represented by Assemblage C in which *Scheuringipollenites* marks the dominance being present up to 20 per cent. *Horriditriletes* (7%) and *Faunipollenites* (11%) occur as subdominants. The percentage of nonstriated-disaccates and striated-disaccates occur at their maximum in this assemblage (29% & 48% respectively). The laevigate+apiculate triletes and varitriletes on the other hand are present up to 12 per cent and 3.5 per cent respectively. Such an assemblage is found in sample nos. 5 and 6.



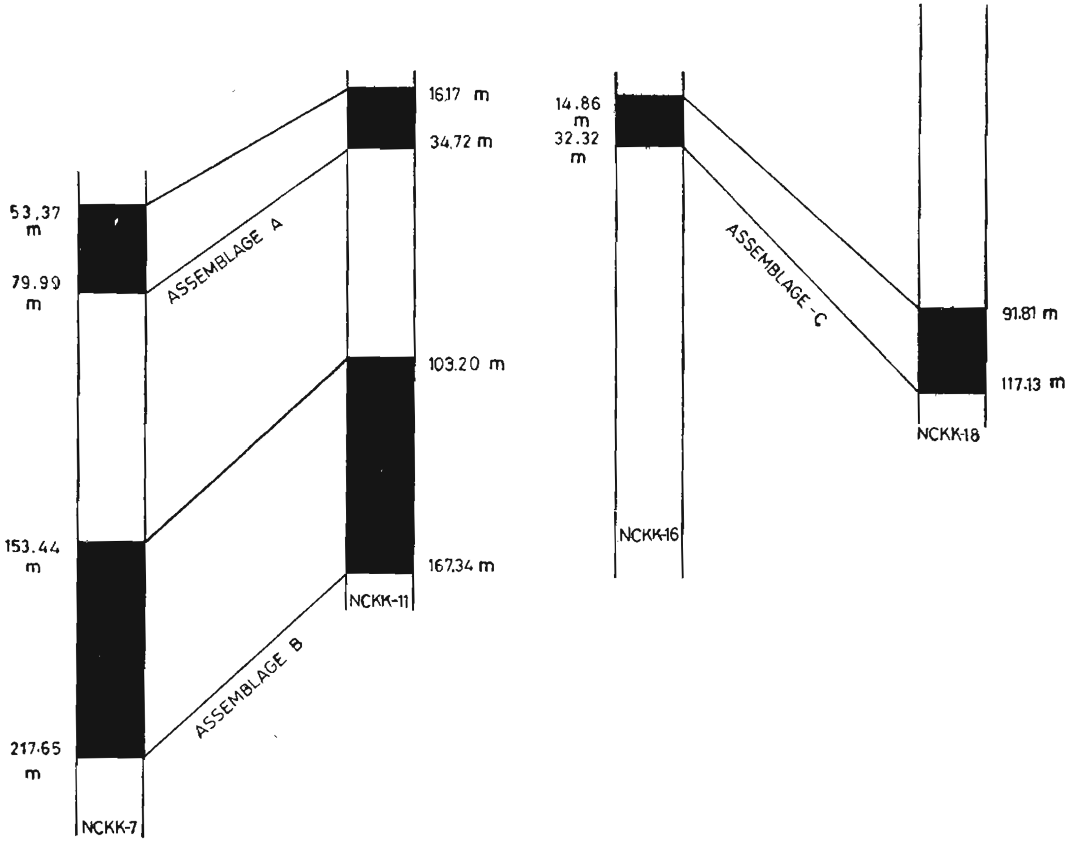
Histogram 2 — Showing percentage of miospores in different assemblages of Kusmunda block, Korba Coalfield.

Assemblage B is characterised by the dominance of *Faunipollenites* (18%) closely associated with *Striatites* (9%), *Sulcatisporites* (8%) and *Horriditriletes* (7%). The assemblage is enriched by the abundance of striated-disaccates (38%) although less commonly than Assemblage C. The nonstriated-dissaccates (18%) also reduce significantly while the laevigate+apiculate triletes (19%) show a slight increase in their percentage. Varitriletes (6%) also mark a significant increase similar to the other triletes. Zonate triletes (6%) are associated significantly in this assemblage whereas in others it is absent. Assemblage B is present in sample nos. 2 and 4.

Assemblage A is considered to be the youngest assemblage in the present investigation and is distributed in sample nos. 1 and 3. The trilete genus *Horriditriletes* marks the dominance by its presence up to 18 per cent while *Faunipollenites* (11%) reduces to subdominance and remains associated with *Striatites* (10%) and *Scheuringipollenites* (7%). The total percentage of laevigate+apiculate triletes increases to their maximum, i.e. 26% while varitriletes decline correspondingly. However, the general dominance of the assemblage is still characterised by the striated-disaccates (37%).

CORRELATION

The quantitative as well the qualitative distribution of various palynotaxa among six samples investigated from Kusmunda block of Korba Coalfield reveals that the miofloras of all the coal seams in general are marked by the overall abundance of striated-disaccate pollen grains. The miospore Assemblage B (Text-fig. 1) characterises the older seams of the bore-hole no. NCKK-7, (Lower Kusmunda seam-sample no. 2) and bore-hole no. NCKK-11 (Lower Kusmunda seam-sample no. 4). The genus *Faunipollenites* marks the dominance over and above other group of miospores. *Horriditriletes* and *Scheuringipollenites* occur as subdominants. *Potonieitriradites* is characteristically associated with the Lower Kusmunda seam while it is absent in others.



TEXT-FIG. 1 — Showing correlation of coal seams in various bore-holes of Kusmunda block, Korba Coalfield.

In the overlying Upper Kusmunda seam of the bore-hole nos. NCKK-7 and NCKK-11 the total population of striated and non-striated-disaccate pollen grains and also varitriletes remain almost similar to that of Lower Kusmunda seam (Assemblage A). However, a sharp increase in the percentage of laevigate+apiculate triletes is distinctly distinguishable in the Upper Kusmunda seam of the bore-hole nos. NCKK-7 (sample no. 1) and NCKK-11 (sample no. 3). The zonate triletes are absent but the monolete miospores maintain the same level of occurrence. Thus, the Upper Kusmunda seam of the above mentioned bore-holes can be easily differentiated from the Lower Kusmunda seam underlying it in their respective bore holes.

The Upper Kusmunda seam of the bore-hole no. NCKK-16 (sample no. 5) and NCKK-18 (sample no. 6) palynologically shows a different association. The overall dominance of the assemblage is marked by the genus *Scheuringipollenites*. The striated-disaccate genera, viz., *Faunipollenites* and *Striatites* follow as subdominants. It is interesting to note that the total representation of laevigate+apiculate triletes and varitriletes is at its minimum in Assemblage C. They increase in Assemblage B and again decrease in Assemblage A. On the other hand, the total representation of nonstriated-disaccate is at its maximum in this seam and so also the striated-disaccate pollen grains which decreases in other assemblages. Thus, a gradual decrease in the percentages of striated and nonstriated-disaccates and a corresponding increase in the percentage of laevigate+apiculate triletes is evident in Assemblage sequence C-B-A. The overall abundance of striated and nonstriated pollen grains suggests its closer relationship with the older coal seams of the bore-hole nos. NCKK-7 and NCKK-11 yet it retains its own identity.

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OCCURRENCE OF ARAUCARIAN WOOD FROM THE NEOGENE OF WEST BENGAL, INDIA

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ABSTRACT

A fossil wood of Araucariaceae is described from the Miocene beds of Bolpur near Santiniketan in West Bengal. The wood shows mostly biseriate, alternate and contiguous hexagonal pits on the tracheidal walls. This finding forms the first record of Araucariaceae in the Neogene of India.

Key-words — Xylotomy, Araucariaceae, *Araucarioxylon*, Neogene, India.

सारांश

पश्चिम बंगाल के पश्च-तृतीयक युग से अॅराकेरिएसी कुल की काष्ठ – गजेन्द्र प्रताप श्रीवास्तव एवं उत्तम प्रकाश

पश्चिम बंगाल में शाँतिनिकेतन के पास बोलपुर की मध्यनूतन युगीन संस्तरों से अॅराकेरिएसी कुल की काष्ठ का वर्णन किया गया है। इस काष्ठाश्म में वाहिनिकीय भित्ति पर प्राय: द्विपंक्तिक, एकान्तर एवं संलग्न षष्टभुजी गर्त्त विद्यमान हैं। भारत के पश्च-तृतीयक युग में अॅराकेरिएसी कुल की उपस्थिति का यह सबसे पहला अभिलेख है।

INTRODUCTION

THIS paper deals with an araucarian fossil wood collected from the Tertiary exposures near Santiniketan in Birbhum District of West Bengal where large number of silicified woods of varying dimensions are found in the ferruginous concretionary beds. The geology of West Bengal has been worked out in detail by Hunday and Banerjee (1967) who state that the presence of Tertiary rocks is known both in peninsular and extrapeninsular regions of this state and these rocks are considered to be of Miocene age. However, it is only in the peninsular region of the state that small patches of Tertiary grits and gravel beds occasionally with clays and dicotyledonous fossil woods have been reported from the parts of Midnapur, Bankura, Birbhum and Bardhaman districts. These isolated patches of the Tertiary rocks over a wide area suggest the presence of a continuous belt of Tertiary formations in this part of the state. Hunday (1954) has shown the resemblance of these formations of Bankura and Midnapur districts with the formations overlying the Baripada limestones (Miocene) in the Mayurbhanj District of Orissa and thought that these might be equivalent to the rocks of Tipam Series of Assam. However, from the palaeobotanical evidence as reflected by the assemblage, a Neogene age was also suggested for the petrified woods by Bande and Prakash (1980) because the presence of dipterocarps and the dominance of legumes is characteristically indicative of a Neogene age in the Tertiary of India.

A rich flora, comprising mainly the fossil woods, has been worked out from the Tertiary of West Bengal by various workers. These include a variety of taxa of petrified woods of *Dipterocarpoxylon bolpurense* Ghosh & Roy (1979c), *Shoreoxylon bengalensis* Roy & Ghosh (1979a), *S. tipamense* Prakash & Awasthi (Bande & Prakash, 1980), *S. robustoides* Roy & Ghosh (1981a) and *Anisopteroxylon santiniketanense* Ghosh & Roy (1980b) of Dipterocarpaceae, *Calophylloxylon bengalense* Ghosh & Roy (1979e) of Guttiferae, *Chisocchetonoxylon bengalensis* Ghosh & Roy (1979d) of Meliaceae, *Dracantomelumoxylon mangiferumoides* (Ghosh & Roy, 1979b; Roy & Ghosh, 1981b), *Glutoxylon burmense* (Holden) Chowdhury

(Roy & Ghosh, 1979b), *Melanorrhoeoxylon garbetaense* (Ghosh & Roy, 1980d; Roy & Ghosh, 1981b), *Mangiferoxylon assamicum* Prakash & Tripathi (Roy & Ghosh, 1981b), *Lanneoxylon grandiosum* Prakash & Tripathi (Roy & Ghosh, 1981b) and *Buchnanioxylon indicum* (Ghosh & Roy, 1980d; Roy & Ghosh, 1981b) of Anacardiaceae, *Canarioxylon indicum* Ghosh & Roy (1978) of Burseraceae, *Pahudioxylon bankurensis* Chowdhury, Ghosh & Kazmi (1960), *P. bengalensis* Ghosh & Roy (1982), *Millettioxylon bengalensis* Ghosh & Roy (1979a), *M. pongamiensis* Prakash (Ghosh & Roy, 1981a), *Cassinium barooahii* Prakash (Bande & Prakash, 1980; Ghosh & Roy, 1982), *C. ballavpurense* Ghosh & Roy (1981b), *Cynometroxylon holdeni* (Gupta) Prakash & Bande (Bande & Prakash, 1980), *Koompasioxylon elegans* Kramar (Bande & Prakash, 1980), *Ormosioxylon bengalensis* Bande & Prakash (1980), *Albizzinium eolebbekianum* Prakash (Ghosh & Roy, 1981a) and *Peltophoroxylon ferrugineoides* Bande & Prakash (1980) of Leguminosae, *Terminalioxylon tertiarum* Prakash (Ghosh & Roy, 1980a), *Terminalioxylon* sp. Deb & Ghosh (1974) and *Anogeissusoxylon bengalensis* Roy & Ghosh (1979b) of Combretaceae, *Mallotoxylon cleidionoides* Roy & Ghosh (1982) of Euphorbiaceae and a palm wood belonging to *Palmoxylon coronatum* Sahni (Roy & Ghosh, 1980).

The present finding forms the first record of an araucarian wood from the Tertiary of West Bengal indicating the presence of this family in the Neogene of India for the first time. Woods of *Araucaria* and *Agathis* are so similar anatomically that there is no certain way of distinguishing them (Greguss, 1955; Jane, 1955, p. 319).

SYSTEMATIC DESCRIPTION

FAMILY — ARAUCARIACEAE

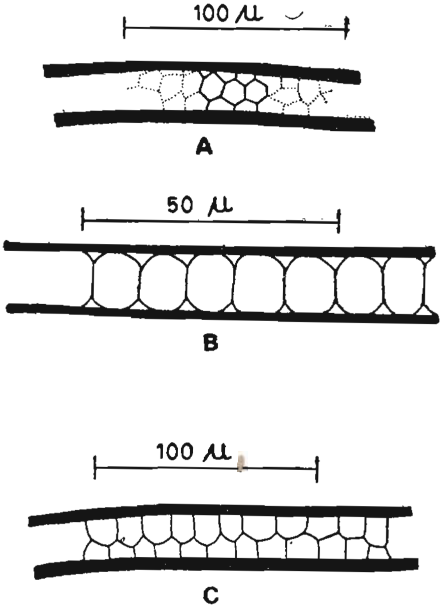
Genus — *Araucarioxylon* Kraus, 1870

Araucarioxylon sp.

Pl. 1, figs 1-5; Text-figs 1-3

The study is based on a piece of secondary wood measuring about 12 cm in length and 3.5 cm in diameter. The preservation is good enough to show most of the structural details except field pits.

Wood non-porous. *Growth rings* distinct, consisting of growth zones 8-42 cells or 646-1520 µm in width, delimited by a thin band of late wood tracheids. Transition from early to late wood abrupt (Pl. 1, figs 1, 2). *Late wood* about 2-5 cells or 115-200 µm in width composed of thick-walled, compactly arranged, squarish to tangentially elongated tracheids measuring about 10-16 µm in radial diameter and 10-25 µm in tangential diameter (Pl. 1, fig. 2). *Early wood* contributes more than 80 per cent of the growth zone (Pl. 1, figs 1, 2), about 6-40 cells or 275-1370 µm in width consisting of comparatively thin-walled, quadrangular, radially elongated tracheids with big lumen arranged in radial rows and measuring 36-40 µm in radial diameter and 24-32 µm in tangential diameter. Tangential walls of the tracheids appear smooth without any pits but radial walls are found pitted at places. *Parenchyma* absent. *Intertracheidal pits* 1-3 (mostly 2) seriate (Pl. 1, fig. 5; Text-fig. 1A-C), alternate, contiguous, hexagonal in shape, and 8-10 µm in diameter. *Bars of Sanio* absent. *Xylem rays* evenly distributed, 7-8 per mm, homogeneous,



TEXT-FIG. 1 — **A**, Radial longitudinal section showing alternate, triseriate tracheid pitting, slide no. 35590-IV; **B**, radial longitudinal section showing uniseriate tracheid pitting, slide no. 35590-IV; **C**, radial longitudinal section showing alternate, biseriate tracheid pitting, slide no. 35590-IV.

almost uniseriate (Pl. 1, figs 3, 4), 1-7 (mostly 2-3) cells or 40-240 μm in height made up of oval to barrel-shaped cells as seen in tangential section. *Cross-field pits* could not be seen due to ill preservation. *Resin canals* not present.

Specimen — B.S.I.P. Museum no. 35590.

Locality — Near Santiniketan, Birbhum District, West Bengal.

Age — Miocene.

DISCUSSION

Presence of growth rings, almost uniseriate xylem rays and tracheids with alternate, hexagonal bordered pits on the radial walls indicate the affinities of the present fossil wood with the family Araucariaceae among the living conifers. Fossil woods showing such characters are usually described either under the generic name *Dadoxylon* Endlicher (1847) or *Araucarioxylon* Kraus (1870, in Schimper, 1870-72). However, there is a difference of opinion among the palaeobotanists as to the nomenclature of fossil woods with araucaroid pitting. For a long time all fossil woods of this type from the Palaeozoic were included in *Dadoxylon* while those from the younger formations were put under *Araucarioxylon* (Seward, 1963) because the former were thought to belong to Cordaitales and the latter to Araucariaceae. Some palaeobotanists thought that the name *Dadoxylon* be used for secondary wood with araucaroid type of tracheidal pitting irrespective of the age of fossil woods (Potonié, 1902; Gothan, 1905). Contrary to this White (1908) opined that the age must be taken into account while distinguishing *Dadoxylon* from *Araucarioxylon*. However, Maheshwari (1972) while revising Lower Gondwana wood taxa suggested that the secondary woods with araucaroid radial pitting and cupressoid cross-field pits having uniseriate or rarely partly biseriate rays should be assigned to the genus *Araucarioxylon* and those with usually more than 1-seriate rays should be placed under *Dadoxylon*. From this it seems that Maheshwari has laid much stress on the width of the rays which according to others (Bailey & Faull, 1934; Dayal, 1972; Lakhanpal, Prakash & Bande, 1977; Prasad, 1978, 1982) is not a constant feature and is quite variable. Lepekhina (1972) has also given a classification of fossil woods with araucaroid pitting (Dadoxyleae). According to her there is no difference in the secondary wood of *Araucarioxylon* and *Dadoxylon*, the xylem rays in both of them as a rule are uni-biseriate and rarely up to 5 seriate. The difference lies in the presence of endarch primary xylem with rather large, nonseptate pith without secretory canals which occur in *Dadoxylon* as against the secondary wood found only in *Araucarioxylon*. Lepekhina's view is also in accordance with the original diagnoses given separately for *Araucarioxylon* Kraus and *Dadoxylon* Endlicher. Recently Prasad (1982), while dealing with Indian Palaeozoic woods, has also instituted a new genus *Parapalaeoxylon* to accommodate exclusively the secondary woods which show araucaroid tracheidal pitting and bordered cross-field pits. As the present fossil wood consists only of secondary xylem and possesses growth rings, almost uniseriate xylem rays and the tracheids with alternate, hexagonal bordered pits on the radial walls, it is assigned to the genus *Araucarioxylon* Kraus. Because the cross-field pits and some other anatomical features could not be ascertained in the present specimen due to bad preservation, the present fossil wood has been described here as *Araucarioxylon* sp. without assigning it to any particular species till better preserved specimens with more details are available.

A survey of literature dealing with the araucarian woods shows that a considerable number of these woods have been recorded from India and abroad (Florin, 1963; Ramanujam, 1976, 1978; Stockey, 1982). The oldest record in India is from the Upper Triassic Maleri beds near Tiki in Central India (Sahni, 1931). The other records are those from the Jurassic onwards (Shukla, 1938, 1944; Billiamoria, 1948; Bharadwaj, 1953; Sah & Jain, 1964; Chitaley, 1949; Suryanarayana, 1956; Singhai, 1958; Lakhanpal, *et al.*, 1977; Bose & Maheshwari, 1974). However, we are dealing here only with the araucarian woods which have been described from the Tertiary of the Indian subcontinent. So far only six woods have been described from the Deccan Intertrappean beds. They are *Dadoxylon deccani* Shukla (1938), *D. resionosum* Shukla (1944), *D. chhindwarensis* Billimoria (1948), *D. eocenum* Chitaley (1949), *D. shuklai* Singhai (1958) and *Araucarioxylon mohgaoensis* Lakhanpal, Prakash & Bande (1977).

Prakash and Bande (1980) have also described an araucarian wood as *Araucarioxylon* sp. from the Tertiary of Burma. Besides, an araucarian wood has been discovered recently from the Tertiary sediments near Jaisalmer in Rajasthan (J. S. Guleria — personal communication). On superficial comparison with these fossil woods we have found that in most of the structural details our fossil wood comes very near to the wood described by Prakash and Bande (1980) from the Tertiary of Burma. However, a detailed comparison is not possible due to lack of some important characters like the cross-field pits in both the fossil woods.

The family Araucariaceae contains two extant genera, *Agathis* Salisbury and *Araucaria* de Jussieu. They are tall coniferous trees and are today confined to the southern hemisphere. The genus *Agathis* has presently been revised by Whitmore (1980) and consists of 13 species and exclusively found in the eastern part of southern hemisphere extending from Philippines to New Zealand and Malaya to New Caledonia. The genus *Araucaria* according to De Laubenfels (1972) has 18 species and is presently distributed in New Caledonia, New Guinea, eastern Australia, Chilean-Argentine Cordillera and Brazil. The fossil records of *Agathis* are meagre and seem to be confined to the southern hemisphere (Florin, 1963), whereas the records of *Araucaria* are much more complete. Thus this genus appears to have been more wide spread in past both in northern and southern hemispheres (Kendall, 1949, 1952; Harris, 1979; Stockey 1981, 1982; Florin, 1963; Ramanujam, 1976, 1977).

The araucarian remains have so far been recorded till the Palaeocene-Eocene in India and it was thought that the family Araucariaceae became extinct afterwards. But the present record of the fossil wood of Araucariaceae from the Neogene of West Bengal extends the presence of this family till the Neogene in India. Besides, a fossil wood of Araucariaceae has also been recorded from the Mio-Pliocene Irrawaddy Series of Burma. However, between the Palaeocene-Eocene of the Deccan Intertrappean beds and the Neogene of West Bengal, we do not have any records of Araucariaceae from the Oligocene and other Neogene formations of the peninsular India. Even the Cuddalore Series of South India, the Kankawati Series of north-west India, the Tipam and Dupitla Series of north-east India from where the fossil woods and other plant remains have extensively been worked out, do not have so far any record of fossil wood or mega- or microremains of Araucariaceae. The absence of Araucariaceae from the Oligocene and other contemporary Neogene floras of India is quite puzzling. However, further extensive studies on the Neogene floras of India would solve its present erratic distribution during the Neogene.

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EXPLANATION OF PLATE

1. Cross section in low power showing growth rings with early and late wood tracheids. × 40; slide no. 35590-1.
2. Cross section magnified to show thin-walled early wood tracheids thick-walled late wood tracheids and the xylem rays. × 100; slide no. 35590-I.
3. Tangential longitudinal section showing uniseriate xylem rays. × 100; slide no. 35590-II.
4. Radial longitudinal section to show homogeneous xylem rays. × 120; slide no. 35590-III.
5. Radial longitudinal section showing biseriate, alternate, hexagonal tracheid pits. × 300; slide no. 35590-III.

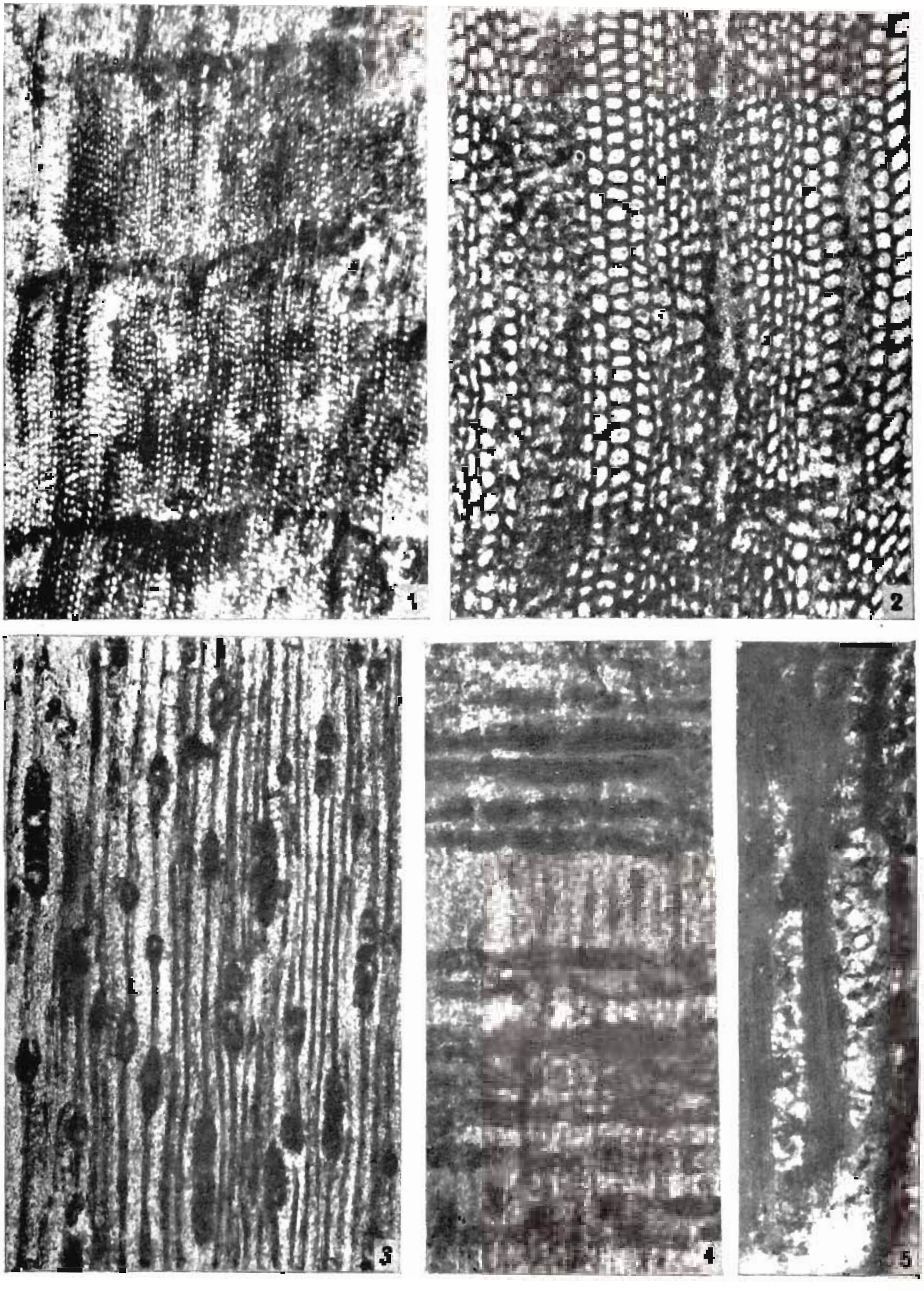

PLATE 1

The Palaeobotanist, 32(3): 243-252, 1984.

MIOFLORAL STUDIES OF THE LOWER GONDWANA SEDIMENTS IN JOHILLA COALFIELD, MADHYA PRADESH, INDIA

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ABSTRACT

The Lower Gondwana sediments (coal-bearing) exposed along Johilla River and also in Pali Coal Mine, Johilla Coalfield, Madhya Pradesh have been studied palynologically. The oldest miofloral assemblage (Zone 1) has been recorded near Manthar comprising *Callumispora*+*Jayantisporites*, which represents the Lower Karharbari mioflora. Miofloral assemblage Zone 2 occurs in the older coal seams (seam III-V) of Johilla Coal Mine and being dominant in *Parasaccites* represents the Upper Karharbari mioflora. Miofloral Zone 3 is marked by the dominance of nostriated-disaccates and occurs in the second coal seam of Johilla Coal Mine, second seam at Ganjra Nala confluence and the coal beds exposed near Lakhanpura. The youngest mioflora (Zone 4), being rich in striated-disaccates, occurs in the youngest coal seam (Seam I) of Johilla Coal Mine and also in the younger two seams exposed at the confluence of Ganjra Nala. Miofloral zones 3 and 4 represent the Lower and Upper Barakar miofloras, respectively. Thus, the coal-bearing horizon of the Johilla Coalfield encompasses not only Karharbari mioflora but also the Barakar mioflora.

Key-words — Palynology, Karharbari mioflora, Barakar mioflora, Johilla Coalfield, Lower Gondwana (India).

साराँश

मध्य प्रदेश (भारत) के जोहिल्ला कोयला-क्षेत्र में अधरि गोंडवाना अवसादों का सूक्ष्मवनस्पतिजातीय अध्ययन—

आनन्द प्रकाश एवं सुरेश चन्द्र श्रीवास्तव

इस शोध-पत्र में मध्य प्रदेश के जोहिल्ला कोयला-क्षेत्र की पाली कोयला खान तथा जोहिल्ला नदी के साथ-साथ अनाच्छादित अधरि गोंडवाना अवसादों (कोयला-धारक) का परागाणविक अध्ययन किया गया है। मन्थार के पास कैलूमिस्पोरा+जयन्तिस्पोराइटिस से युक्त सबसे अधिक आयु वाली सूक्ष्मवनस्पतिजातीय समुच्चय (मंडल-1) अभिलिखित की गई है जो कि अधरि करहरबारी सूक्ष्मवनस्पतिजात का निरूपण करती है। सूक्ष्मवनस्पतिजातीय समुच्चय (मंडल-2) जोहिल्ला कोयला खान की प्राचीनतर कोयलासीमों में मिलती है तथा पैरासेक्काइटिस की बाहुल्यता के साथ-साथ उपरि करहरबारी सूक्ष्मवनस्पतिजात का निरूपण करती है। सूक्ष्मवनस्पतिजातीय मंडल-3 रेखित-द्विकोष्ठीय परागकणों से प्रभावी है तथा जोहिल्ला कोयलाखान की द्वितीय कोयला सीम, गंजरा नाला संगम पर स्थित द्वितीय सीम तथा लखनपुरा के पास अनावरित कोयला संस्तरों में मिलता है। रेखित-द्विकोष्ठीयों से भरपूर अल्पतम् आयु वाला सूक्ष्मवनस्पतिजात (मंडल-4) जोहिल्ला कोयलाखान की अल्पतम् आयु वाली कोयला सीम (प्रथम सीम) तथा गंजरा नाला संगम पर अनावरित अल्पतर आयु की दो सीमों में विद्यमान है। सूक्ष्मवनस्पतिजात मंडल 3 और 4 क्रमशः अधरि एवं उपरि बाराकार सूक्ष्मवनस्पतिजातों का निरूपण करते हैं। इस प्रकार जोहिल्ला कोयला खान का कोयला-धारक संस्तर करहरबारी को ही नहीं अपितु बराकार सूक्ष्मवनस्पतिजात को भी परिवेष्टित किये हुए है।

INTRODUCTION

THE Johilla Coalfield is situated in the valley of Johilla River, Shahdol District, M.P. (Latitudes 23°16′-23° 23′ and Longitudes 85°57′-81°05′) and has attracted the attention of the geologists and palaeobotanists with respect to the age of the Ganjra Nala beds. Hughes (1884) and Fox (1932) considered the coal-bearing beds to represent a Barakar age while Feistmantel (1884) opined a Karharbari age. Mehta (1945) and Virkki (1946) equated these beds with the Pali beds. Basu

(1964) considered these beds to be equivalent to the Karharbari Formation on the basis of chemical analyses of coal. Saksena (1952, 1971) also worked out the plant fossils and microfossils of Ganjra Nala beds and opined a Karharbari age. Later Maithy (1969) studied the plant fossils and microfossils from the same horizon and favoured an opinion similar to that of Saksena (1952, 1971). Deshmukh (1971), while mapping the area in detail, grouped these beds within the Barakar. Recently, Chandra and Srivastava (1982) have again investigated plant fossils from a number of localities of the Johilla Coalfield and have considered them to represent the Karharbari age. Thus, the majority of workers favoured a Karharbari age while only a few advocated a Barakar age. In view of these divided opinions, the present investigation was undertaken in order to evaluate the succession of the coal-bearing beds palynologically.

GEOLOGY

Hughes (1884) first mapped the area systematically. The known geological sequence in the area is as follows:

Traps
Lametas
Supra Barakars
Barakar
Talchir
..........Unconformity..........
Metamorphics

Metamorphic rocks form the basement which are exposed in the form of an inlier separating the Gondwana sediments into two patches (Map 1). In the northern part the Talchir sediments overlie the basement rocks and underlie the coal-bearing Barakar sediments. In the southern part the Talchirs are in faulted contact with the Archeans. The coal-bearing sediments are composed of gritty to fine-grained sandstones and interbedded shale and coal seams. The Supra Barakar overlies the coal measures in the northern area while in the southern part they overlap the Talchirs and have faulted contact with the Archeans. The most important seam is the Johilla seam in the northern part.

The material for the present investigation was collected along Johilla River from Lakhanpura in south up to the confluence of Ganjra Nala in the north (Map 1). Coal samples were also collected from the working faces of the Johilla Coal Mine and the details of samples collected are presented in Table 1.

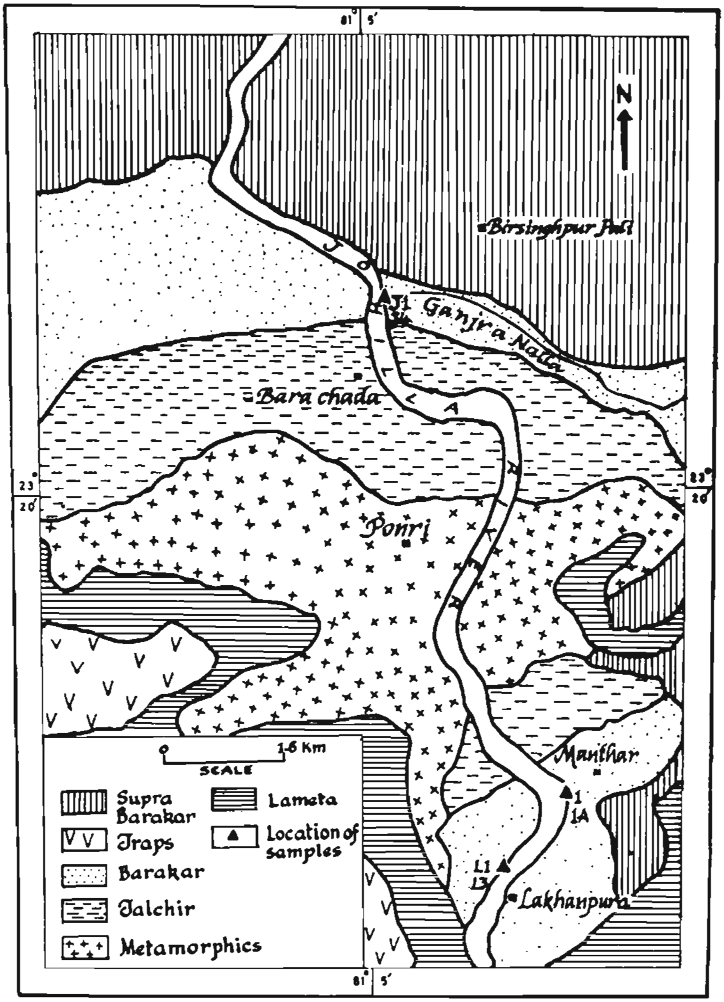
MIOFLORAL COMPOSITION

The mioflora of the Johilla Coalfield consists of the following 55 genera:

Leiotriletes, *Callumispora*, *Hennellysporites*, *Cyclogranisporites*, *Granulatisporites*, *Lophotriletes*, *Godavarisporites*, *Brevitriletes*, *Horriditriletes*, *Pseudoreticulatispora*, *Lacinitriletes*, *Microbaculispora*, *Indotriradites*, *Dentatispora*, *Jayantisporites*, *Latosporites*, *Densipollenites*, *Barakarites*, *Divarisaccus*, *Parasaccites*, *Caheniasaccites*, *Vestigisporites*, *Potonieisporites*, *Plicatipollenites*, *Virkkipollenites*, *Crucisaccites*, *Cuneatisporites*, *Platysaccus*, *Lueckisporites*, *Schizopollis*, *Striatites*, *Rhizomaspora*, *Primuspollenites*, *Lahirites*, *Verticipollenites*, *Hindipollenites*, *Striatopodocarpites*, *Crescentipollenites*, *Faunipollenites*, *Striapollenites*, *Illinites*, *Vesicaspora*, *Scheuringipollenites*, *Ibisporites*, *Tiwariasporis*, *Weylandites*, *Ginkgocycadophy-Pilasporites*, *Brazilea*, *Circulisporis*, *Hindisporis*, *Quadrisporites*, *Balmeella*, *Peltacystia* and *Leiosphaeridia*.

Amongst these only few genera characterise the miospore spectrum by their overall dominance, viz., *Callumispora*, *Jayantisporites*, *Parasaccites*, *Platysaccus*, *Scheuringipollenites*, *Striatopodocarpites* and *Faunipollenites*. In addition to these dominant taxa some genera, viz., *Brevitriletes*, *Microbaculispora*, *Virkkipollenites*, *Lahirites* and *Vesicaspora* also mark their presence by their subdominance. The rest of the genera are present in low amounts and are inconsistent in occurrence, hence insignificant. The quantitative association of the above miospores suggests the occurrence of a number of miofloral assemblages which are diagrammatically represented in histogram 1 and the description of these assemblages in different localities are as follows:

Manthar area — A coal bed (sample no. 1) is exposed on the east bank of Johilla River, west of the village Manthar and another coal bed (sample no. 1A) occurs nearly three meters southwards. Sample no. 1 (Table 2) is marked by the dominance of the genus *Callumispora* (66%) and is associated with *Ginkgocycadophytus* (9%), *Brevitriletes* (4%) and *Cyclogranisporites* (4%).

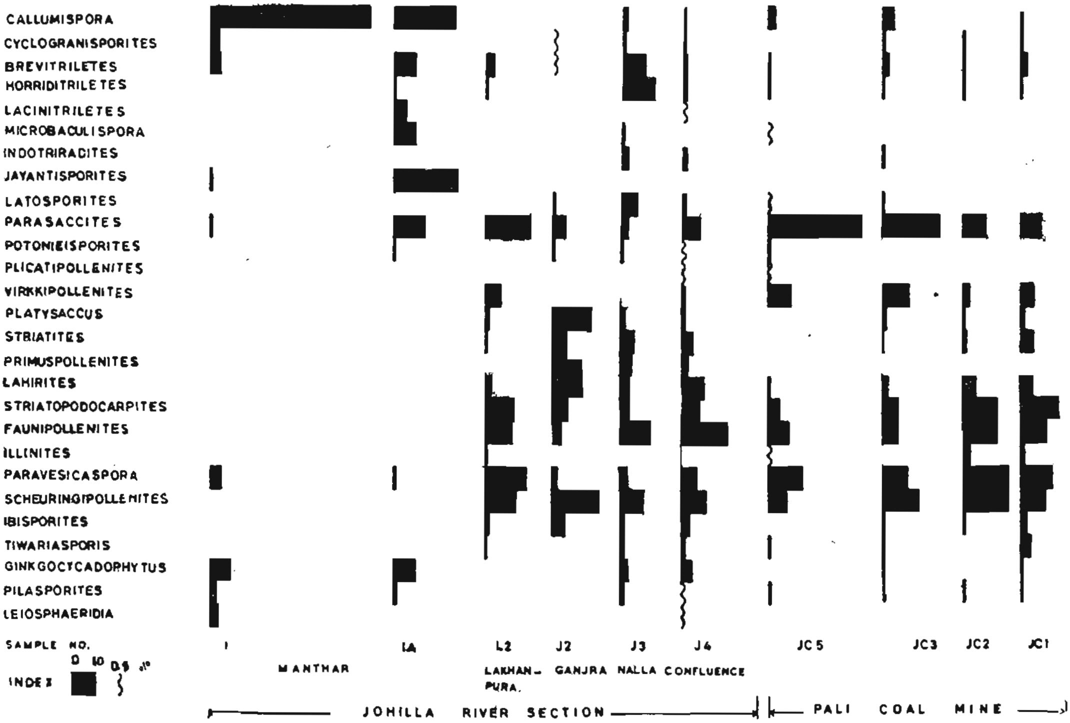


MAP 1 — Geological map of Johilla Coalfield, M.P., India (after Hughes, 1884).

The mioflora is characterised by the overall abundance of laevigate trilete miospores (67%) while apiculate trilete spores (9%) and colpate (9%) pollen grains follow next in order of dominance (Histogram 2, Table 3).

In sample no. 1A, *Callumispora* declines sharply to 20 per cent. On the other hand, *Jayantisporites* rises to attain the dominance (27%). *Microbaculispora* (10%), *Parasaccites* (13%) and *Lacinitriletes* (6%) also increase to attain significance. *Ginkgocycadophytus* (10%) maintains almost a uniform trend. In this sample the total percentage of laevigate triletes is reduced to 27 per cent giving way to zonate triletes (27%) and varitriletes (17%). Monosaccate pollen also rise to 14 per cent.

Lakhanpura area — On the west bank of Johilla River, north of the village Lakhanpura, another sequence of coal is exposed which shows a different miofloral succession. In sample no. L2 the maximum percentage is attained by *Parasaccites* (19%) and *Vesicaspora* (18%). The subdominance is attained by *Scheuringipollenites* (14%), *Striatopodocarpites* (13%) and *Faunipollenites* (12%). Thus, the overall dominance is marked by the nonstriate-disaccate (37%) followed by striate-disaccate (30%) and monosaccate (28%) pollen grains.



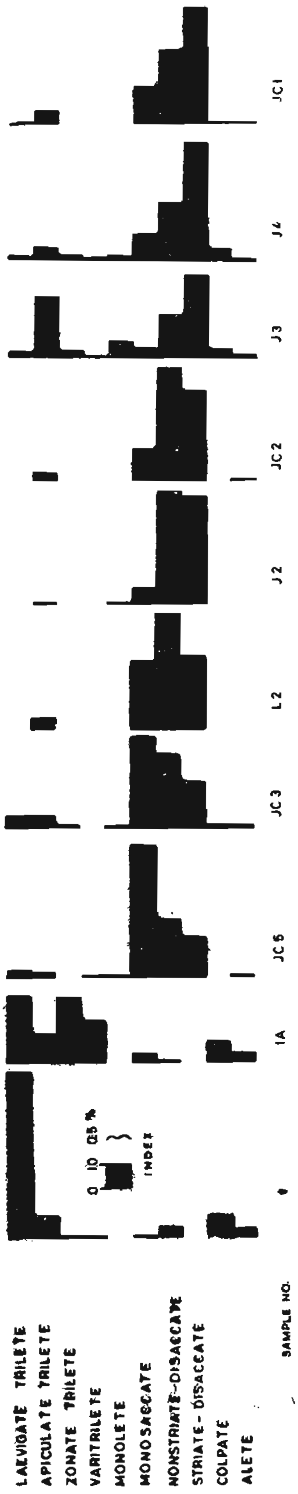
HISTOGRAM 1 — Palynological composition of the Lower Gondwana sediments in Johilla Coalfield, M.P., India.

TABLE 1 — SHOWING DETAILS OF SAMPLES COLLECTED FROM THE JOHILLA COALFIELD, MADHYA PRADESH

SAMPLE No.	LOCATION	DESCRIPTION OF LITHOTYPES	RECORD OF MIOSPORES
JOHILLA RIVER SECTION			
1	Manthar Village	Coal	Present
1A	do	Coal — Three meters south of sample 1	do
L1	Lakhanpura	I Seam (Lowermost)	do
L2	do	II Seam	
L3	do	III Seam (Uppermost)	
J1	At the confluence with Ganjra Nala	Carbonaceous shale — I Seam (Lowermost)	
J2	do	Carbonaceous shale — II Seam	Present
J3	do	Coal (60 cm)— III Seam	do
J4	do	Coal (1.2 m)—IV Seam (Uppermost)	do
JOHILLA COAL MINE			
JC1		Carbonaceous shale (Upper most)	Present
JC2		Coal	do
JC3		Carbonaceous shale (15 cm)	do
JC4		Coal	
JC5		Carbonaceous shale	

TABLE 2 — PERCENTAGE COMPOSITION OF DIFFERENT MIOSPORE GENERA IN THE LOWER GONDWANA SEDIMENTS OF JOHILLA COALFIELD, MADHYA PRADESH

Locality	Manpur		[illegible]	Ganda Nala Confluence			Johilla Coal Mine			
Genera/Sample No.		1A	L2	J2	J3	J4	JC3	JC4	JC2	JC1
Leiotriletes	1.0	4.0			1					
Callumispora	66	20			0.5	5	2	4		
Hennellysporites		5			1.0	0.5	0.5	1		1
Cyclogranisporites	4			0.5	0.5			0.5	1	0.5
Granulatisporites										0.5
Lophotriletes			0.5		2	0.5		0.5		
Cyclobaculisporites	1	8								
Brevitriletes	4	7	4	0.5	10	2	1	3	1	3
Horriditriletes		1	0.5		12	2		1	0.5	1
Pseudoreticulatispora										
Lacinitriletes	1	6				0.5				
Microbaculispora		10			0.5		0.5			
Indotriradites					3	2		1		
Dentatispora		0.5								
Jayantisporites	1	27								
Latosporites				1.0	7	7	0.5	1		
Densipollenites					0.5					
Barakarites			0.5							
Divarisaccus			0.5	0.5	0.5	1				
Parasaccites		3	19	4.0	2	6	25	22	10	9
Caheniasaccites		0.5	1			1	5	3		
Vestigisporites		1.5			1	0.5	1			
Potonieisporites				1.0						
Plicatipollenites						0.5	0.5			
Virkkipollenites			1			2	10	12	5	6
Crucisaccites							1			
Cuneatisporites			2					1		2
Platysaccus				17.0	2	2		1	1	
Lueckisporites									1	
Striatites			1	6.0	6	6		1	1	6
Rhizomaspora				5.0						
Primuspollenites				8.0	5	3				
Lahirites			2	12.0	4	10	1	2	4	5
Verticipollenites						1				
Crescentipollenites								1		2
Striatopodocarpites			10	7.0	4	6	5	6	15	15
Hindipollenites			5	2.0			0.5	1	2	1
Faunipollenites			12	4.0	10	20	9	7	15	12
Strotersporites					0.5					
Illinites			1				0.5		3	2
Vesicaspora	5	1.5	15	2.0	4	2	15	11	20	15
Scheuringipollenites			14	21.0	10	11	7	16	20	11
Ibisporites			2	6.0	2	2		1	1	3
Tiwariasporis			1		2	3	1	1		5
Welwitschiapites					0.5					
Ginkgocycadophytus	9	16			5	5.5		1		1
Pilasporites	3	2			5	0.5	1	1	0.5	0.5
Brazilea									0.5	
Circulisporites									0.5	
Hardisporis										0.5
Peltacystia					0.5					
Leiosphaeridia	4					0.5				



HISTOGRAM 2 — Distribution of miospore groups in the Johilla Coalfield, Madhya Pradesh, India.

Ganjra Nala (*Johilla River confluence*)— The sequence of coal beds exposed at the junction of Ganjra Nala and Johilla River shows three different assemblages. Sample no. J2 contains maximum percentage of *Scheuringipollenites* (21%) followed by *Platysaccus* (17%) and *Lahirites* (12%). The miofloral assemblage, in general, is dominated by nonstriated-disaccate (46%) and striate-disaccate (44%) pollen grains while the other groups of miospores are poor in representation.

The next younger coal bed (sample no. J3) shows dominance of *Faunipollenites* (13%) and *Horriditriletes* (12%). *Brevitriletes* (10%) and *Latosporites* (7%) show their maximum development in this sequence. *Scheuringipollenites* (10%) shows a decreasing tendency from this sample upwards. As compared to sample no. J2, the striated-disaccates attain the maximum percentage (34%) in sample no. J3; apiculate triletes also increase to attain subdominance (25%) but nonstriated-disaccates (18%) show a decreasing trend.

The uppermost coal (sample no. J4) of the present sequence shows maximum proliferation of *Faunipollenites* (20%) as compared to the older two coal beds at Ganjra Nala-Johilla River confluence. *Lahirites* rises to 10 per cent while *Scheuringipollenites* (11%) remains almost similar to the underlying coal bed. Striated-disaccates in sample no. J4 rise further to maintain the overall dominance while the other group of miospores further decreases in their percentages.

Johilla Coal Mine — The mioflora in coal seams of Johilla Coal Mine is rich in monosaccate and disaccate pollen grains. *Parasaccites* is dominant (35%) in sample no. JC5 and declines in the younger beds. *Virkkipollenites* follows a similar trend. *Scheuringipollenites* and *Vesicaspora* record their maximum (20%) in sample no. JC2 and then again declines. The striate-disaccate pollen grains, chiefly *Striatopodocarpites* and *Faunipollenites*, however, follow a reverse sequence thereby increasing in their percentages towards younger seams. Thus the monosaccates are maximum (53% & 37%) in sample nos. JC5 and JC3 and the nonstriate-disaccates follow the subdominat (23% & 30%) trend but in sample no. JC2 the nonstriate-disaccates rise to overall dominance being

TABLE 3 — DISTRIBUTION OF MIOSPORE GROUPS IN THE JOHILLA COALFIELD, MADHYA PRADESH

LOCALITY	MANTHAR		LAKHANPURA	GANJRA NALA CONFLUENCE			JOHILLA COAL MINE			
Miospore Groups/ Sample No.	1	1A	L2	J2	J3	J4	JC5	JC3	JC2	JC1
Laevigate trilete	67	27			2	1	3	5		1
Apiculate trilete	9	11	5	1	25	5	2	5	3	5
Zonate trilete	1	27			3	2		1		
Varitrilete	1	17			1	1	1			
Monolete				1	7	2	1	1		
Monosaccate	1	14	28	7	4	11	53	37	13	15
Nonstriated-disaccate	5	1	37	46	18	24	23	30	46	30
Striated-disaccate			30	44	34	48	16	19	37	47
Colpate	9	9			4	5		1		1
Alete	4	4			2	1	1	1	1	1

present up to 46 per cent. Striate-disaccates also rise to subdominance (37%), while the monosaccates show a decreasing trend from this seam. In sample no. JC1 the striate-disaccate pollen grains attain maximum (47%), whereas nonstriate-disaccates reduce to subdominance (30%).

PALYNOSTRATIGRAPHY

The present investigation has revealed the oldest miofloral assemblage near the village Manthar where *Callumispora* characterises the palynological spectrum. The dominance of this genus is known in the Lower Karharbari seam of the Giridih Coalfield (Srivastava, 1973) where the same is associated with *Parasaccites* and *Brevitriletes*. In Korba Coalfield, *Callumispora* dominant assemblage occurs immediately above the monosaccate dominant Talchir mioflora (Bharadwaj & Srivastava, 1973; younger subzone of Zone 1). The Karharbari sediments of Jayanti Coalfield (Lele & Makada, 1974) also contains the dominance of *Callumispora* (*Punctatisporites* + *Callumispora*). Similar succession also occurs in the lowermost coal facies overlying the Talchir Formation in the Paradol-Chirimiri railway cutting of the Chirimiri Coalfield (Srivastava, 1980b; sample no. CR/15) in which *Callumispora* is associated with *Microbaculispora* and *Jayantisporites*. The latter genus attains dominance in the second coal bed (sample no. 1A) near Manthar village presumably at the cost of *Callumispora* which usually shows a decreasing tendency towards the younger sediments as has been observed in the Umrar Nala section of the Umaria Coalfield also (Srivastava & Anand Prakash, 1984; sample nos. G15-G-13), thus represnting a comparatively younger aspect within this biozone. The Lower Karharbari assemblage of the West Raniganj Coalfield (Sonbad Nala, Pusai-Shampur area) also contains the dominance of *Callumispora* (Tiwari, 1973, Zone 1) and is comparable with sample no. 1 of Manthar Village. In the North Karanpura Coalfield (Srivastava, 1980a; sample nos. B/5 & B/3, Honhe area) *Callumispora* is associated with *Brevitriletes*, *Microbaculispora* and *Jayantispora* and thus bears a closer resemblance with the present mioflora. The coal-bearing sediments above the Talchir Formation of West Bokaro Coalfield also shows the dominance of *Callumispora* associated with *Brevitriletes*, *Microbaculispora* and *Lacinitriletes* (Anand Prakash *et al.*, 1979). All these assemblages occur in the coal-bearing sediments overlying the Talchir Formation and if a similar significance be attached to the miofloral assemblage of Manthar Village it should represent the Lower Karharbari mioflora in the Johilla Coalfield and is designated here as miofloral assemblage Zone 1.

The lower two coal seams represented by sample nos. JC5 and JC3 in Johilla Coal Mine show the dominance of *Parasaccites*. The total percentage of radial monosaccate pollen grains exceed the nonstriate-disaccates.

The lower coal bed near Lakhanpura Village (sample no. L2) also shows a similar association of monosaccates and nonstriated-disaccates *Vesicaspora* and *Scheuringipollenites* but with increased percentages of striated-disaccates and in this respect it shows a younger aspect as compared with the above two coal seams of Johilla Coal Mine. In Korba Coalfield, *Parasaccites* assumes dominance once again above the *Callumispora* dominant zone (Bharadwaj & Srivastava, 1973; Bore-hole NCKB-19; older subzone of Zone 2) and is associated with the coal bearing sediments. As opposed to the monosaccate dominant phase of the Talchir Formation it is distinguished by the incoming of nonstriate-disaccate pollen grains and in this respect the above samples of the Johilla Coalfield contain a closely comparable mioflora. Similar succession has been also observed in the Raniganj Coalfield (Tiwari, 1973; Sonbad Nala section, Pusai-Shampur area, Zone 2). In North Karanpura Coalfield also a monosaccate dominant Upper Karharbari assemblage underlies the Lower Barakar nonstriate-disaccate assemblage (Kar, 1973; Bore-core no. KB21, 481.8 m, p. 312). Considering the above successions the lower two coal seams of Johilla Coal Mine and the lower coal bed near Lakhanpura Village (sample no. L2) are suggested to represent the Upper Karharbari mioflora in the Johilla Coalfield and have been designated as Zone 2.

The coal-bearing beds exposed at the Ganjra Nala-Johilla River confluence (sample nos. J2 & J3) and the third coal seam (sample no. JC2) of Johilla Coal Mine contain a nonstriate-disaccate assemblage and are placed in Zone 3 of the Johilla Coalfield. The subsurface palynological investigation of the Lower Gondwana sediments of Korba Coalfield has shown that nonstriate-disaccate dominant mioflora occurs above the monosaccate dominant phase and represents the Lower Barakar mioflora (Bharadwaj & Srivastava, 1973; Bore-hole no. NCKB-19, older subzone of Zone 3). Similarly in Bore core no. KB 21 (405.6 m) of the North Karanpura Coalfield (Kar, 1973, p. 312) nonstriate-disaccate mioflora succeeds the monosaccate dominant phase. Tiwari (1973) has also recorded a very closely comparable assemblage from the Raniganj Coalfield (Zone 4, Pusai Nala Section). Thus, the lower coal beds (sample nos. J2 & J3) of the Ganjra Nala-Johilla River confluence and the third coal seam (sample no. JC2) of the Johilla Coal Mine represent the Lower Barakar mioflora of the Johilla Coalfield (Zone 3).

The youngest coal seam of the Johilla Coal Mine (sample no. JC1) and the upper most coal bed exposed at the confluence of Ganjra Nala-Johilla River (sample no. J4) shows maximum development of striated-disaccate pollen grains and the association of nonstriated-disaccates is reduced to subdominance. Such association is known in the Raniganj Coalfield (Tiwari, 1973; Zone 5, Khudia Nala section) where the striated-disaccate mioflora occurs above the nonstriated-disaccate dominant zone representing the Upper Barakar mioflora. In the miofloral succession of South Karanpura Coalfield (Bharadwaj & Tripathi, 1978) also the striate-disaccate dominant phase succeeds nonstriate-disaccate dominant phase. Similarly, the Upper Barakar assemblage in the North Karanpura Coalfield (Kar, 1973) is also dominated by striated-disaccate pollen grains but the percentage of nonstriate-disaccates in the above samples of Johilla Coalfield is comparatively higher and represents an older aspect.

The palaeobotanical investigation of mega- and microfossils in the coal-bearing sediments exposed at Ganjra Nala-Johilla River confluence by Saksena (1952, 1971) and Lele and Maithy (1969) have suggested a Karharbari age. Recently, Chandra and Srivastava (1982) have opined a similar view for all the coal-bearing beds exposed at Manthar, Lakhanpura, Ganjra Nala-Johilla confluence on the basis of plant fossils which are mostly fragmentary. The present investigation, however, has shown that the coal-bearing sediments exposed at Lakhanpura, Manthar, Ganjra Nala-Johilla River confluence and Johilla Coal Mine encompasses a succession of Lower Karharbari to Upper Barakar miofloras. The lithological distinction between the Karharbari and Barakar formations may not be as sharp as the miofloral assemblages studied which are developed in comparatively very narrow thicknesses of the Lower Gondwana sediments in Johilla Coalfield presumably because of the truncated and undulatory development of the coal-bearing sediments in the various areas of Johilla Coalfield.

Thus, the miofloral succession in Johilla Coalfield investigated may be summarised as given below:

		Miofloral zone	Manthar	Lakhanpura	Johilla Coal Mine	Ganjra Nala Confluence	Miofloral Association
BARAKAR	UPPER	4			Sample No. JC1	Sample No. J4	*Faunipollenites* – Striate + nonstriate-bisaccate
	LOWER	3			Sample No. JC2	Sample Nos. J2 and J3	*Scheuringipollenites* + *Faunipollenites*
KARHARBARI	UPPER	2		Sample No. L2	Sample Nos. JC3-JC5		*Parasaccites* + nonstriate-bisaccates
	LOWER	1	Sample Nos. 1 and 1A				*Callumispora* + *Jayantisporites* + *Microbaculispora*

CONCLUSIONS

The palynological investigations carried out from the coal-bearing sediments of Johilla Coalfield suggest that a succession of Lower Karharbari to Upper Barakar miofloras is distinctly developed as opposed to the earlier contention of their being mostly Karharbaris. The oldest mioflora has been recorded at Manthar Village and is comparable to the known Lower Karharbari miofloras of the Lower Gondwanas of India. Coal bed exposed near Lakhanpura village bears an Upper Karharbari affinity.

The miofloras in the coal seams of Johilla Coal Mine, being distinctly different in all the coal seams, incorporate a succession of Upper Karharbari to Upper Barakar miofloras. The sequence of coal seams exposed at Ganjra Nala-Johilla River confluence is not Karharbari as suggested earlier since the miofloral succession indicates a Lower Barakar to Upper Barakar affinity. All the three coal seams can be palynologically differentiated from each other.

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TRIASSIC PLANT MEGAFOSSILS FROM THE TIKI FORMATION, SOUTH REWA GONDWANA BASIN, INDIA

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ABSTRACT

Plant megafossils are for the first time described from the Tiki Formation. The specimens are from two regions, Janar River Section, near Harai and Son River Section, near Giar, Shahdol District, Madhya Pradesh.

From the Janar River Section *Lepidopteris madagascariensis* Carpentier, *Dicroidium hughesii* (Feistmantel) Gothan, *D. zuberi* (Szajnocha) Archangelsky, *D.* sp., *Xylopteris* sp., *Sphenobaiera janarensis* Pal sp. nov. and *Baiera* sp. have been described. On the basis of this assemblage an Early Upper Triassic age has been suggested for Janar River beds.

Son River Section, near Giar has yielded *Lepidopteris stormbergensis* (Seward) Townrow, *Dicroidium giarensis* Pal sp. nov., *D. coriaceum* (Johnston) Townrow, *D. zuberi* (Szajnocha) Archangelsky, *D.* sp. cf. *D. odontopteroides* (Morris) Gothan, *Elatocladus denticulatus* Pal sp. nov., *E. raoi* Pal sp. nov., *Pagiophyllum bosei* Pal sp. nov., *Yabiella indica* Pal sp. nov. and *Desmiophyllum singhii* Pal sp. nov. Beside these, a few impressions of equisetaceous stem, leaf-sheath and nodal diaphragm have also been described. A Late Upper Triassic age has been proposed for the beds exposed in the Son River.

Key-words — Megafossils, Sphenopsida, Peltaspermales, Corystospermales, Ginkgoales, Coniferales, Tiki Formation, Upper Triassic (India).

सारांश

दक्षिण रीवा गोंडवाना द्रोणी (भारत) में स्थित टिकी शैल-समूह से त्रिसंघी कालीन गुरुपादपाश्म – पंकज कुमार पाल

इस शोध-पत्र में टिकी शैल-समूह से प्राप्त गुरुपादपाश्मों का पहली बार वर्णन किया गया है। ये प्रादर्श मध्य प्रदेश के शहदोल जनपद में हराई के समीप जनार नदी खंड तथा गियार के पास सोन नदी खंड से एकत्र किये गये थे।

जनार नदी खंड से लैपिडॉप्टेरिस मेडागास्करेन्सिस कारपेन्टियर, डाइक्रोइडियम् ह्यूजेसाई (फ़ाइस्टमॅन्टेॅल) गोथान, डा० जुबेराई (स्ज़ाजनोचा) आरचेन्जेलसकी, डा० जाति, जाइलॉप्टेरिस जाति, स्फ़ीनोबेयरा जनारेन्सिस पाल नव जाति एवं बेयरा जाति वर्णित की गई हैं। इस समुच्चय के आधार पर जनार नदी संस्तरों की आयु प्रारम्भिक उपरि त्रिसंघी प्रस्तावित की गई है।

गियार के समीपस्थ सोन नदी खंड से लैपिडॉप्टेरिस स्ट्रोमबर्जेन्सिस (सिवर्ड) टाउनरॉ, डाइक्रोइडियम् गियारेन्सिस पाल नव जाति, डा० कोरिएसियम् (जॉह्न्सटन) टाउनरॉ, डा० जुबेराई (स्ज़ाज़नोचा) आरचेन्जेलसकी, डा० जाति सजातीय डा० ओडोन्टॉप्टेरॉयडिस (मौरिस) गोथान, इलेटोक्लेडस डेन्टीकुलेटस पाल नव जाति, इ० रावई पाल नव जाति, पेजियोफ़िल्लम् बोसाई पाल नव जाति, याबियॅल्ला इन्डिका पाल नव जाति एवं डेस्मिओफ़िल्लम् सिंघाई पाल नव जाति उपलब्ध हुए हैं। इनके अतिरिक्त इक्वीसिटेली तनों, पर्ण आच्छद एवं पर्वसंधीय तनुच्छद के कुछ छापाश्मों का भी वर्णन किया गया है। सोन नदी में अनाच्छादित इन संस्तरों की आयु प्रारम्भिक उपरि त्रिसंघी प्रस्तावित की गई है।

INTRODUCTION

In South Rewa Gondwana Basin the Tiki Formation comprises huge sedimentary strata distributed in the low lying vast tract from Neosi (23°35′53″N: 81°11′39″E) to Tiki (23°56′2″N: 81°21′59″E). Excepting the reports by Rao (in Krishnan, 1958, p. 12) and Singh (in Sastry *et al.*, 1977, p. 73) no plant megafossil has so far been described from this region. During the last four years I collected fairly well-preserved plant remains mostly with 'phytolemma' from Janar River Section near

Harai (23°40′53″N: 81°12′40″E) and Son River Section near Giar (locally spelled as Ghiyar; 23°49′58″N: 81°16′14″E), Shahdol District, Madhya Pradesh.

MEGAFLORA FROM JANAR RIVER SECTION

Recently, fairly well-diversified mega- and microspore assemblages have been described from the Janar River Section by Banerji, Kumaran and Maheshwari (1978); Sundaram, Maithy and Singh (1979) and Kumaran and Maheshwari (1980). On the basis of palynoflora Maheshwari, Kumaran and Bose (1978) have suggested the age of these beds as Norian. Unlike the miofloral assemblages from this region megafloral record is rather poor. Rao (in Krishnan, 1958, p. 12) reported the occurrence of *Thinnfeldia hughesii* (*Dicroidium hughesii*) and *Thinnfeldia* sp. (*Dicroidium* sp.) from South bank of Janar River about 0.75 km north-east of Harai Village. He, however, did not give any description or figure of his specimens. The specimens described in this paper were collected from grey micaceous sandy shales exposed on the east bank of Janar River about 1.25 km south-south-west of Harai and on the north bank of Janar River about 0.75 km north-north-east of Harai (Map 1).

DESCRIPTION

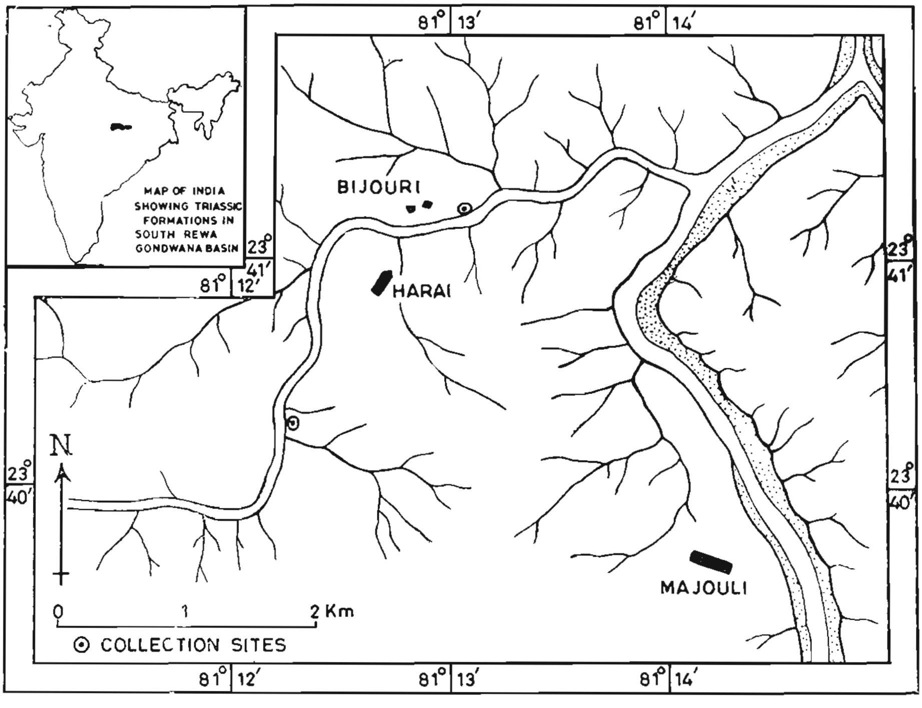
Class — Pteridospermopsida
Order — Peltaspermales
Family — Peltaspermaceae

Genus — *Lepidopteris* Schimper, 1869

Lepidopteris madagascariensis Carpentier

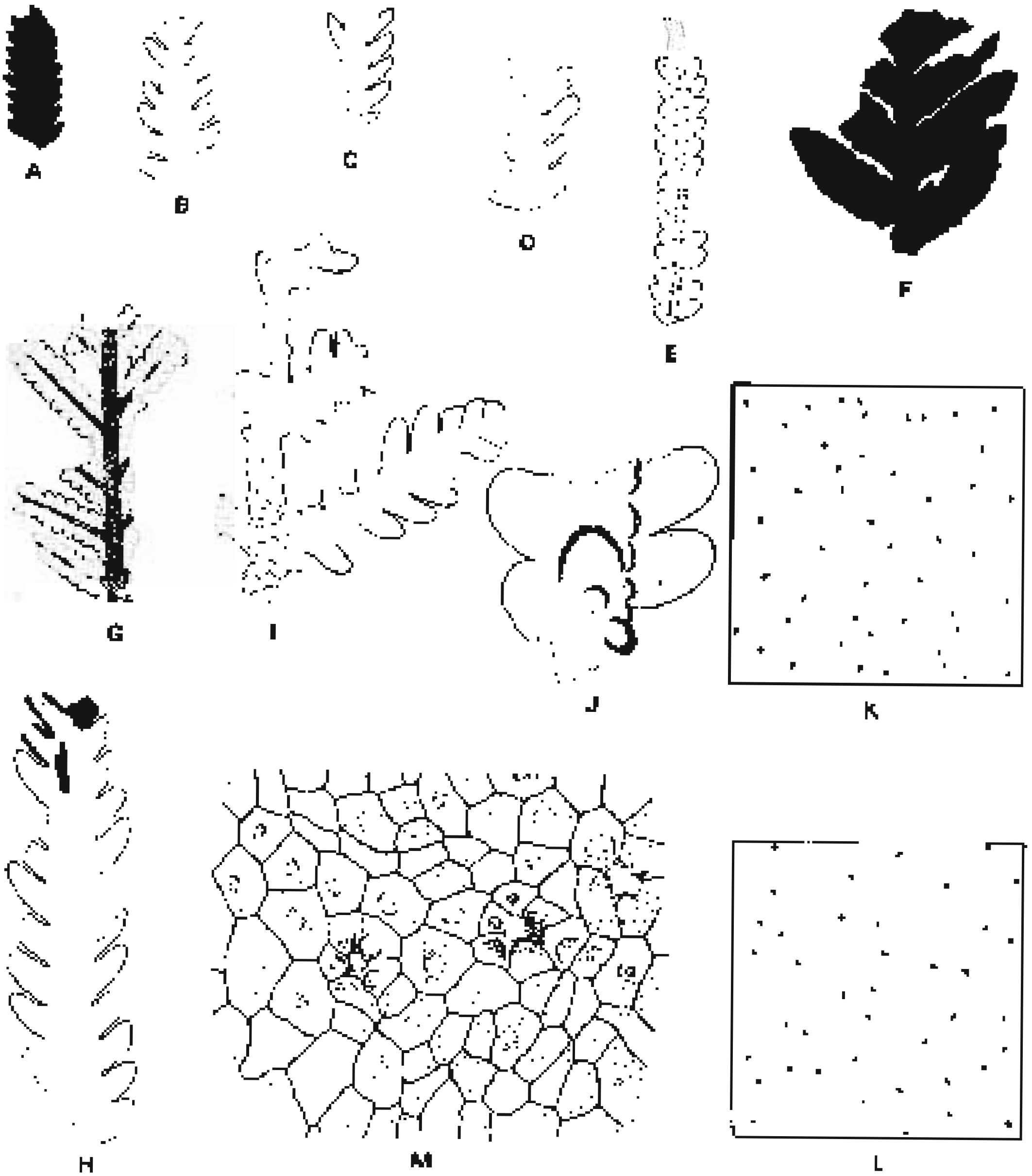
Pl. 1, figs 1-12; Text-fig. 1A-M

Description — Leaf bipinnate, incomplete at base and apex, largest specimen measuring 5 cm in length. Substance of lamina thick. Rachis 5 mm wide, covered with about 1 mm wide lumps. Lumps low, compressed edges of lumps raised on all sides. Pinnae subopposite, arising at an angle of about 60°, ±2 cm apart, largest available pinna 6 cm long, pinnules of adjacent pinna not touching each other. 'Zwischerfiedern'



Map 1 — Showing the fossiliferous localities near Harai, Shahdol District, Madhya Pradesh, India.

more or less triangular in shape, about 1 mm long and 1 mm wide, attached by entire base, margins entire, apex obtuse, rarely subacute. Pinna rachis 4 mm wide, near base with minute lumps, remaining part smooth. Pinnules subopposite, arising at an angle of about 60°, usually lying slightly away from one another, rarely at places lateral margins of adjacent pinnules touching or overlapping each other. Pinnules typically oblong, 4-8 mm long and 2-4 mm wide, rarely slightly falcate, attached by

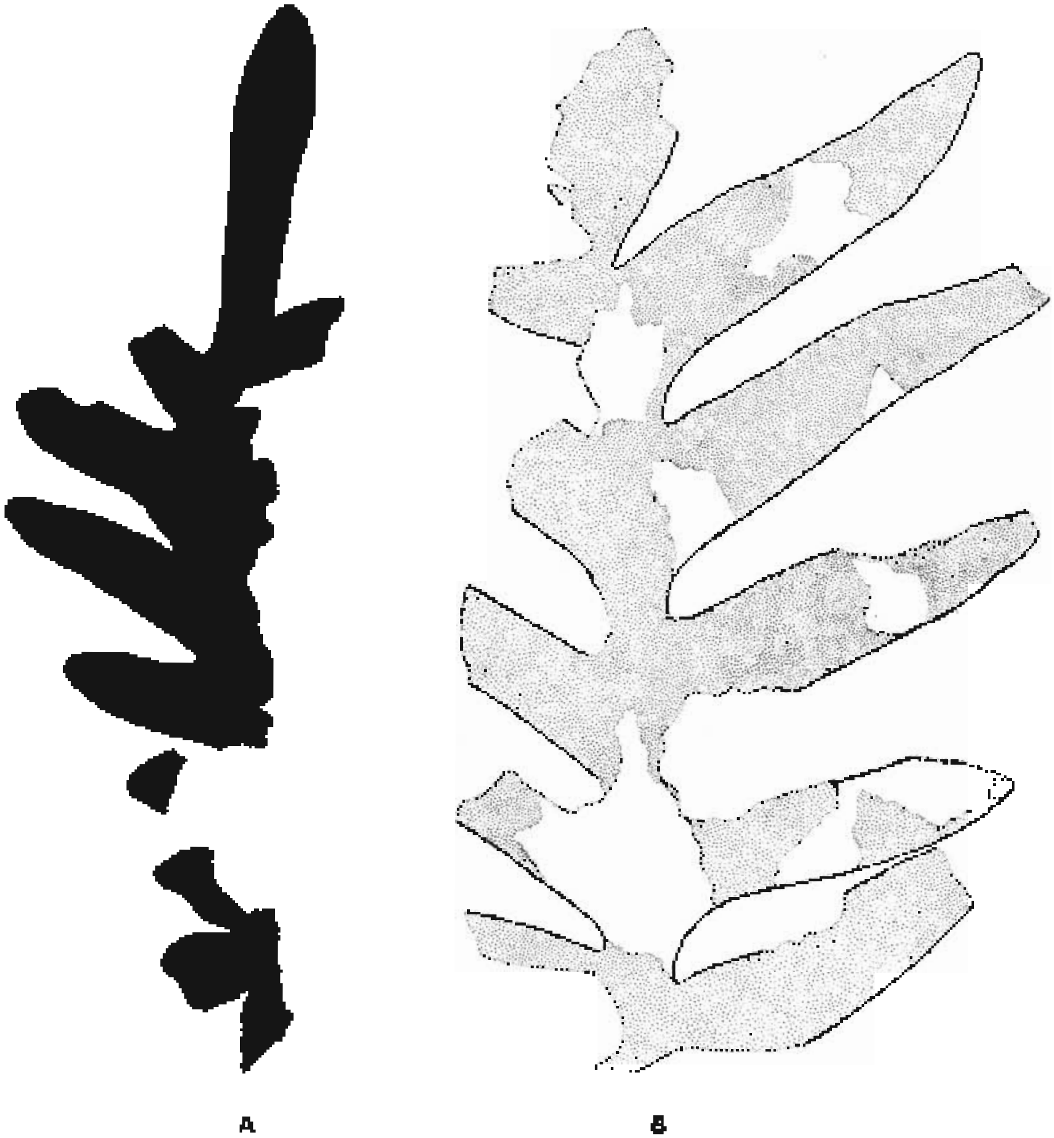


TEXT-FIG. 1 — *Lepidopteris madagascariensis* Carpentier. — A-I, B.S.I.P. nos. 35610, 35614, 35606, 35615, 35611, 35607, 35612, 35613, 35600; all × 1; J, part of specimen in fig. F magnified showing detail of lumps over the rachis, B.S.I.P. slide no. 35611-1. — K, L, distribution of stomata on two surfaces of lamina, B.S.I.P. slide no. 35606-3, × 40; M, cuticle of lamina showing epidermal cells and a few stomata, B.S.I.P. slide no. 35606-2, × 250.

entire base, margins entire or slightly lobed, apex obtuse or subacute. Midrib distinct, running up to apex; lateral veins scarcely visible, subopposite, forked or unforked.

Cuticle of rachis about 3 µm thick, amphistomatic; cells polygonal, somewhat isodiametric, often slightly elongated along middle region of rachis; anticlinal walls straight, at places slightly sinuous or with minute projections, often pitted; periclinal wall usually with a well-developed solid papilla. Stomatal frequency more or less similar on both surfaces. Subsidiary cells 4-7 in number, usually 5 or 6, each with a solid well-cutinized papilla overhanging the stomatal pit; stomatal pit round to oval; inner wall of subsidiary cells forming stomatal pit strongly thickened; guard cells sunken; aperture slit-like.

Cuticle of lamina about 2.5 µm thick. Cells polygonal, more or less isodiametric, sometimes cells along veins slightly



TEXT-FIG. 2 — *Dicroidium hughesii* (Feistmantel) Gothan. A, B. B.S.I.P. nos. 35618 and 35619, both, × 1.

elongated; anticlinal walls 2-5 μm thick, usually straight sometimes minutely undulated, at places broken by pits; periclinal wall mostly with a low solid papilla, at places papilla indistinct or absent, cell surface occasionally showing faint radiating striations. Stomatal frequency in both surfaces almost similar, irregularly distributed, typically monocyclic. Subsidiary cells usually 5-6, rarely 4, each with a cutinized solid lappet overhanging stomatal pit; stomatal pit round or oval. Guard cells sunken; aperture slit-like.

Occurrence — East bank of Janar River, 1.25 km south-south-west of Harai.

Comparison & Discussion — The specimens from Janar River agree with *Lepidopteris medagascariensis*, described by Townrow (1966), from Lower to Middle Triassic of Australia, Madagascar and South Africa, in size, shape and venation pattern of pinnules as well as in cuticular features. Like the specimens earlier described from Australia and other localities the present specimens, too, show variations in shape and size of the pinnules.

Order — Corystospermales
Family — Corystospermaceae

Genus — *Dicroidium* Gothan, 1912

Dicroidium hughesii (Feistmantel) Gothan

Pl. 2, figs 13-19; Text-figs 2A, B; 3A-E

Description — Leaf imparipinnate, maximum available length 14 cm. Rachis up to 18 mm wide. Pinnae opposite or sub-opposite, oblong to linear lanceolate, often slightly curving towards the pinna lying below, typically 6×1.5 cm, closer to base pinnae gradually decreasing in size, finally at extreme base becoming almost orbicular in shape. Pinna attached to rachis by entire base; basiscopic margin decurrent; lateral margins mostly entire, at places slightly wavy; apex obtuse or subacute. Typically each pinna with a distinct midvein, besides midvein a few veins arising directly from rachis. They are mostly confined below the midvein. Secondary veins arising from the midvein at an angle of ±40°, slightly arching, mostly once forked, towards apex lateral veins may be unforked.

Cuticle of rachis about 6 μm thick, slightly thinner on one side; amphistomatic. Cells usually squarish or rectangular in shape, sometimes polygonal, tending to be in rows; anticlinal walls straight; periclinal wall on thinner side smooth but often papillate on thicker side. Stomata sparse, about 15 per sq mm, mostly transversely or obliquely orientated.

Cuticle of lamina about 4 μm thick, one surface slightly thicker than the other; amphistomatic. Cells along veins often elongated arranged in rows, other epidermal cells mostly isodiametric-polygonal. Cells of thinner side mostly with somewhat rounded corners and also larger in size than those on the thicker surface. On both surfaces 4-6 rows of elongated cells present along lamina margins. Anticlinal walls of cells usually straight, at places slightly undulated; periclinal wall unspecialized or with a low, solid papilla. Papillae rare on thinner side but very common and comparatively distinct on the thicker side. Stomata slightly more in number on thicker surface, irregularly distributed and orientated, monocyclic or imperfectly dicyclic. Subsidiary cells usually 4 (2+2), sometimes 5, on thinner side rarely with a low papilla, on thicker surface subsidiary cells often papillate and sometimes papilla overhanging the stomatal pit. Stomatal pit typically rectangular, guard cells thinly cutinized, moderately sunken on thinner surface but relatively more sunken or thicker surface. Aperture slit-like or narrowly elliptical, lateral subsidiary cells frequently accompanied by encircling cells.

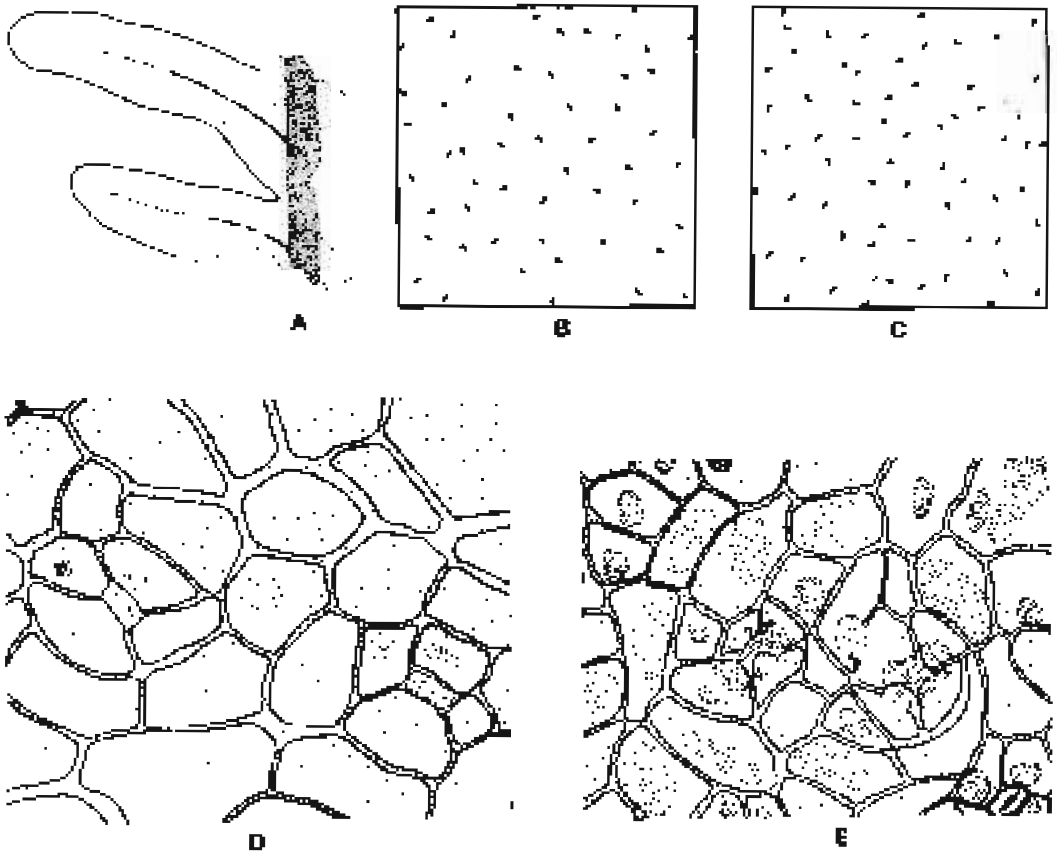
Occurrence — East bank of Janar River, 1.25 km south-south-west of Harai.

Comparison & discussion — The present specimens in their gross features and cuticular characters resemble *Dicroidium hughesii* described by Lele (1962a) from the Parsora Formation.

Dicroidium zuberi (Szajnocha) Archangelsky

Pl. 3, figs 20-32; Text-figs 4A-M, 5A-D

Description (for description assumed to be bipinnate) — Detached pinnae, imparipinnate, largest available pinna 8 cm long and 3 cm wide. Pinna rachis 2-5 mm wide, having a distinct median ridge. Pinnules closely spaced, often touching or overlapping each other; rhomboidal or broadly oval, 4×3 mm to 18×16 mm in size; usually

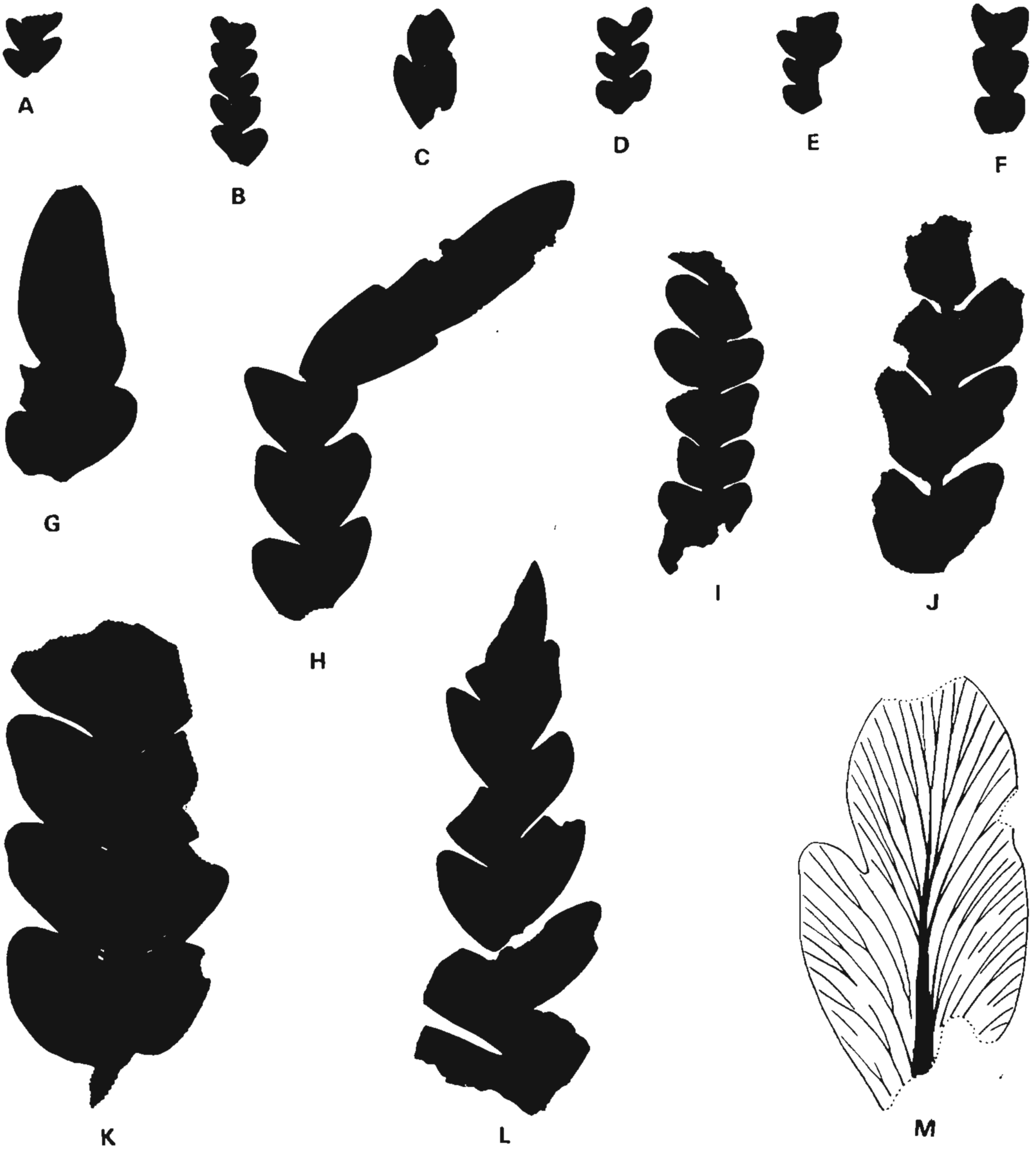


TEXT-FIG. 5 — *Dicroidium hughesii* (Feistmantel) Gothan. A, B.S.I.P. no. 35617, × 1; B, distribution of stomata over thinner side of lamina cuticle, B.S.I.P. slide no. 35618-2, × 40; C, distribution of stomata over thicker side of lamina cuticle, B.S.I.P. slide no. 35618-2, × 40; D, cuticle of lamina, thinner side, showing epidermal cells and two stomata, B.S.I.P. slide no. 35619-1, × 250; E, cuticle of lamina, thicker side, showing two stomata and epidermal cells, B.S.I.P. slide no. 35619-1, × 250.

slightly contracted at base, margins entire or slightly lobed; apex obtuse. Terminal pinnule oval or oblong. Three to four veins arising close to basiscopic side of pinnule base, each of these veins forking 1-3 times and arching towards margins. Substance of lamina thick.

Cuticle of pinnule on both surfaces more or less similar, rarely one surface slightly thinner, 6 μm thick, amphistomatic. Epidermal cells mostly isodiametric-polygonal, rarely at places slightly elongated, anticlinal walls 3-4 μm thick, usually straight, sometimes slightly undulated, rarely cell outlines with about 2 μm high cutin processes; periclinal wall usually having a low solid papilla, papilla often relatively more distinct on thicker surface. Stomatal frequency almost similar on both surfaces, evenly distributed over entire surface, irregularly orientated. Subsidiary cells 4-6 in number, mostly 5, occasionally differentiated into polar and lateral subsidiary cells, very rarely papillate. Rarely subsidiary cells of adjacent stomata touching each other. Stomatal pit typically rectangular, thickly cutinized on lateral sides; guard cells sunken, thinly cutinized, aperture slit-like. Encircling cells absent.

Rachis cuticle about 8 μm thick (one surface slightly thicker than the other), amphistomatic. On thicker side cells usually longitudinally elongated, at places isodiametric-polygonal. Stomata mostly transversely or obliquely orientated, sometimes longitudinally placed. Other details similar



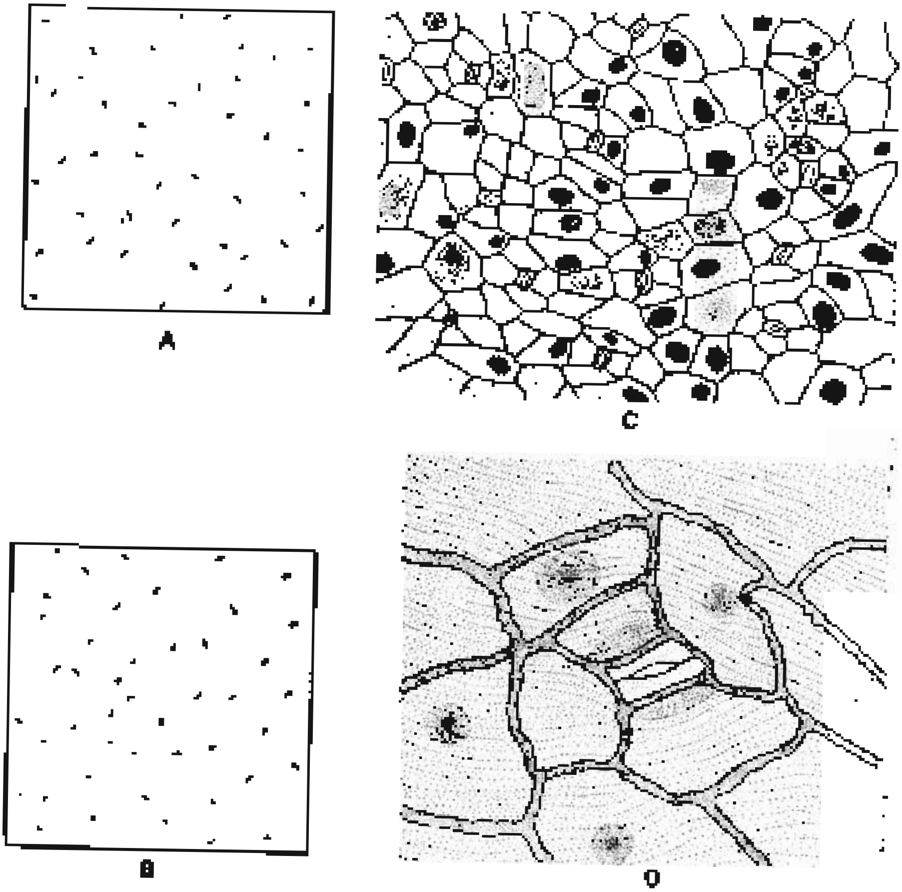
TEXT-FIG. 4 — *Dicroidium zuberi* (Szajnocha) Archangelsky. A-L, B.S.I.P. nos. 35630, 35621, 35631, 35632, 35633, 35620, 35636, 35623, 35635, 35628, 35627 and 5634, all × 1; M, specimen in fig. C magnified showing venation, B.S.I.P. slide no. 35631-1, × 4.

to the ones occurring over the pinnule surfaces.

Occurrence — East Bank of Janar River, about 1.25 km south-south-west of Harai and north bank of Janar River about 0.75 km east-north-east of Harai.

Remarks — In some of the specimens epidermal cells show parallel striations. Striations usually continuous along adjacent cells, often converging towards the cell papilla. In some specimens striations are quite distinct, whereas, in others they are very faint or even absent.

Discussion & Comparison — The Janar River assemblage is dominated by *Dicroidium zuberi*, however, so far no bipinnate frond



TEXT-FIG. 5 — *Dicroidium zuberi* (Szajnocha) Archangelsky. A, B, Distribution of stomata on two surfaces of lamina, B.S.I.P. slide no. 35627-5, × 40; C, cuticle of lamina showing epidermal cells and stomata, B.S.I.P. slide no. 35634-1, × 125; D, a stoma and the surrounding epidermal cells with striations over the surface, B.S.I.P. slide no. 35634-2, × 500.

have been collected from this region. In gross features: thickness of cuticle, size, shape and outlines of epidermal cells and nature of stomatal apparatus the present specimens agree with those of *D. zuberi* described by Archangelsky (1968) from Middle to Upper Triassic of Argentina.

Dicroidium sp.

Pl. 4, figs 33-40, Text-fig. 6A-F

Description (based on fragmentary specimens, largest specimen 2.3 cm in length)— Leaf at least once pinnate. Pinna sub-opposite, elliptic or linear lanceolate, 4-11 mm long and 2-3 mm wide, attached by whole base, basiscopic margin decurrent, lateral margins entire, apex obtuse. Mid-vein distinct in the basal half of the pinna, evanescent towards apex. Lateral veins arising at an acute angle, once or twice forked.

Cuticle of lamina about 2.5 μm thick, one surface slightly thicker than the other. Epidermal cells mostly polygonal, ± isodiametric, on thicker side veins marked by rows of elongated cells, on both surfaces few rows of elongated cells present along lamina margin. Anticlinal walls of epidermal cells straight, often faintly sinuous, periclinal wall with a low solid papilla. Stomata more or less equally numerous on both surfaces of lamina, evenly distributed and irregularly orientated. Subsidiary cells mostly 4 (2+2) in number, sometimes 5; often subsidiary cell bearing a low papilla on its surface. Stomatal pit rectangular, guard cells sunken, common wall between guard cells and lateral subsidiary cells thickened, aperture slit-like or narrowly elliptic. Frequently lateral subsidiary cell accompanied by an encircling cell outside it.

Rachis cuticle about 3 μm thick, one surface slightly thicker than the other. Cells of median region rectangular or square, serially arranged, more distinct on thicker side. Cells of marginal region polygonal, ± isodiametric. Anticlinal walls of epidermal cells straight or minutely sinuous, periclinal wall with a papilla. Stomata sparse, irregularly distributed and orientated.

Locality — East Bank of Janar River, about 1.25 km south-south-west of Harai.

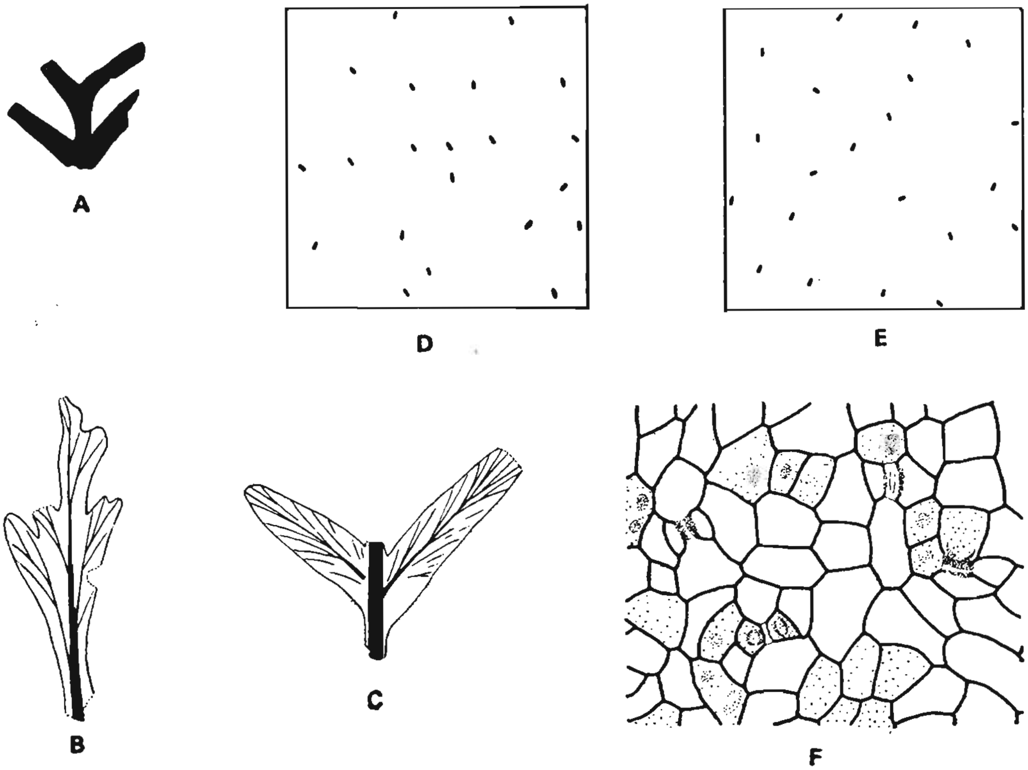
Comparison — *Dicroidium* sp. resembles some specimens of *D. coriaceum* (Johnston) Townrow described by Archangelsky (1968) from the Middle-Upper Triassic of Argentina in gross features and cuticular characters. But assignment of the present specimens to any particular species has been avoided due to their fragmentary nature.

Genus — *Xylopteris* Frenguelli, 1943

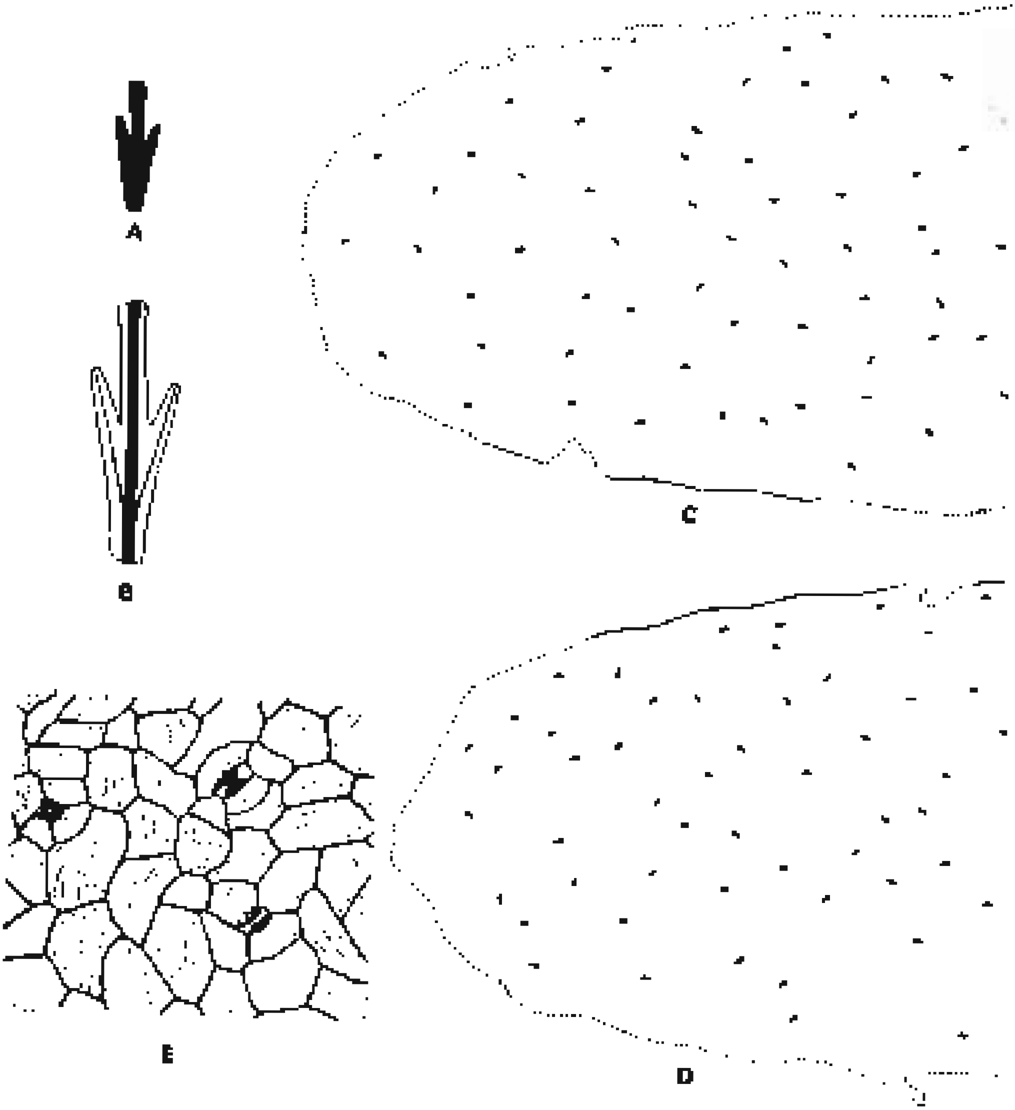
Xylopteris sp.

Pl. 4, figs 41-43; Text-fig. 7A-E

Description (based on single fragment, 1.6 cm in length, broken at both ends) — Leaf at least once pinnate. Rachis 1.5-2 mm wide, winged. Lamina segments subopposite, arising at an angle of about 20°, linear, 5 mm long, 1-1.5 mm wide, attached by entire base, basiscopic margin decurrent lateral margins entire, apex rounded,



TEXT-FIG. 6 — *Dicroidium* sp. **A**, B.S.I.P. no. 35639, × 1; **B**, **C**, B.S.I.P. slide nos. 35641-1 and 35640-1, both, × 2; **D**, **E**, distribution of stomata in thinner and thicker cuticle surfaces, B.S.I.P. slide no. 35640-2, × 40; **F**, thinner cuticle surface of lamina showing epidermal cells and a few stomata, B.S.I.P. slide no. 35640-2, × 150.



TEXT-FIG. 7 — *Uptopteris* sp. A, B.S.I.P. no. 35642, × 1; B, same, × 2, showing venation. C, D, distribution of stomata on thinner and thicker surfaces of lamina cuticle, B.S.I.P. slide no. 35642-2, × 50; E, thicker cuticle surface of lamina showing epidermal cells and stomata, B.S.I.P. slide no. 35642-2, × 150.

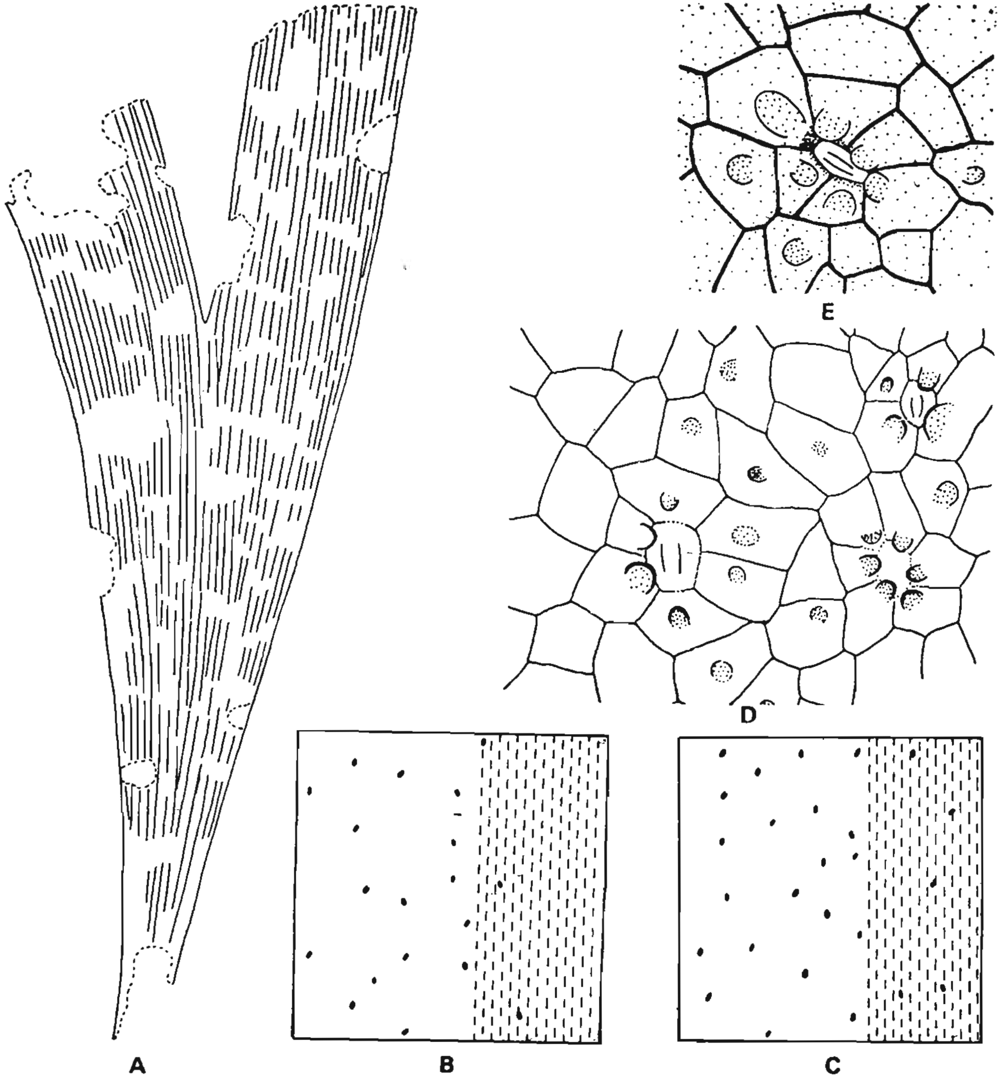
single median vein running from base to apex.

Rachis cuticle about 3 µm thick, one side thicker than the other. On thicker side cells along the middle region longitudinally elongated, serially arranged, along the wing cells polygonal, ± isodiametric or slightly elongated. On thinner side cells polygonal, mostly isodiametric, sometimes elongated. Anticlinal walls of epidermal cells straight, at places slightly undulated, periclinal wall with faint longitudinal striations, rarely with an indistinct papilla. Stomata ± equally numerous on two surfaces, irregularly distributed, longitudinally or obliquely placed.

Lamina cuticle about 2.5 µm thick, one surface slightly thicker than the other. On thicker side cells rectangular, ± serially arranged, over the vein cells narrower and more regularly arranged. On thinner side cells polygonal, ± isodiametric, sometimes squarish. Anticlinal walls of epidermal cells mostly straight, at places minutely wavy or sinuous. Periclinal wall smooth or mottled. Stomata almost equal in frequency on both surfaces, evenly distributed mostly longitudinally or obliquely orientated, rarely transversely placed. Subsidiary cells 4 in number, two polar and two lateral, sometimes five. Guard cells ± sunken, common wall between guard cells and lateral subsidiary cell moderately thickened. Stomatal pit typically rectangular. Lateral subsidiary cell occassionally with an encircling cell outside it.

Occurrence — East bank of Jarar River, about 1.25 km south-south-west of Harai.

Comparison — In size, shape and disposition of lamina segments and in cuticular details the present specimen resembles



TEXT-FIG. 8 — *Sphenobaiera janarensis* Pal sp. nov., **A**, holotype, B.S.I.P. no. 35637, × 1; **B**, **C**, distribution of stomata on thicker and thinner sides of lamina cuticle, dotted areas represent venal region, B.S.I.P. slide no. 35637-1, × 40; **D**, three stomata and epidermal cells in the intervenal region of thinner side of lamina cuticle, B.S.I.P. slide no. 35637-1, × 250; **E**, a stoma, B.S.I.P. slide no. 35637-2, × 500.

Xylopteris spinifolia (Tenison-Woods) Frenguelli described from Middle-Upper Triassic of Australia by Frenguelli (1943) and Jones and de Jersey (1947, as *Stenopteris spinifolia*).

Class — Coniferopsida
Order — Ginkgoales

Genus — *Sphenobaiera* Florin, 1936

Sphenobaiera janarensis Pal sp. nov.

Pl. 5, figs 44-48; Text-fig. 8A-E

Diagnosis — Leaf as a whole obcuneate, lamina deeply dissected, forming two distinct lobes, exceeding 14 cm in length, lamina below the point of bifurcation more than 9 cm long and 4 cm wide, gradually tapering towards base, lobes diverging at an angle of about 30°, each lobe about 2.2 cm wide near middle, up to atleast 4 cm long. Leaf margin entire. Veins 10-12 per cm.

Cuticle moderately thick, amphistomatic, one surface slightly thicker than the other. On thicker side cells along veins and margins serially arranged, elongated, 4-6 times longer than broad with oblique end-walls; cells between veins shorter in dimension, less regularly arranged. On thinner side cells along veins and margins serially arranged, 4-6 times longer than broad, end-walls oblique, interveinal cells polygonal, ±isodiametric. Anticlinal walls of cells distinct, ±straight; periclinal walls of cells on both surfaces usually with a distinct papilla, at places papilla indistinct. Stomata mostly confined to intervenal region, sometimes occurring along veins, irregularly distributed, longitudinally or obliquely orientated. Subsidiary cells 4-6, usually 5 in number, each with a papilla overhanging stomatal pit. Stomatal pit round or oval. Guard cells sunken, thinly cutinized; aperture slit-like.

Holotype — Specimen no. 35637 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Janar River, about 1.25 km south-south-west of Harai.

Comparison — *Sphenobaiera janarensis* resembles *S. argentinae* described from the Middle Triassic of Argentina (Frenguelli, 1946; Jain & Delevoryas, 1967) and Australia (Retallack, Gould & Runnegar, 1977) in gross features as well as in venation pattern, but *S. janarensis* differs from *S. argentinae* in having more closely spaced veins and wider segments. Moreover, cuticular features of *S. argentinae* are not known so far. *S. janarensis* resembles the specimens of *S. spectabilis* (Nathorst) Florin (1936) in general shape and size. Its cuticle, however, resembles more the cuticle of *Baiera spectabilis* described by Harris (1926, 1935) from the Upper Triassic of Greenland (Harris' specimens of *B. spectabilis* were later described by Florin, 1936 as *Sphenobaiera spectabilis*). The present species differs from *S. spectabilis* in having leaf segments which are two times wider than the largest Greenland specimens. Also in the Greenland specimens the veins are more closely spaced which are forking more frequently.

Genus — *Baiera* Braun, 1843

Baiera sp.

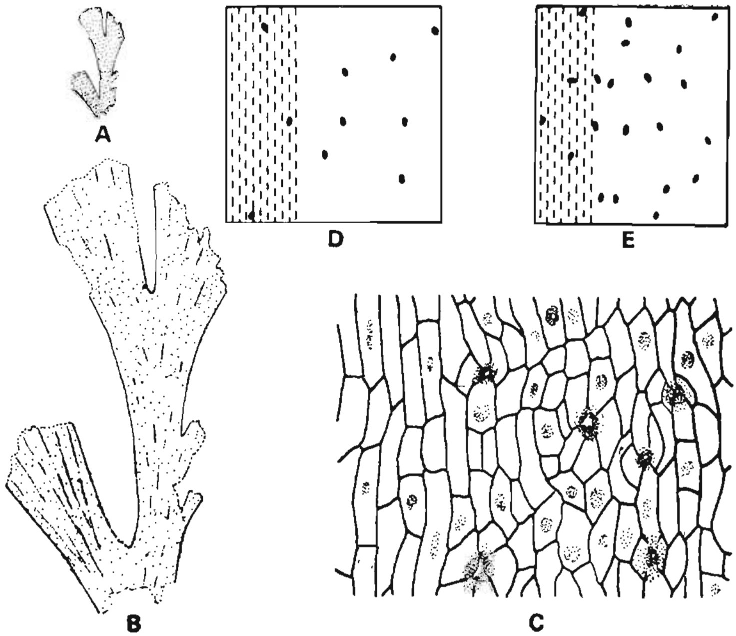
Pl. 6, figs 49-52; Text-fig. 9A-E

Description — Leaf fragment 1.5 cm long, divided by two successive dichotomies at angles of 35-40°. Segments about 2 mm wide at base gradually growing broader towards apex. Venation dichotomous.

Cuticle about 2 μm thick, amphistomatic. Epidermal cells along veins and margins narrowly elongated, rectangular or polygonal, serially arranged. In between veins cells wider and shorter, less regularly arranged. Anticlinal walls ± straight, at places broken by pits. Periclinal wall usually smooth, sometimes with faint striations, rarely with a low papilla. Stomata more numerous on one surface than on the other, mostly occurring in between veins with irregular distribution, at places forming ill-defined files of 3-4 stomata, mostly longitudinal or oblique in orientation, rarely transversely placed. Subsidiary cells 4-7 in number, usually 4 or 5. Inner walls of subsidiary cells heavily cutinized forming a crator-like stomatal pit. Frequently subsidiary cell bearing a cutin lappet overhanging the stomatal pit. Stomatal pit round to oval, sometimes elliptical. Guard cells deeply sunken, aperture slit-like.

Occurrence — East bank of Janar River, about 1.25 km south-south-west of Harai.

Comparison — In its available gross features *Baiera* sp. resembles *B. munsteriana* (Presl) Heer described by Harris (1926) from the Upper Triassic of Greenland. But



TEXT-FIG. 9 — *Baiera* sp. **A**, B.S.I.P. no. 35638, × 1; **B**, same, × 4; showing venation; **C**, **D**, distribution of stomata over two surfaces of lamina, dotted areas represent venal region, B.S.I.P. slide no. 35638-2, × 50; **E**, lamina cuticle showing epidermal cells and few stomata, on left note the elongated cells along vein, B.S.I.P. slide no. 35638-2, × 150.

it differs from the Greenland specimens in having more number of veins per segment. Also the cells outlines of *B. munsteriana* are distinctly sinuous. The Janar River specimen in having narrow segments and in cuticular features resembles *B. leptophylla* Harris (1935) from the Upper Triassic of Greenland, but differs from *B. leptophylla* in having more frequent dichotomies and more number of veins per segment.

MEGAFLORA FROM SON RIVER SECTION NEAR GIAR

Rao (in Krishnan, 1958, p. 12) for the first time reported the occurrence of *Thinnfeldia* sp. (*Dicroidium* sp.) and *Taeniopteris* sp. from east bank of Son River, north-west of Giar. Singh (in Sastry *et al.*, 1977, p. 73) reported *Dicroidium*, *Pachypteris*, *Noeggerathiopsis* and *Taeniopteris* from the Giar beds. Unfortunately both these authors have not given any description or figure of their specimens. According to Maheshwari, Kumaran and Bose (1978) *Gondwanoxylon ghiarii* Saksena (1962), a dicotyledonous wood described from Giar, is probably derived from the younger beds. Beside these, no other plant megafossils have so far been described from the Son River Section near Giar. However, a detailed description of miospores has been given by Maheshwari and Kumaran (1979).

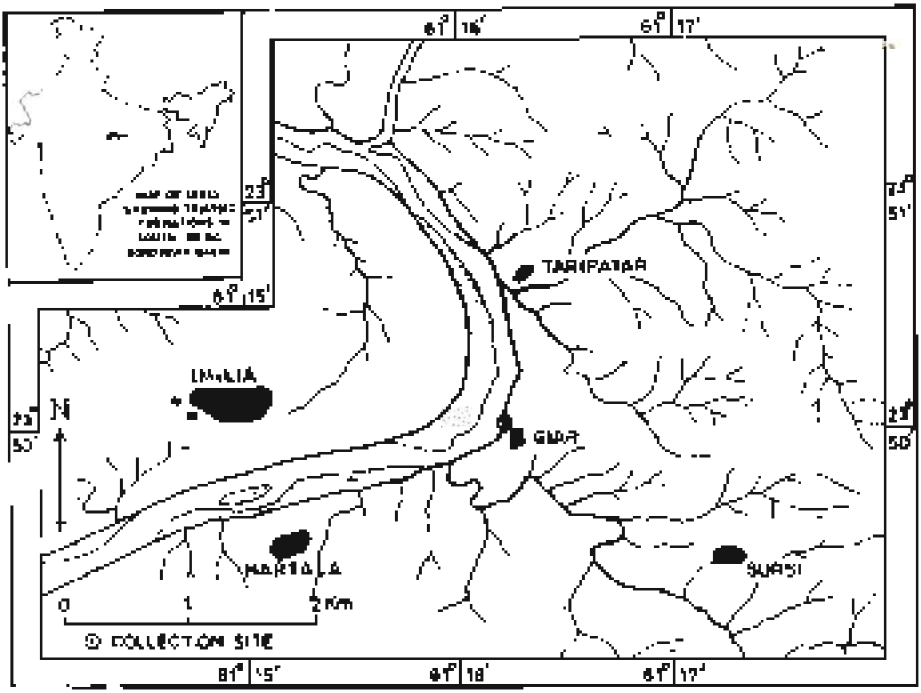
Plant megafossils described here were recovered from the greenish sandy shales exposed on the east bank of Son River about 150 m north-west of Giar (Map 2).

CLASS — SPHENOPSIDA

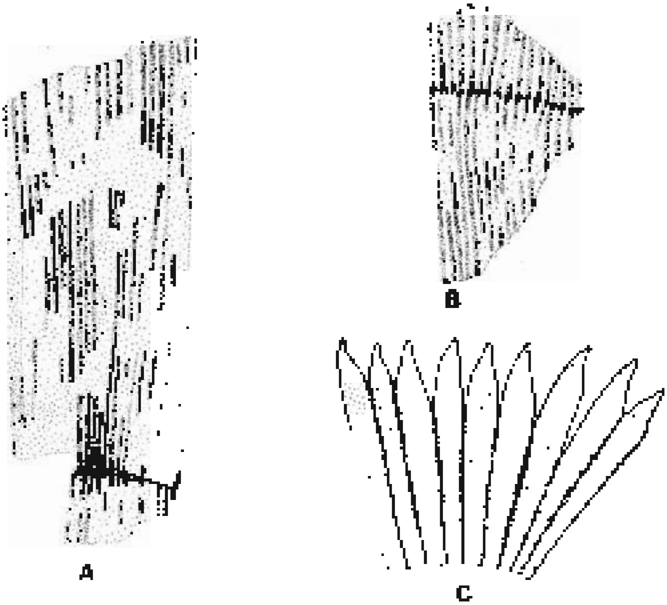
STEM

Pl. 6, figs 56-58; Text-fig. 10A, B

Description — Stem differentiated into nodes and internodes, ± 1.5 cm in diameter. Internodes characterized by alternately arranged parallel ridges and furrows in longitudinal direction, ridges and furrows continuous between internodes, 32-40 per cm. Node showing ± rounded scars, presumably representing leaf bases. Internodal region showing rectangular cells arranged in longitudinal rows.



MAP 2 — Showing fossiliferous locality near Giar, Shahdol District, Madhya Pradesh, India.



TEXT-FIG. 10 — A, B, equisetaceous stems, B.S.I.P. nos. 35646 and 35645, both × 2; C, equisetaceous leaf-sheath, B.S.I.P. no. 35643, × 6.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Remarks — The specimens are preserved in the form of impression and cast. All the specimens are fragmentary, in none of them the internode region is complete. In the number of ridges per cm the present specimens resemble *Neocalamites foxii* Lele (1956) from the Parsora Formation. But the identity of *N. foxii* has been doubted by Bose (1974), continuous ridges between successive internodes occur not only in the genus *Neocalamites* but also in *Schizoneura* and *Phyllotheca*. Therefore, such leafless stems can not undoubtedly be assigned to any particular genus.

LEAF SHEATH

Pl. 6, figs 53, 54; Text-fig. 10C

Description — Leaf sheath 4.5 mm long; divided segments; commisural flanges depressed, extending about 2-2.5 mm below the free tips. Segments linear-lanceolate, 0.5 mm wide, margin entire, apex acuminate.

Occurrence — East bank of Son River, 150 m north-west of Giar.

NODAL DIAPHRAGM

Pl. 6, fig. 55

Description — Nodal diaphragm 12 mm in diameter. Margin fimbriated. At the centre a circular scar present. Other details obscure.

Occurrence — East bank of Son River, 150 m north-west of Giar.

Class — Pteridospermopsida
Order — Peltaspermales
Family — Peltaspermaceae

Genus — *Lepidopteris* Schimper, 1869

Lepidopteris stormbergensis (Seward) Townrow

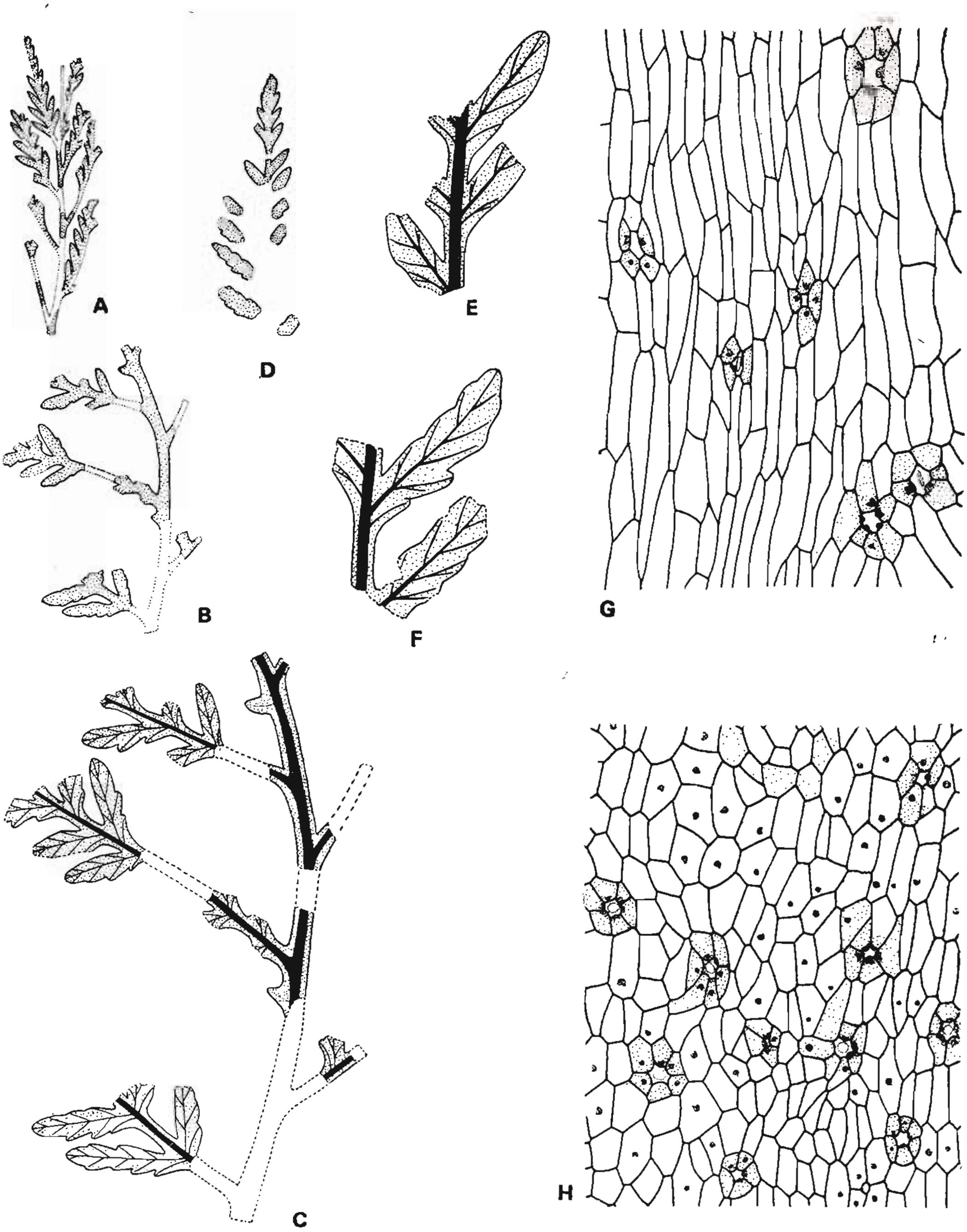
Pl. 7, figs 59-66; Pl. 8, figs 67-74; Text-figs 11A-H, 12A-G, 13A-I

Description — Leaf bipinnate, gradually tapering towards apex; principal rachis 1.5 mm wide, smooth, winged; 'zwischerfiedern' laterally borne, ovate, attached by entire base, margin entire, apex obtuse. Pinnae lanceolate, alternate, 0.5-1.0 cm apart, emerging at an angle of about 70° in midregion, gradually diminishing to about 30° near apex, ±4 cm long. Pinna rachis 0.5-0.7 mm wide, winged. Pinnules subopposite, arising at angle of 50°-60°, lanceolate, slightly falcate, typically 9 mm long and 2 mm wide near middle region, attached by broad base; acroscopic margin constricted, basiscopic margin decurrent extending downwards along rachis to pinnules lying below; lateral margins of basal pinnules mostly deeply lobed and their basiscopic margins more incised than acroscopic margin, distal pinnules becoming entire; pinnules apex subacute. Midrib in each pinnule running assymmetrically up to apex; lateral veins alternate or subopposite, mostly unforked, sometimes once forked. Lowermost pinnule lobe of the basiscopic side having a direct vascular supply from the pinna rachis.

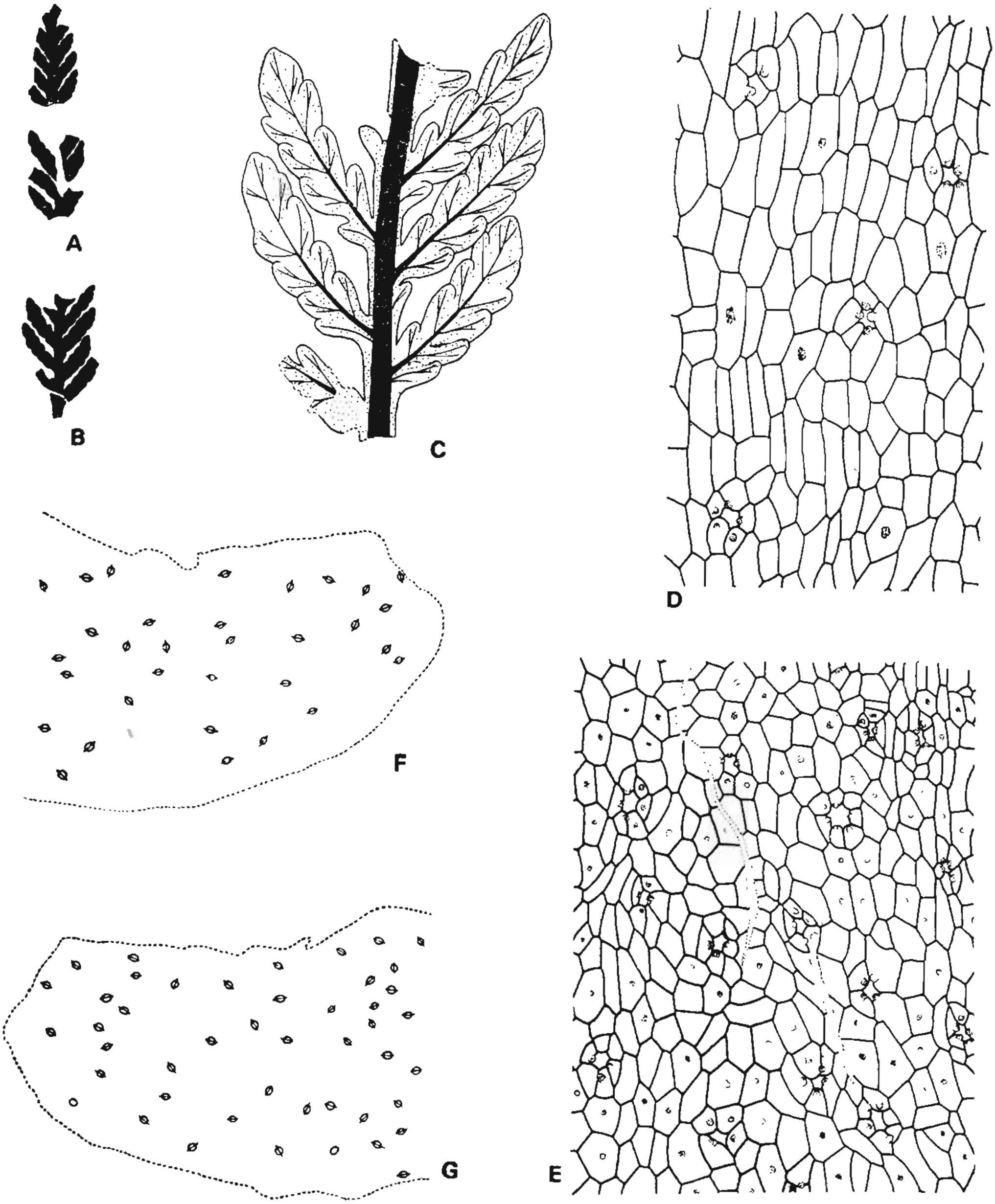
Cuticle of main rachis about 2.0 μm thick, one side slightly thicker than other, amphistomatic, stomata more numerous on thicker side. Epidermal cells on thicker surface polygonal, sometimes much longer than broad, cells of thinner surface much longer than broad, tending to be serially arranged. Anticlinal walls of epidermal cells straight, periclinal wall with a hollow papilla of about 5 μm in diameter or smooth. Stomata irregularly distributed, longitudinally or obliquely orientated. Subsidiary cells 4-6 in number (usually 5 or 6), very rarely 7, each with a papilla overhanging the stomatal pit, sometimes papilla placed little away from inner margin, papilla usually hollow, rarely subsidiary cells devoid of papillae. Stomatal pit round or broadly oval, guard cells sunken, aperture slit-like. Occasionally encircling cells present.

Cuticle of pinna rachis more or less similar to that of main rachis.

Cuticle of laminaa bout 1.5 μm thick, usually one surface slightly thicker than the other, amphistomatic, frequency of stomata more on thicker side more or less equally numerous on both surfaces of lamina. Veins faintly marked by few rows of elongated cells, other epidermal cells polygonal, mostly longer than broad, sometimes isodiametric; anticlinal walls sinuous or wavy, at places with 2-3 μm high cutin projections; periclinal wall with a hollow papilla, about 8 μm in diameter, sometimes periclinal walls devoid of papillae. Stomata irregularly

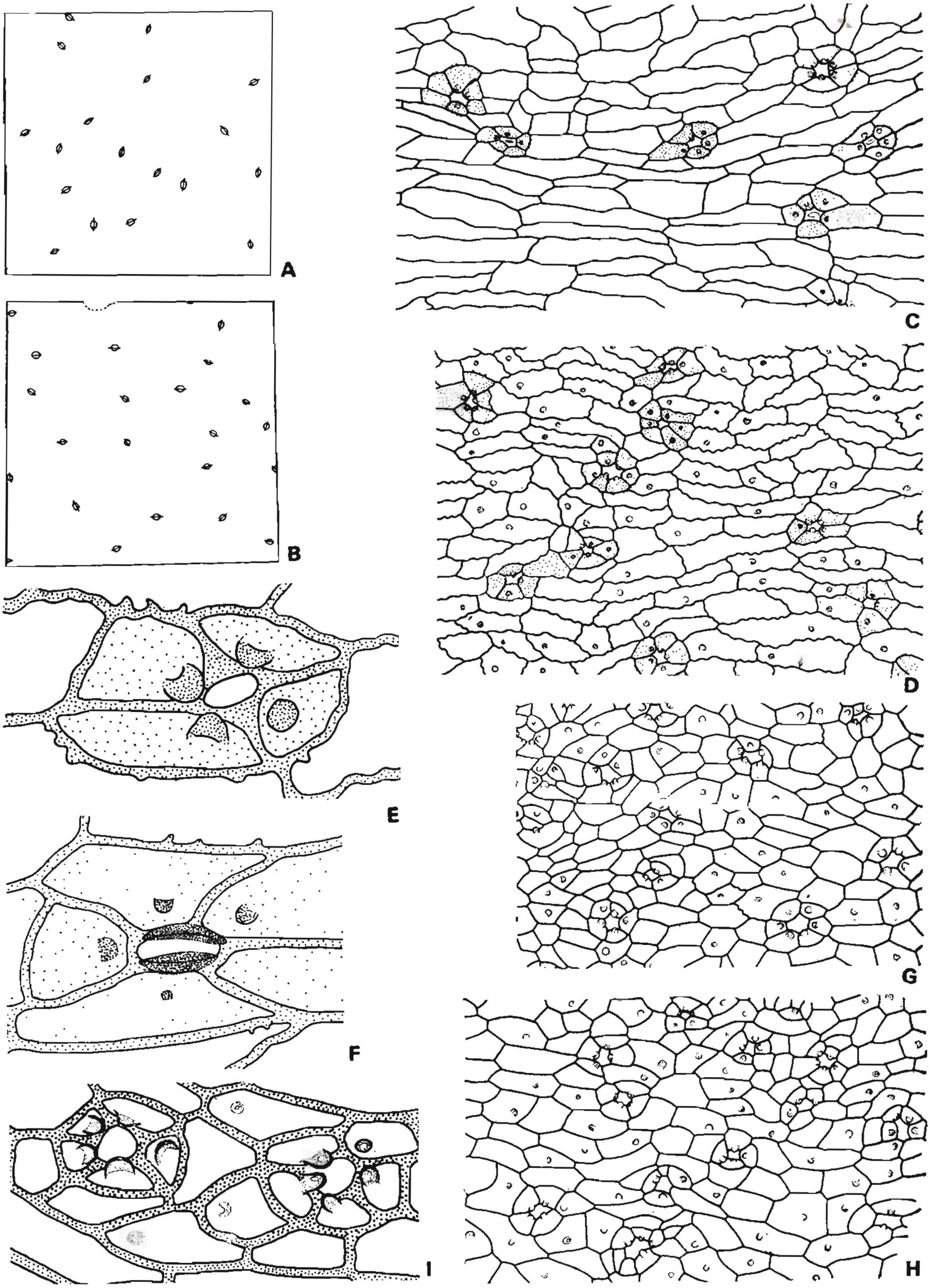


TEXT-FIG. 11 — *Lepidopteris stormbergensis* (Seward) Townrow. **A**, drawing of the part and counterpart of a specimen superimposed on each other, B.S.I.P. nos. 35653 and 35653 (CP), × 1; **B**, B.S.I.P. no. 35652, × 1; **C**, specimen in fig. B, × 2, showing venation of the pinnules; **D**, B.S.I.P. no. 35648, × 1; **E**, **F**, pinna fragments, recovered by bulk maceration, showing venation, B.S.I.P. slide no. 8140, both × 4; **G**, **H**, thinner and thicker surfaces of rachis cuticle, B.S.I.P. slide no. 35652-3, × 100.



TEXT-FIG. 12 — *Lepidopteris stormbergensis* (Seward) Townrow. **A**, **B**, B.S.I.P. nos. 35651 and 35650, both × 1; **C**, specimen in fig. B, showing venation, × 4; **D**, **E**, thinner and thicker cuticle surfaces of pinna rachis, B.S.I.P. slide no. 35650-4, × 100; **F**, **G**, distribution of stomata on thinner and thicker cuticle surfaces of a lamina segment, B.S.I.P. slide no. 35650-2, × 40.

distributed and orientated, mostly distantly placed, rarely subsidiary cells of adjacent stomata touching each other, subsidiary cells 5-7 in number, usually 5 or 6, each with a hollow papilla, usually overhanging the stomatal pit, sometimes papilla placed away from stomatal pit, anticlinal wall of subsidiary cell often with brush-like cutin



TEXT-FIG. 13

projections. Subsidiary cells sometimes more cutinized than ordinary epidermal cells. Stomatal pit round to oval, guard cells sunken, thinly cutinized, aperture slit-like. Subsidiary cells sometimes with encircling cells, usually forming incomplete ring.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Remarks — *Lepidopteris stormbergensis* (Seward) Townrow is fairly common at Giar. The present specimens fall in two distinct groups. In one group pinnules are smaller in size with relatively less incised margins; ordinary epidermal cells ± elongated, only the cells of the thicker side of lamina cuticle are papillate, those on thinner side are smooth, cell outlines are distinctly sinuous or wavy and with cutin processes; stomatal frequency is unequal on two surfaces of lamina and subsidiary cells are more cutinized than ordinary epidermal cells (Pl. 7, figs 59, 62-66; Pl. 8, figs 68, 71, 72; Text-figs 11A-H, 13A-F). In the second group pinnules are larger in size and deeply lobed (almost becoming pinnate again), ordinary epidermal cells ± isodiametric, cells of both surfaces of lamina are papillate, cell outlines almost straight; stomata ± equally numerous on both surfaces of lamina and subsidiary cells and ordinary epidermal cells are of similar thickness (Pl. 7, figs 60, 61; Pl. 8, figs 67, 69, 70, 73, 74; Text-figs 12A-E, 13G-I). Specimens of first group are relatively more abundant than those of the second group. Similar variations in gross features as well as in cuticular details of this species have already been noticed by Townrow (1956, 1960) in the specimens from the Triassic of South Africa, Australia and Argentina. In all the specimens the rachises are entirely smooth excepting that in Pl. 7, fig. 60 (a pinna fragment) which shows small bumps over the rachis. Townrow (1960) also has mentioned about some specimens of *Lepidopteris stormbergensis* in which the rachises are smooth.

Order — Corystospermales
Family — Corystospermaceae

Genus — *Dicroidium* Gothan, 1912

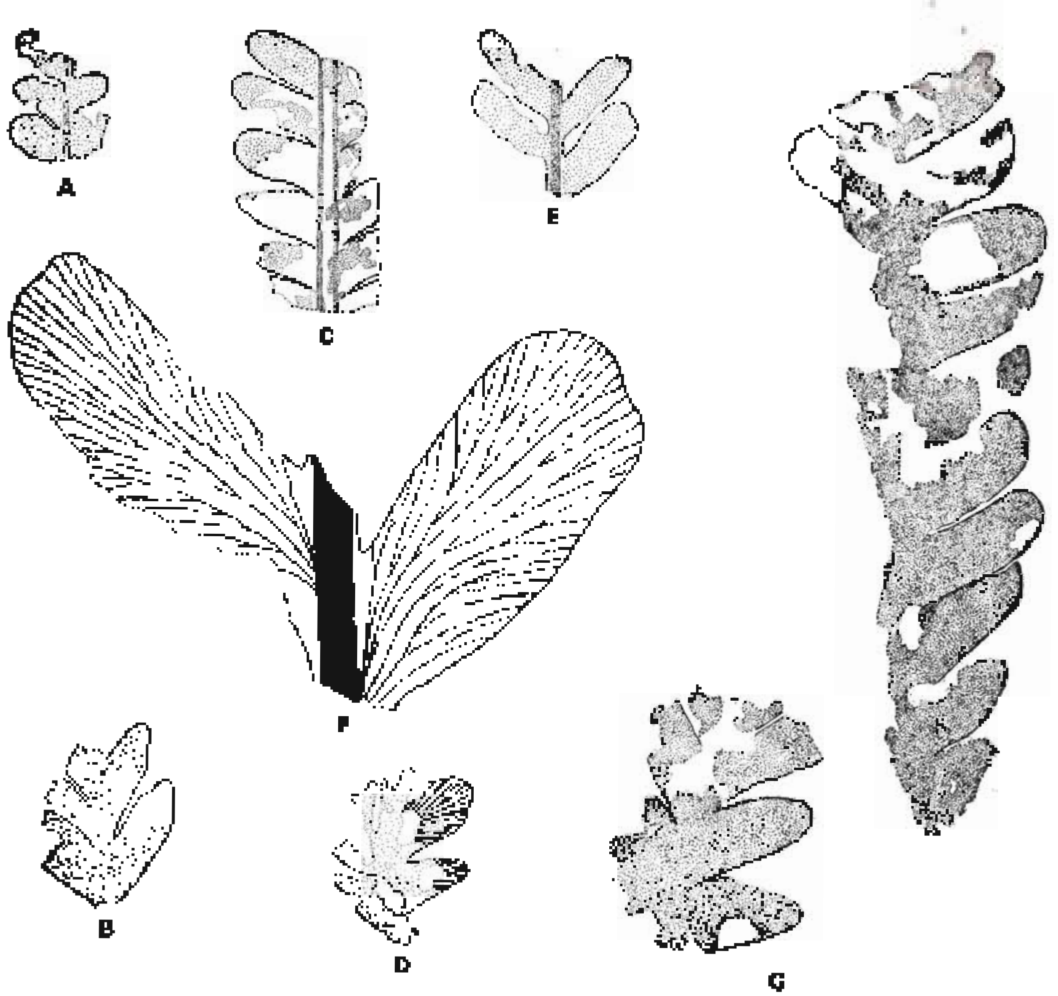
Dicroidium giarensis Pal sp. nov.

Pl. 9, figs 75-81; Text-figs 14A-G, 15A-F

Diagnosis — Pinnate frond; rachis 3-5 mm wide. Pinnae alternate, opposite or subopposite, arising at angle of 50°-60°, elliptic-oblong, 1-1.5 cm long and 5-8 mm broad, attached by broad base, acroscopic margin constricted, basiscopic margin decurrent, lateral margins entire or at places wavy. Venation consisting of 2-3 veins, tending to concentrate in one basiscopic point, uppermost vein strongest forking 3-5 times and supplying major part of lamina, lower veins forking once or twice.

Rachis cuticle about 2 µm thick, amphistomatic, frequency of stomata slightly more on lower side. Epidermal cells at places tending to be serially arranged, squarish, rectangular or polygonal, cells towards margin slightly more elongated, anticlinal walls undulated or rarely at places straight; periclinal wall unspecialized or with a faintly marked papilla (15 µm in diameter). Stomata irregularly distributed, transversely or obliquely orientated, rarely longitudinally placed. Subsidiary cells 4-6 in number, when 4 (2+2); rarely two adjacent stomata sharing a common subsidiary cell, surface wall mottled or papillate. Stomatal pit mostly rectangular, sometimes broadly oval; guard cells sunken, thinly cutinized, aperture narrowly elliptic. Lateral subsidiary cells sometimes with one or rarely with two encircling cells.

TEXT-FIG. 13 — *Lepidopteris stormbergensis* (Seward) Townrow. A, B. distribution and orientation of stomata over thinner and thicker sides of pinnule cuticle. B.S.I.P. slide no. 35652-2, × 40; C, D. thinner and thicker side of pinnule cuticle showing epidermal cells and stomata, note the epidermal cells of thinner side are not papillate but those of thicker surface are papillate. B.S.I.P. slide no. 35652-2, × 100; E. a stoma having four subsidiary cells with well developed papillae close to the stomatal pit. B.S.I.P. slide no. 35651-1, × 500; F. a stoma with five subsidiary cells, papillae over subsidiary cells are relatively small and away from the stomatal pit. B.S.I.P. slide no. 35654-1, × 500; G, H. cuticle of two surfaces of lamina, note the epidermal cells of both surfaces are papillate. B.S.I.P., slide no. 35650-2, × 100; I. two stomata. B.S.I.P. slide no. 35650-2, × 250.

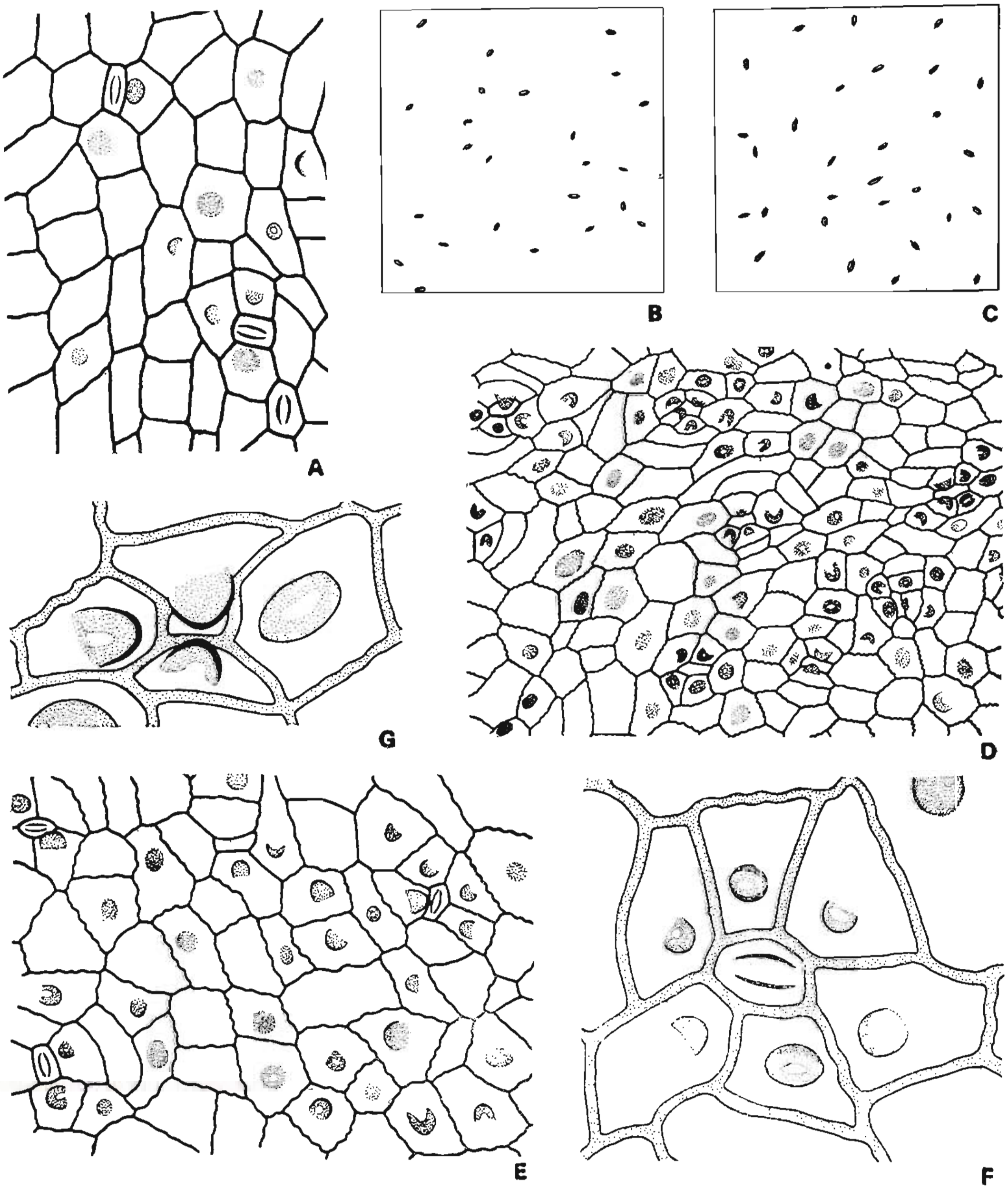


TEXT-FIG. 14 — *Dicroidium giarensis* Pal sp. nov.: A-E, B.S.I.P. nos. 35655, 35656, 35658, 35660 and 35661, all × 1; F, part of specimen in fig. E showing venation, × 4; G, holotype, B.S.I.P. no. 35659, × 1.

Cuticle of lamina about 1.5 μm thick, one surface slightly thicker than the other, amphistomatic with more or less similar frequency of stomata on both surfaces. On thicker surface cells along veins often rectangular, tending to be serially arranged. Ordinary epidermal cells on both surfaces polygonal. Cell outlines sinuous, surface usually papillate, papillae hollow, more distinct on thicker side of lamina cuticle, sometimes cells devoid of papillae. Stomata irregularly distributed and orientated. Stomata exposed or with exposed poles and sunken apperture. Subsidiary cells 4-7 in number, usually 4 or 5, on thicker side subsidiary cells mostly papillate, sometimes papillae overhanging the stomatal pit, on thinner side subsidiary cells usually devoid of papillae. Stomatal pit broadly oval or rectangular, guard cells thinly cutinized, aperture narrowly elliptic. Common wall between guard cell and lateral subsidiary cell little more cutinized in stomata with sunken apperture. Lateral subsidiary cell with one or two encircling cells outside it.

Holotype — Specimen no. 35659 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.



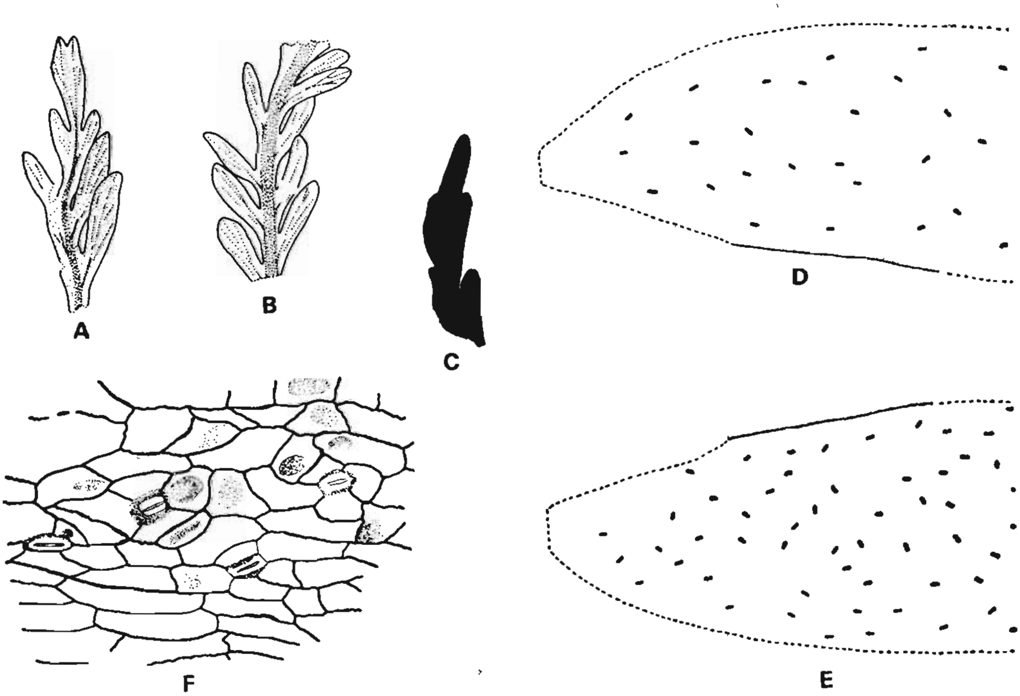
TEXT-FIG. 15 — *Dicroidium giarensis* Pal sp. nov.: **A**, rachis cuticle showing epidermal cells and a few stomata, B.S.I.P. slide no. 35661-2, × 200; **B**, **C**, distribution and orientation of stomata over thicker and thinner surface of lamina cuticle, B.S.I.P. slide no. 35659-1, ×40; **D**, cuticle of lamina, thinner side, B.S.I.P. slide no. 35659-1, × 100; **E**, epidermal cells and a few stomata of lamina cuticle, B.S.I.P. slide no. 35659-1, × 200; **F**, a stoma with six subsidiary cells, note the subsidiary cell papillae away from the stomatal pit, B.S.I.P. slide no. 35659-1, × 500; **G**, a stoma with four subsidiary cells, papillae over two lateral subsidiary cells overhanging the stomatal pit, B.S.I.P. slide no. 35659-1, × 500.

Comparison — *Dicroidium giarensis* is fairly common at Giar. In gross features it resembles some specimens of *D. odontopteroides* (Morris) Gothan and *D. feistmantelii* described by Townrow (1957) from the Triassic of South Africa, Australia and Argentina. But *D. giarensis* could be distinguished from *D. odontopteroides* and *D. feistmantelii* in venation pattern of pinnae and having mostly papillate subsidiary cells. In *D. odontopteroides* all the veins have a common point of origin whereas in *D. giarensis* 2-3 veins arise independently at the basiscopic side of the pinna base. Papillate subsidiary cells have been noted by Townrow (1957) in some exceptional specimens of *D. odontopteroides* but in *D. giarensis* it is a constant feature. In the shape of lamina segments and venation pattern *D. giarensis* could be compared with *D. feistmantelii* (Johnston) Gothan and *D. zuberi* (Szajnocha) Archangelsky, but *D. giarensis* could readily be distinguished from *D. feistmantelii* by its papillate subsidiary cells and from *D. zuberi* by its relatively thin lamina substance and much thinner cuticle. In having papillate subsidiary cells *D. giarensis* resembles *D. papillosum* Bose & Srivastava (1971) described from the Triassic of Nidpur, India. But in contrast to *D. giarensis*, papilla of a subsidiary cell in *D. papillosum* never overhangs the stomatal pit.

Dicroidium coriaceum (Johnston) Townrow

Pl. 10, figs 82-89; Text-fig. 16A-E

Description — Leaf pinnate, segments incipiently or fully developed. Rachis ± 1 mm wide. Pinnae alternate or subopposite, arising at an angle of 30°-40°, typically oblanceolate, 3-6 mm long and 1-1.5 mm wide, slightly contracted at base, acroscopic margin constricted, basiscopic margin decurrent, lateral margins entire, apex obtuse or subacute. Venation rather obscure, visible only in transmitted light, single vein entering each segment, forks twice or thrice. Leaf substance moderately thick, lamina



TEXT-FIG. 16 — *Dicroidium coriaceum* (Johnston) Townrow: **A-C**, B.S.I.P. slide nos. 8143, 8142 and 8166 all, × 4; **D, E**, distribution and orientation of stomata in two surfaces of lamina cuticle, B.S.I.P. slide no. 8142-1, × 50; **E**, cuticle of lamina showing epidermal cells and a few stomata, B.S.I.P. slide no. 8142-1, × 200.

shows a marginal rim of cutin in transmitted light.

Lamina cuticle about 2.5 µm thick, amphistomatic, stomata more numerous on one surface than on other. Epidermal cells usually isodiametric polygonal, sometimes elongated. Cells along lamina margin often narrowly rectangular. Anticlinal walls of epidermal cells minutely sinuous, often with cutin projections, at places broken by pits; periclinal wall with a papilla, sometimes papilla indistinct or absent. Stomata irregularly distributed and obliquely or longitudinally placed. Imperfectly dicyclic. Subsidiary cells basically four in number, two polar and two lateral, very often lateral subsidiary cells radially divided. Subsidiary cells usually with a papilla over its surface, rarely papillae overhanging the stomatal pit. Usually stomata well-seperated, very rarely subsidiary cells of adjacent stomata touching each other. Stomatal pit typically rectangular. Guard cells thinly cutinized, aperture usually exposed, at places slightly sunken.

Rachis cuticle about 3 µm thick, amphistomatic. Cells rectangular, ± serially arranged, more distinct on one surface than on the other, sometimes cells isodiametric, cell outlines straight or minutely sinuous, frequently with cutin projections, surface smooth or with a faint papilla. Stomata sparse, irregularly orientated.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Discussion & Comparison — The description is based on a good number of leaf fragments mostly recovered from the shale samples macerated in bulk. However, in none of the specimen the forked portion of rachis has been found. The present material shows some variations in the extent of differentiation of leaf-segments but in venation as well as in cuticular features they all are essentially similar. In this species transition from slightly incised lamina to well-differentiated pinnae has already been noted by Archangelsky (1968) in materials from Argentine Triassic. The present specimens agree in gross features as well as in cuticular structures with the specimens of *D. coriaceum* (Johnston) Townrow described by Archangelsky (1966) from Middle to Upper Triassic of Argentina.

Dicroidium zuberi (Sazajnocha) Archangelsky

Pl. 10, figs 90, 91; Pl. 11, figs 92, 93; Text-fig. 17A-E

Description — Pinnate leaf (for description assumed to be bipinnate), pinnules subopposite, closely spaced, rhomboidal to oval, about 2.5×2 mm in size, attached by broad base, margin entire, apex obtuse. Venation obscure, only visible by transmitted light, 2 or 3 veins arise independently from the basiscopic side of pinnule base, each forking 2-4 times. Substance of lamina thick.

Pinnule cuticle about 5 µm thick, amphistomatic. Epidermal cells polygonal, mostly isodiametric, at places slightly longer than broad. Cell outlines ± straight, at places slightly sinuous, surface usually with a papilla. Stomata irregularly distributed and orientated. Subsidiary cells 4-6 in number, usually 4 or 5, often with a papilla on surface, rarely papilla overhanging the stomatal pit. Stomatal pit rectangular or broadly oval. Guard cells sunken, common wall between guard cells and subsidiary cells sometimes thickly cutinized, aperture slit-like or narrowly elliptical.

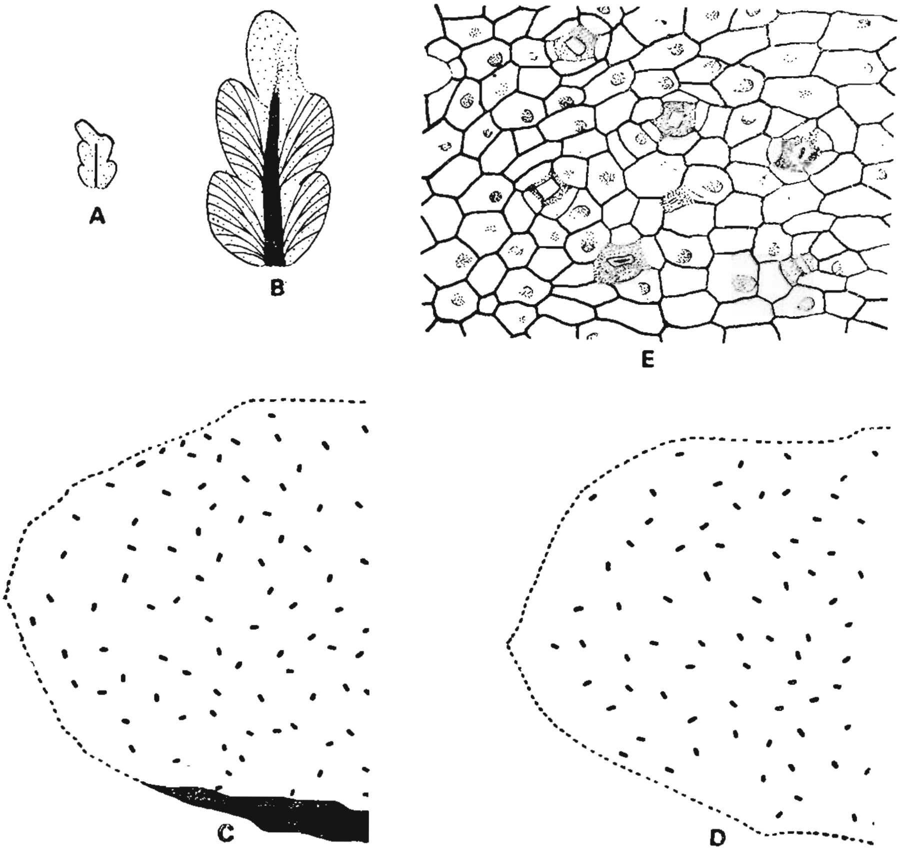
Occurrence — East bank of Son River, about 150 m north-west of Giar.

Comparison — *Dicroidium zuberi* (Sazajnocha) Archangelsky is very rare at Giar. The above description is based on a single pinna fragment. In shape, size and venation pattern of pinnules and also in cuticular details the specimen agrees with some specimens of *D. zuberi* described by Archangelsky (1968) from the Triassic of Argentina and also described in this paper from Janar River Section near Harai.

Dicroidium sp. cf. *D. odontopteroides* (Morris) Gothan

Pl. 11, figs 94-98; Text-fig. 18A-J

Description — Pinnate leaf. Rachis 1.5 mm wide. Pinnules more or less opposite, attached at an angle of about 45°, somewhat deltoid in shape, 5-6 mm long and 5-6 mm wide at base; margin entire; apex subacute; acroscopic margin slightly constricted; basiscopic margin decurrent joining acroscopic margin of the pinnule lying below. Venation odontopteroid type, veins arising at an angle of about 50°, mostly forked.



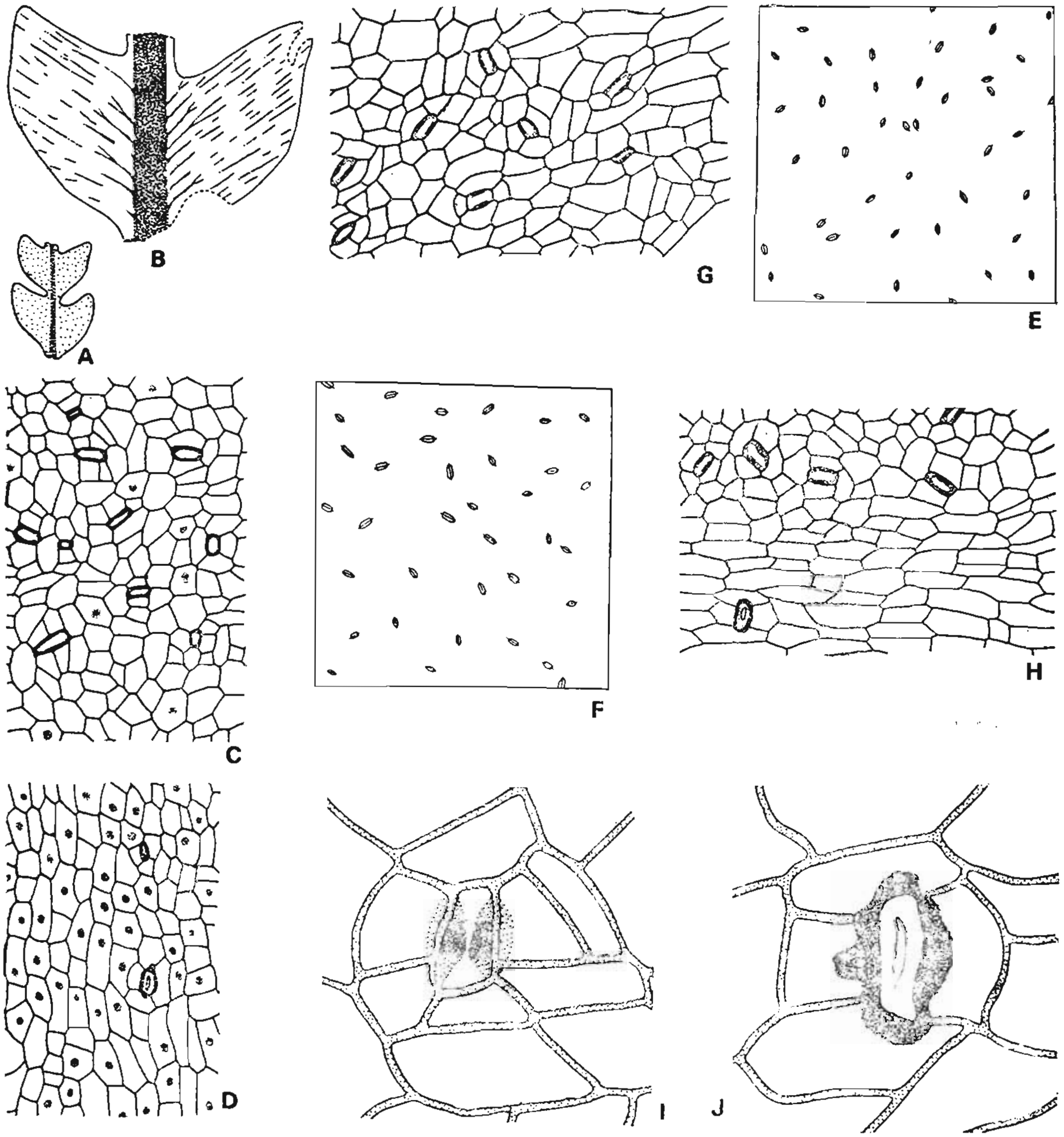
TEXT-FIG. 17 — *Dicroidium zuberi* (Szajnocha) Archangelsky. **A**, B.S.I.P. no. 35662, × 1; **B**, same, showing venation, × 3.25; **C**, **D**, distribution and orientation of stomata in two surfaces of lamina cuticle, B.S.I.P. slide no. 35662-2, × 50; **E**, cuticle of lamina showing epidermal cells and stomata, B.S.I.P. slide no. 35662-2, × 150.

Cuticle about 1 μm thick, amphistomatic, with more or less equal number of stomata on both surfaces. On lower surface cells along veins somewhat serially arranged, on upper surface cells along vein faintly marked by rows of squarish or rectangular cells. Ordinary epidermal cells on both surfaces isodiametric, polygonal or squarish in shape, cells along margin rectangular or squarish. Anticlinal walls straight at places, slightly wavy; periclinal wall smooth. Stomata irregularly distributed and orientated. Subsidiary cells 4-6; when 4 (2+2); often slightly less cutinized than ordinary epidermal cells. Stomatal pit typically oval, common wall between guard cells and lateral subsidiary cell thickened. Guard cells thinly cutinized; aperture narrowly elliptic.

Rachis cuticle about 1.5 μm thick, amphistomatic. Epidermal cells squarish or rectangular, at places polygonal, tending to be serially arranged; anticlinal walls straight; periclinal wall of cells smooth or mottled. Stomata irregularly distributed, mostly transversely orientated, sometimes obliquely or longitudinally placed.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Remarks — In shape and size of lamina segments as well as in cuticular features the present specimen resembles *Dicroidium odontopteroides* (Morris) Gothan described by Townrow (1957) from the Triassic of South Africa, Australia and Argentina. But the Giar specimen differs from *D. odontopteroides* in having veins arising independently rather



TEXT-FIG. 18 — *Dicroidium* sp. cf. *D. odontopteroides* (Morris) Gothan: **A**, B.S.I.P. no. 35663, × 1; **B**, part of specimen in fig. A, showing venation, × 4; **C**, **D**, two surfaces of rachis cuticle showing epidermal cells and stomata, B.S.I.P. slide no. 35663-1, × 100; **E**, **F**, distribution and orientation of stomata in two surfaces of lamina cuticle, B.S.I.P. slide no. 35663-2, × 40; **G**, **H**, two surfaces of lamina cuticle, note the elongated cells along vein in fig. H, B.S.I.P. slide no 35663-2, × 100; **I**, a typical stoma from lamina cuticle B.S.I.P. slide no. 35663-2, × 500; **J**, a stoma with cutinization around stomatal pit, B.S.I.P. slide no. 35663-2, × 500.

than from a common point of origin. Moreover, the description is based on a single fragmentary specimen. Therefore, it has been described as *Dicroidium* sp. cf. *D. odontopteroides* (Morris) Gothan.

Class — Coniferopsida

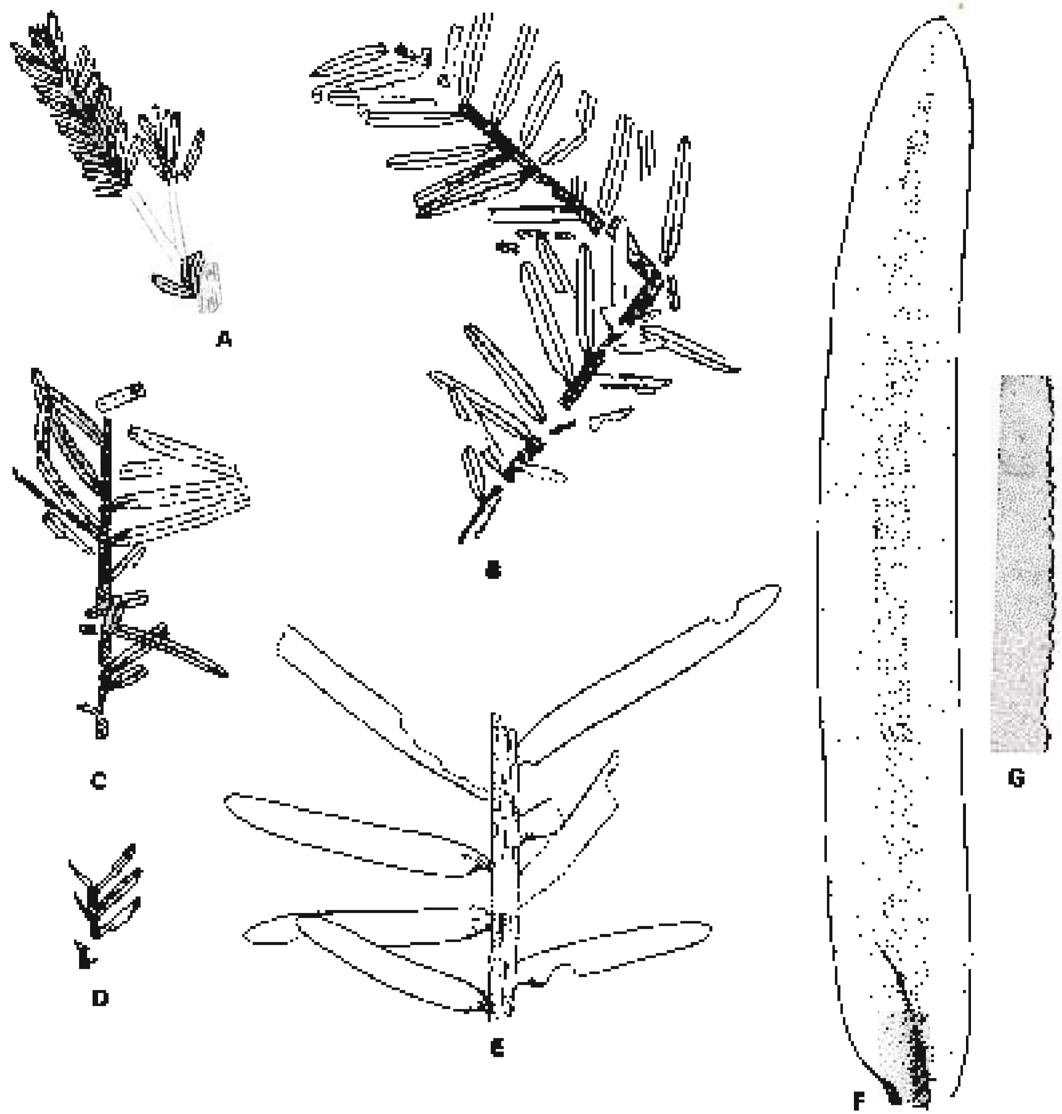
Order — Coniferales

Genus — *Elatocladus* Halle, 1913

Elatocladus denticulatus Pal sp. nov.

Pl. 12, figs 99-104; Pl. 13, figs 105, 106; Text-figs 19A-G; 20A-D

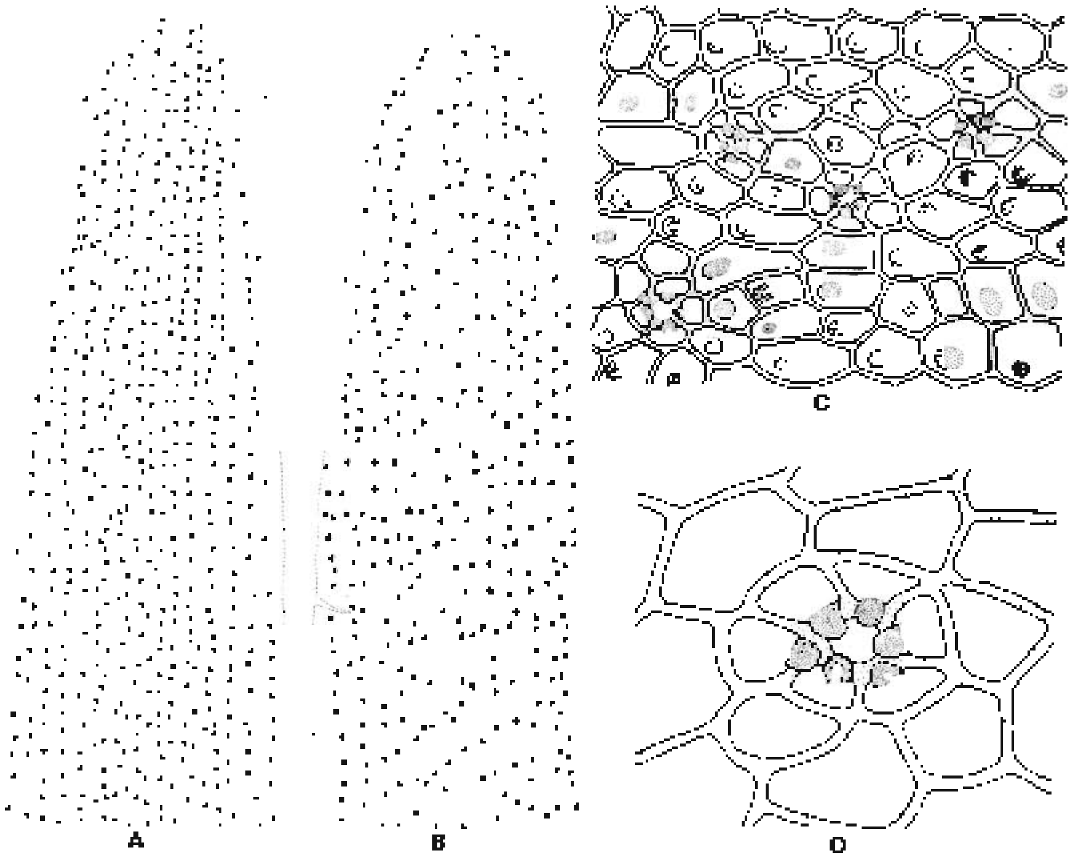
Diagnosis — Branched leafy-shoot, branching at an angle of 30°. Axis about 2 mm thick; near apex diminishing to about 1 mm.



TEXT-FIG. 10 — *Elatocladus dentulatus* Pal sp. nov.: A, B.S.I.P. no. 35664, × 1; B, holotype, B.S.I.P. no. 35665, × 1; C, D, B.S.I.P. nos. 35666 and 35667, both × 1; E, a part of the counterpart of holotype enlarged showing disposition of leaves, × 2; F, a leaf from the holotype enlarged, B.S.I.P. Slide no. 35665-1, × 1; G, a portion of leaf in fig. F magnified showing minute dentation of margin, × 50.

Leaves about 2 mm apart, spirally arranged, (with 1/5 phyllotaxy), but all appear in one plane due to bending and twisting at their bases, near shoot apex leaves closely spaced and overlapping; usually arising at angle of 70°-80°, but towards apex angle of divergence less. Leaves dorsiventrally flattened, linear, 7-20 mm long and 2-2.5 mm wide, near base and apex of shoot leaves markedly reduced in size; base slightly constricted; margins almost parallel to each other, minutely dentate; apex obtuse; surface somewhat scabrous. Midrib prominent, traversing from base to apex.

Cuticle about 2 μm thick, amphistomatic with almost equal number of stomata on both surfaces. Stomata fairly crowded, irregularly distributed over entire surface,



TEXT-FIG. 20 — *Elatocladus denticulatus* Pal sp. nov. — **A, B,** distribution and orientation of stomata in two surfaces of leaf, B.S.I.P. slide no. 35665-2, × 20. **C,** leaf cuticle showing epidermal cells and a few stomata, B.S.I.P. slide no. 35665-1, × 250; **D,** a stoma magnified, B.S.I.P. slide no. 35665-1, × 500.

at places tending to form discontinuous files, 2-4 cells apart; usually longitudinally orientated, sometimes obliquely, or rarely transversely placed. On lower surface cells along vein arranged in longitudinal rows, elongated, with straight lateral walls and straight or oblique end walls. Other epidermal cells usually polygonal or rarely rectangular in shape, slightly shorter than cells along vein, at times isodiametric. On upper surface cells polygonal, more or less isodiametric, at places elongated, rarely squarish. On both surfaces close to margin 2-3 rows of rectangular cells present. Anticlinal walls of ordinary epidermal cells straight or very rarely at places slightly wavy; periclinal wall with a solid well-cutinized papilla. Stomata radially symmetrical, mostly amphicyclic, sometimes monocyclic; subsidiary cells 4-7, usually 5, rarely 7, each subsidiary cell with a overhanging papilla mostly concealing stomatal pit, rarely two adjacent stomata sharing a common subsidiary cell. Stomatal pit round to oval, guard cells rarely preserved, sunken.

Holotype — Specimen no. 35665 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Remarks — The above species is based on four specimens and a large number of detached leaves isolated by bulk maceration. Two of the specimens belong to apical part of twigs and only one specimen shows branching habit. The holotype exhibits transition in leaf size from base to apex. At its proximal part the leaves are 15 mm long and then gradually attain maximum length (20 mm) near middle region. Thereafter again gradually decreasing in size towards apical end.

The specific name refers to the minutely dentate margin of the leaves.

Comparison — *Elatocladus denticulatus* resembles shoots of *Rissikia media* (Tenison-Wood) Townrow (1967) described from the Upper Triassic of South Africa in shape and size of leaves and in the papillate nature of cuticle. But *E. denticulatus* differs from *R. media* in having leaves whose margins are microscopically dentate. In both the taxa leaves are amphistomatic, but in *E. denticulatus* stomata are relatively crowded and distributed all over the leaf surfaces, whereas in *R. media* stomata are relatively sparse and distributed in four diffused zones, a zone per flank. In *R. media*, subsidiary cells are 4 (2+2) in number, more or less similar to ordinary epidermal cells, whereas in *E. denticulatus* subsidiary cells are 4-7 in number, and their shape and size are different from those of ordinary epidermal cells. Moreover, in *E. denticulatus* each subsidiary cell has a well-developed papilla, whereas in *R. media* papillae over subsidiary cells are comparatively ill-developed and they are sometimes even absent. Also the epidermal cells of *E. denticulatus* are papillate but those of *R. media* are usually smooth.

E. denticulatus resembles *E. nitidus* Harris (1935) described from the Rhaetic of Greenland having cuticle with papillate epidermal cells, but the former differs from the latter in its amphistomatic nature of leaf. *E. denticulatus* resembles *E. ramosus* (Florin) Harris (1979) and *E. zamoides* (Leckenby) Harris (1979), reported from the Jurassic of Yorkshire, in shape and size of leaves, but the former can readily be distinguished by its amphistomatic nature of leaves.

Elatocladus raoi Pal sp. nov.

Pl. 13, figs 107-111; Text-fig. 21A-G

Diagnosis — Leafy shoot. Axis entirely concealed by sheathing leaf-bases. Leaves spirally inserted but in compressed state seem to be in one plane, typically 20 mm long, 1-1.5 mm broad at base and sheathing up to 2.5 mm in length, afterwards abruptly spreading out and forming an angle of 70°-80° with axis; towards distal part of shoot leaves gradually reducing in size and forming narrower angle with axis. Leaves dorsiventrally flattened, linear, widest at base; margin entire; apex obtuse or subacute. Single median vein traversing from base to apex.

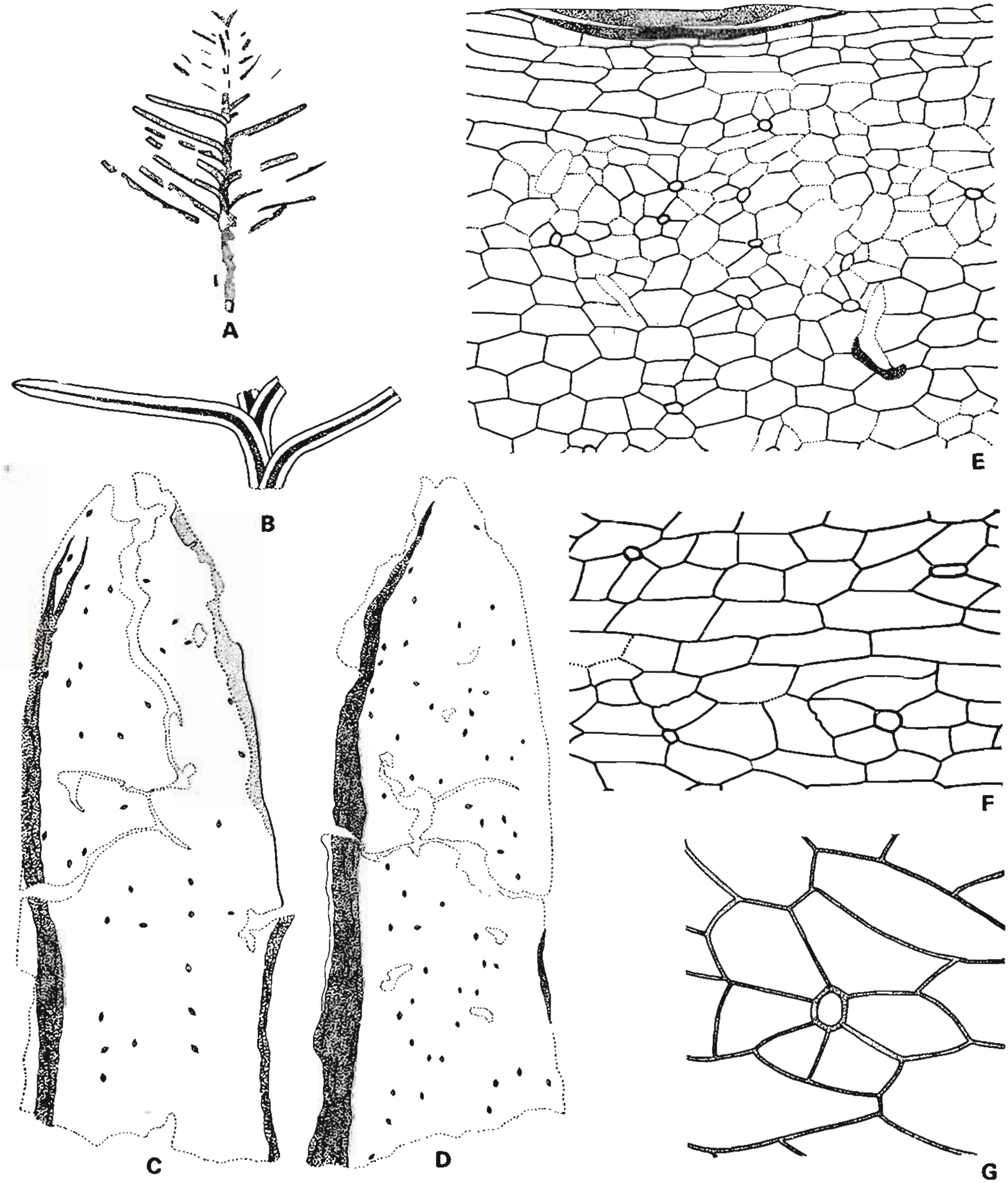
Cuticle about 1.5 μm thick, amphistomatic, frequency of stomata slightly more on one surface. Stomata sparsely placed, irregularly distributed over entire surface, at place forming 3-5 stomata having discontinuous files mostly longitudinally or obliquely orientated, rarely transversely placed. Cells along vein arranged in longitudinal rows, elongated, with straight lateral and usually oblique end-walls; ordinary epidermal cells polygonal, sometimes slightly longer than broad with more or less straight anticlinal walls; cells along margin elongated, narrower than cells along vein, with straight lateral- and usually oblique end-walls; all the cells having and smooth periclinal wall. Stomata monocyclic, subsidiary cells 4-6 in number, usually 5, shape varied, unspecialized, sometimes subsidiary cells of adjacent stomata touching each other, rarely two stomata sharing a common subsidiary cell; pit oval or elliptic, at times polygonal. Guard cells rarely preserved, sunken.

Specific name is after C. Nageswara Rao, Director, Geological Survey of India, who for the first time recorded plant megafossils from the Giar beds.

Holotype — Specimen no. 35668 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Comparison — *Elatocladus raoi* could readily be distinguished from *E. denticulatus* described in this paper from the same bed by its narrower leaves and absence of cuticular papillae. *E. raoi* in gross features somewhat resembles *E. plana* (Feistmantel) Seward, described by Sahni (1928) from the Jurassic Lower Cretaceous formations of India. But the former differs in having leaves which are smaller and linear in shape. In *E. plana* leaves are acicular, near base of twigs reduced scale leaves are present, a feature which is missing in all the Giar specimens. *E. raoi* may also be compared with *E. zignoi* Wesley (1956) reported from



TEXT-FIG. 21 — *Elatocladus raoi* Pal sp. nov.: **A**, holotype, B.S.I.P. no. 35668, × 1; **B**, part of holotype enlarged, showing disposition of leaves, × 3; **C**, **D**, distribution and orientation of stomata in two surfaces of lamina cuticle, shaded areas represent folds in the cuticle where no stomata could be seen, B.S.I.P. slide no. 35668-2, × 40; **E**, cuticle of lamina, on top note the rows of elongated cells along vein, B.S.I.P. slide no. 35668-2, × 100; **F**, lamina cuticle showing a few stomata and epidermal cells, B.S.I.P. slide no. 35668-1, × 200; **G**, a stoma magnified, B.S.I.P. slide no. 35668-1, × 500.

the Jurassic of Italy in size and form of leaves, but the latter differs in having leaves which are spirally disposed as compared to *E. singhii* where all the leaves appear to be in one plane.

In the amphistomatic nature of leaves, *E. raoi* resembles *E. sehorensis* Maheshwari & Kumaran (1976) and *E. bosei* Maheshwari & Kumaran (1976) described from the Jurassic of Jabalpur Formation, India. But the latter two species have much shorter leaves with constricted bases, whereas in *E. raoi* leaves are much longer and their maximum width is at their bases. Moreover, in *E. sehorensis* stomata are distributed in two lateral bands on one surface and on the other surface a stomatic band is confined to central region only, whereas in *E. raoi* stomata are irregularly scattered on both the surfaces. Also in *E. sehorensis* subsidiary cells are mostly 4 in number. In *E. bosei* too, subsidiary cells are usually 4 in number which are less cutinized than ordinary epidermal cells. *E. raoi* resembles *E. polystictus* Harris (1935) which is based on dispersed leaves, because the leaves in both are amphistomatic, but they differ from each other in the details of cuticular structure. In *E. polystictus* stomata are distributed either in two broad bands on under side and two narrow bands on the upper side or stomata scattered in lower surface and on upper surface being rare. Also in *E. polystictus* surface of subsidiary cells and epidermal cells is thickened as compared to *E. raoi*. Both *E. setosus* (Phillips) Harris (1979) and *E. sideriticus* (Bose) Harris (1979) described from the Jurassic of Yorkshire are amphistomatic like *E. raoi*, but they differ from *E. raoi* in size, and shape of leaves is quite different and also in the pattern of stomatal distribution.

Genus — *Pagiophyllum* Heer, 1881

Pagiophyllum bosei Pal sp. nov.

Pl. 14, figs 113-120; Text-fig. 22A-O

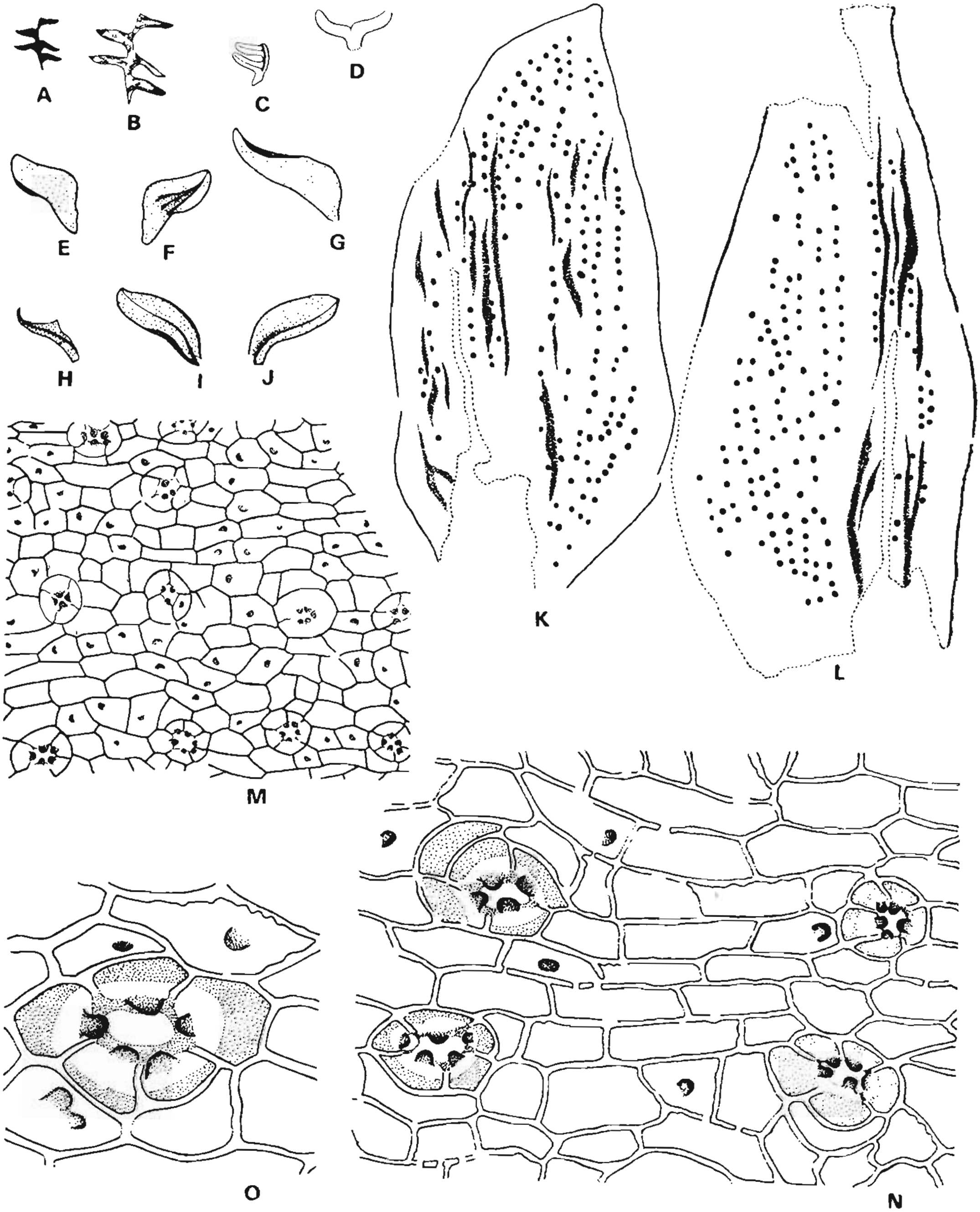
Diagnosis — Leafy twig, ±6 mm wide. Leaves spirally arranged, spreading, base distinctly decurrent, free part projecting radially at an angle of about 80° to axis. Leaf-blade lanceolate, 4 mm long and 1.8 mm wide near middle, slightly curving upwards, contracted to about 0.8 mm near base; margin entire, near apex rarely minutely dentate; apex sharply pointed or somewhat apiculate. Upper surface concave; lower surface convex, keeled.

Leaf cuticle about 2.5 μm thick, amphistomatic. Stomata on both surfaces occurring in two triangular but ill defined zones avoiding central and peripheral regions. Stomatal zones converging towards apex, within stomatal zones stomata arranged in discontinuous files, stomatal files commonly 3-6 cells apart. Cells along non-stomatiferous region mostly rectangular, 2-4 times longer than broad, more or less arranged in longitudinal rows. Cells along stomatal files and between stomata often polygonal or squarish. Anticlinal walls straight or slightly undulated, sometimes broken by pits. Periclinal wall with a solid well-cutinized papilla, typically 8 μm in diameter, sometimes papilla indistinct or absent. Stomatal apparatus monocyclic or incompletely dicyclic. Subsidiary cells 4-7 in number (usually 5); forming a ring; slightly more cutinized than ordinary cells, each subsidiary cell with a well-developed papilla overhanging stomatal pit. Stomatal pit round to oval; guard cells mostly not preserved, sunken; aperture slit-like. The species is named after Dr M. N. Bose, Director, Birbal Sahni Institute of Palaeobotany, Lucknow.

Holotype — Slide no. 8144 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Comparison — *Pagiophyllum bosei* shows close similarity with *P. simpsonii* Ash (1970) described from the Chinle Formation (Upper Triassic), Arizona. Both the species agree in shape and size of leaves and in the presence of papillae over epidermal cells as well as subsidiary cells. But *P. bosei* differs from *P. simpsonii* in the absence of acutely pointed trichomes on leaves and in the pattern of stomatal distribution. In *P. simpsonii* stomata are scattered all over the leaf surfaces. The present species resembles *P. kurrii* (Schimper) Salfeld, described by Harris (1979) from the Jurassic of Yorkshire in having subsidiary cells with papillae overarching the stomatal pit, but they differ from each others as far as leaf size and shape are concerned. Moreover, in *P. kurrii* stomata are evenly distributed all over the surfaces and its epidermal cells are devoid of papillae.



TEXT-FIG. 22 — *Pagiophyllum bosei* Pal sp. nov.: **A**, holotype, B.S.I.P. slide no. 8144, × 1; **B**, holotype, × 2; **C**, **D**, fragmentary twigs, B.S.I.P. slide nos. 8147 and 8145, both × 3; **E**, **F**, ventral and dorsal view of a detached leaf, B.S.I.P. slide no. 8148, × 3; **G**, **H**, detached leaves, lateral view, B.S.I.P. nos. 8149 and 8167, G × 3, H, × 2; **I**, **J**, ventral and dorsal view of a detached leaf, B.S.I.P. no. 8146, both × 3; **K**, **L**, distribution and orientation of stomata in upper and lower cuticles of a dorsiventrally compressed leaf, B.S.I.P. slide no. 8146-1, × 40; **M**, cuticle of lamina, B.S.I.P. slide no. 8144-1, × 125; **N**, lamina cuticle showing epidermal cells and a few stomata, B.S.I.P. slide no. 8144-1, × 250; **O**, a stoma, B.S.I.P. slide no. 8144-1, × 500.

Among the Indian species of *Pagiophyllum*, in its external features *P. bosei* resembles *P. peragrinum* (L & H) Schnek described by Sahni (1928) from the Jurassic-Lower Cretaceous beds of India, *P. bansaensis* Bose & Sukh-Dev (1972) described from the Lower Cretaceous beds of Bansa and *P. sherensis* Maheshwari & Kumaran (1976) described from Jabalpur Series. But *P. bosei* can easily be distinguished from all those species by the manner in which the stomata are distributed and by its papillate nature of cuticle.

UNCLASSIFIED GYMNOSPERMS

Genus — *Yabiella* Oishi, 1931

Oishi (1931a) instituted the genus *Yabiella* based on specimens collected from the Triassic of Argentina and South Africa. He also provisionally included the specimens of *Macrotaeniopteris crassinervis* Feistmantel (1877) from the Jurassic of Rajmahal Hills, India in his genus *Yabiella*. But recently Bose and Banerji (1981) have identified the specimens of *Macroteniopteris crasinervis* Feistmantel (1877) as *Taeniopteris buskoghatensis* Bose & Banerji. Sukh-Dev (1980) described *Yabiella hirsuta* (Bose & Sukh-Dev) Sukh-Dev from the Lower Cretaceous of Bansa, India. As his specimens yielded cuticle and as the cuticular structure of the genus *Yabiella* was unknown at that time Sukh-Dev (1980) emended the generic diagnosis of *Yabiella*. But except Sukh-Dev's specimens all the other specimens of *Yabiella* are restricted to Triassic and its occurrence in the Lower Cretaceous without any representation in the intervening strata, viz., Jurassic, is quite unusual. Moreover, in the specimen of *Yabiella hirsuta* (B.S.I.P. no. 33759, figured by Sukh-Dev, 1980) the marginal vein is not clear, rather the leaf exhibits a thickened margin. Similar type of leaf margin is sometimes met with in taeniopteroid leaves due to the presence of fibrous bundle or slight curvation of lamina margin.

In my collection from Giar there is a specimen of *Yabiella* with well-preserved cuticle. In contrast to the specimens from Bansa (Sukh-Dev, 1980) the cuticle of Giar specimen is amphistomatic. In my opinion *Y. hirsuta* (Bose & Sukh-Dev) Sukh-Dev belongs to a different genus altogether. The venation of *Y. hirsuta* (Bose & Sukh-Dev) Sukh-Dev (1980, text-fig. 1C) is like that of *Macrotaeniopteris buskoghatensis* Bose & Banerji. Based on the present specimen from Giar as well as other specimens of *Yabiella*, the diagnosis of the genus is further emended here.

Emended diagnosis — Leaf spathulate to lanceolate, gradually tapering towards base, petiole short. Lamina attached laterally to the midrib. Midrib strong, distinct from base to apex; lateral veins simple or forked, sometimes uniting with adjacent veins at varying distances from the midrib; close to the lamina margin lateral veins join a marginal vein. Stomata evenly distributed on both the surfaces of lamina. Subsidiary cells 4-6 (2+2 or 2+4). Guard cells little sunken.

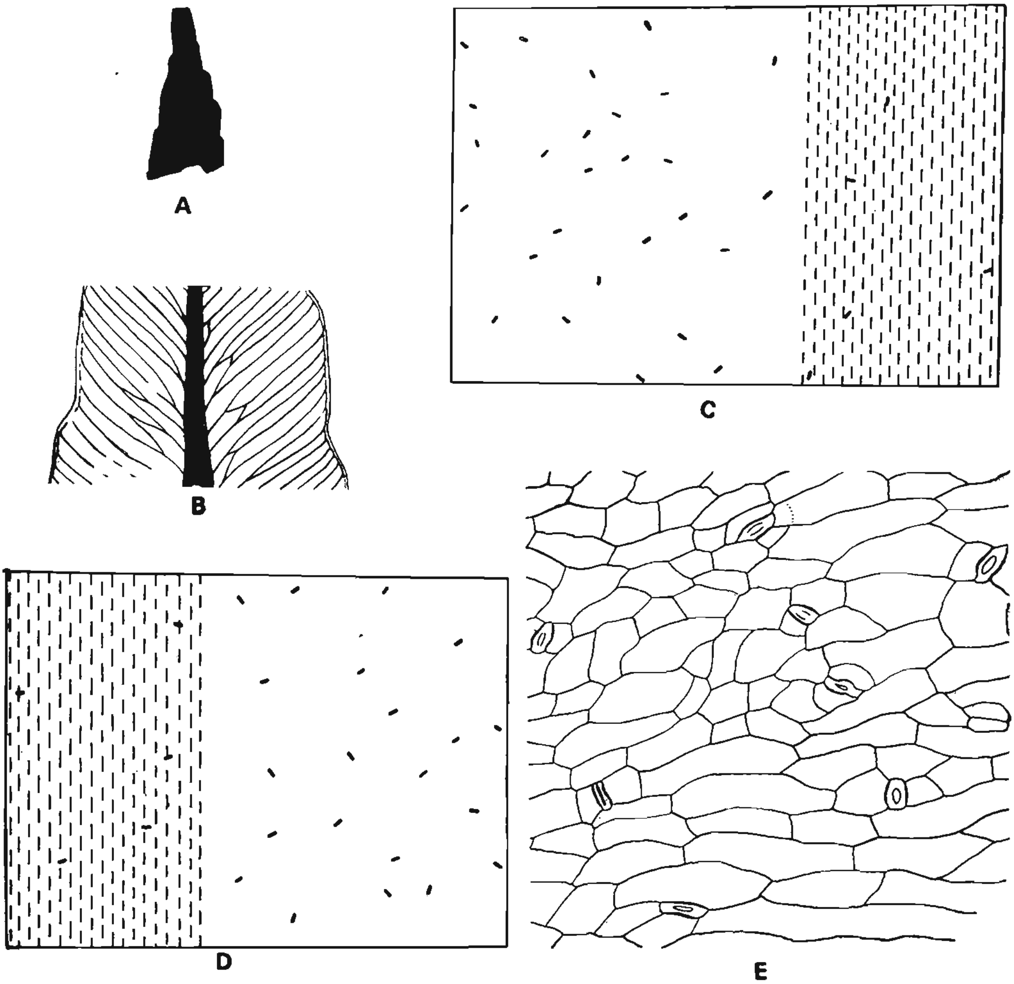
Type Species — *Taeniopteris mareyesiaca* Geinitz, 1876.

Yabiella indica sp. nov.

Pl. 15, figs 121-128; Text-fig. 23A-E

Diagnosis (leaf incomplete at base)— Leaf lanceolate, available length 2.2 cm; 1 cm wide, gradually narrowing to an acute apex; margin distantly lobed. Substance of lamina moderately thick. Midrib distinct, resembling up to apex, ± 1 mm wide at the broadest part of lamina; lateral veins forming an angle of about 50° with the midrib, simple or once forked, at places away from the midrib uniting with adjacent vein at different levels; close to the leaf margin veins about 20 per cm, slightly curving upwards and finally joining a marginal vein. Marginal vein prominent all along leaf margin.

Cuticle 3 μm thick, amphistomatic. Epidermal cells along the midrib mostly squarish, at places polygonal, rarely slightly elongated; cells along lamina margin ± isodiametric, polygonal or squarish; other epidermal cells usually polygonal, elongated along the direction of lateral veins, sometimes isodiametric. Anticlinal walls of epidermal cells ± straight, in the midrib region cell outlines sometimes with nodular thickenings. Periclinal wall usually unspecialized, rarely with a papilla. Stomata ± equally numerous on two surfaces of lamina, evenly distributed and irregularly orientated. Subsidiary cells 4-6 in number (2+2 or 2+4), inner wall of subsidiary



TEXT-FIG. 23 — *Yabiella indica* Pal sp. nov.: **A**, holotype, B.S.I.P. no. 35670, × 1; **B**, part of holotype showing venation, × 4; **C**, **D**, distribution and orientation of stomata in thinner and thicker cuticle surfaces, dotted areas represent the portion of midrib, B.S.I.P. slide no. 35670-2, × 50; **E**, lamina cuticle showing epidermal cells and stomata, B.S.I.P. slide no. 35670-2, × 100.

cells forming stomatal pit often thickened. Stomatal pit rectangular or oval. Guard cells slightly sunken, aperture slit-like, thickly cutinized. Sometimes subsidiary cells accompanied by encircling cells.

Holotype — Specimen no. 35670 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

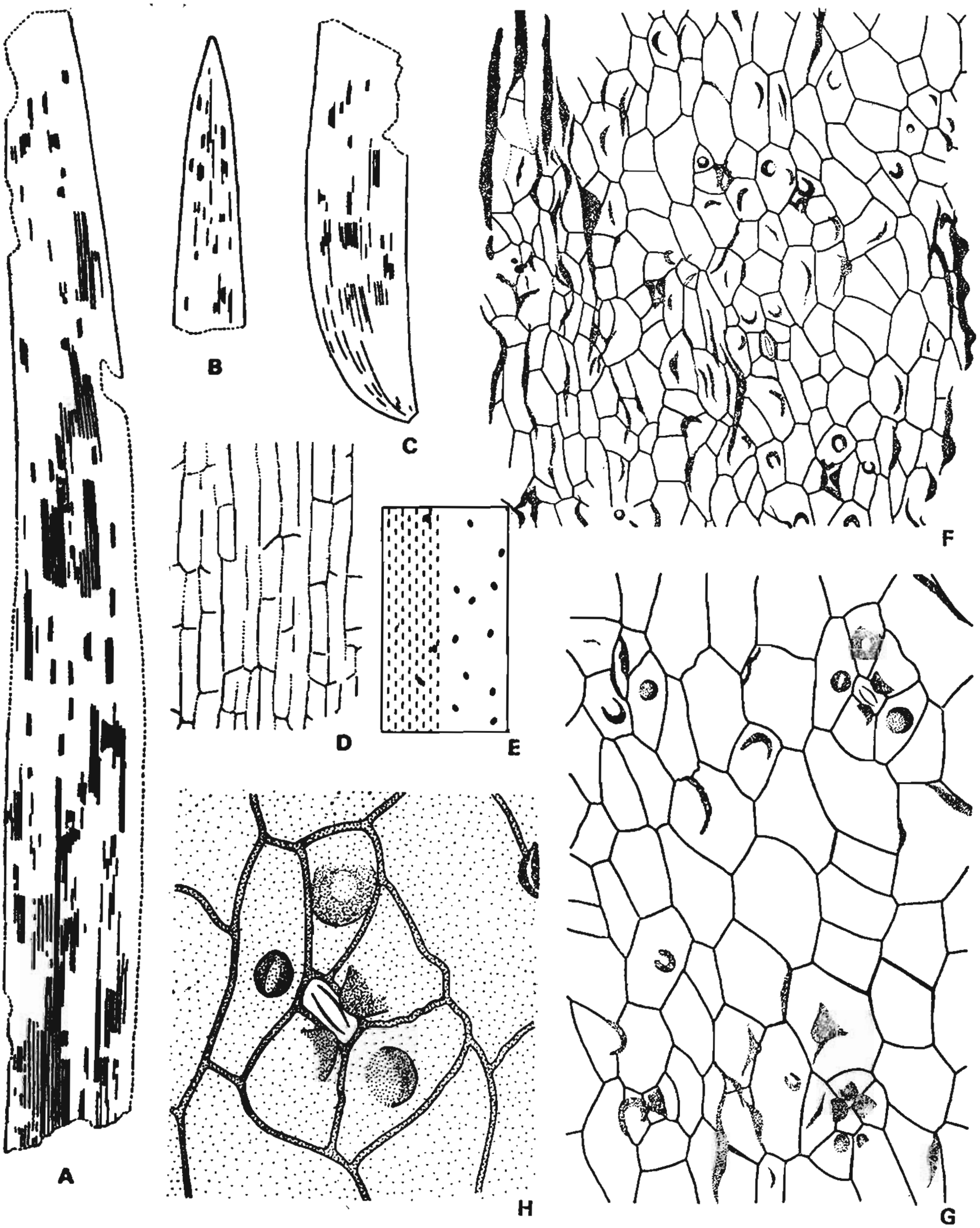
Comparison & discussion — In size, shape and venation pattern *Yabiella indica* resembles closely *Y. brackebushiana* (Kurtz) Oishi described from the Triassic of Argentina (Kurtz, 1921; Jain & Delevoryas, 1967). But their detail comparison is not possible because the cuticular structure of *Y. brackebushiana* is so far not known.

Genus — *Desmiophyllum* Lesquereux, 1878

Desmiophyllum singhii sp. nov.

Pl. 16, figs 129-132; Pl. 17, figs 133-136; Text-fig. 24A-H

Diagnosis — Leaves elongated lanceolate, often slightly falcate, ±2 cm wide, base constricted, margin entire, apex acute.



TEXT-FIG. 24 — *Desmiophyllum singhii* Pal sp. nov.: **A**, holotpye, B.S.I.P. no. 35671, × 1; **B**, fragment showing leaf apex, B.S.I.P. no. 35674, × 1; **C**, basal portion of the lamina, B.S.I.P. no. 35672, × 1; **D**, upper cuticle, B.S.I.P. slide no. 35671-2, × 125; **E**, orientation and distribution of stomata in lower cuticle surface, dotted area represents the venal region, B.S.I.P. slide no. 35671-2, × 20; **F**, lower cuticle showing epidermal cells and stomata, B.S.I.P. slide no. 35671-2, × 125; **G**, a few stomata and epidermal cells, B.S.I.P. slide no. 35671-2, × 250; **H**, a stoma magnified, B.S.I.P. slide no. 35671-2, × 500.

Veins numerous, unbranched, parallel, diverging at leaf base, converging towards apex. Near middle region of lamina concentration of veins about 20 per cm. Interstitial dark strands present between pairs of veins.

Cuticle thin and fragile. Upper surface devoid of stomata, divided into venal and intervenal bands. Cells along vein arranged in longitudinal files, rectangular. Cells between veins squarish or polygonal, nearly isodiametric; surface wall of cells mostly unspecialized, sometimes at places slightly thickened or mottled; lateral- and end-walls straight. Lower cuticle thinner than upper, divided into veinal and intervenal bands. Stomata mainly confined to intervenal bands but at places one or two stomata occurring on a vein. Cells along veins rectangular or elongated polygonal, arranged in longitudinal rows, lateral- and end-walls straight, surface bulging, centrally thickened and forming a low papilla. Cells of intervenal regions polygonal, usually isodiametric, sometimes elongated, outlines straight, surface varied, cells in some flat while in others convex and in still others conspicuously thickened forming a flat hollow papilla. Stomata rather sparsely distributed but more or less evenly scattered in intervenal regions, longitudinally or obliquely orientated. Subsidiary cells 4-6 usually 5, mostly with a distinct hollow papilla either close to stomatal pit or overhanging it but sometimes, medianly placed. Stomatal pit rectangular; guard cells sunken, thinly cutinized; apperture slit-like.

Holotype — Specimen no. 35671 of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Occurrence — East bank of Son River, about 150 m north-west of Giar.

Remarks — Ribbon-shaped leaves found in detached condition are sometimes described as *Phoenicopsis* (Seward, 1903; Retallack, Gould Runnegar, 1977) or *Podozamites* (Anderson, 1978). The affinities of such isolated leaves are uncertain, they may be ginkgoalean (cf. *Phoenicopsis*) or coniferous (cf. *Podozamites*) or even may be cycadalean (cf. detached pinna of *Pseudoctenis*). Therefore, the comprehensive generic name *Desmiophyllum* has been used here to accommodate the Giar specimens.

Desmiophyllum singhii is fairly common in Giar and frequently occurs in bundles. However, no complete leaf has so far been collected. The largest fragment is 17 cm long and is incomplete at both ends. It is considerably narrowed above and slightly narrowed below. I estimate its original length at about 30 cm. Other fragments show bases and apices. The only specimen exhibiting the very base is assymmetrically constricted. The origin of veins at the leaf base could not be seen but as soon as they are visible they are diverging and then running parallel and nowhere could branches be seen. There is no evidence whether the interstitial dark strands are ducts or bundles of fibres. In most of the specimens the lamina are slightly curved, but in a few are straight.

The specific name is after Mr Gopal Singh, Geological Survey of India, who reported plant megafossils from the Giar beds.

Comparison — Ribbon-shaped isolated leaf fragments resembling *Desmiophyllum singhii* have been described from the Middle — Upper Triassic of Australia (as *Phoenicopsis elongatus* by Retallack, 1977) and South Africa (as *Podozamites elongatus* by Anderson, 1978). But the Giar specimens differ from the Australian and South African specimens in having densely spaced veins and in the presence of interstitial strands. The cuticular features of the South African specimens have been desciibed by Anderson (1978). The cuticle of *D. singhii* resembles the cuticle of *Podozamites elongatus* in being hypostomatic and in having papillate cells on lower cuticle. But in the former the surface wall of epidermal cells on lower side are strongly convex in contrast to those of the South African specimens. *D. singhii* resembles *D. gothanii* described from Rhaeto-Liassic of Nürnberg (Gothan, 1914; Florin, 1936) in gross features but the former differs from the latter in having papillate epidermal cells.

GENERAL DISCUSSION

Megafloral assemblage recovered from Janar River Section near Harai is represented by *Lepidopteris madagascariensis* Carpentier, *Dicroidium hughesii* (Feistmantel) Gothan, *D. zuberi* (Szajnocha) Archangelsky, *Dicroidium* sp., *Xylopteris* sp., *Sphenobaiera janarensis* Pal sp. nov. and *Baiera* sp. Out of these *Lepidopteris madagascariensis* and *Dicroidium zuberi* are most common. *D. hughesii* and *D.* sp. are next in abundance;

Xylopteris sp., *Sphenobaiera janarensis* and *Baiera* sp. are rather rare. In having the dominance of *Lepidopteris madagascariensis* and *Dicroidium zuberi* the Harai assemblage resembles the Late Triassic assemblage from the Upper Narrabeen Group of Australia (Townrow, 1966; Betallack *et al.*, 1977) and the Middle Triassic assemblages known from the Upper Beaufort beds of South Africa, Nymboida Coal Measures and Hawkesbury Sandstone of Australia and Esk Trough of Queensland (Townrow, 1966; Anderson & Anderson, 1974; Retallacket *et al.*, 1977; Flint & Gould, 1975). Because of the presence of *Xylopteris* and *Sphenobaiera* the Harai flora may be slightly younger in age. Thus on the basis of megafloral contents the Janar River beds, exposed near Harai, appear to be of Early Upper Triassic age. Among the known Indian Triassic floras, the Harai assemblage resembles the flora known from the Parsora Formation (Lele, 1969; Bose, 1974) in having common occurrence of *Dicroidium hughesii*. Besides *D. hughesii*, no other element is common to these floras. The genus *Glossopteris*, which is dominant in the Upper Permian, has been described from the Parsora Formation (Lele, 1962b), but it is totally missing at Harai. Therefore, the Harai assemblage seems to be relatively younger than the Parsora assemblage.

From Son River Section near Giar, *Lepidopteris stormbergensis* (Seward) Townrow, *Dicroidium giarensis* Pal sp. nov., *D. coriaceum* (Johnston) Townrow, *D. zuberi* (Szajnocha) Archangelsky, *D.* sp. cf. *D. odontopteroides* (Morris) Gothan, *Elatocladus denticulatus* Pal sp. nov., *E. raoi* Pal sp. nov., *Pagiophyllum bosei* Pal sp. nov., *Yabiella indica* Pal sp. nov. and *Desmiophyllum singhii* Pal sp. nov. have been described. Among these *Lepidopteris stormbergensis*, *Dicroidium giarensis* and *Elatocladus denticulatus* are most common. *Dicroidium coriaceum*, *Pagiophyllum bosei* and *Desmiophyllum singhii* are next in abundance. *Dicroidium zuberi*, *D.* sp. cf. *D. odontopteroides*, *Elatocladus raoi* and *Yabiella indica* are rather rare. Singh (in Sastry *et al.*, 1977) reported the occurrence of *Dicroidium*, *Pachypteris*, *Noeggerathiopsis* and *Taeniopteris* from Giar. Unfortunately, at present his collection is not traceable in the Geological Survey of India, Calcutta. But I had the opportunity to show my collection from Giar to Mr Gopal Singh of the Geological Survey of India, Northern Circle, Palaeontology Division and he agreed with me that *Dicroidium*, *Pachypteris*, *Noeggerathiopsis* and *Taeniopteris* identified by him were infact *Dicroidium giarensis*, *Lepidopteris stormbergensis*, *Desiophyllum singhii* and *Yabiella indica*.

The only common element at Harai and Giar is *Dicroidium zuberi*. However, *D. zuberi* is most common at Harai, whereas at Giar it is rather rare. *Lepidopteris* is represented by *L. madagascariensis* at Harai and by *L. stormbergensis* at Giar. *L. madagascariensis* mostly occur in older rocks whereas *L. stormbergensis* is present in the beds of younger age (Townrow, 1960). *Elatocladus* and *Pagiophyllum* which are commonly met with at Giar are totally absent at Harai. Thus as far as the megaflora is concerned the Giar beds seem to be younger in age than the beds exposed in Janar River near Harai. However, a just reverse view was proposed by Maheshwari *et al.* (1973). According to them the Harai beds are younger than the Giar beds. While assigning the Carnian age to the Giar beds and Norian age to Harai beds their conclusion was based on palynological data and they gave the emphasis on the occurrence of the megaspore taxa *Banksisporites pinguis* (Harris) Dettmann, *Horstisporites areolatus* (Harris) Potonié and *Nathorstisporites hopliticus* Jung. So far no megaspore has been described from Giar. However, I have recovered some megaspores from the Giar beds (which are yet to be described), majority of which are similar to *Banksisporites pinguis* (Harris) Dettmann described by Banerji *et al.* (1978) from Harai.

Lepidopteris stormbergensis, *Dicroidium coriaceum* and *D. odontopteroides* are known to occur in the Middle-Upper Triassic of South Africa, Argentina and Australia (Townrow, 1960; Archangelsky, 1968; Anderson & Anderson, 1974; Retallack *et al.*,1977). The genus *Yabiella* is a characteristic Upper Triassic form (Oishi, 1931a, 1931b; Jain & Delevoryas, 1967; Retallack, 1977). *Elatocladus* and *Pagiophyllum* which are commonly met with at Giar are more prevalent in the Indian Jurassic-Lower Cretaceous strata. Thus the megaflora indicates a Late Upper Triassic age for the beds exposed in Son River near Giar.

Pagiophyllum bosei and *Desmiophyllum singhii* from Giar in gross features look similar respectively to *Pagiophyllum* sp. and *Desmiophyllum* sp. described from the Rhaeto-Liassic beds of the Hartala Hill, South Rewa Basin, India (Pal, 1984). The Hartala fossiliferous bed is younger in age than the Tiki beds. It has *Brachyphyllum* and lacks the characteristic Triassic forms like *Lepidopteris* and *Dicroidium*.

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EXPLANATION OF PLATES

Plate 1

1-12. *Lepidopteris madagascariensis* Carpentier
1. B.S.I.P. specimen no. 35606. × 1.
2. B.S.I.P. specimen no. 35607. × 1.
3. Specimen showing lumpy rachis, B.S.I.P. specimen no. 35608. × 1.
4. Specimen showing bipinnate nature of the frond, rachis with low lumps near base (see also text-fig. 1C). B.S.I.P. specimen no. 35609. × 1.
5. B.S.I.P. specimen no. 35610. × 1.
6. Specimen showing paired small lumps over the rachis (see also text-fig. 1D). B.S.I.P. specimen no. 35611. × 1.
7. Bipinnate specimen, B.S.I.P. specimen no. 35612. × 1.
8. B.S.I.P. no. 35613. × 1.
9. A part of specimen in fig. 8 showing venation, photographed in transmitted light after preparing transfer. B.S.I.P. slide no. 35613-1. × 4.
10. Cuticle of lamina showing epidermal cells and some stomata, B.S.I.P. slide no. 35609-1. × 150.
11. Single stoma of lamina, B.S.I.P. slide no. 35609-1. × 400.
12. Single stoma of lamina, showing much well-developed cutin lappets. B.S.I.P. slide no. 35609-1. × 400.

Plate 2

13-19. *Dicroidium hughesii* (Feistmantel) Gothan.

13-15. B.S.I.P. specimen nos. 35616, 35617 and 35618, all × 1.
16. Cuticle of lamina, thinner surface, B.S.I.P. slide no. 35618-1. × 150.
17. Cuticle of lamina, thicker surface, B.S.I.P. slide no. 35618-1. × 150.
18. A stoma from the thinner side of lamina cuticle, B.S.I.P. slide no. 35619-1. × 400.
19. A stoma from the thicker side of the lamina cuticle, subsidiary cells with well-developed papillae overhanging the stomatal pit. B.S.I.P. slide no. 35619-1. × 400.

Plate 3

20-32. *Dicroidium zuberi* (Szajnocha) Archangelsky. Specimen in fig. 5 from Janar River, ENE of Harai, rest of the specimens from Janar River, SSW of Harai.

20-28. B.S.I.P. specimen nos. 35620, 35621, 35622, 35623, 35624, 35625, 35626, 35627 and 35628, all × 1.

29. Specimen photographed in transmitted light after preparing transfer, showing venation of the pinnules. B.S.I.P. slide no. 35526-1 × 4.
30. Cuticle of lamina showing epidermal cells and stomata. B.S.I.P. slide no. 35627-1 × 150.
31. Cuticle of lamina showing distinct striations over epidermal cells. B.S.I.P. slide no. 35627-2 × 200.
32. Cuticle of lamina showing two stomata magnified, B.S.I.P. slide no. 35627-3. × 400.

PLATE 4

33-40. *Dicroidium* sp.

33. B.S.I.P. no. 35639. × 1.
34. B.S.I.P. no. 35640. × 1.
35. Transfer of the specimen in fig. 34 showing venation, B.S.I.P. slide no. 35640-1. × 2.
36. B.S.I.P. no. 35641. × 1.
37. Transfer of the specimen in fig. 36 showing venation. B.S.I.P. slide no. 35641-1. × 2.
38. Cuticle of lamina, thinner side. B.S.I.P. slide no. 35641-2. × 100.
39. Cuticle of lamina, thicker side. B.S.I.P. slide no. 35641-2. × 100.
40. A stoma from lamina cuticle magnified. B.S.I.P. slide no. 35641-2. × 400.
41-43. *[illegible]* sp.
41. B.S.I.P. no. 35642. × 1.
42. Specimen in fig. 41 in transfer showing venation. B.S.I.P. slide no. 35642-1. × 2.
43. Epidermal cells and a stoma of the lamina cuticle. B.S.I.P. slide no. 35642-2. × 400.

PLATE 5

44-48. *Sphenobaiera [illegible]* Pal sp. nov.

44. Holotype. B.S.I.P. specimen no. 35637. × 1.
45. Cuticle from the marginal region of leaf, thicker side, on right hand side of the photograph files of marginal cells are visible, B.S.I.P. slide no. 35637-1. × 150.
46. Thinner side of the cuticle from the marginal region of leaf, files of elongated cells along lamina margin visible on right hand side of the photograph. B.S.I.P. slide no. 35637-1. × 150.
47. Thinner side of the cuticle from middle region of lamina showing elongated cells along vein and isodiametric cells in the intervenal region. B.S.I.P. slide no. 35637-2. × 150.
48. A stoma magnified, B.S.I.P. slide no. 35637-2. × 500.

PLATE 6

49-52. *Baiera* sp.

49. B.S.I.P. slide no. 35638-1. × 2.
50, 51. Cuticle of the two surfaces of lamina. B.S.I.P. slide no. 35638-2. × 100.
52. Cuticle of lamina showing epidermal cells and two stomata magnified. B.S.I.P. slide no. 35638-2. × 400.

53, 54. Equisetaceous leaf-sheath.
53. B.S.I.P. no. 35643. × 1.
54. Same × 2.
55. Equisetaceous nodal diaphragm, B.S.I.P. no. 35644. × 1.

56-58. Equisetaceous stems.

56. B.S.I.P. no. 35645, note the rounded scars in the nodal region × 1.
57. B.S.I.P. no. 35646. × 1.
58. B.S.I.P. no. 35647. × 2.

PLATE 7

59-66. *Lepidopteris stormbergensis* (Seward) Townrow.

59. Apical portion of a pinna. B.S.I.P. no. 35648. × 1.
60. Pinna fragment showing minute lumps over the rachis. B.S.I.P. no. 35649. × 1.
61. Pinna fragment showing larger pinnules with deeply lobed margins. B.S.I.P. no. 35650. × 1.
62. Specimen showing bipinnate nature of leaf, B.S.I.P. no. 35651. × 1.
63. Specimen showing the apical portion of the bipinnate leaf. B.S.I.P. no. 35652. × 2.
64. Specimen in fig. 62 photographed under liquid paraffin. × 2.
65, 66. Cuticle of the two surfaces of lamina. B.S.I.P. slide no. 35141, fig. 65 representing the thicker side of the cuticle with papillate epidermal cells, fig. 66 the thinner side of cuticle having ordinary epidermal cells devoid of papillae × 100.

PLATE 8

67-74. *Lepidopteris stormbergensis* (Seward) Townrow.

67. Transfer of the specimen in pl. 7, fig. 61, photographed in transmitted light showing venation of the pinnules. B.S.I.P. slide no. 35650-1. × 3.
68. Transfer of a pinna apex from the counterpart of the specimen in pl. 7, fig. 62, photographed in transmitted light showing venation in pinnules, B.S.I.P. slide no. 35652cp-1. × 2.
69, 70. Cuticle of the two surfaces of pinnules, ordinary epidermal cells of both surface papillate. B.S.I.P. slide no. 35651-2. × 100.
71. Cuticle of lamina showing epidermal cells and two stomata. B.S.I.P. slide no. 35652-1. × 200.
72. A stoma from lamina cuticle showing six subsidiary cells, note the solid projections from the subsidiary cell outline. B.S.I.P. slide no. 35141. × 400.
73. Cuticle of lamina showing two stomata with their subsidiary cells in contact. B.S.I.P. slide no. 35650-1. × 400.
74. A stoma, B.S.I.P. slide no. 35650-2. × 400.

PLATE 9

75-81. *Dicroidium [illegible]* Pal sp. nov.

75. B.S.I.P. no. 35655. × 1.
76. Specimen photographed in transmitted light after preparing transfer showing the venation, B.S.I.P. slide no. 35655-1. × 2.
77, 78. B.S.I.P. nos. 35656 and 35658. Both × 1.
79. Holotype. B.S.I.P. no. 35659. × 1.
80. Cuticle of the lamina, thicker side, note the elongated cells along a vein. B.S.I.P. slide no. 35659-1. × 100.
81. Cuticle of lamina, thinner side. B.S.I.P. slide no. 35659-1. × 100.

Plate 10

82-89. *Dicroidium coriaceum* (Johnston) Townrow

82, 83. B.S.I.P. slide nos. 8142 and 8143. Both × 1.
84. B.S.I.P. slide no. 8144 × 5.
85. Specimen in fig. 83 magnified. × 4.
86. Specimen in fig. 82 magnified. × 4.
87, 88. Cuticle of two surfaces of lamina. B.S.I.P. slide no. 8142-1 × 150.
89. A stoma of lamina cuticle magnified. B.S.I.P. slide no. 8142-2 × 500.

90, 91. *Dicroidium zuberi* (Szajnocha) Archangelsky
90. B.S.I.P. no. 35662. × 1.
91. Cuticle of lamina, B.S.I.P. slide no. 35662-1. × 100.

Plate 11

92, 93. *Dicroidium zuberi* (Szajnocha) Archangelsky

92. Transfer of the specimen in pl. 10, fig. 90, photographed in transmitted light, showing the venation. B.S.I.P. slide no. 35662-1. × 6.
93. Cuticle of lamina showing epidermal cells and two stomata. B.S.I.P. slide no. 35662-2 × 400.

94-98. *Dicroidium* sp. cf. *D. odontopteroides* (Morris) Gothan.

94. B.S.I.P. no. 35663 × 2.
95, 96. Cuticle of two surfaces of lamina respectively, B.S.I.P. slide no. 35663-2. × 100.
97. A typical stoma. B.S.I.P. slide no. 35663-2 × 400.
98. An unusual stoma showing cutinization around the stomatal pit. B.S.I.P. slide no. 35663-3 × 400.

Plate 12

99-104. [illegible] Pal sp. nov.

99. Specimen showing distal portion of a branched twig. B.S.I.P. no. 35664. × 1.
100. Holotype. B.S.I.P. no. 35665. × 1.
101, 102. Cuticles of the two surfaces of leaf, B.S.I.P. slide no. 35664-1 × 50.
103. Cuticle of leaf showing epidermal cells and some stomata. B.S.I.P. slide no. 35665-1. × 100.
104. A stoma with 7 subsidiary cells. B.S.I.P. slide no. 35665-1. × 400.

Plate 13

105, 106. [illegible] Pal sp. nov.

105. B.S.I.P. no. 35667 × 2.
106. Cuticle of leaf showing three stomata with their subsidiary cells in contact. B.S.I.P. slide no. 35665-2. × 400.

107-108. [illegible] Pal sp. nov.

107. Holotype. B.S.I.P. no. 35668 × 1.
108. Same. × 2.
109. Cuticle of lamina. B.S.I.P. slide no. 35668-1. × 150.
110. A stoma with rectangular stomatal pit surrounded by four subsidiary cells. B.S.I.P. slide no. 35668-1. × 500.
111. A stoma showing five subsidiary cells surrounding the polygonal stomatal pit. B.S.I.P. slide no. 35668-1. × 500.

Plate 14

112. *Pagiophyllum* sp. from East Bank of Son River, NW of [illegible], preserved as impression. B.S.I.P. no. 35669. × 1.

113-120. [illegible] Pal sp. nov.

113. Holotype, a small fragment of a twig with four spirally borne leaves. B.S.I.P. slide no. 8144 × 1.
114. Twig fragment with two leaves. B.S.I.P. slide no. 8145 × 2.
115. A detached leaf, dorsal view. B.S.I.P. slide no. 8146. × 4.
116. Fragmentary twig bearing two leaves, B.S.I.P. slide no. 8147. × 1.
117. Holotype × 4.
118. Cuticle of two surfaces of a laterally compressed leaf showing distribution of stomata, B.S.I.P. slide no. 8144-1. × 50.
119. Cuticle of lamina showing epidermal cells and stomata, B.S.I.P. slide no. 8144-1 × 100.
120. A stoma magnified, B.S.I.P. slide no. 8144-2 × 500.

Plate 15

121-128. *Yabeiella indica* Pal sp. nov.

121. Holotype, B.S.I.P. no. 35670 × 1.
122. Holotype, photographed in transmitted light after preparing transfer showing venation. B.S.I.P. slide no. 35670-1. × 2.5.
123. Part of the transfer of the holotype magnified. B.S.I.P. slide no. 35670-1 × 6.
124, 125. Cuticle of the midrib region of the leaf, thicker and thinner sides respectively, B.S.I.P. slide no. 35670-2. × 100.
126, 127. Cuticle of lamina, thicker and thinner sides respectively. B.S.I.P. slide no. 35670-2 × 100.
128. A stoma photographed before maceration showing the guard cells. B.S.I.P. slide no. 35670-2. × 400.

Plate 16

129-132. *Desmiophyllum* [illegible] Pal sp. nov.

129. Basal portion of the leaf, B.S.I.P. no. 35672. × 1.
130. B.S.I.P. no. 35673. × 1.
131. Holotype, showing the fragments of leaves preserved parallelly, B.S.I.P. no. 35671 × 1.
132. Transfer of a leaf fragment, photographed in transmitted light showing details of venation and interveinal strands. B.S.I.P. slide no. 35671-1. × 15.

Plate 17

133-136. [illegible] Pal sp. nov.

133. Upper cuticle of the leaf, B.S.I.P. slide no. 35671-2. × 50.
134. Lower cuticle of leaf, veinal area. B.S.I.P. slide no. 35671-2 × 150.
135. Lower cuticle of leaf, interveinal region, B.S.I.P. slide no. 35671-2 × 150.
136. A stoma magnified. B.S.I.P. slide no. 35671-2. × 500.


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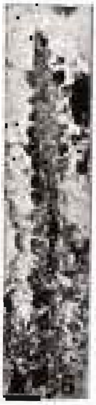
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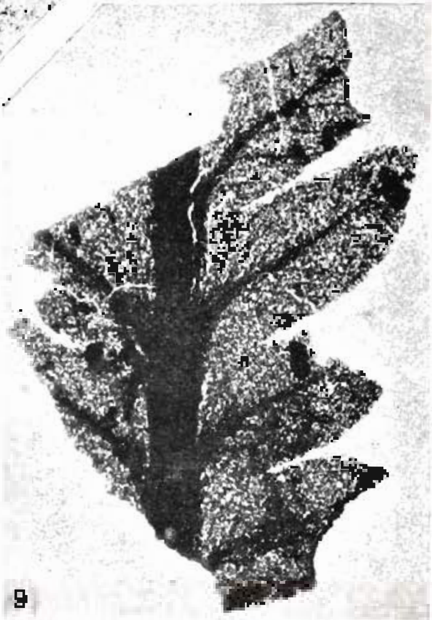
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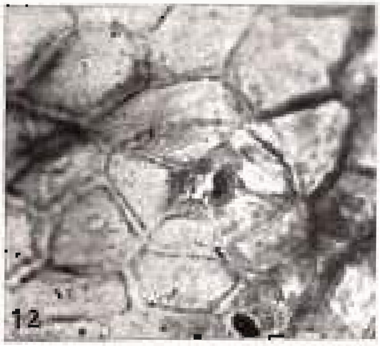
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PLATE 1


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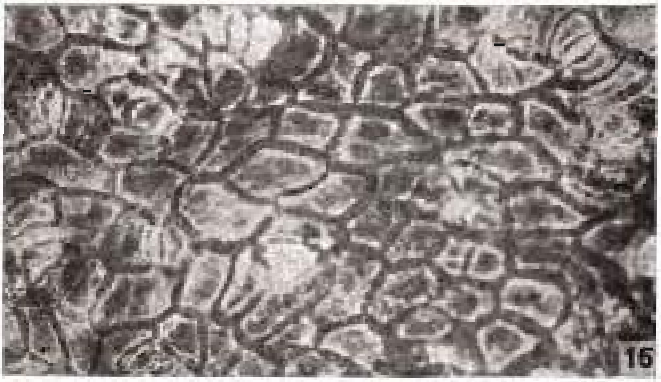
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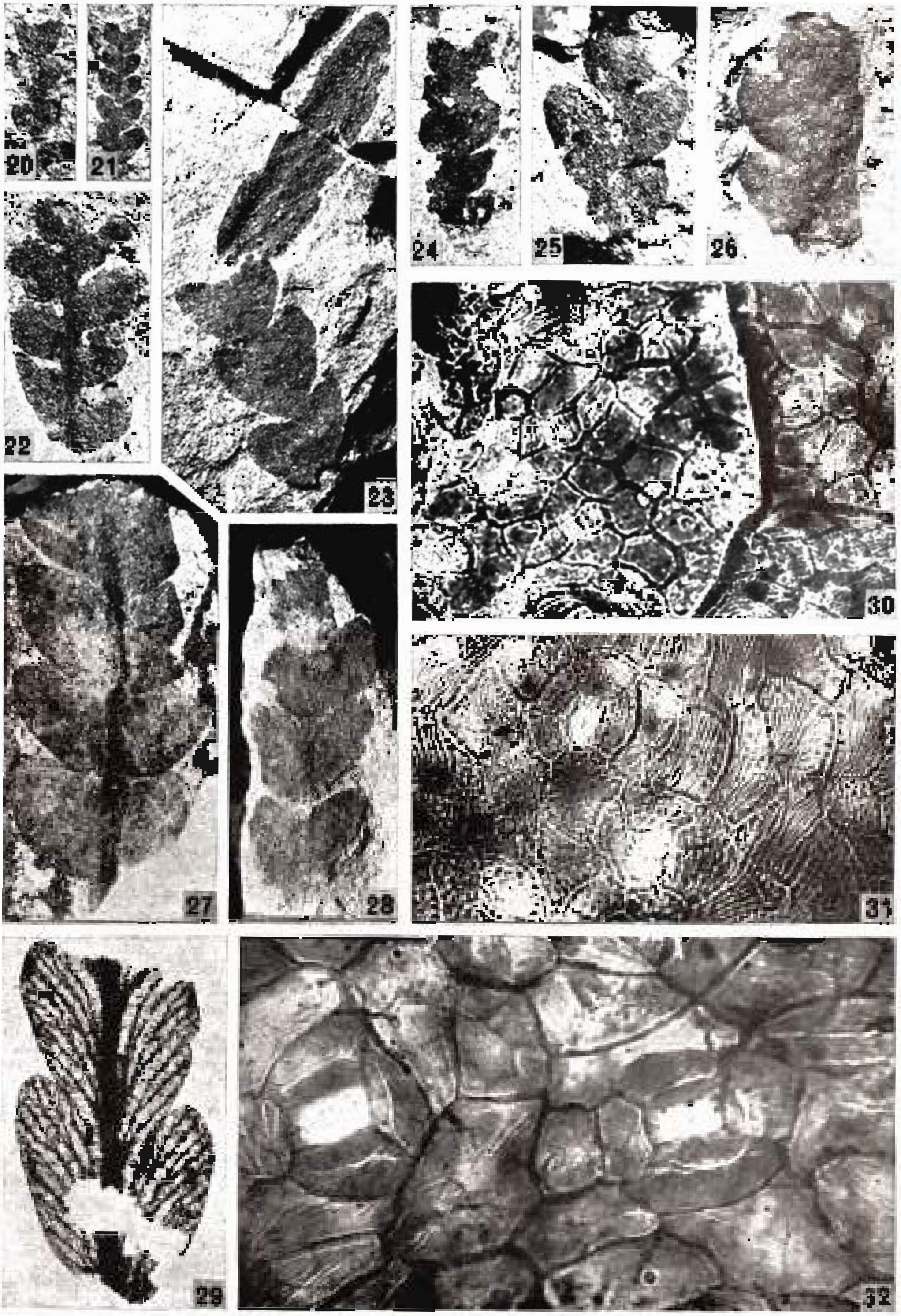

PLATE 3

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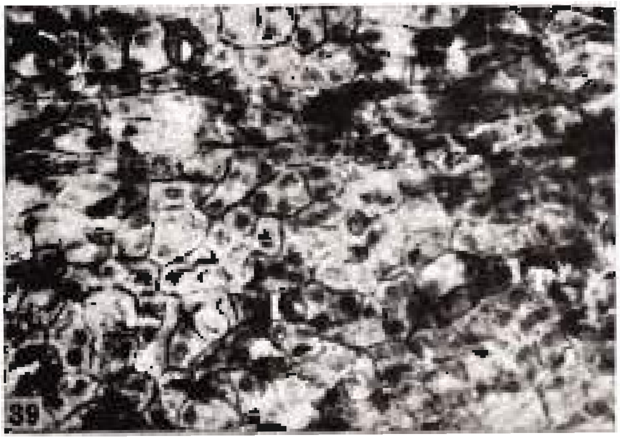

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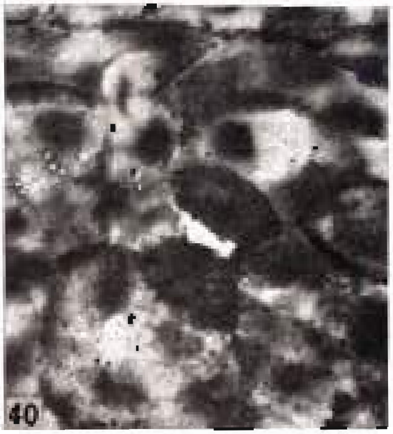

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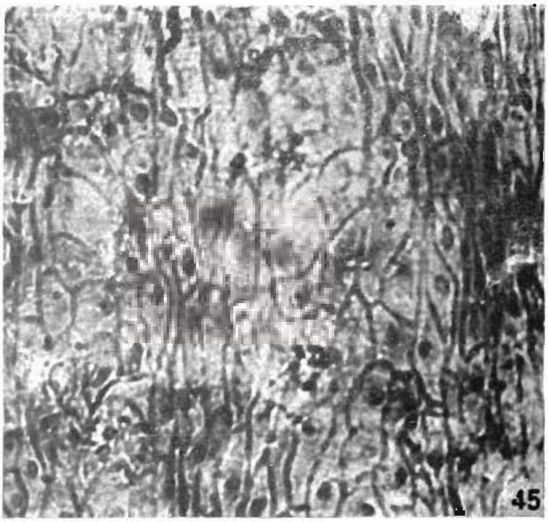
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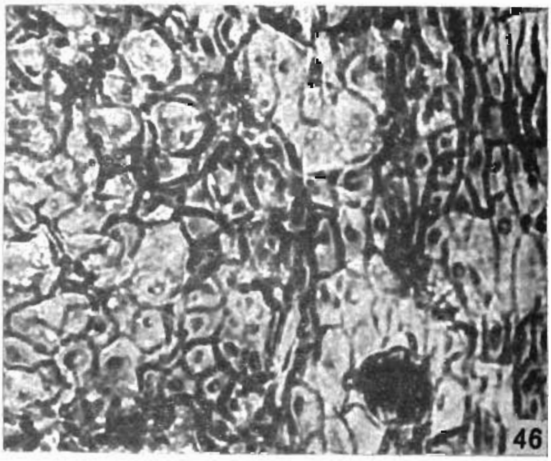
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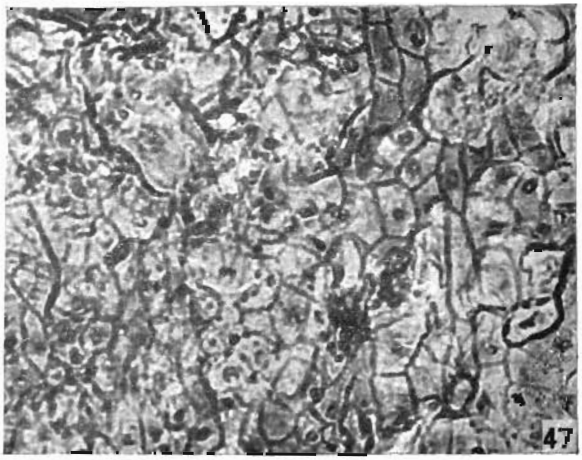
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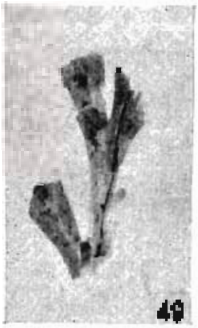
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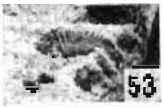
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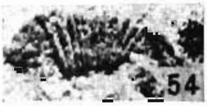
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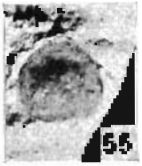
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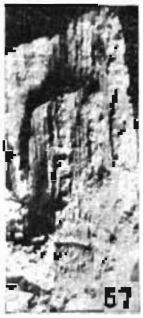
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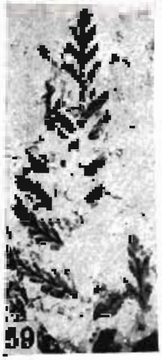
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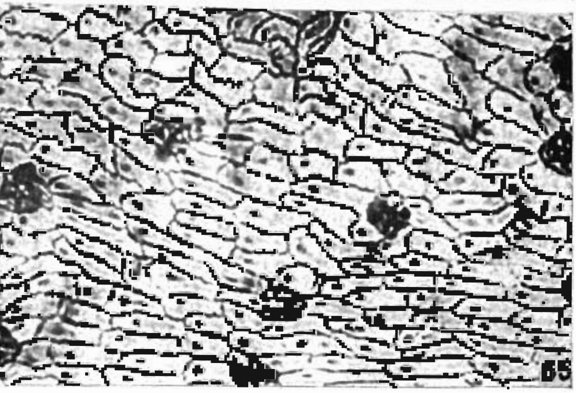
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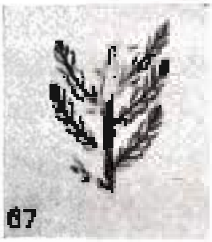
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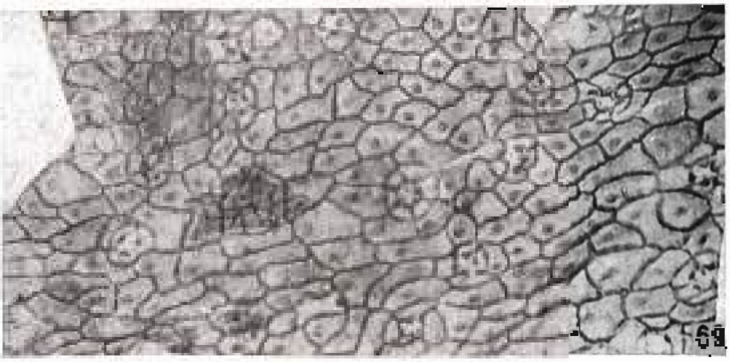
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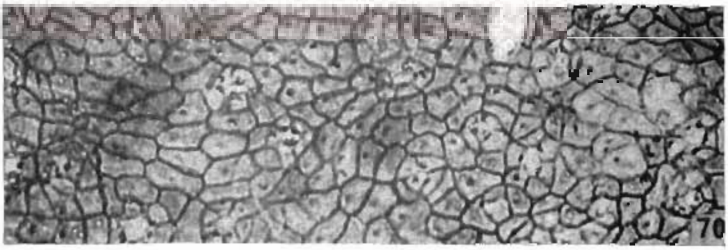
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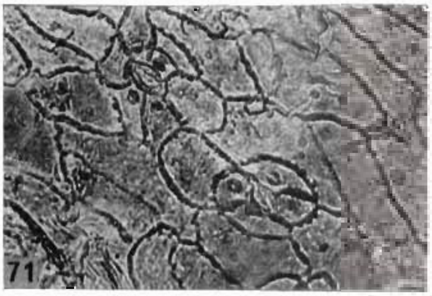
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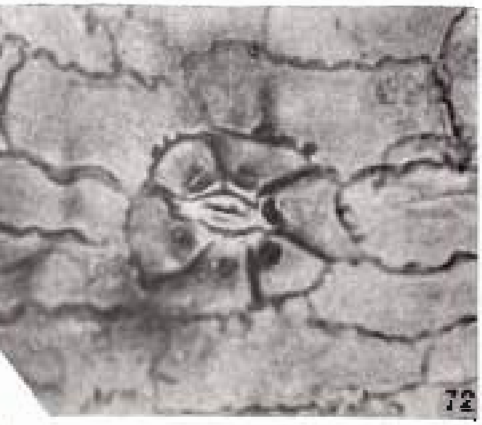
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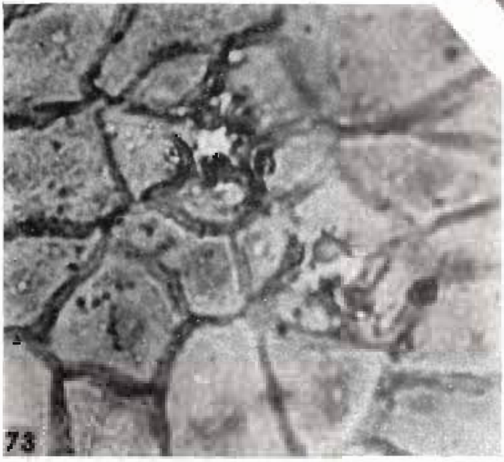
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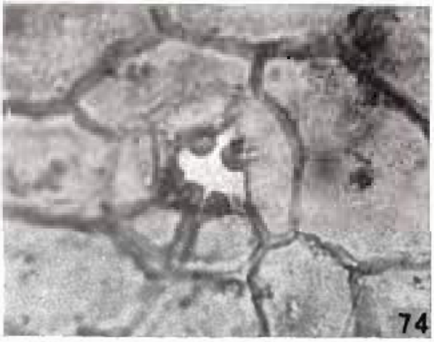
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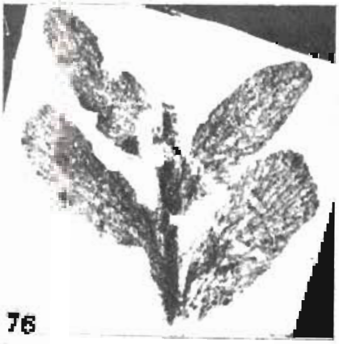
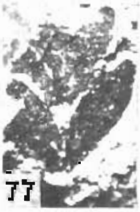
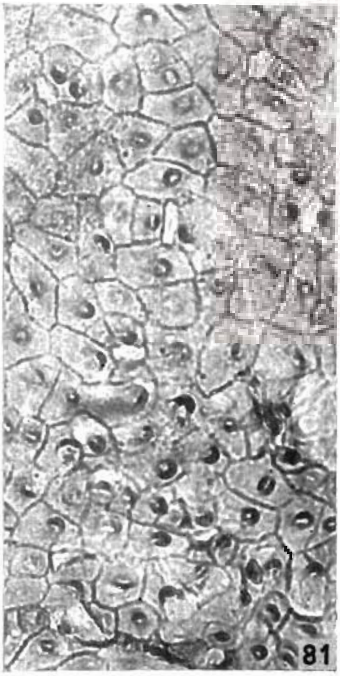
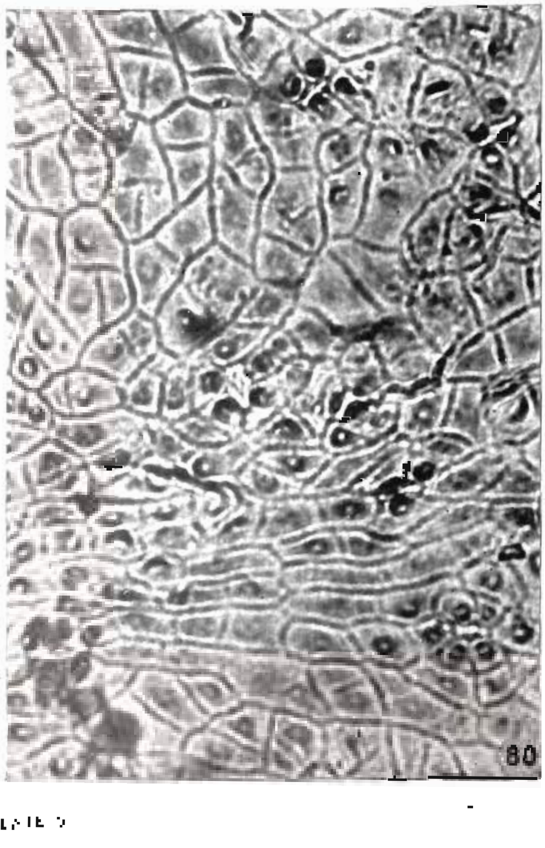
PLATE X









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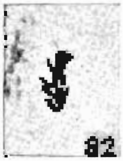
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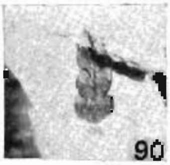
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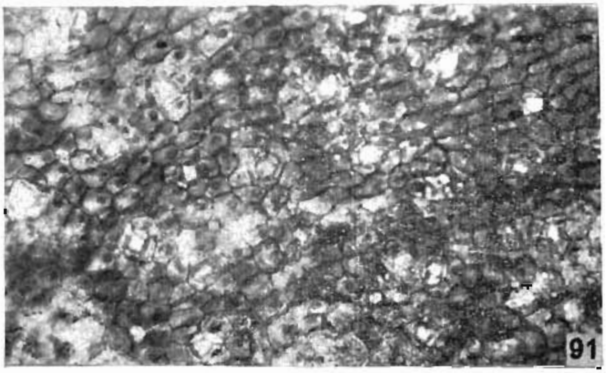
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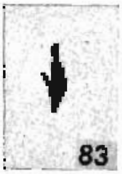
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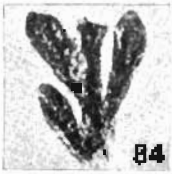
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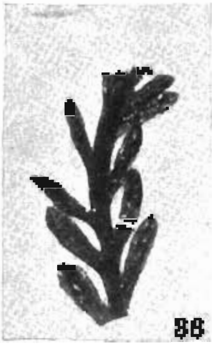
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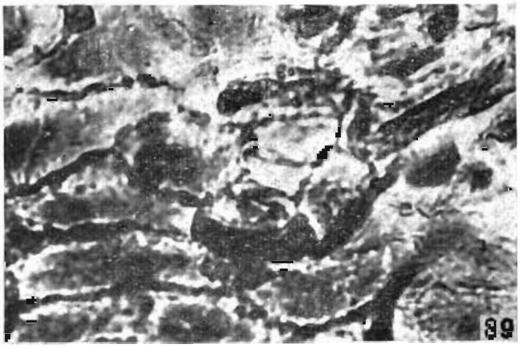
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PLATE 10


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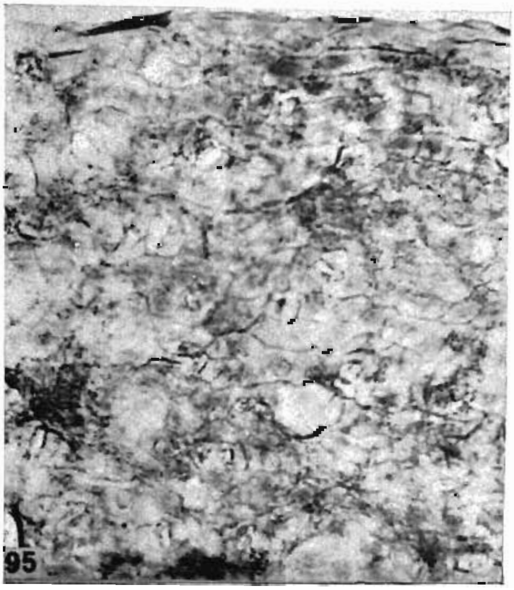
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PLATE 16

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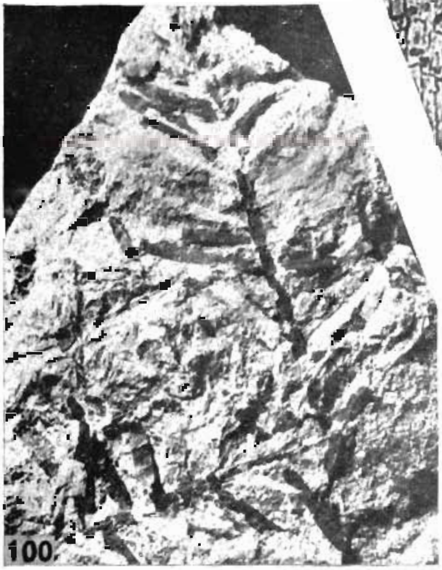

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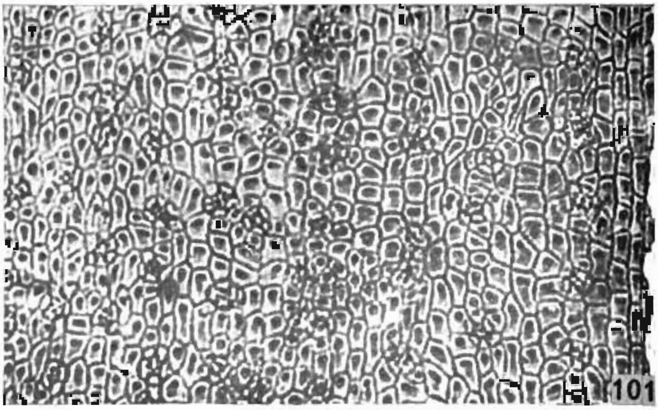

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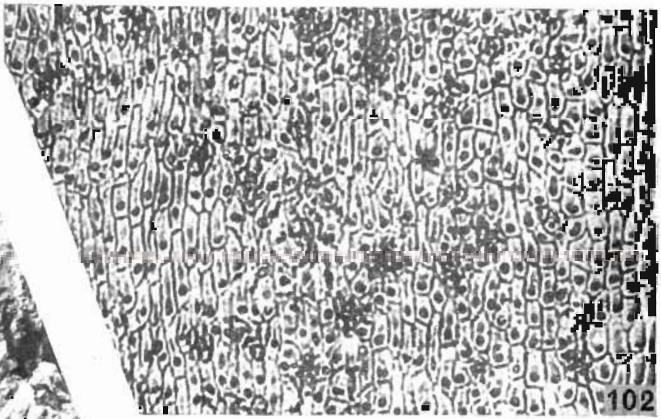

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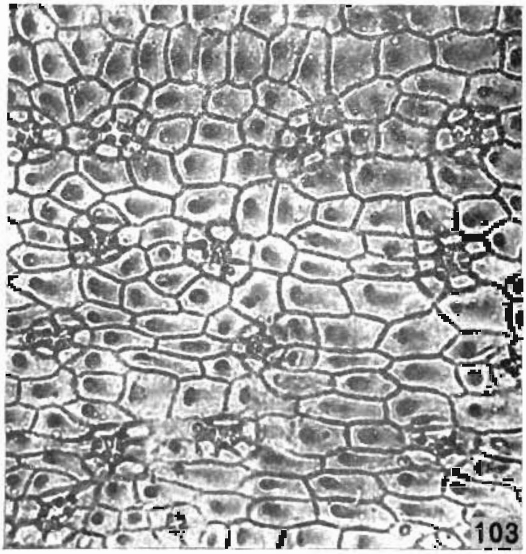

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PLATE 12


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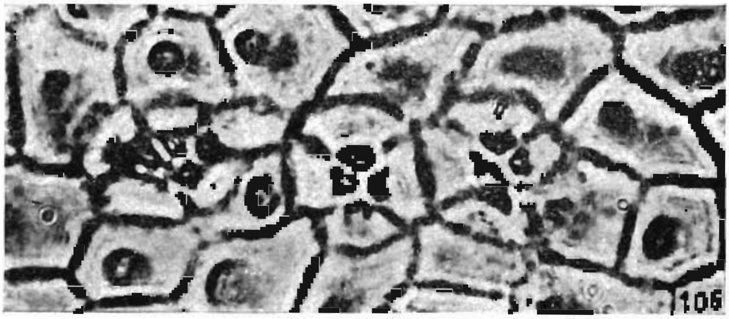
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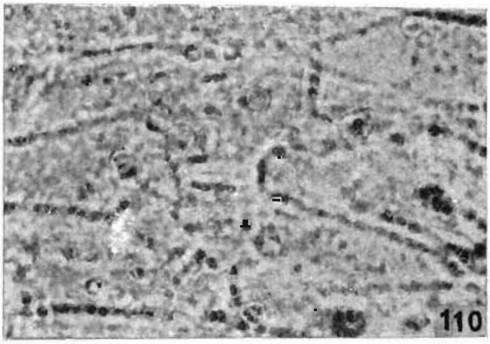
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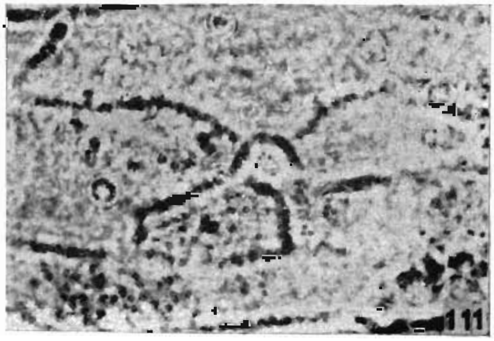
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PLATE 13


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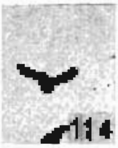
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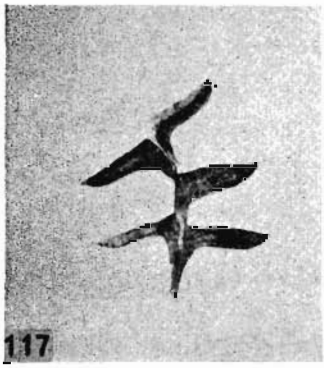
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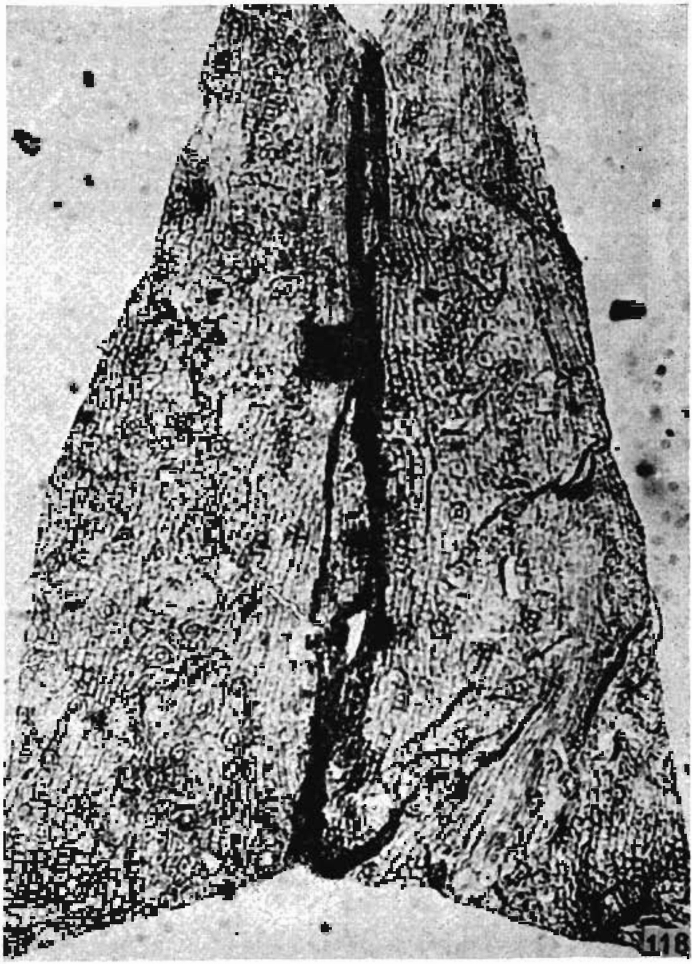
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PLATE 14


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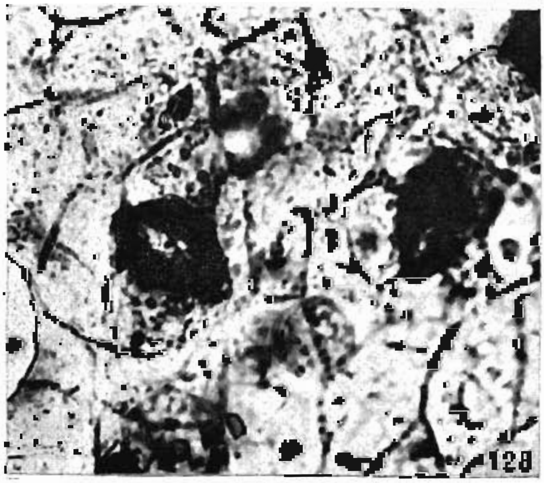
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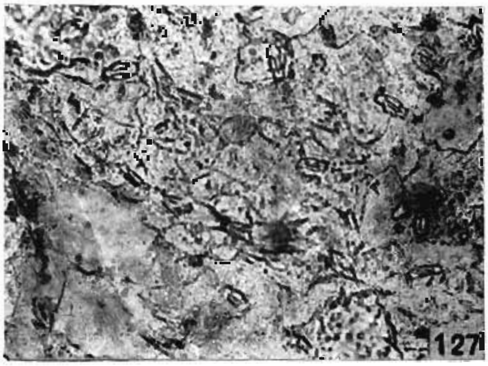
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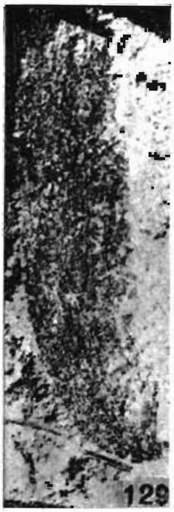
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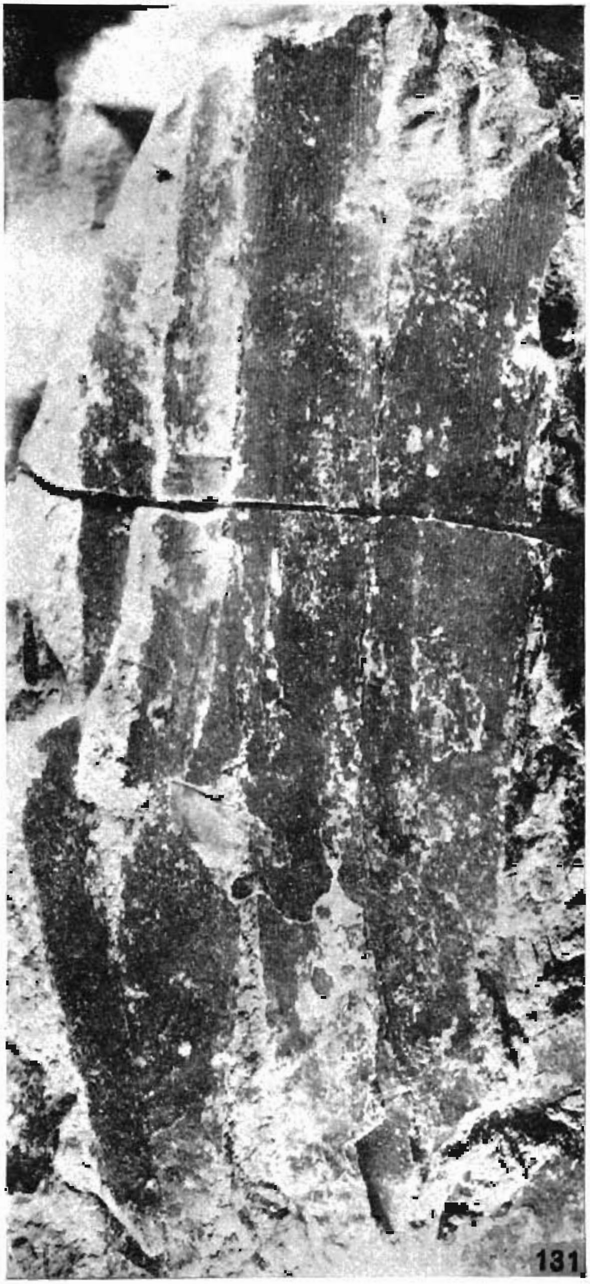
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PLATE 16


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PLATE 37

The Palaeobotanist, **32**(3): 310-320, 1984.

FOSSIL WOODS OF *LOPHOPETALUM* AND *ARTOCARPUS* FROM THE DECCAN INTERTRAPPEAN BEDS OF MANDLA DISTRICT, MADHYA PRADESH, INDIA

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ABSTRACT

Two fossil dicotyledonous woods, viz., *Lophopetalumoxylon indicum* gen. et sp. nov. from Ghughua near Shahpura and *Artocarpoxylon deccanensis* sp. nov. from a new locality of Sylthar in Mandla District, Madhya Pradesh have been described. The former closely compares with *Lophopetalum littorale* Ridley of Celastraceae while the latter shows maximum resemblance with *Artocarpus heterophyllus* Lamk. of Moraceae.

Key-words — Xylotomy, *Lophopetalum*, *Artocarpus*, Celastraceae, Moraceae, Deccan Intertrappean beds (India).

साराँश

मध्य प्रदेश (भारत) के मँडला जनपद की दक्खिन अन्तर्ट्रैपी संस्तरों से लोफ़ोपैटेलम् एवं आर्टोकार्पस – राकेश चन्द्र मेहरोत्रा, उत्तम प्रकाश एवं मोहन बलवंत बाँडे

मध्य प्रदेश के मँडला जनपद में शाहपुरा के समीपस्थ घुघुआ ग्राम के पास से लोफ़ोपैटेलमॉक्सीलॉन इन्डिकम् नव वंश व नव जाति तथा सिलथर के पास एक नवीन स्थान से आर्टोकार्पोक्सीलॉन दक्खिनेन्सिस नव जाति का वर्णन किया गया है। इनमें से पहला काष्ठ सिलेस्ट्रेसी कुल के लोफ़ोपैटेलम् लिटोरॅल रिडले तथा दूसरा काष्ठ मौरेसी कुल के आर्टोकार्पस हैट्रोफिल्लस लैम्क॰ से घनिष्ठ समानता प्रदर्शित करता है।

INTRODUCTION

THE flora of the Deccan Intertrappean beds is generally considered as a single unit even though the plant fossils may often belong to the Intertrappean layers far removed from each other in time and space (Lakhanpal, 1973). Lakhanpal (1973) has divided the Deccan Intertrappean flora into the following three florules or assemblages which can easily be distinguished on the basis of their fossil forms: (i) the Nagpur-Chhindwara assemblage, (ii) the Rajahmundry assemblage, and (iii) the Bombay-Malabar-Worli assemblage. Beside the above assemblages, since nearly last one decade a good number of plant fossils have also been described from various Deccan Intertrappean localities of Mandla District in Madhya Pradesh. Here the fossil flora is very rich in dicotyledonous woods which have been listed by Bande and Prakash (1983). These woods have been assigned to the families Verbenaceae, Annonaceae, Myrtaceae, Flacourtiaceae, Euphorbiaceae, Sterculiaceae, Tiliaceae, Elaeocarpaceae, Rutaceae, Guttiferae, Icacinaceae, Lecythidaceae, Anacardiaceae, Burseraceae, Meliaceae and Lauraceae. Two more dicotyledonous woods, viz., *Zizyphoxylon mandlaensis* and *Aglaioxylon mandlaense* have further been described from this area (Trivedi & Srivastava, 1982a, 1982b). In addition to the dicotyledonous woods, a few fruits, viz., *Hyphaeneocarpon indicum* (Bande, Prakash & Ambwani, 1982) and *Euphorbiocarpon drypeteoides* (Mehrotra, Prakash & Bande, 1983) resembling the modern genera *Hyphaene* and *Drypetes* and four monocotyledonous woods of Palmae are also known from here (Lakhanpal, Prakash & Ambwani, 1979; Ambwani, 1983; Ambwani & Prakash, 1983). The studies made so far on these fossils indicate that the fossil flora of Mandla District constitutes a separate assemblage of plants (Bande & Prakash, 1982).

In this paper two more fossil woods resembling *Lophopetalum* of Celastraceae and *Artocarpus* of Moraceae are being described. The former was collected from the already known locality of Ghughua situated near Shahpura, while the latter was recovered from near the village Sylthar situated at a distance of about 22 km south-west of Shahpura in Mandla District of Madhya Pradesh.

SYSTEMATIC DESCRIPTION

FAMILY — CELASTRACEAE

Genus — *Lophopetalumoxylon* gen. nov.

Lophopetalumoxylon indicum gen. et sp. nov.

Pl. 1, figs 1, 3; Pl. 2, figs 5, 6, 7

Material — A single piece of wood measuring about 10 cm in length and 4 cm in diameter.

Topography — *Wood* diffuse-porous. *Growth rings* absent (Pl. 1, fig. 1). *Vessels* usually small, sometimes medium-sized, mostly in radial multiples of 2-5, occasionally solitary and also in tangential pairs or clusters, and evenly distributed, about 13-31 per sq mm; tyloses wanting (Pl. 1, fig. 1; Pl. 2, fig. 5). *Parenchyma* apotracheal in the form of 2-5 seriate continuous to interrupted tangential bands (Pl. 1, fig. 1; Pl. 2, fig. 5). *Xylem rays* closely spaced, 12-19 per mm, almost exclusively uniseriate, rarely with paired cells, made up of procumbent cells only, 8-12 μm in width and 4-48 cells or 80-720 μm in height (Pl. 1, fig. 3); ray tissue homogeneous (Pl. 2, fig. 6). *Fibres* arranged in tangential bands alternating with bands of parenchyma (Pl. 2, fig. 5).

Elements — *Vessels* mostly circular to oval when solitary, with flat contact walls when in multiples, t.d. 40-140 μm, r.d. 40-160 μm; vessel members 200-460 μm long with oblique to transverse ends; perforations simple; intervessel pit-pairs bordered, alternate, small, about 4 μm in diameter, circular to oval in shape with linear apertures (Pl. 2, fig. 7). *Parenchyma cells* thin-walled, 52-198 μm in height and 20-40 μm in diameter. *Ray cells* thin-walled, 32-52 μm in radial length and 16-32 μm in tangential height. *Fibres* semi-libriform, polygonal in cross-section, non-septate, 12-16 μm in diameter and 440-520 μm in length (Pl. 1, fig. 3); interfibre pits could not be seen.

Affinities — Important anatomical characters of the fossil wood, namely small to medium-sized vessels, apotracheal bands of parencyma, fine, homogeneous xylem rays, and non-septate fibres strongly indicate its affinities with the family Celastraceae (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Nigam, 1963). Further, it also shows a superficial resemblance with the modern woods of Sapindaceae. However, in this family the parenchyma is paratracheal banded and terminal as against the apotracheal bands of parenchyma present in our fossil wood (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Ramesh Rao, 1963).

Based on the wood structure, Nigam (1963, pp. 180, 181) has given a key for the identification of various Indian genera of Celastraceae. According to this key it is evident that our fossil wood shows maximum similarity with the woods of *Lophopetalum* Wight and *Kokoona littoralis* Lawson mainly in possessing thin, apotracheal bands of parenchyma and in having vessels arranged in short, radial rows. According to Hill's Index Kewensis (1921-25) *Lophopetalum littorale* Ridley and *Kokoona littoralis* Lawson are synonyms. Therefore, the fossil wood has been compared with various modern species of *Lophopetalum* including *L. littorale*. Slides of six species of *Lophopetalum*, viz., *L. fimbriatum* Wight, *L. wightianum* Arn., *L. littorale* Ridley, *L. wallichii* Kurz, *L. javanicum* Turcz. and *L. pachyphyllum* King were examined in detail. Besides, photographs and published descriptions of *Lophopetalum fimbriatum*, *L. wallichii*, *L. wightianum*, *L. littorale* and *Lophopetalum* sp. were also studied (Pearson & Brown, 1932; Henderson, 1953; Nigam, 1963). After detailed comparison with all these species, it was found that the fossil wood is very similar to *Lophopetalum littorale*. A number of modern wood samples of *L. littorale* belonging to different parts of the Indian subcontinent were available for study in the Forest Research Institute, Dehradun. All these samples exhibited some anatomical variations and the anatomical characters of the fossil wood were found to occur in different wood samples of this species belonging to different areas. In shape, size and distribution of vessels, the fossil wood is very similar to the wood sample no. 2300 belonging to Andamans but in another wood sample no. 2513 from Burma, the vessels are bigger and fewer in number than in the present fossil wood. In parenchyma and ray pattern the fossil wood shows close similarity with all the samples of *L. littorale* so far studied. In the fossil as well as in the modern species, the parenchyma is in 2-5 seriate, continuous to interrupted, tangential bands and the rays are almost exclusively uniseriate made up of procumbent cells only. Lastly the fibres in the fossil wood are non-septate like that of the wood sample nos. 2513 and 278. However, in the wood sample no. 2300 they are septate.

As the present fossil wood shows close similarity with the modern woods of *Lophopetalum littorale* in its anatomical characters (Pl. 1, figs 1-4) and this being the first record of a fossil wood of *Lophopetalum*, it has been placed under a new genus *Lophopetalumoxylon*. The specific name *Lophopetalumoxylon indicum* indicates its occurrence in India.

Although this is the first record of a fossil wood of *Lophopetalum*, the leaves, fruits and woods of Celastraceae are not unknown in the fossil state from different parts of the world. A wood of Celastraceae was first described from the Tertiary of Egypt as *Celastrinoxylon affine* (Schenk, 1888). Later on few more species were further described from different parts of the world. These are: *Celastrinoxylon celastroides* and *Celastrinoxylon* sp. from Egypt (Kraüsel, 1939), *C. meyeri* Schönfeld (1956) from Germany, *C. dakshinense* Ramanujam (1960) from South India and *Celastrinoxylon* sp. Kramer (1974) from south-east Asia. However, the species described by Ramanujam (1960) has recently been transferred to *Ailanthoxylon indicum* Prakash (Awasthi, 1975). The leaves of Celastraceae were recorded as *Celastrinites venulosus* from the Tertiary of France (Saporta, 1865a, 1868) and *Celastrophyllum attenuatum* from the Tertiary of Java (Goeppert, 1854). A capsule of Celastraceae was described by Berry (1930) from the Eocene of Wilcox Group as *Celastrocarpus eocenicus* and another fruit belonging to this family was also described as *Celastrinanthium hauchecornei* (Conwentz, 1886) from the Early Tertiary amber deposits of West Prussia.

Lophopetalum Wight embraces about 20 Indo-Malayan species of trees and shrubs and is distributed in India, Malaya and Java (Nigam, 1963; Santpau & Henry, 1973). According to Santpau and Henry (1973) three species of this genus are found in India. *Lophopetalum littorale* with which the fossil wood shows maximum similarity, grows in Pegu and Tenasserim especially on the inundated low lands along rivers (Gamble, 1972).

GENERIC DIAGNOSIS

Lophopetalumoxylon gen. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* usually small, sometimes medium-sized, mostly in radial multiples occasionally solitary; perforations simple; intervessel pit-pairs bordered, alternate and small. *Parenchyma* in continuous to interrupted, apotracheal tangential bands. *Xylem rays* fine; ray tissue homogeneous. *Fibres* semi-libriform and non-septate or septate.

Genotype — *Lophopetalumoxylon indicum* gen. et sp. nov.

SPECIFIC DIAGNOSIS

Lophopetalumoxylon indicum sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* usually small to sometimes medium-sized, t.d. 40-140 μm, r.d. 40-160 μm, mostly in radial multiples of 2-5, occasionally solitary and also in tangential pairs or clusters, 13-31 per sq mm; vessel members 200-460 μm long; perforations simple; intervessel pit-pairs bordered, alternate, about 4 μm in diameter, circular to oval in shape with linear apertures. *Parenchyma* apotracheal in the form of 2-5 seriate, continuous to interrupted, tangential bands. *Xylem rays* almost exclusively uniseriate, rarely with paired cells, 12-19 per mm; ray tissue homogeneous. *Fibres* semi-libriform and non-septate, 12-16 μm in diameter and 440-520 μm in length.

Holotype — B.S.I.P. Museum no. 35535.

Locality — Ghughua near Shahpura in Mandla District of Madhya Pradesh.

Age — Early Tertiary.

FAMILY — MORACEAE

Genus — *Artocarpoxylon* Prakash & Lalitha, 1978

Artocarpoxylon deccanensis sp. nov.

Pl. 2, figs 9, 10, 11, 13; Pl. 3, figs 14, 16

Material — A single piece of secondary wood measuring about 25 cm in length and 12 cm in diameter. It shows quite good preservation.

Topography — *Wood* diffuse-porous. *Growth rings* absent (Pl. 3, fig. 14). *Vessels* mostly small to medium in size, very rarely large, solitary and in radial multiples of 2-4-(6), rarely in tangential pairs or clusters, evenly distributed, 9-20 per sq mm (Pl. 3, fig. 14); tyloses occasionally present. *Parenchyma* paratracheal, usually vasicentric, forming 1-3 seriate sheath, rarely aliform and confluent enclosing adjacent vessels (Pl. 2, fig. 9; Pl. 3, fig. 14). *Xylem rays* 1-6 (mostly 4-6) seriate, 7-9 per mm (Pl. 3, fig. 16); ray tissue heterogeneous (Pl. 2, fig. 11); rays divisible into two types: (i) uniseriate rays made up of either only upright cells or both of procumbent and upright cells, 12-16 µm wide and 3-8 cells or 120-320 µm in height, and (ii) multiseriate rays made up of procumbent cells in the central portion and 1-2 (usually 1) rows of upright cells at one or both the ends, 20-64 µm wide and 9-48 cells or 200-800 µm in height; sheath cells present in some of the rays; end to end ray fusion rarely seen. *Fibres* aligned in somewhat irregular radial rows in between the xylem rays. *Latex tubes* observed in some of the rays, circular to oval in shape and 16-36 µm in diameter (Pl. 2, fig. 10).

Elements — *Vessels* circular to oval when solitary, with flat contact walls when in groups, t.d. 80-180 µm, r.d. 64-220 µm, vessel members 200-400 µm in length with oblique to horizontal ends; perforations simple; intervessel pit-pairs bordered, alternate, 8-12 µm in diameter, circular to oval in shape with lenticular apertures (Pl. 2, fig. 13). *Parenchyma cells* thin-walled, 20-40 µm in diameter and 32-80 µm in length. *Ray cells* thin-walled; procumbent cells 12-24 µm in tangential height and 28-72 µm in radial length, upright cells 40-100 µm in tangential height and 20-40 µm in radial length. *Fibres* non-libriform, oval to polygonal in cross section, non-septate (Pl. 3, fig. 16), 12-20 µm in diameter and 525-1260 µm in length; interfibre pits not seen.

Affinities — Important anatomical characters of the fossil wood are small to medium-sized vessels, vasicentric to rarely aliform and confluent parenchyma, 1-6 seriate heterocellular xylem rays with latex tubes and non-libriform and non-septate fibres. All these characters indicate the affinities of the present fossil wood with the woods of the family Moraceae (Pearson & Brown, 1932; Tippo, 1938; Metcalfe & Chalk, 1950; Kribs, 1959). Beside Moraceae, the fossil wood also shows some similarities with Datiscaceae. However, the latex tubes in the rays and non-storied fibres and parenchyma of the fossil wood separate it from Datiscaceae where fibres and parenchyma are storied and the latex tubes are absent (Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Kribs, 1959). Among the various genera of Moraceae, the fossil wood shows similarity with the modern woods of the genus *Artocarpus* Forst. and differs from other taxa of this family especially in the presence of sheath cells and latex tubes in xylem rays and in having mostly vasicentric parenchyma (Pearson & Brown, 1932; Tippo, 1938; Metcalfe & Chalk, 1950; Kribs, 1959). Wood slides of 10 species of *Artocarpus* available at the Xylaria of the Birbal Sahni Institute of Palaeobotany, Lucknow and the Forest Research Institute, Dehradun, were examined in detail for comparison with the fossil. These species are *Artocarpus chaplasha* Roxb., *A. gomeziana* Wall. ex Trec., *A. heterophyllus* Lamk., *A. hirsuta* Lamk., *A. elastica* Reinw., *A. lakoocha* Roxb., *A. sericicarpus* Jarrett, *A. sepicanus* Diels, *A.* [illegible] Jarrett and *A. nitida* Trec. Besides, photographs and published descriptions of *Artocarpus communis* Forster, *A. cumingiana* Trecul, *A. chaplasha* Roxb., *A. lakoocha* Roxb., *A. gomeziana* Wall. ex Trec. and *A. hirsuta* Lamk. were also studied (Kanehira, 1924a, 1924b; Pearson & Brown, 1932; Henderson, 1953; Kribs, 1959; Purkayastha, Juneja & Kazmi, 1976). Thus after a detailed comparison with all these species it was found that the fossil shows close resemblance with *Artocarpus heterophyllus*. Several wood samples of *A. heterophyllus* collected from different places of the Indian subcontinent were also examined. The study shows that there is some variation in the amount of parenchyma and in the size and distribution of vessels in all these different wood samples (see F.R.I. slide nos. 756, 3444, 8184 & 8252). The fossil wood shows maximum similarity with F.R.I. slide no. 8184 in parenchyma and vessel distribution, shape and size of intervessel pits and in the structure of fibres and xylem rays (Pl. 2, figs 12-13; Pl. 3, figs 14-17) but differs from it only in the size of vessels which are slightly smaller in the fossil. However, similar size, shape and distribution of vessels may be seen in F.R.I. slide no. 8252.

Prakash and Lalitha (1978) instituted a new genus *Artocarpoxylon* for the fossil woods of *Artocarpus* of Moraceae and described *Artocarpoxylon kartikcherraensis* from the Tertiary of Assam which is the only record of a fossil wood of this genus from India and abroad. However, the present fossil wood is different from *A. kartikcherraensis* in size and distribution of vessels and in parenchyma pattern. In the present fossil wood the vessels are mostly small to medium in size (t.d. 80-180 μm) against mostly medium to large (t.d. 105-315 μm) vessels in *A. kartikcherraensis*. Moreover, the frequency of the vessels in *A. kartikcherraensis* is comparatively very less, i.e. only 2 to 3 per sq mm, whereas the vessels are 9-20 per sq mm in the present fossil. Further, the parenchyma is vasicentric to mostly aliform and rarely confluent joining two adjacent vessels in *A. kartikcherraensis* whereas in the present fossil wood, it is comparatively less, varying from mostly vasicentric to rarely aliform and confluent joining two adjacent vessels. As the fossil wood is quite different from *Artocarpoxylon kartikcherraensis*, it is being described as a new species of *Artocarpoxylon*, *Artocarpoxylon deccanensis* sp. nov., the specific name indicating its occurrence in the Deccan Trap country.

Besides the woods, leaves and fruit remains of *Artocarpus* are also known in the fossil state from the different parts of the world. First record of this genus is in 1851 when Unger described a leaf fragment as *Artocarpidium integrifolium* from the Tertiary of Austria. Saporta (1865a, 1868) also described the leaves as *Artocarpoides* [illegible] and *A. conocephaloidea* from the Eocene of France. Two more species *A. bellii* Henry and *A.* [illegible] were later on described from the Eocene of Texas (Ball, 1931). Dawson (1894) also described a leaf fragment from the Cretaceous of Canada as *Artocarpophyllum occidentale*. Nathorst (1908) described both leaves and parts of the fruit of *Artocarpus dicksoni* from the Cretaceous of Greenland. He also pointed out that certain leaves described by Lesquereux (1874, 1878) as *Myrica* (?) *lessigiana* and *Myrica* (?) *lessigii* from the Laramie beds of Boulder County, Colorado were really those of *Artocarpus*. So, Knowlton (1893) transferred both these species of *Myrica* into *Artocarpus lessigiana* (Lesquereux) Knowlton. In 1883, Lesquereux further recorded certain leaves as *Aralia pungens* from the Denver Formation at Golden, Colorado. Hollick (1899) discovered similar type of leaves from the Lower Eocene of Louisiana and recognized their true affinity as belonging to the genus *Artocarpus* and described them as *Artocarpus pungens*. He also recorded a new species *A. dubia*. Its two more species *A. similis* and *A. dissecta* were later on described by Knowlton (1917) from the Cretaceous of the Raton and Vermejo formations. Ball (1930) collected a number of leaves of *Artocarpus* from the Eocene of Texas and by their detailed study he concluded that all the above five species of *Artocarpus* are actually variations of one and the same species and these five species should be combined under the name *Artocarpus lessigiana* (Lesquereux) Knowlton which has the right of priority. From India also leaf impressions of *Artocarpus* have been reported. Sharma and Gupta (1972) described a leaf of *Artocarpus murreeensis* from the Lower Miocene Murree shales near Lirianwali in Thanamandi area of Jammu and Kashmir. Recently Bhattacharyya (1983) also described a leaf impression of *Artocarpus garoensis* from the Tura Formation of Eocene age in Garo Hills, Meghalaya.

Artocarpus is an evergreen or deciduous tree consisting of 50 species which are widely distributed through Indo-Malaya and Polynesia, a few occurring in tropical Africa, tropical Australia and Madagascar (Pearson & Brown, 1932; Santapau & Henry, 1973). There are 18 species of *Artocarpus* indigenous to India (Santapau & Henry, 1973). *Artocarpus heterophyllus*, with which the present fossil shows a near resemblance, is a native of Western Ghats (Hooker, 1885; Santapau & Henry, 1973).

SPECIFIC DIAGNOSIS

Artocarpoxylon deccanensis sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* mostly small to medium-sized, t.d. 80-180 µm, r.d. 64-220 µm, solitary and in radial multiples of 2-4 (6), circular to oval, 9-20 per sq mm, occasionally tylosed; vessel members 200-400 µm long with oblique to horizontal ends; perforations simple; inter-vessel pit-pairs bordered, alternate, 8-12 µm in diameter, circular to oval with lenticular apertures. *Parenchyma* usually vasicentric forming 1-3 seriate sheath, rarely aliform and confluent enclosing adjacent vessels. *Xylem rays* 1-6 (mostly 4-6) seriate, occasionally with latex tubes, 7-9 per mm; ray tissue heterogeneous; rays divisible into two types: (i) uniseriate rays made up of only upright cells or with both procumbent and upright cells, and (ii) multiseriate rays made up procumbent cells in the central portion and 1-3 (usually 1) rows of upright cells at one or both the ends; sheath cells present in some of the rays; end to end ray fusion rarely seen. *Fibres* non-libriform, oval to polygonal in cross section, non-septate, 12-20 µm in diameter and 160-620 µm in length; interfibre pits could not be seen.

Holotype — B.S.I.P. Museum no. 35536.

Locality — Sylthar near Shahpura in Mandla District of Madhya Pradesh.

Age — Early Tertiary.

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EXPLANATION OF PLATES

PLATE 1

1. *Lophopetaloxylon indicum* gen. et sp. nov. — Cross section of the fossil wood in low power showing shape, size and distribution of vessels and bands of parenchyma. × 30; slide no. 7043.
2. *Lophopetalum littorale*. Cross section of the modern wood showing similar shape, size and distribution of vessels and parenchyma bands. × 30.
3. *Lophopetaloxylon indicum* gen. et sp. nov. — Tangential longitudinal section of the fossil wood showing exclusively uniseriate xylem rays and non-septate fibres. × 80; slide no. 7044.
4. *Lophopetalum littorale* — Tangential longitudinal section of the modern wood showing similar type of xylem rays and fibres. × 80.

PLATE 2

5. *Lophopetaloxylon indicum* gen. et sp. nov. — Magnified cross section of the fossil wood showing parenchyma bands alternating with the bands of fibres. × 90; slide no. 7043.
6. *Lophopetaloxylon indicum* gen. et sp. nov. — Radial longitudinal section of the fossil wood showing homocellular xylem rays composed of procumbent cells. × 190; slide no. 7045.
7. *Lophopetaloxylon indicum* gen. et sp. nov. — Magnified intervessel pit-pairs of the fossil wood. × 500; slide no. 7044.
8. *Lophopetalum littorale* — Similar intervessel pit-pairs of the modern wood. × 500.
9. *Artocarpoxylon deccanensis* sp. nov. — Magnified cross section of the fossil wood showing parenchyma distribution. × 15; slide no. 7046.

10. *Artocarpoxylon deccanensis* sp. nov.—Tangential longitudinal section magnified to show latex tube in the ray. × 165; slide no. 7047.
11. *Artocarpoxylon deccanensis* sp. nov.— Radial longitudinal section of the fossil wood showing heterocellular xylem rays. × 120; slide no. 7048.
12. *Artocarpus heterophyllus* — Magnified intervessel pit-pairs of the modern wood. × 310.
13. *Artocarpoxylon deccanensis* sp. nov.— Magnified intervessel pit-pairs. × 310; slide no. 7047.

PLATE 3

14. *Artocarpoxylon deccanensis* sp. nov.— Cross section of fossil wood in low power showing shape, size and distribution of vessels and parenchyma pattern. × 45; slide no. 7046.
15. *Artocarpus heterophyllus* — Cross section of the modern wood showing similar distribution of vessels and parenchyma. × 45.
16. *Artocarpoxylon deccanensis* sp. nov.— Tangential longitudinal section of the fossil wood showing xylem rays and non-septate fibres. × 70; slide no. 7047.
17. *Artocarpus heterophyllus* — Tangential longitudinal section of the modern wood showing similar xylem rays and fibres. × 70.


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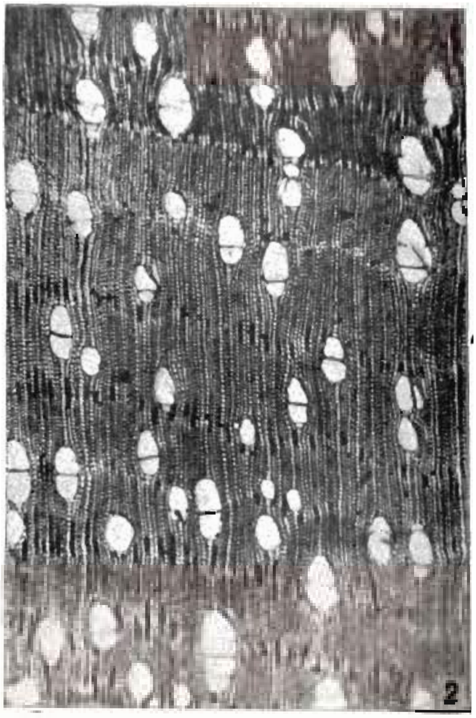
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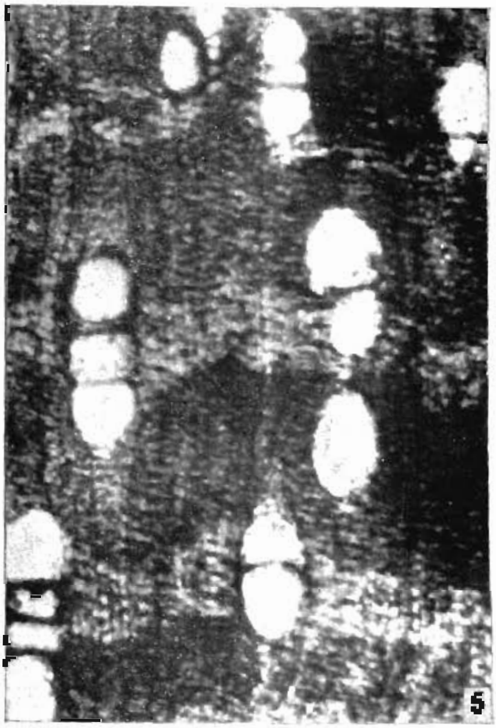
PLATE 1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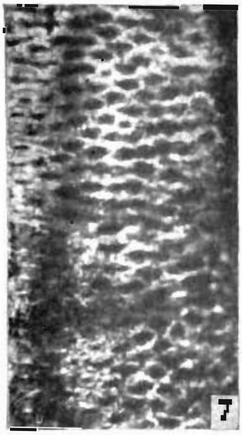
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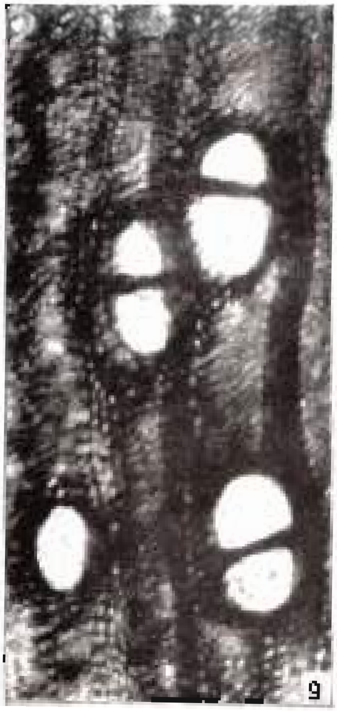
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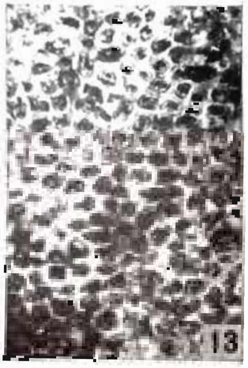
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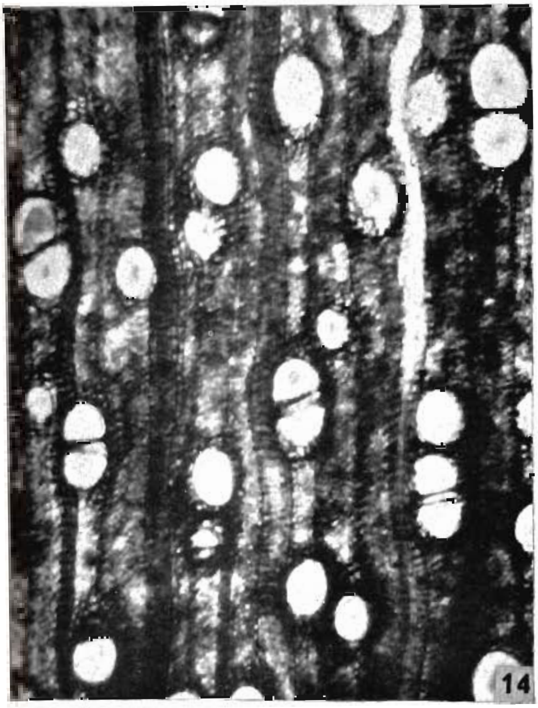
PLATE 2



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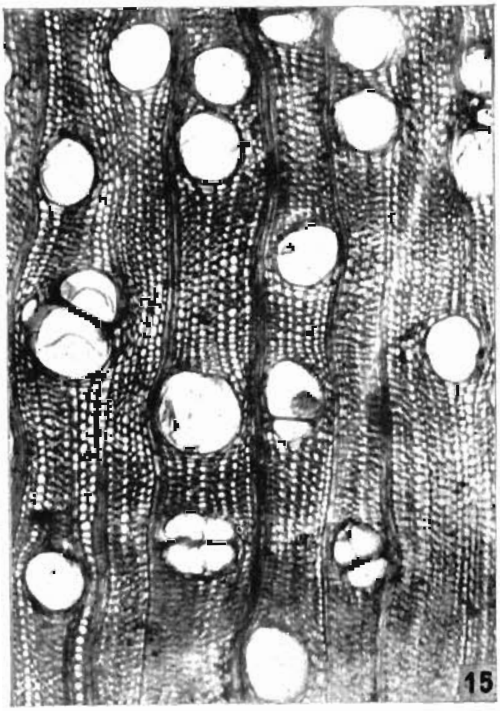

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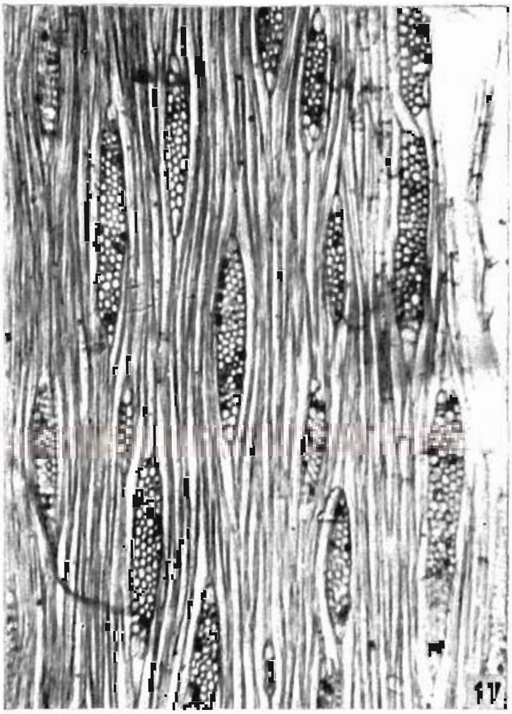

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PLATE 2

The Palaeobotanist, **32**(3): 321-325, 1984.

MORPHOTAXONOMY OF HETEROPHYLLOUS LYCOPSID SHOOT FROM THE RAJMAHAL HILLS, INDIA

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ABSTRACT

Morphology of the herbaceous lycopsid shoot occurring commonly in several localities of Rajmahal Hills, India has been studied. In earlier records the fossil was figured as *Araucarites*(?) *gracilis*. Later, it was described as *Cheirolepis gracilis* and thereafter as *Lycopodites gracilis*. However, the present study reveals that the form of the shoot is precisely like that of a creeping *Selaginella* having two dorsal and two ventral ranks of microphyllous leaves. Therefore, it is being described here as *Selaginellites gracilis*.

Key-words — Morphotaxonomy, Lycopsida, *Selaginellites*, Rajmahal Hills, Jurassic (India).

साराँश

भारत में राजमहल पहाड़ियों से विषमपर्णी लाइकोप्सिड प्ररोह का बाह्यवर्गीकीय अध्ययन – पंकज कुमार पाल

भारत में राजमहल पहाड़ियों में कई स्थानों से साधारणतया मिलने वाले शाखीय लाइकोप्सिड प्ररोह का बाह्य-आकारिकीय अध्ययन किया गया है। इससे पहले के अभिलेखों में यह प्ररोह अॅराकेराइटिस? ग्रेसिलिस के नाम से विदित था। परन्तु इसके बाद यह चीरोलेपिस ग्रेसिलिस तथा तत्पश्चात् लाइकोपोडाइटिस ग्रेसिलिस के नाम से वर्णित किया गया। तथापि, इस अध्ययन से यह व्यक्त होता है कि यह प्ररोह निश्चित रूप से विसर्पी सिलेजिनेला का है जिसमें कि अपाक्ष एवं अभ्यक्ष की ओर अलग-अलग दो प्रकार की पत्तियाँ विद्यमान हैं। अतएव इस प्ररोढ को सिलेजिनेलाइटिस ग्रेसिलिस से नामाँकित किया गया है।

INTRODUCTION

THE lycopsid shoots, occurring commonly in several localities of the Rajmahal Hills, were first considered as a conifer (Oldham & Morris, 1863; Feistmantel, 1877). Later, Feistmantel (1880) thought them to be a lycopod and transferred to the genus *Lycopodites* Brongniart. Sharma (1971) described such shoots as *Selaginellites* sp. A and *Selaginellites* sp. B. Later, Sharma (1980) in a review paper considered that the heterophyllous lycopsid shoots from the Rajmahal Hills belong to three distinct taxa, viz., *Lycopodites gracilis*, *Selaginellites* sp. A and *Selaginellites* sp. B.

My observations are based on about 50 specimens collected from Bindaban, Chunakhali and Balbhadri Hill of the Rajmahal Hills. I have also re-examined the holotype and other specimens figured by Oldham and Morris (1863) and the figured specimens of Bose and Sah (1968).

DESCRIPTION

***Selaginellites* Zeiller, 1906**

Selaginellites gracilis (Oldham & Morris) Pal comb. nov.

Pl. 1, figs 1-3, 5, 6; Text-fig. 1A-F

Basionym:

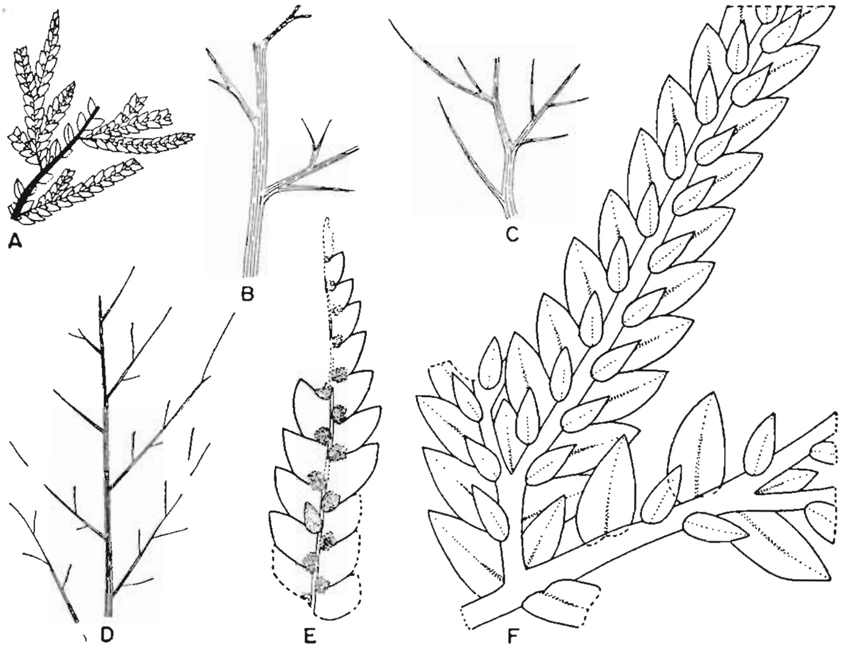
Araucarites (?) *gracilis* Oldham & Morris, *Memoir Geological Survey of India Palaeontologica indica*, *Ser.* 2, **1** (1), 1863, pl. 33, figs 1, 2; pl. 35, figs 1, 2 — Bindaban (figs. with explanation).

Synonyms:

1877 *Cheirolepis gracilis* (Oldham & Morris) Feistmantel, p. 87 (description, figs of Oldham & Morris, 1863 referred).

1880 *Lycopodites gracilis* Feistmantel, p. XIV (Preface) (name only).

1881 *Lycopodites gracilis* (Oldham & Morris) Feistmantel, p. 150, pl. 2, fig. 2 (new



TEXT-FIG. 1A-F — *Selaginellites gracilis* (Oldham & Morris) Pal comb. nov. **A**, general habit of the plant, B.S.I.P. no. 35524, × 1; **B**, **C**, **D**, branching pattern of shoots, B.S.I.P. nos. 25575, 35525 and 35526, all × 1; **E**, apical part of a shoot, note the dorsal leaves not fully exposed, mostly their basal part being exposed appearing as circular scars, B.S.I.P. no. 35524 (a), × 4; **F**, idealized drawing of leafy shoot based on a part of the specimen in text-fig. 1A, B.S.I.P. no. 35524, × 6.

specimen figured, ' cone-like structure ' mentioned).

1920 *Lycopodites gracilis* Morris: Seward & Sahni, p. 18, pl. 7, figs 77, 77a (specimen of Oldham & Morris, 1863 redrawn).

1966 *Lycopodites gracilis* (Oldham & Morris) Seward & Sahni: Surange, p. 16, fig. 7A-C (description, new specimen photographed, text-fig. of Seward & Sahni, 1920 repeated).

1968 *Lycopodites gracilis* (Oldham & Morris) Feistmantel: Bose & Sah, p. 18, pl. 1, figs 7, 8 (description, new specimen figured).

1971 *Selaginellites* sp. A: Sharma, p. 66, pl. 19, fig. 6; pl. 20, fig. 16; text-figs 9-12 (description & new specimens figured).

1971 *Selaginellites* sp. B: Sharma, p. 69, pl. 20, fig. 11; text-figs 13, 14 (description & new specimens figured).

1972 *Selaginellites* sp. B: Sharma, p. 132, pl. 1, fig. 9 (figure of Sharma, 1971 repeated).

1975 *Selaginellites* sp. A: Sharma, p. 83, pl. 1, figs 1, 2 (figures of Sharma, 1971 repeated).

Diagnosis — Shoots dorsiventral, heterophyllous, monopodially branched in one plane. Main stem more or less straight, up to 1 mm thick. Lateral branches alternate, arising at irregular intervals at an angle of 40°-50°, about 0.5 mm thick. Ultimate branches about 0.25 mm thick. In broad stems upper surface showing two ridges separated by a groove, but no clear ridges visible in narrow stems. Lower surface showing three round ridges separated by grooves in broadest stem, two ridges in medium-sized stems and a single ridge in narrow stems. Leaves in four rows, two ventral rows of larger spreading leaves, two dorsal rows of small, more forward pointing leaves; each ventral leaf lying opposite a dorsal leaf. A single ventral leaf present in the angle of dichotomy and pointing forward. Leaves rather distantly placed in main stem, but more crowded on smaller branches. Ventral leaves on larger shoots up to 4 mm long but more commonly 2.5 mm long, 1.5 mm on smaller shoots; base contracted (but seldom clearly seen, not suitably exposed to show a ligule); midrib well-marked; margins entire, of unequal length; apex acute. Dorsal leaves appressed to stem below, up to 1 mm long, lanceolate, base constricted.

Holotype — Specimen no. 4487 of the Geological Survey of India, Calcutta.

Occurrence — Bindaban (*Locus typicus*), Chunakhali and Balbhadri Hill of the Rajmahal Hills, Bihar, India.

Age — Upper Jurassic.

DISCUSSION

The generic name *Selaginellites* Zeiller has been preferred to *Lycopodites* Brongniart because the form of the shoots in all the specimens is precisely that of a creeping *Selaginella*. A good many species of *Lycopodium* have flattened shoots and are heterophyllous, but though these show varied arrangement of small leaves above and sometimes below the stem, in not one is the arrangement that of *Selaginella* or the present specimens. The Rajmahal specimens also show a forward pointing leaf in the angle of a dichotomy, a character of *Selaginella*. Some authors, e.g. Lundblad (1950) refrained from using the name *Selaginellites* or *Selaginella* for a fossil with leaf arrangement as in creeping *Selaginella*, when their material fails to show the heterospory. However, though there is no cone, *Selaginellites gracilis* as mentioned above does show another character which is exclusive to *Selaginella*, i.e. the leaf in the angle of dichotomy, and this I take as confirmation. I have also found a cast of megaspore, about 1000 μm in diameter (Pl. 1, fig. 4), in close association, which provides additional evidence for the affinity of the present material with heterosporous *Selaginella*. There is no morphological difference between *Selaginella* Linn. and *Selaginellites* Zeiller, but merely a widely used convention for prefering a distinct name for a Mesozoic plant. The ribs on the stem surface of *Selaginellites gracilis*, which vary in number in branches of different order, probably represent the vascular strands (some authors called them steles).

Feistmantel (1877) thought that *S. gracilis* is a conifer and though he stated that he could only see a dorsal and two lateral rows of leaves he felt sure there should be a ventral rank concealed below. This idea was accepted by later workers (Surange, 1966; Bose & Sah, 1968). However, several of the present specimens in which the ventral surface is clearly exposed show conclusively that there are no additional small ventral leaves; there are four ranks, as in ordinary *Selaginella*. Nearly all the shoots show their under surface because the rock has split in the plane of the spreading ventral leaves, but in a few specimens the dorsal surface is exposed. Even where the ventral surface is exposed small shoots may show the small dorsal leaves because a small amount of rock above them has broken away and exposed them though not as a rule completely. However, more rocks may be degaged by damaging the ventral leaves. Where just a little of the dorsal leaves is seen the specimen looks exactly like the figure in Sharma, 1971, text-fig. 10 (where they were taken to be sporangia). Until fully degaged they do indeed look like sporangia.

I consider that all the specimens of Sharma (1971, 1972, 1975) are *S. gracilis*. The locality he gives as Dhokuti is the name of a village close to Bindaban Village otherwise Bindaban and Dhokuti are same locality. He divides his specimens in two groups based on the branching pattern and nature of the stem surface. But the individual lateral branches of his ‘ sp. A ’ represent the branching pattern of his ‘ sp. B ’. The nature of the stem surface has also been found variable in the branches of different order in the same shoot. Thus it is quite clear that Sharma's *Selaginellites* sp. B is a lateral branch of his *Selaginellites* sp. A.

Rigby (1978) considered a specimen from Queensland Jurassic to be identical with the Rajmahal specimens and described it as *Lycopodites gracilis*. But unlike Indian *Selaginellites gracilis* the Queensland specimen possesses falcate and more spreading ventral leaves. The Queensland specimen (as observed from the photograph) appears more like *Lycopodites falcatus* Lindley & Hutton.

COMPARISON

Selaginellites gracilis resembles *Lycopodites scanicus* Nathorst ex Halle described by Lundblad (1950) from the Rhaetic of

Sweden in having heterophyllous shoots with leaves of similar size and arrangement. But unlike *S. gracilis*, *L. [illegible]* has leaves with almost rounded apices and finely denticulate margins. *Selaginella [illegible]* described by Velenovsky and Viniklar (1931) from the Cretaceous of Bohemia differs from *S. gracilis* in being larger in size and having more spreading somewhat falcate ventral leaves. *L. ghoshii* Bose *et al.* (1984) from the Lower Cretaceous of Gardeshwar, Gujarat is also heterophyllous with two dorsal rows of smaller leaves and two ventral rows of larger leaves, but it differs from *S. gracilis* in having narrower shoots and shorter ventral leaves having mucronate apices. *L. falcatus* Lindley & Hutton redescribed by Harris (1961) from the Middle Jurassic of Yorkshire has falcate ventral leaves and small leaves both above and below the stem.

ACKNOWLEDGEMENTS

I am extremely indebted to the Late Professor T. M. Harris, F.R.S. for his kind guidance during this work and for making relevant modification of the manuscript after going through it. I am indeed grateful to Dr M. N. Bose for his keen interest in the work and many other kindness.

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EXPLANATION OF PLATE

1-3. *Selaginellites gracilis* (Oldham & Morris) Pal comb. nov.

1. B.S.I.P. specimen no. 35527. × 1.
2. B.S.I.P. specimen no. 35528. × 2.
3. Syntype specimen G.S.I. no. 4476. × 1.
4. Megaspore, found in close association of the shoot shown in text-fig. 1A, B.S.I.P. specimen no. 35524. × 10.

5, 6. *Selaginellites gracilis* (Oldham & Morris) Pal comb. nov.

5. Magnified view of a shoot showing ridges and grooves over the stem surface, note the ventral spreading leaves at places showing distinct midvein (×). B.S.I.P. specimen no. 35525. × 2.5.
6. Magnified view of a part of the shoot shown in text-fig. 1A, showing forms and arrangement of leaves (d1 — dorsal leaves, v1 — ventral leaves). B.S.I.P. specimen no. 35524. × 8.

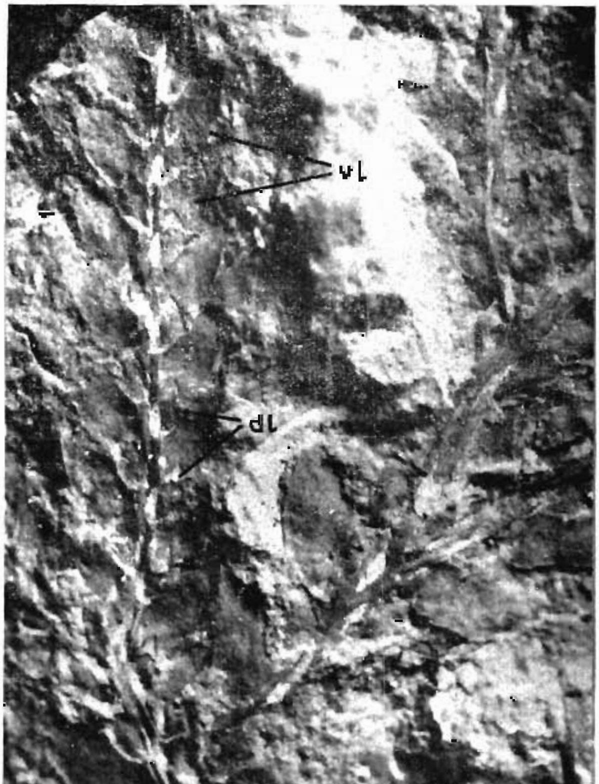

PLATE 1

The Palaeobotanist, **32**(3): 326-336, 1984.

STUDIES ON SOME MORE CARBONISED WOODS FROM THE NEOGENE OF KERALA COAST, INDIA

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ABSTRACT

More carbonised woods from Varkala Cliff Section and Payangadi Clay Mine belonging to Warkalli beds (Miocene-Pliocene) have been investigated. These woods show close resemblance with the extant woods of *Leea*, *Gluta* and *Gonystylus* and have been named as *Leeoxylon cannanorense* sp. nov., *Glutoxylon burmense* (Hold.) Chowdhury, *Gonystyloxylon indicum* gen. et sp. nov. and *G. tertiarum* sp. nov. Almost all the modern taxa with which these carbonised woods show closest resemblance are confined to the tropical evergreen forests of Malayan and Indonesian archipelagoes.

Key-words — Xylotomy, Carbonised woods, *Leea*, *Gluta*, *Gonystylus* Miocene-Pliocene (India).

साराँश

केरल तट (भारत) के पश्च-तृतीयक कल्प से कुछ और कार्बनी काष्ठों का अध्ययन – नीलाम्बर अवस्थी एवं मधु पंजवानी

वरकली संस्तरों (मध्यनूतन-आदिनूतन) से सम्बद्ध वरकला क्लिफ़ खंड एवं पयाँगदी मृत्तिका खान से और एकत्र किये गये कार्बनी काष्ठों का इस शोध-पत्र में वर्णन किया गया है। ये काष्ठ लीआ, ग्लूटा एवं गोनीस्टाइलस की वर्तमान काष्ठों से घनिष्ठ सजातीयता प्रदर्शित करते हैं तथा इन्हें लीऑक्सीलॉन कैन्नेनोरेन्से नव जाति, ग्लूटॉक्सीलॉन बर्मेन्से (होल्डन) चौधरी, गोनीस्टाइलॉक्सीलॉन इन्डिकम् नव वंश व नव जाति तथा गो० टर्शियेरम् नव जाति से नामाँकित किया गया है। जिन वर्तमान वर्गकों से ये कार्बनी काष्ठ समानता प्रदर्शित करते हैं वे सभी प्राय: मलाया एवं इंडोनेशिया के प्रायद्वीपों के उष्णकटिबंधीय सदाहरित वनों में पाये जाते हैं।

INTRODUCTION

IN the Neogene rocks of Kerala Coast the megaplant remains chiefly occur in the form of carbonised (lignitised) woods associated with lignites and carbonaceous clays. The associated lignites and carbonaceous clays have been considerably analysed by various workers (Vimal, 1953; Ramanujam, 1960, 1972; Ramanujam & Rao, 1973a, 1973b, 1977, 1978; Ramanujam & Srisailam, 1980; Ramanujam, Srisailam & Reddy, 1981; Rao & Ramanujam, 1975, 1976, 1978; Jain & Gupta, 1972; Jain & Kar, 1979; Kar & Jain, 1981) and reported the occurrence of fungal remains, spores and pollen contents mainly for stratigraphical correlations. However, keeping in view the great significance of plant megafossils in deciphering the palaeo-ecology and palaeophytogeography the present authors have initiated the systematic study of carbonised woods from the Neogene deposits of Kerala Coast. Awasthi and Ahuja (1982) reported six dicotyledonous woods, viz., *Calophyllum*, *Dryobalanops*, *Swintonia*, *Cynometra*, *Terminalia*, *Diospyros* and a lauraceous member having close resemblance with some of the species of *Cinnamomum* — *Litsea* and anatomically allied genera from the Varkala Coast. The material investigated here is a part of collection made from the Varkala Cliff Section and from the Payangadi Super Clay Mine in Cannanore District. The Payangadi Super Clay Mine is considered to be the extension of Warkalli beds.

SYSTEMATIC DESCRIPTION

FAMILY — AMPELIDACEAE

Genus — *Leeoxylon* Prakash & Dayal, 1964

Leeoxylon cannanorense sp. nov.

Pl. 1, figs 1-6

Description — *Wood* diffuse-porous. *Growth rings* not observed. *Vessels* solitary and in radial multiples of 2-3 (Pl. 1, figs 1, 2), small to medium, round to oval, t.d. 96-160 μm, r.d. 114-192 μm, evenly distributed, 3-8 per sq mm; vessel-members 272-1,280 μm long with truncate to tailed ends; perforations simple; intervascular pitting scalariform (Pl. 1, figs 5, 6); pits leading to parenchyma cells and rays opposite, large, usually with long axis placed horizontally; tyloses not seen. *Parenchyma* paratracheal, scanty, a few cells occurring round the vessels (Pl. 1, fig. 2). *Rays* broad (Pl. 1, fig. 4), up to 12-seriate and up to 225 μm wide, very high, mostly of indeterminate height, heterocellular, consisting of upright and square cells (Pl. 1, fig. 3); upright cells 40-80 μm in vertical length, 32-40 μm in radial length; square cells 32-40 μm in vertical and radial length; uniseriate rays rare, composed wholly of upright cells. *Fibres* aligned in radial rows in crosssection, semilibriform, moderately thick-walled and septate.

Affinities with modern woods — The salient features of the present fossil wood are small to medium vessels, scanty paratracheal parenchyma, broad, and very tall, multiseriate rays with a few homocellular uniseriate rays and scalariform intervessel pitting. These may be considered as cogent features in bringing the present fossil wood closer to the genus *Leea* Royen ex Linn. of the family Ampelidaceae (Hess, 1936; Dadswell & Record, 1936; Metcalfe & Chalk, 1950). Thin sections of the woods of seven species of *Leea*, viz., *L. sambucina* Willd., *L. philippinensis* Merill, *L. indica* Merill, *L. alata* Edgew, *L. brunoniana* C. B. Clarke, *L. angulata* Korth. and the descriptions and illustrations of the woods of *Leea quineense* Don. (Metcalfe & Chalk, 1950, p. 417, fig. 956), *L. sundaica* Miq., *L. javanica* Bl. (Moll & Janssonius, 1908, pp. 314, 315), *L. gigantea* Griff. (Desch, 1954, p. 5) were examined in order to find out the nearest living counter part of the present fossil wood. This thorough task enabled us to put our fossil wood more closer to *Leea angulata* and *L. philippinensis*. The former shows similarity in the nature and distribution of vessels, parenchyma and fibres while the latter has similar xylem rays. But none of the above species of *Leea* seems to be exactly identical to our fossil.

Affinities with fossil species — As the fossil shows closest resemblance with the modern wood of *Leea* of the family Ampelidaceae, it has been placed under the genus *Leeoxylon* Prakash & Dayal (1964). So far only four fossil woods having close resemblance with *Leea* are known. They are *Leeoxylon multiseriatum* Prakash & Dayal (1964) from the Deccan Intertrappean beds of Mahurzari near Nagpur, India *Leeoxylon eojaponicum* (Watari) Kramer (1974) (*Leea eojaponica* Watari, 1951) from the Lower Miocene of Simane, Japan, *Leeoxylon altiradiatum* Kramer (1974) from the Tertiary of Java and *Leeoxylon* sp. Lemoigne (1978) from the Pliocene-Pleistocene of Omo Basin, Ethiopia. Our fossil though resembles these species in the nature and distribution of vessels, parenchyma, xylem rays and scalariform intervessel pitting, yet it can easily be differentiated in the size and frequency of vessels, height and width of xylem rays. In *Leeoxylon multiseriatum* the vessels are relatively smaller in size, i.e. up to 120 μm in diameter and their frequency is 8-15 per sq mm; the xylem rays are up to 18 cells wide and 375-2775 μm high; whereas in the present fossil the vessels are less frequent, i.e. 3-8 per sq mm and relatively bigger, up to 192 μm in diameter and the xylem rays are up to 12 cells wide and extremely tall, so much so that the height of most of the rays is indeterminable. *Leeoxylon eojaponicum* shows considerable differences from the present species particularly in the absence of uniseriate rays, presence of raphids in ray cells, relatively larger vessels and complete sheath of paratracheal parenchyma around the vessels. The broad xylem rays in *Leeoxylon eojoponicum* are 2-10 (mostly 7-8) seriate and are still higher than in the present fossil. Lastly, *Leeoxylon* sp. Lemoigne also differs in having diffuse parenchyma. Therefore, the present fossil is named as *Leeoxylon cannanorense* sp. nov.; the specific name is after Cannanore District.

SPECIFIC DIAGNOSIS

Lecoxylon cannorense sp. nov.

Wood diffuse-porous. *Growth rings* not observed. *Vessels* solitary and in radial multiples of 2-3, small to medium, t.d. 96-160 μm, r.d. 144-192 μm; vessel-members 272-1280 μm long with truncate to tailed ends; perforations simple; intervessel pitting scalariform. *Parenchyma* scanty paratracheal, only a few cells associated with vessels. *Rays* 1-12 seriate, heterocellular, consisting of mostly upright and square cells, very tall; uniseriate rays occasionally present, homocellular, consisting of only upright cells. *Fibres* semilibriform and septate.

Holotype — B.S.I.P. Specimen no. 35529.

Locality — China Clay Mine, Payangadi, district Cannanore, Kerala.

FAMILY — THYMELAEACEAE

Genus — *Gonystyloxylon* gen. nov.

Gonystyloxylon indicum sp. nov.

Pl. 2, figs 7-11

Description — *Wood* diffuse-porous. *Growth rings* indistinct (Pl. 2, fig. 7) though at places narrow zones of relatively small-sized fibres indicate the annual growth marks. *Vessels* solitary and in radial multiples of 2-3, sometimes in tangential groups of 2-3, small to medium, somewhat angular in shape, t.d. 80-90 μm, r.d. 60-120 μm, 3-9 per sq mm; vessel-members short, up to 352 μm high with truncate or slightly tailed-ends; perforations simple; intervascular pitting small, alternate, bordered (Pl. 2, fig. 9). *Parenchyma* abundant, paratracheal, forming 2-3 seriate, incomplete or mostly complete sheath around vessels, and frequently extending laterally across several rays forming fine tangential lines of usually 1-2 cells in width, sometimes aliform parenchyma bifurcating into fine lines (Pl. 2, fig. 7); lines about 4-5 per mm; parenchyma cells 20-42 μm in tangential diameter and up to 16 μm in radial diameter. *Rays* predominantly uniseriate (Pl. 2, fig. 8), occasionally biseriate due to pairing of procumbent cells through the median portion, homogeneous to weakly heterogeneous (Pl. 2, fig. 10), 15-17 cells and 88-640 μm high, 16-32 μm wide, about 10-12 per mm; solitary crystal sometimes present in ray cells. *Fibres* aligned in radial rows, angular to mostly hexagonal in shape (Pl. 2, fig. 7), t.d. up to 36 μm, bigger than parenchyma cells, short, somewhat fusiform, thin-walled with numerous simple as well as bordered pits on both radial and tangential walls (Pl. 2, figs 8, 9), nonlibriform, non-septate. *Included phloem* absent.

Affinities with modern woods — The salient anatomical features of the present carbonised wood are: vessels solitary and in short radial multiples of 2-3, sometimes in groups of double rows, parenchyma paratracheal, vasicentric and confluent, forming narrow tangential lines, rays uniseriate to biseriate and fibres frequently pitted. These features strongly suggest the affinities of our fossil with the woods of the genus *Gonystylus* of the family Thymelaeaceae. The other genera of this family which have uniseriate to bi-celled rays are *Aquilaria*, *Daphne*, *Gyrinops* and *Passerina*. However, comparatively long radial multiples of vessels and abundant patches of included phloem in *Aquilaria* distinguish it from the present fossil. Extremely small vessels and scanty paratracheal parenchyma limited to the vessels in *Passerina*, *Daphne* and *Gyrinops* are the anatomical characters different from our specimen. So *Gonystylus* is the only genus which comes closer to the present fossil wood in almost all its anatomical characters.

The taxonomic position of the genus *Gonystylus* is controversial. This genus is referred to Thymelaeaceae by some botanists (Janssonius, 1930; Willis, 1972; Desch, 1954) while others have placed it under a separate family Gonystylaceae (Hutchinson, 1926; Metcalfe & Chalk, 1950; Miles, 1978). According to Metcalfe and Chalk (1950) " the lack of intraxylary phloem serves to distinguish *Gonystylus* from most of the Thymelaeaceae, although it should be noted that this is also absent from *Lagetta*, *Microsenima* and *Solusia*, and the rather specialized *Drapets* ". In this connection the authors examined thin sections of the woods of *Gonystylus*, viz., *G. bancanus* Gilg., *G. macrophyllus* (Miq.) Airy Shaw and *Gonystylus* sp. and found that a few patches of intraxylary phloem are present in one of the species of *Gonystylus*, viz., *G. macro-*

phyllus, although no where in the literature there is any report about the presence of the intraxylary phloem in this genus. So this character seems to be a variable one and it is a matter of opinion whether *Gonystylus* be treated in a distinct family or be retained in Thymelaeaceae.

The fossil wood was also compared with the published literature of *G. bancanus* Gilg and *G. miquelianus* Teijsm et Binn. (Metcalfe & Chalk, 1950, pp. 1178-1181, fig. 283A-B), *G. warburgianus* Gilg (Desh, 1954, pp. 208, 209). *G. macrophyllus* (Miq.) Airy Shaw [(syn. *G. bancanus* (Miq.) Kurz], Miles, 1978, p. 66) and it was found that the fossil wood resembles all the above mentioned species in the distribution pattern of vessels, parenchyma, fibres and rays. However, it differs in having smaller vessels. Besides, the fossil can be further differentiated from *G. macrophyllus* in the absence of intraxylary phloem.

Since the fossil woods shows resemblance with the woods of *Gonystylus*, it is placed under a new genus *Gonystyloxylon*, instituted to include all the fossil woods having close similarity with the woods of *Gonystylus* of the family Thymelaeaceae. It is specifically named as *Gonystyloxylon indicum* sp. nov.

With regard to other fossil records of Thymelaeaceae, Ramanujam (1966) recovered the pollen grains of this family from the Neyveli Lignite and placed them under the artificial genus *Clavatiperiporites* and named *C. jacobi*. He has shown their affinities with the pollen grains of *Wikstroemia*. This also confirms that the family Thymelaeaceae had existed in South India in the geological past.

DIAGNOSIS

Gonystyloxylon gen. nov.

Wood diffuse-porous. *Growth rings* present or absent. *Vessels* small to medium, solitary and in radial multiples of 2-4 or more, cells sometimes in double rows, vessel-members usually short in height; perforations simple; intervessel pitting alternate, small to medium, bordered. *Parenchyma* abundant, paratracheal, forming 2-3 seriate complete or incomplete sheath around the vessels, often extending tangentially forming narrow lines. *Rays* 1-2 seriate, almost homogeneous to weakly heterogeneous; crystals present in ray cells. *Fibres* nonlibriform, non-septate with simple or bordered pits on radial and tangential walls. *Included phloem* present or absent.

Genotype — *Gonystyloxylon indicum* sp. nov.

Gonystyloxylon indicum sp. nov.

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* solitary and also in radial multiples of 2-3, small to medium, t.d. 80-100 μm, r.d. 60-120 μm, somewhat angular in shape; vessel-members up to 352 μm long with truncate or slightly tailed ends; perforations simple; intervessel pitting alternate, small, 4-6 μm, bordered. *Parenchyma* abundant, paratracheal, forming 2-3 seriate complete or incomplete sheath around vessels and extending laterally across several rays forming fine tangential lines of 2-4 cells in thickness, about 4-5 lines per mm. *Rays* predominantly uniseriate, occasionally bicelled, homogeneous to weakly heterogeneous, 5-17 (88-640 μm) cells high, 16-32 μm wide, about 10-12 per mm; solitary crystal sometimes present in ray cells. *Fibres* aligned in radial rows, hexagonal to elongated, t.d. up to 36 μm, r.d. 32-60 μm, bigger than parenchyma cells, thin-walled with numerous simple as well as bordered pits on both radial and tangential walls, nonlibriform, non-septate. *Included phloem* absent.

Holotype — B.S.I.P. no. 35530.

Locality — Varkala Cliff Section, Varkala, Kerala.

Gonystyloxylon tertiarum sp. nov.

Pl. 2, figs 13, 15, 16; Pl. 3, figs 17, 19, 21

Description — *Wood* diffuse-porous. *Growth rings* present, delimited by narrow zone of thick-walled fibres (Pl. 2, fig. 12). *Vessels* solitary and also in radial multiples of 2-4 as well as in double rows (Pl. 2, fig. 12), occasionally in clusters of small vessels, almost uniformly distributed, circular to oval, t.d. 40-160 μm, r.d. 50-160 μm, small to medium, 3-13 per sq mm; vessel-members 180-600 μm long with truncate to slightly inclined ends; intervascular pitting alternate, small or minute, bordered, crowded, pits 4-5 μm in diameter with circular to lenticular aperture (Pl. 2, fig. 15). *Parenchyma* paratracheal, completely enclosing vessels and extending laterally forming 1-2 seriate fine lines (Pl. 2, figs 12, 13; Pl. 3, fig. 17), about 8 lines per mm; parenchyma cells oval to elongated, 16-32 μm in diameter, those occurring around vessels peripherally flattened. *Rays* very fine, uniseriate to rarely biseriate (Pl. 3, fig. 19), 12-18 per mm in cross-section, 4-24 cells high; ray tissue homogeneous to weakly heterogeneous (Pl. 3, fig. 21), consisting of procumbent cells, sometimes with one squarish cell; vertical height of procumbent cells 20-32 μm, radial length 40-80 μm; vertical height of squarish cells 48-52 μm, radial length 36-40 μm; crystals present in almost all the cells (Pl. 3, fig. 21). *Fibres* aligned in radial rows, circular to oval in cross section, about 8-30 μm in diameter, moderately thick-walled, thicker and narrower towards the close of the ring (Pl. 2, fig. 12), nonlibriform, with numerous bordered pits on the radial as well as tangential walls (Pl. 2, fig. 16). *Included phloem* present, cells thin-walled, irregular in shape and size. These anatomical features of the fossil wood are more or less similar as shown by the previous fossil and hence it is also being placed under the genus *Gonystyloxylon*.

On the basis of the studies of modern species of *Gonystylus*, it was found that the present fossil closely resembles *G. macrophyllus* in having intraxylary phloem which is absent in *Gonystyloxylon indicum*. However, in almost all other characters, such as distribution of vessels, parenchyma lines, rays, crystals, thickness of fibres the fossil wood is more closer to *Gonystylus* sp. (B.S.I.P. slide no. 1472).

The present fossil wood differs from *Gonystyloxylon indicum* in having interxylary phloem, relatively bigger vessels and greater frequency of xylem rays and presence of crystals in almost all ray cells. Hence it is being described here as *Gonystyloxylon tertiarum* sp. nov.

SPECIFIC DIAGNOSIS

Gonystyloxylon tertiarum sp. nov.

Wood diffuse-porous. *Growth rings* present. *Vessels* solitary and also in radial multiples of 2-4, as well as in double rows, circular to oval, t.d. 40-160 μm, r.d. 50-150 μm, small to medium, 3-13 per sq mm, vessel-members 180-600 μm long with truncate to slightly tailed ends, intervessel pitting alternate, minute, bordered, pits 4-5 μm in diameter with circular to lenticular aperture. *Parenchyma* paratracheal completely enclosing the vessels and extending laterally forming 1-2 seriate lines, about 8 lines per mm. *Rays* uniseriate to rarely biseriate; ray tissue homogeneous to weakly heterogeneous, solitary crystals frequent in ray cells. *Fibres* circular to oval in cross section, moderately thick-walled, thicker and narrower towards the close of the ring, nonlibriform with numerous bordered pits on the radial walls. *Included phloem* present, thin-walled, cells irregular in shape and size.

Holotype — B.S.I.P. specimen no. 35531.

Locality — China Clay Mine, Payangadi, Cannanore District, Kerala.

FAMILY — ANACARDIACEAE

Genus — *Glutoxylon* Chowdhury, 1934

Glutoxylon burmense (Hold.) Chowdhury, 1952

Pl. 3, figs 23, 24

Description — *Wood* diffuse porous. *Growth rings* not seen. *Vessels* small to large in size, t.d. 80-160 μm, r.d. 144-240 μm, oval in shape, solitary and also in radial multiples of 2-5 (mostly 2-3), 2-8 per sq mm, heavily tylosed (Pl. 3, fig. 23); perforations simple; intervessel pits bordered, large, alternate, orbicular with lenticular aperture. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma scanty; apotracheal in the form of 2-4 (rarely up to 5) cells wide incomplete bands (Pl. 3, fig. 23), 2-4 per mm. *Xylem rays* simple and fusiform (Pl. 3, fig. 24), simple rays fine, 1-2 (mostly 1) seriate, homocellular, consisting of procumbent cells, up to 11 cells in height; fusiform rays 2-5 seriate with single radial gum duct in the centre (Pl. 3, fig. 24), homocellular, consisting of procumbent cells; gum ducts lined with single row of epithelial cells; rays 8-10 per mm. *Fibres* semilibriform, non-septate, thick-walled.

Affinities — In all its anatomical features the present carbonised wood shows closest resemblance with the woods of *Gluta*, and hence placed under the genus *Glutoxylon* Chowdhury, 1934. This genus was created by Chowdhury (1934) for the fossil woods of *Gluta* and those melanorrhoeas which have thin apotracheal parenchyma lines or bands. Since then a large number of fossil woods have been described by several workers from various Neogene deposits of India and Burma and all of them have been placed under this fossil genus. However, to accommodate those fossils having broad parenchyma lines or bands as seen in a few species of *Malanorrhoea*, Prakash and Tripathi (1969) proposed a new genus *Melanorrhoeoxylon*. Ghosh and Roy (1980) described a fossil wood under this genus as *Melanorrhoeoxylon garbetaense* from the Tertiary of West Bengal.

Recently Ding Hou (1978), who made taxonomic study of the Malesian Anacardiaceae, has merged all the species of *Melanorrhoea* to the genus *Gluta*. As a consequence the genus *Melanorrhoeoxylon* Prakash & Tripathi becomes superfluous and hence merged with *Glutoxylon* (Hold.) Chowdhury. Among the fossil woods referred to the genus *Glutoxylon* our carbonised wood shows the structural details similar to *Glutoxylon burmense* (Hold.) Chowdhury. It is, therefore, placed under the same species.

Specimen — B.S.I.P. specimen no. 35532.

DISCUSSION

The carbonised woods identified as *Leea*, *Gonystylus* and *Gluta* are quite significant from the ecological and phytogeographical point of view. The genus *Leea* Royen ex L. consists of 70 species of climbers, climbing shrubs or small trees, distributed in palaeotropical regions (Willis, 1973, p. 643). In India, the species of *Leea* are generally found in the under-growth of the forest and one or two also in open grasslands like *Leea macrophylla* Roxb. and *L. alata* Edgw. Among the forest ones *L. aspera* Wall. is very common in deciduous forest all over India. *Leea crispa* Willd. and *L. sambucina* Willd. are common in the Darjeeling Terai. *Leea umbraculifera* C. B. Clarke and *L. robusta* Roxb. are found in the forests of the Sikkim-Himalaya, Terai up to 1,000 m in the undergrowth forests, and also in North Kanara, West coast (Gamble, 1972, p. 191). Of the species comparable to the present carbonised wood, *Leea angulata* is distributed in the evergreen forests of Malay peninsula, while *L. philippinensis* is known to occur in similar forest of Philippines.

The other genus *Gluta* consists of about 30 species as a consequence of the reduction of *Melanorrhoea* to *Gluta*. It is distributed in Madagascar, India, Burma, Thailand, Indochina, China and throughout Malaysia (Ding Hou, 1978). In India this genus is represented by *Gluta travancorica*, occurring in dense moist forests on the hills of Travancore and Tinnevelly. The genus *Gonystylus* which is totally absent from the Indian subcontinent, consists of about 30 species (Willis, 1973) confined to the evergreen forests of Malayan and Indonesian archipelagoes.

Since the modern equivalents of the present fossil woods are the important elements of the tropical evergreen forests, it is thus envisaged that somewhat similar climatic conditions prevailed during Neogene times all along the Kerala Coast.

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EXPLANATION OF PLATES

PLATE 1

Leeoxylon cannanorense sp. nov.

1. Cross section showing gross features. × 40; B.S.I.P. slide no. 7016.
2. Cross section at higher magnification showing vessels and scanty paratracheal parenchyma. × 100; B.S.I.P. slide no. 7016.
3. Radial longitudinal section showing heterocellular xylem rays made up of upright and square cells. × 100; B.S.I.P. slide no. 7017.
4. Tangential longitudinal section showing broad rays of indeterminate height. × 100; B.S.I.P. slide no. 7018.
5. Tangential longitudinal section showing scalariform intervessel pitting. × 400; B.S.I.P. slide no. 7018.
6. Tangential longitudinal section magnified to show bars of scalariform intervessel pitting. × 400; B.S.I.P. slide no. 7019.

PLATE 2

Gonystyloxylon indicum gen. et sp. nov.

7. Cross section showing shape, size and distribution of vessels, parenchyma and fibres. × 40; B.S.I.P. slide no. 7020.
8. Tangential longitudinal section showing homocellular to weakly heterocellular xylem rays. × 100; B.S.I.P. slide no. 7021.
9. Tangential longitudinal section showing intervessel pits. × 400; B.S.I.P. slide no. 7021.
10. Radial longitudinal section showing crystals in ray cells. × 400; B.S.I.P. slide no. 7022.

11. Bordered pits on the radial walls of fibres. × 400, B.S.I.P. slide no. 7022.

Gonystyloxylon tertiarum sp. nov.

12. Cross section showing growth rings and distribution of vessels and parenchyma. × 100, B.S.I.P. slide no. 7023.
13. Cross section showing nature and distribution of vessels, parenchyma and fibres. × 40, B.S.I.P. slide no. 7023.

Gonystylus sp.

14. Cross section showing similar type and distribution of vessels and parenchyma as in fossil. × 40.
15. *Gonystyloxylon tertiarum* sp. nov. showing intervessel pitting. × 400, B.S.I.P. slide no. 7024.
16. *G. tertiarum* sp. nov. showing fibre pits. × 400, B.S.I.P. slide no. 7025.

PLATE 3

17. *Gonystyloxylon tertiarum* sp. nov.: Cross section showing vessels, parenchyma and included phloem. × 40; B.S.I.P. slide no. 7023.
18. *Gonystylus macrophyllus*. Cross section showing similar included (interxylary) phloem, vessels and parenchyma. × 40.
19. *Gonystyloxylon tertiarum* sp. nov.: Tangential longitudinal section showing homocellular to weakly heterocellular xylem rays. × 100. B.S.I.P. slide no. 7024.
20. *Gonystylus* sp.: Tangential longitudinal section showing similar type of rays. × 100.
21. *Gonystyloxylon tertiarum* sp. nov.: Radial longitudinal section showing ray cells with crystals. × 100. B.S.I.P. slide no. 7025.
22. *Gonystylus* sp.: Radial longitudinal section showing similar type of ray cells with crystals as in fossil. × 100.

Glutoxylon burmense (Hold.) Chowdhury

23. Cross section showing distribution of vessels (with tyloses) and apotracheal parenchyma (dark bands or lines). × 40; B.S.I.P. slide no. 7026.
24. Tangential longitudinal section showing simple uniseriate xylem rays and a fusiform ray with gum canal. × 100, B.S.I.P. slide no. 7027.

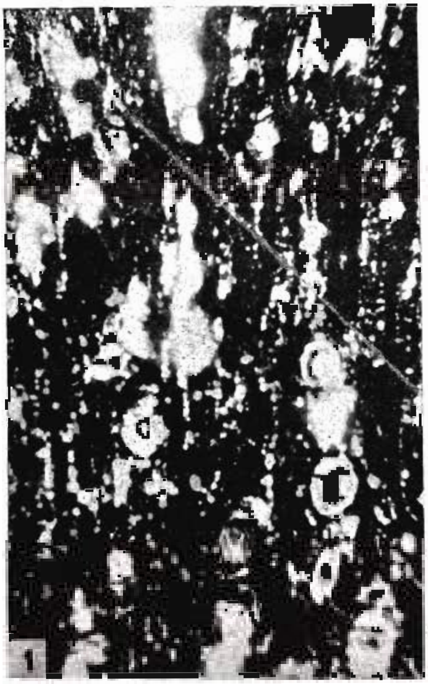
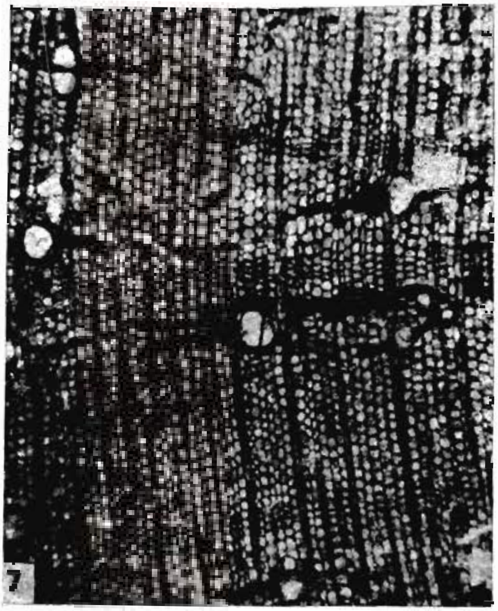


PLATE I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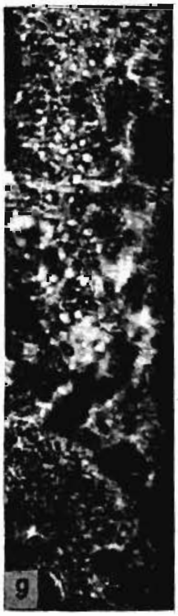
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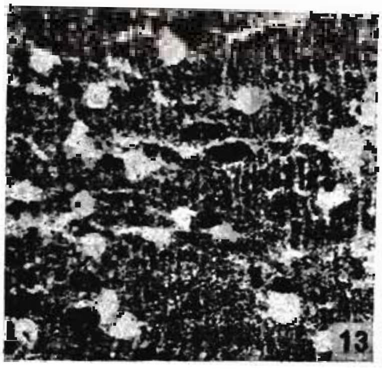
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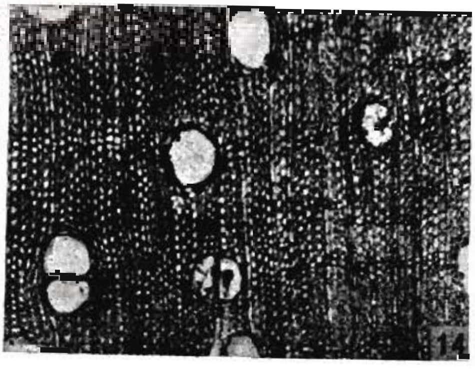
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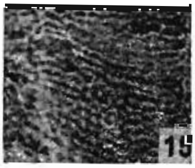
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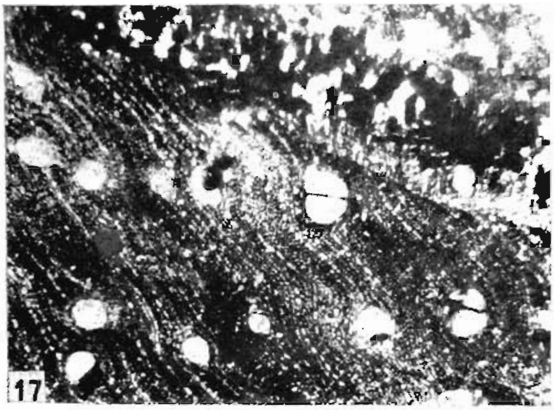
PLATE 4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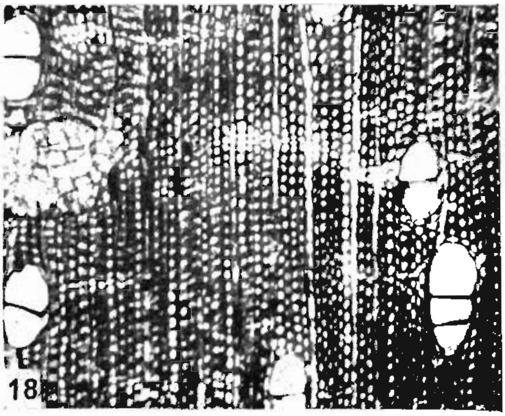
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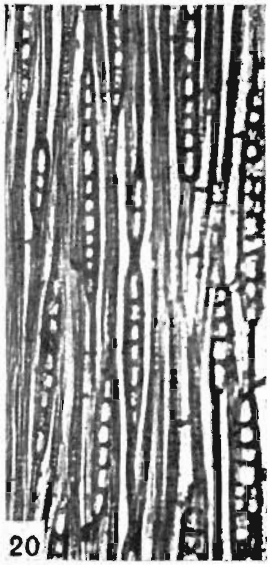
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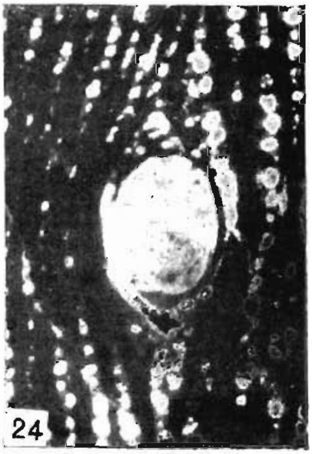
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PLATE 3

The Palaeobotanist, **32**(3): 337-340, 1984.

ROSSIELLA AND *BOGOROVIA*: TWO FOSSIL DIATOM GENERA

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ABSTRACT

The genus *Rossiella* Desikachary & Maheshwari occurs in the Miocene deposits, both in onshore deposits and in deep-sea cores. Six species of this genus, viz., *R. paleacea*, *R. elongata* (Barron) Desikachary comb. nov., *R. tatsunokuchiensis*, *R. praepaleacea*, *R. moholensis* (Schrader) Desikachary comb. nov. and *R. gombosi* Desikachary sp. nov. are described and discussed. The authors consider *Rossiella* and *Cussia* Schrader as congeneric. *Bogorovia* Jouse, as typified by *B. veniamini*, is considered distinct from *Rossiella*.

Key-words — Diatom, *Rossiella*, *Bogorovia*, Miocene (India).

सारांश

रोसियॅल्ला एवं बोगोरॉविया : दो डाएटमाश्म वंश – टी० वी० देसिकाचार्य, वाई० लथा एवं के० ए० रन्जीथा देवी

रोसियॅल्ला देसिकाचार्य व माहेश्वरी वंश मध्यनूतन निक्षेपों, अर्थात् तट के पास वाले निक्षेपों एवं गहरे समुद्र की क्रोड़ों दोनों में ही पाया जाता है। इस वंश की छ: जातियाँ अर्थात् रो० पैलिएसिया, रो० इलोंगेटा (बैरॉन) देसिकाचार्य नव संयोजन, रो० तात्सुनोकुचियेन्सिस, रो० प्रीपैलिएसिया, रो० मोहोलेन्सिस (स्क्रेडर) देसिकाचार्य नव संयोजन तथा रो० गॅमबोसाई देसिकाचार्य नव जाति का वर्णन एवं विवेचन किया गया है। इस शोध-पत्र के लेखक रोसियॅल्ला एवं कुसिया को समवंशी मानते हैं। बोगोरॉविया जूस को रोसियॅल्ला से अलग माना गया है।

ROSSIELLA was created by Desikachary and Maheshwari (1958) to receive *Stoschia*(?) *paleacea* Grunow in Van Heurck (≡*Coscinodiscus paleaceus* Grunow in Van Heurck, 1883; Rattray, 1889). Schrader (1974a) created a new genus *Cussia* with the same species as the type. *Cussia* is, therefore, a superfluous name. Schrader also created a number of new species under *Cussia*, but these do not agree with *R. paleacea* and need a new dispensation. Jouse (1974) created another genus *Bogorovia*, but based on *B. veniamini* as the type. *Stoschia paleacea* was, however, wrongly included by him in *Bogorovia*. *B. veniamini* Jouse occurring in the Upper Oligocene — Lower Miocene is so different from *Stoschia paleacea* in having transverse rows of areolae with distinct transverse costae (see Jouse, 1974, figs 1-3). Unfortunately, a number of other species which have a different structure got included in *Bogorovia* and *Rossiella* (*Cussia*). The diatoms under consideration here are all very important in biostratigraphy being largely restricted to the Miocene. We have recorded these same diatoms from new localities in India and the Indian Ocean. The results are being reported here.

Rossiella Desikachary & Maheshwari

1. *Rossiella paleacea* (Grun. in Van Heurck) Desikachary & Maheshwari 1958, p. 128, fig. 6.

Length (20.9-) 33-88 μm, width (5.5-) 13-19 μm, areolae 3-5 in 10 μm.

Middle Miocene, Nancoori (Sturt BMNH 46063, Pl. 1, figs 2, 3); Colebrook Island (TVD & CLM no. 49, Pl. 1, figs 8-11); Kamortha, M. S. Srinivasan (no. MF 221, Pl. 1, fig. 4).

R. paleacea was first recorded from the Middle Miocene Nancoori deposits (Grun. in Van Heurck, 1883; Rattray, 1889; see Pl. 1, figs 2, 3) and again from the southern Naparima beds (Rattray, 1889; see Pl. 1, fig. 5). It was reported later from the Colebrook islands (Desikachary & Maheshwari, 1958, see Pl. 1, figs 8-11) and now by one of us from the Kamortha Island (Pl. 1, fig. 4). This species has been recorded to occur in a number of Neogene (especially Early & Middle Miocene) cores from the Mediterranian Sea, the Pacific, the Atlantic, and the Indian Ocean and is considered a marker for designating diatom zones in cores.

2. *Rossiella elongata* (Barron) Desikachary comb. nov.

1981a *Bogorovia paleacea* var. *elongata* Barron, p. 528, pl. 4, figs 11, 12; 1981b, p. 140, pl. 2, fig. 2.

This diatom has elongated and symmetrical valves and does not resemble *R. paleacea* which is essentially asymmetrical. It is known from the lower Upper Miocene (Burckle, 1972) of eastern and North Pacific.

Three other taxa have been attributed to the genus *Rossiella*.

3. *Rossiella tatsunokuchiensis* (Koizumi) Gersonde, 1980, p. 272.

1972 *Raphoneis tatsunokuchiensis* Koizumi, p. 349, pl. 42, figs 3, 4.

Length 33.6 μm, width 9.6 μm and areolae 8 in 10 μm.

This was found earlier from Pliocene and late Miocene cores from DSDP sites 213, 215, elsewhere and in the tropical Indian Ocean (Schrader, 1974). It is now reported from the top section of core (0-2 cm) MSN 37-P taken at 8°48′S, 109°38′E (Pl. 1, fig. 7).

4. *Rossiella praepaleacea* (Schrader) Gersonde, 1980, p. 272.

1973 *Coscinodiscus praepaleacea* Schrader, p. 703, pl. 3, fig. 1.

1974a *Cussia praepaleacea* (Schrader) Schrader, p. 914.

1973 *Bogorovia praepaleacea* (Schrader) Jouse, p. 351.

Length 38.4 μm, width 8.4 μm, areolae 8 in 10 μm. It has been reported from MSN 37-P, taken at 8°48′S, 109°38′E (Pl. 1, fig. 1).

5. *Rossiella moholensis* (Schrader) Desikachary comb. nov.

1974a *Cussia moholensis* Schrader, p. 542, Pl. 1, fig. 1, pp. 1-4.

This differs from *Rossiella paleacea* but resembles somewhat *R. elongata*.

A few other species do not resemble *Rossiella* (=Cussia) or even *Bogorovia*. They differ from the former in having transversely arranged areolae and from the latter in not having a costate condition.

6. *Cussia*(?) *lancettula* Schrader, 1974b, p. 914, pl. 1, figs 9, 10.

Length 45.6 μm, width 10.8 μm and areolae 7 in 10 μm. It occurs in the Core LSDA SCS 2G taken 6°48′N, 114°44′E (0-5 cm) (Pl. 1, fig. 12).

7. *Bogorovia*(?) *cypriata* Gardette, 1978.

Length 36 μm, width 10.8 μm and areolae 8 in 10 μm. It has been reported in Core LSDA SCS 3G taken at 8°14′N, 115°37′E (0-4 cm) (Pl. 1, fig. 6).

Jouse (1974, p. 351), Gardette (1978) and Hendey (1981) have rightly pointed out their resemblance to *Cymatosira*. *Cussia lancettula* and *Bogorovia cypriata* resemble very closely *Cymatosira*, but the same cannot be said of *Bogorovia mediopunctata* (Hajós) Jouse (=*Rhaphoneis sparsipunctata* Hajos, 1968, p. 143, pl. 41, figs 16-27), *B. mediopunctata* v. *matraensis* (Hajós) Jouse and *B. sparsipunctata* Hendey. These latter ones cannot be placed in *Cymatosira*, as we have no definite information about the pattern of colony formation in them.

8. *Rossiella gombosi* Desikachary sp. nov.

1983 *Rossiella* sp. Gombos, A. M. & Cieselski, P. F. Initial Repts. DSDP 71: 604, pl. 24, fig. 1-2.

Valves linear-lanceolate, symmetrical, apices rounded, 11.3-12.8 μm broad, 70-78.8 μm long; aerolate, areolae 6-7 in 10 μm.

Type Specimen — Gombos, 1983, loc. cit. pl. 24, fig. 1.

Locality — DSDP 513A-13-1, 67-69 cm; 47°34.99′S 24°38.40′W.

Gombos and Cieselski did not name the species pending a review of the species of *Rossiella*. This form is so different from the other species of *Rossiella*. Hence, it is described as a new species here.

ACKNOWLEDGEMENTS

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EXPLANATION OF PLATE

1. *Rossiella praepaleacea* (Schrader) Gersonde, MSN 27-P. × 1600.
2-5 & 8-11. *Rossiella paleacea* (Grun. in VH) Desikachary & Maheshwari.
2-3. Nancoori. × 1600.
4. Kamortha. × 1600.
5. South Naparenu. × 1600.
8-11. Colebrook Island. × 1600.
6. *Bogorovia*(?) *cypriata* Gardette, Core LSDA SCS 3G. × 1600.
7. *Rossiella tatsunokuchiensis* (Koizumi) Gersonde Core DSDP, sites 211, 215. × 1600.
12. *Cussia*(?) *lancettula* Schrader, Core LSDA SCS 4a. × 1600.


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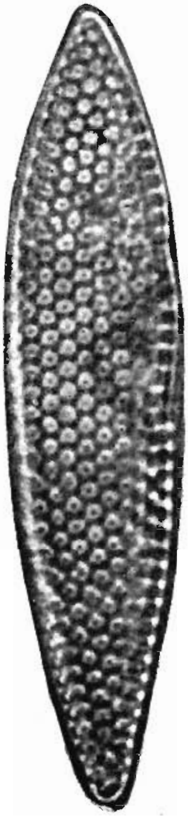
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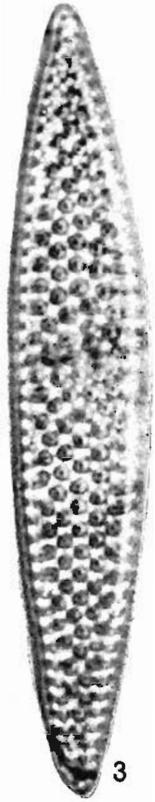
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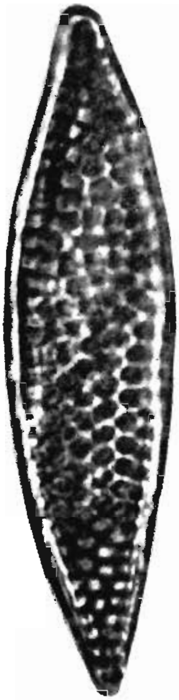
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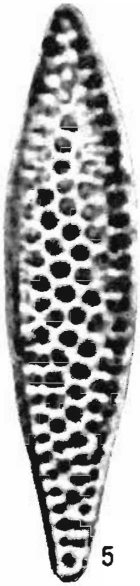
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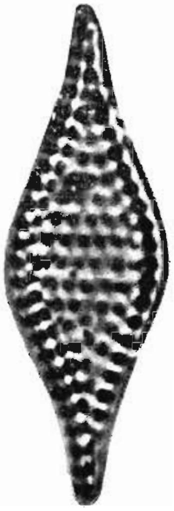
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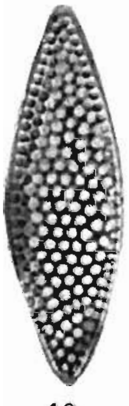
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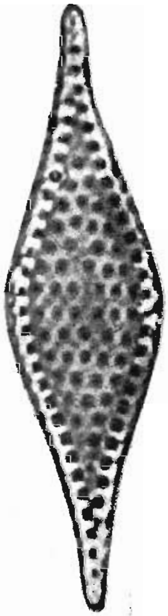
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Plate 1

The Palaeobotanist, **32**(3): 341-367, 1984.

PALYNOLOGICAL STUDIES OF THE TETHYAN SEQUENCE IN MALLA JOHAR AREA, KUMAON HIMALAYA, INDIA

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ABSTRACT

The sediments ranging from Palaeozoic to Mesozoic in the Tethyan sequence of Malla Johar were palynologically analysed. In spite of ill-preservation a significant assemblage has been recovered from the Upper Permian to Jurassic comprising 35 genera and 45 species of pollen and spores, and a number of fungal as well as other alete forms. The Devonian sediments have also yielded a characteristic assemblage of Chitinozoa. The miospore assemblages show a general resemblance with the constituents of the corresponding miofloras known from the Peninsular India. The comparisons with other miofloras indicate a Gondwana affinity rather than the Angarian resemblance.

Key-words — Palynology, Palaeozoic, Mesozoic, Tethyan sequence, Chitinizoa, Gondwana (India).

साराँश

कुमायूँ हिमालय (भारत) के मल्ला जोहर क्षेत्र में स्थित टॅथियन अनुक्रम का परागाणविक अध्ययन – राम शंकर तिवारी, विजया सिंह, सुरेन्द्र कुमार एवं इन्द्रबीर सिंह

मल्ला जोहर के टॅथियन अनुक्रम में पुराजीवी से मध्यजीवी कल्प तक विस्तृत अवसादों का परागाणविक विश्लेषण किया गया। क्षुद्र परिरक्षित होने पर भी उपरि परमी से जूराई कल्प तक विस्तृत एक विशिष्ट समुच्चय खोजी गई है जिससे कि परागकणों व बीजाणुओं के 35 वंश तथा 45 प्रजातियाँ तथा काफी मात्रा में कवकीय एवं अन्य अरहीन प्रारूप प्राप्त हुए हैं। डिवोनी अवसादों से काइटीनोजीवीयों से युक्त एक लाक्षणिक समुच्चय उपलब्ध हुई है। प्रायद्वीपीय भारत से विदित सम्बद्ध सूक्ष्मवनस्पतिजातों के अवयवों से मिओबीजाणु समुच्चय प्रायः समानता प्रदर्शित करते हैं। उपलब्ध प्रारूपों तथा अन्य सूक्ष्मवनस्पतिजातों की तुलना करने से ये अँगारा से समानता व्यक्त करने के बजाय गोंडवाना से सम्बन्ध प्रदर्शित करते हैं।

INTRODUCTION

THE sediments of Tethyan zone attaining a great thickness of more than 15,000 m and covering a time span from Precambrian to Cretaceous, are well-exposed in the northern-most part of the Kumaon and Himachal Himalaya. The Tethyan-zone-sediments differ in tectonic setting, lithologic frame-work and stratigraphic attributes from the sedimentary sequences exposed in the Lesser Himalaya which are separated from the Tethys sequence by a well-defined zone of high grade metamorphic rocks of the Central Crystallines of possibly Archean to Early Proterozoic age(?).

The present paper deals with the palynological study of the Tethys sediments exposed in Malla Johar area of the Kumaon Himalaya (U.P.). Tiwari *et al.* (1980) were the first to give a preliminary account of the palynological study of these sediments and the present paper is the final report of the same work which examines the data in detail.

GEOLOGICAL SETTING

The Tethys sediments of Malla Johar area occupy a terrain where height ranges from 3,500 to 7,000 m. Because of the extreme height and remoteness, the accessibility of the area is not only difficult but hazardous too. Except for the period from July to October, the area is covered throughout the year with snow. It is approachable from Rishikesh up to Malari by bus and from Malari by mule-tracks.

The Tethys sediments show almost continuous sequence from Precambrian to Cretaceous. In the southern part of the area, these rocks show a tectonic contact with the rocks of the Central Crystallines and in the north they are bounded by rocks of the exotic formation with a thrusted contact. Recently, the entire Tethys sequence has been designated as the Malla Johar Supergroup by Kumar *et al.* (1977). The Malla Johar Supergroup has been lithostratigraphically subdivided into four groups, viz., Malari Group, Sumna Group, Rawalibagar Group and Sancha Malla Group. Each group has been further subdivided into a number of formations. The lithostratigraphic scheme is given in Table 1.

The succession of the Malla Johar Supergroup represents deposits of a single sedimentation basin without any significant intermittent breaks (Kumar *et al.*, 1977). However, there are suggestions for a time-gap from Carboniferous to Lower Permian or epirogranic change in sedimentation between the deposition of the Sumna and Rawalibagar groups. The sediments of the Malla Johar Supergroup are dominantly shallow-water-deposits except in the case of rocks of the Sancha Malla Group which show characteristics of the deeper-water-deposits (Heim & Gansser, 1939; Kumar *et al.*, 1977).

The rocks of the area, in general, show effects of very low grade of metamorphism and are tectonically deformed. Geomorphologically the area shows juvenile landscape.

TABLE 1 — LIST OF SAMPLES FROM MALLA JOHAR AREA

FORMATION	LITHOLOGY	SAMPLE No.
SPITI SHALE	Shale	L 28*
	Shale	L 27*
	Shale	1*-10* (except 4, 9)
KIOTO LIMESTONE	Shale	117*, 116*
	Limestone	110*, 109*
PASSAGE FORMATION	Limestone	103*
	Shale	96*
KUTI SHALE	Shale	91
	Shale	KK 9
	Shale	KK 2
	Shale	KK 1
	Shale	382
	Shale	380, 379*
	Shale	377
	Shale	376
	Shale	375
	Shale	374
	Limestone	372*
	Limestone	371
KALAPANI LIMESTONE	Limestone	370 to 365
	Ammonoid	E_3 1
	Ammonoid	E_2 2
	Ammonoid	E_1 3
	Shale	364
	Limestone	363*
KULING SHALE	Shale	384
	Shale	385*, 386*, 387*
	Shale	388
	Sandstone	389*
	Siltstone	390
	Sandstone	391*, 392*, 393*
	Siltstone	394
	Siltstone	395
MUTH FORMATION	Sandstone	KP 31
	Siltstone	KP 32
	Shale	KP 33*
	Siltstone	KP 34*

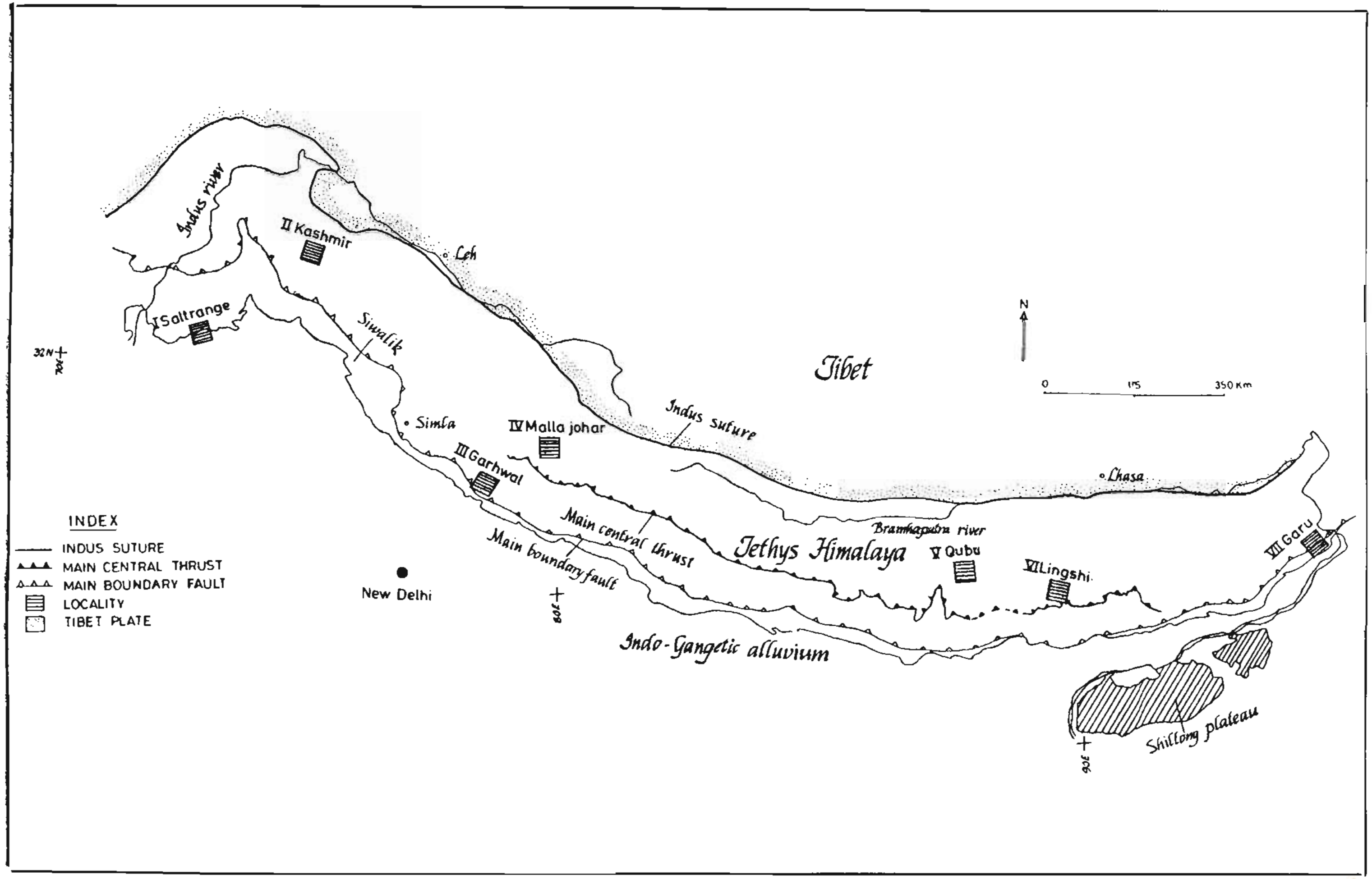
*Productive samples.

MATERIAL AND METHODS

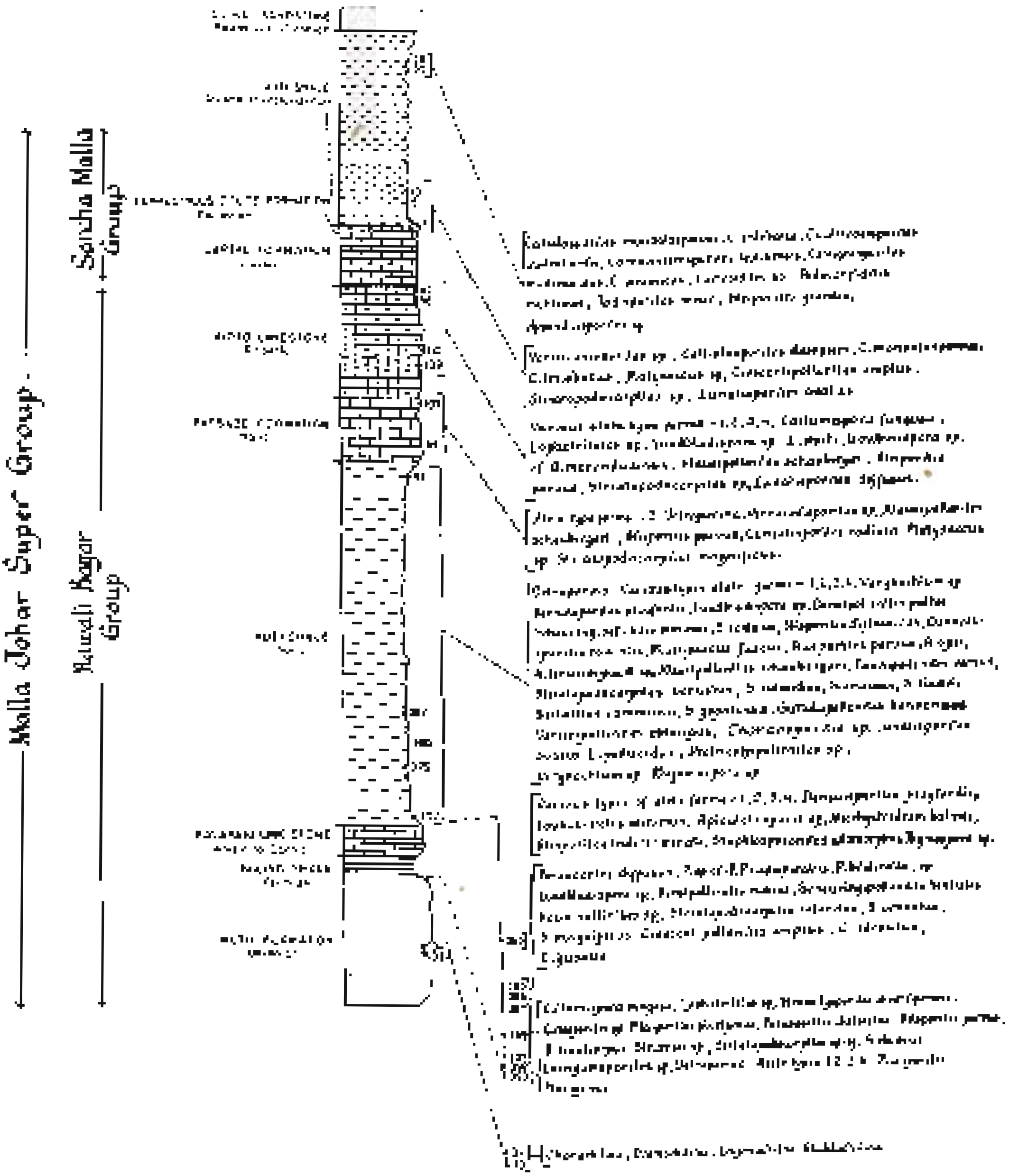
The samples analysed in the present investigation were collected by the members of an expedition organised by the Department of Geology, Lucknow University, Lucknow of which two of us (S.K. & I.B.S.) were the members. The systematic samples were collected along Sumna-Yong Mule-track and Sumna-Sancha-Malla Mule-track (Text-fig. 1; Table 1) in Malla Johar area. Detailed lithological characteristics of the beds met within these traverses are given by Kumar *et al.* (1977). The lithostratigraphy of these sequences alongwith the position of samples studied is given here in Text-fig. 2.

The miofloras were extracted from the samples by using usual method of maceration except that precautions were taken for slow reactions. In all, 58 samples were macerated, out of which 28 yielded the pollen-spore assemblage.

In general, the palynological yield in the samples under study was poor as well as difficult. Some of the specimens are charred,



TEXT-FIG. 1 — Locations of palaeobotanical finds along the Himalayan belt which show a Gondwanic affinity in their constituent, indicating thereby the continuation of Indian Plate up to that extent.



TEXT-FIG. 2 — Succession of miospore assemblages through the sections of Malla Johar area representing Devonian to Jurassic sediments (vertical scale 1 cm = 100 m). In Ferruginous Oolite Formation samples 2, 3, 6, 7 and 8 also yielded

blackened or otherwise distorted. The reason for general poverty of the mioflora population and their bad preservation may be attributed to the metamorphism and tectonic deformation to which these rocks have been subjected.

DESCRIPTION

The samples from the Garbyang Formation (Cambrian) to Balcha Dhura Formation belonging to Upper Cretaceous were macerated for palynological studies. However, no miospores could be recovered in the rocks of Malari and Sumna groups. The best yield was from the rocks of Rawalibagar Group. In the Sancha Malla Group, only the Spiti Shale yielded a few miospore species. However, Jain *et al.* (in press) have recovered a rich assemblage from the upper reaches of the Spiti Shale.

The following brief descriptions of *sporae dispersae* are being given in order to assess the identification because the photomicrographs do not always exhibit full details due to ill preservation. A few species, however, have neither been illustrated nor described but only included in the list, after identification under microscope.

LIST OF SPECIES

Triletes

Callumispora Bharadwaj & Srivastava, 1969; *C. fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977 (Pl. 1, fig. 1); *Hennellysporites* Tiwari, 1968; *H. diversiformis* (Balme & Hennelly) Tiwari, 1968; *Lophotriletes* emend. Potonié & Kremp, 1954; *Lophotriletes* sp.; *L. minimus* Salujha, 1965; *Apiculatisporites* Potonié & Kremp, 1954; *Apiculatisporites* sp.; *Densoisporites* Weyland & Krieger emend. Dettmann, 1963; *D. playfordii* (Balme) Dettmann, 1963 (Pl. 1, fig. 6); *Verrucosisporites* Ibrahim emend. Smith *et al.*, 1967; *Verrucosisporites* sp. (Pl. 1, fig. 7) *Lundbladispora* Balme emend. Playford, 1965; *Lundbladispora* sp.

Monoletes

Laevigatosporites Ibrahim, 1933; *Thymospora* Wilson & Venkatachala, 1963.

Monocolpate

Pretricolpipollenites Danze-Corsin & Laevine, 1963; *P. bharadwajii* Balme, 1970.

Monosaccates

Parasaccites Bharadwaj & Tiwari, 1964; *P.* sp. cf. *P. radiaplicatus* Maithy, 1965; *P. diffusus* Tiwari, 1965 (Pl. 1, fig. 2); *P. distinctus* Tiwari, 1965 (Pl. 1, fig. 8); *P. bilateralis* Tiwari, 1965 (Pl. 3, fig. 16); *Densipollenites* Bharadwaj, 1962; *D. indicus* Bharadwaj, 1962; *D. densus* Bharadwaj & Srivastava, 1969 (Pl. 2, fig. 15); *D. pullus* Segroves, 1969 (Pl. 2, fig. 14); *Guttulapollenites* Goubin emend. Venkatachala & Kar, 1967; *G. hannonicus* Goubin, 1965 (Pl. 2, fig. 12); *Callialasporites* Dev, 1961; *C. trilobatus* (Balme) Dev, 1961 (Pl. 2, fig. 9); *C. dampieri* (Balme) Dev, 1961 (Pl. 2, fig. 11); *C. monoalasporus* Dev, 1961 (Pl. 2, fig. 10); *Goubinispora* Tiwari & Rana, 1981; *G.* sp. cf. *G. morondavensis* (Goubin) Tiwari & Rana, 1981 (Pl. 4, fig. 26).

Dsaccates (Non-striate)

Scheuringipollenites Tiwari, 1973; *S. maximus* (Hart) Tiwari, 1973; *S. tentulus* (Tiwari) Tiwari, 1973 (Pl. 3, fig. 19); *Alisporites* Daugherty emend. Jansonius, 1971; *A.* sp. cf. *A. opii* Daugherty, 1941 (Pl. 2, fig. 13); *A. parvus* Thiergart & Frantz, 1962; *A. tenuicorpus* Balme, 1970; *A.* sp. A; *Piceaepollenites* Potonié, 1931; *Piceaepollenites* sp; *Platysaccus* (Naum.) Pot. & Kl., 1954; *P. fuscus* Goubin, 1965; *Klausipollenites* Jansonius, 1962; *K. schaubergeri* (Pot. & Kl.) Janson., 1962 (Pl. 1, fig. 5); *Ibisporites* Tiwari, 1968; *I. diplosaccus* Tiwari, 1968; *Cuneatisporites* Leschik, 1955; *C. radialis* Leschik, 1955 (Pl. 4, fig. 30).

Disaccates (Striate)

Faunipollenites Bharadwaj, 1962; *F. varius* Bharadwaj, 1962; *F.* sp.; *Crescentipollenites* Bharadwaj, Tiwari & Kar, 1974; *C. amplus* (Balme & Hennelly) Tiwari & Rana, 1980 (Pl. 3, fig. 17); *C. fuscus* (Bharad.) Bharad., Tiwari & Kar, 1974; *C.* sp. (Pl. 3, fig. 20); *C. hirsutus* (Kar) Bharadwaj, Tiwari & Kar, 1974; *Striatopodocarpites* Soritsch. & Sedova, 1956; *S. magnificus* Bharad. & Salujha, 1964, (Pl. 1, fig. 3); *S.* sp. cf. *S. decorus* Bharad. & Salujha, 1964 (Pl. 3, fig. 21); *S. venustus* Bharadwaj & Salujha, 1965 (Pl. 3, fig. 18); *S. crassus* Tiwari, 1965; *S. rotundus* (Maheshwari) Bharadwaj & Dwivedi, 1981 (Pl. 3, fig. 23); *S. tiwarii* Bharadwaj & Dwivedi, 1981 (Pl. 3, fig. 22); *Striatites* Pant emend. Bharadwaj 1962; *S. communis* Bharadwaj & Salujha, 1964 (Pl. 4, fig. 25); *S. varius* Kar, 1968 (Pl. 4, fig. 24); *S. gopalensis* Srivastava, 1970 (Pl. 4, fig. 28); *S.* sp. (Pl. 1, fig. 4); *Verticipollenites* Bharadwaj, 1962; *V. oblongus* Bharadwaj, 1962 (Pl. 4, fig. 29); *Rhizomaspora* Wilson, 1962; *Rhizomaspora* sp.

Taeniate

Lunatisporites Leschik emend. Bharadwaj, 1974; *L. ovatus* (Goubin) Maheshwari & Banerji, 1975 (Pl. 4, fig. 31); *L. pellucidus* (Goubin) Maheshwari & Banerji, 1975; *L. diffusus* Bharadwaj & Tiwari 1977; *Chordasporites* Klaus, 1960; *Chordasporites* sp. (Pl. 4, fig. 27).

Incertae sedis (Aletes)

Pilasporites Balme & Hennelly emend. Tiwari & Navale, 1967; *P. plurigenus* Balme & Hennelly, 1956 (Pl. 5, fig. 43); *Tetraporina* Naumova ex Naumova, 1956; *Tetraporina* sp.

Fungal Spores

Type — 1 (Pl. 5, figs 47, 48, 49)
Type — 2 (Pl. 5, figs 45, 46)
Type — 3 (Pl. 5, figs 34, 35, 50, 51, 53, 54)
Type — 4 (Pl. 5, figs 40, 41)
Indeterminate (Pl. 5, figs 33, 36-39)

Achritarchs

Varyhachium Denuff, 1954; *Varyhachium* sp. (Pl. 5, fig. 32); *Staphlosporonites* Sheffy & Dilcher, 1971; *Staphlosporonites allomorphus* Sheffy & Dilcher, 1971; (Pl. 5, figs 42, 52); *Micrhystridium* Deflandre emend. Downie & Sarjeant, 1963; *M. balmei* Sarjeant, 1971 (Pl. 5, fig. 44).

Chitinozoa

Cyathochitina Eisenack, 1955 (Pl. 6, fig. 67); *Ancyrochitina* Eisenack, 1955 (Pl. 6, fig. 62); *Chonochitina* Eisenack, 1931 restr. Eisenack, 1955 (Pl. 6, figs 60, 65); cf. *Chonochitina* sp. (Pl. 6, fig. 69); *Angochitina* Eisenack, 1931 (Pl. 6, figs 56, 59); *Rhabdochitina* Eisenack, 1931 (Pl. 6, fig. 58); *Lagenochitina* Eisenack, 1931 (Pl. 6, figs 61, 68); cf. *Lagenochitina* (Pl. 6, fig. 64); *Desmochitina* Eisenack emend. Eisenack, 1962 (Pl. 6, figs 55, 57, 63, 66).

Genus — *Callumispora* Bharadwaj & Srivastava, 1969

Type species — *Callumispora barakarensis* Bharadwaj & Srivastava, 1969.

Callumispora fungosa (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977

Pl. 1. fig. 1

Holotype — Balme, 1963; pl. 4, fig. 10.

Description — Subcircular, trilete spore, 95 μm in diameter; exine 3 μm thick, uniformly and coarsely infrapunctate. *Extrema lineamenta* smooth.

Remarks — It is typically a Triassic species in the Indian Gondwana sequence.

Genus — *Densoisporites* Weyland & Krieger emend. Dettmann, 1963

Type Species — *Densoisporites velatus* Weyland & Krieger, 1953.

Densoisporites playfordii (Balme) Dettmann, 1963

Pl. 1, fig. 6

Holotype — Balme, 1963; pl. 5, fig. 4.

Description — Ill-preserved, trilete, cavate spore with thick laevigate cingulum. Exine laevigate, indistinctly infrapunctate; *extrema lineamenta* smooth.

Genus — *Verrucosisporites* Ibrahim emend. Smith. *et al.*, 1971

Type Species — *Verrucosisporites verrucosus* Ibrahim, 1933.

Verrucosisporites sp.

Pl. 1, fig. 7

Description — Subtriangular, 90×70 μm. Trilete mark not clear; big rounded verrucae-like bodies present which being closely placed along the equator.

Remarks — The massive nature of verrucae on equator is characteristic for this specimen.

Genus — *Lundbladispora* Balme emend. Playford, 1965

Type Species — *Lundbladispora willmotti* Balme, 1963.

Lundbladispora sp.

Description — A badly preserved, cingulate, cavate spore; Y-mark represented by folds; cingulum thick showing verrucae, coni, mixed ornamentation, central body area apparent, not clearly defined.

Remarks — Since no haptotypic characters are visible, the identification has not been possible up to the specific level.

Genus — *Parasaccites* Bharadwaj & Tiwari, 1964

Type Species — *Parasaccites korbaensis* Bharadwaj & Tiwari, 1964.

Parasaccites diffusus Tiwari, 1965

Pl. 1, fig. 2

Holotype — Bharadwaj & Tiwari, 1964; pl. 2, fig. 11.

Description — Pollen circular, saccus 10-20 μm wide. Central body thin, outline indistinct, Y-mark not seen. Saccus attachment in para-condition, encroaching sub-equatorially on both the surfaces; saccus intrareticulation mediumly coarse.

Remarks — The saccus is restricted to only equatorial region and does not cover the distal side as in *Cordaitina*. The latter organization is not known from the Indian Gondwana assemblages.

Parasaccites distinctus Tiwari, 1965

Pl. 1, fig. 8

Holotype — Tiwari, 1965; pl. 4, fig. 77.

Description — Subcircular 108-120 μm, with girdling monosaccus. Central body thin, outline visible, 90-110 μm in diameter. Saccus uniformly wide, 24 μm in one specimen (Pl. 1, fig. 12) tending to be lobed, para-condition of saccus attachment clear, saccus intrareticulation mediumly coarse.

Parasaccites bilateralis Tiwari, 1965

Pl. 3, fig. 16

Holotype — Bharadwaj & Tiwari, 1964; pl. 2, fig. 12.

Description — Monosaccate, 130×90 μm, saccus 8 μm wide at lateral sides and 36 μm at terminal sides. Central body thin, subcircular. Y-mark not visible. Saccus structure obscure.

Remarks — This species is characterised by its bilateral symmetry resulted by widening of sacci at two opposite terminal sides.

Genus — *Densipollenites* Bharadwaj, 1962

Type Species — *Densipollenites indicus* Bharadwaj, 1962.

Densipollenites pullus Segroves, 1969

Pl. 2, fig. 14

Holotype — Segroves, 1969; pl. 4, fig. A.

Description — Roundly subtriangular in flattened condition, 110×80 μm. Central body seen at the margin due to shifting in certain specimens, circular, dark brown 42 μm in diameter. Saccus enveloping-type, having thick irregular and broken muri; limbus-like structure at equatorial region present.

Remarks — *D. indicus* Bharadwaj, 1962 has a thin body with distinct outline. In the structure of the saccus intrareticulation also, the present specimen differs from the type species.

Densipollenites densus Bharadwaj & Srivastava, 1969

Pl. 2, fig. 15

Holotype — Bharadwaj & Srivastava, 1969; pl. 24, fig. 5.

Description — Pollen grain 100×80 μm; central body 44 μm, subcircular, well-defined, darker than the saccus. Saccus with medium-sized reticulum. Limbus-like structure not clear.

Remarks — Comparatively dense, distinct and big body is the characteristics of this species.

Genus — *Guttulapollenites* Goubin emend. Venkatachala & Kar, 1967

Type Species — *Guttulapollenites hannonicus* Goubin, 1965.

Guttulapollenites hannonicus Goubin, 1965

Pl. 2, fig. 12

Holotype — Goubin, 1965; pl. 6, figs 5, 6.

Description — Pollen subcircular to oval, 72×72 μm. Central body oval. Sacci pyriform, more or less equal in size. Two sets of double sacci-like structures covering the body alternately on two sides. Broken or laterally preserved specimens showing apparently irregular arrangement of the four sacci. Intrareticulation of sacci fine with thick muri.

Genus — *Callialasporites* Dev, 1961

Type Species — *Callialasporites trilobatus* (Balme) Dev, 1961.

Remarks — The specimens described under this genus are blackish and charred in appearance due to high degree of diagenesis.

Callialasporites trilobatus (Balme) Dev, 1961

Pl. 2, fig. 9

Holotype — Balme, 1957; pl. 8, fig. 91.

Description — Roundly subtriangular miospores, 72-74 μm in size. Central body triangular with broad round ends, 50-52 μm; Y-mark not prominent; exine 1-2 μm thick, dark, having a thinner region in the centre. Sacci three, with distinct, complete or incomplete delimitation, 10-12 μm wide at their maximum with ridge-like thickening at the equator but without prominent radiating folds; finely verrucose to chagrinate sculpture seen.

Remarks — The specimens showing three distinct sacci without radiating ridges are included in this species. They are black and appear to be 'charred' hence the infra-structure of exine is not clear.

Callialasporites dampieri (Balme) Dev, 1961

Pl. 2, fig. 11

Holotype — Balme, 1957; pl. 8, fig. 88.

Description — Sub-oval, size 75×68 μm; bladder wide with frilling appearance due to radiating folds, incompletely trilobed, 2 μm thick, granulose to chagrinate; central body subcircular, dark brown. Trilete mark not clear.

Remarks — This species differs from *C. trilobatus* in the absence of clear trilobate condition.

Callialasporites monoalasporus Dev, 1961

Pl. 2, fig. 10

Holotype — Dev, 1961; pl. 4, fig. 59.

Description — Subcircular to oval, size 72-83 μm. Saccus unlobed, 8 μm wide, granulose. Body big, usually not sharply defined. In the central region a thin circular area visible.

Genus — *Goubinispora* Tiwari & Rana, 1981

Type Species — *Goubinispora indica* Tiwari & Rana, 1981.

Goubinispora sp. cf. *G. morondavensis* (Goubin) Tiwari & Rana, 1981

Pl. 4, fig. 26

Holotype — Goubin, 1965; pl. 1, fig. 5.

Description — Badly preserved monosaccate pollen, saccus apparently girdling, lobed, attachment not clear. Central, body showing chagrinate exine.

Remarks — The tendency of saccus to make lobes and to widen at terminal ends has been noticed, as in the illustrated specimen. This indicates its affinity with the genus *Goubinispora*.

Genus — *Alisporites* Daugherty emend. Jansonius, 1971

Type Species — *Alisporites opii* Daugherty, 1941.

Alisporites sp. cf. *A. opii* Daugherty, 1941

Pl. 2, fig. 13

Holotype — Daugherty, 1941; pl. 34, fig. 2.

Description — Bisaccate, haploxylonoid. Central body distinct, big, vertically oval; exine intramicroreticulate, without striations. Sacci less than hemisphere, 15 μm wide, laterally close to each other and distally inclined to leave a 20 μm wide sulcus; sacci finely intrareticulate.

Remarks — *A. opii* includes grains with finely infragranulose exine.

Genus — *Klausipollenites* Jansonius, 1962

Type Species — *Klausipollenites schaubergeri* (Potonié & Klaus) Jansonius, 1962.

Klausipollenites schaubergeri (Potonié & Klaus) Jansonius, 1962

Pl. 1, fig. 5

Holotype — Potonié & Klaus, 1954; pl. 10, figs 7, 8.

Description — Disaccate, bilaterally oval, haploxylonoid pollen with non-striate, vertically oval central body with clearly inframicroreticulate exine. Size of grain 49.5×

36 μm. Sacci small, narrow, laterally close to each other. Distal sulcus apparently wide and ill-defined. Saccus intrareticulation fine.

Remarks — *Klausipollenites* group of pollen are simple non-striate disaccate having small sacci. The characters being not diversified, no attempts have been made to circumscribe the species in this genus. Most of the Triassic forms reported from India have been described under *K. schaubergeri* (see Bharadwaj & Tiwari, 1977; Maheshwari & Banerji, 1975); as such, they have finely infrareticulate exine structure of the body.

Genus — *Crescentipollenites* Bharadwaj, Tiwari & Kar, 1974

Type Species — *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj, Tiwari & Kar, 1974.

Crescentipollenites amplus (Balme & Henn.) Tiwari & Rana, 1980

Pl. 3, fig. 17

Holotype — Balme & Hennelly, 1956; pl. 3, fig. 24.

Description — Bilateral disaccate, haploxylonoid pollen with rhomboid central body. Distal sulcus distinct, 30 μm wide, in the middle but narrower — 15 μm wide, at lateral sides; zone of saccus attachment of distal side associated with distinct, semilunar folds. Striations 8-10, no vertical partitions between the striations. Exine of body finely intrareticulate; sacci also showing fine meshes as structure.

Crescentipollenites sp.

Pl. 3, fig. 20

Description — Bilateral bisaccate, slightly diploxylonoid pollen. Central body broadly oval with round ends, 44×66 μm, striations 7, distinct; distal sulcus biconvex, 18 μm; sacci laterally close to each other, finely intrareticulate.

Comparison — This species resembles *C. notabilis* (Tiwari) Bharadwaj, Tiwari & Kar, 1974 but does not show the dumb-bell-shaped sulcus. *C. hirsutus* (Kar) Tiwari & Rana, 1980 has an equatorial ridge in the body and the striations are zig zag, hence it is different.

Genus — *Striatopodocarpites* Soritsch & Sedova, emend. Bharadwaj, 1962

Type Species — *Striatopodocarpites tojmensis* Sedova, 1956.

Striatopodocarpites rotundus (Maheshwari) Bharadwaj & Dwivedi, 1981

Pl. 3, fig. 23

Holotype—Maheshwari, 1967; pl. 7, fig. 57.

Description — Badly preserved bilateral, disaccate, diploxylonoid, 84×96 μm. Central body big, subcircular; sacci narrow smaller than the body, laterally widely separated from each other. Zone of sacci attachment at distal side straight without lunar folds; sulcus being wide. Sacci finely intrareticulate.

Striatopodocarpites sp. cf. *S. decorus* Bharadwaj & Salujha, 1964

Pl. 3, fig. 21

Holotype — Bharadwaj & Salujha, 1964; pl. 10, fig. 140.

Description — Slightly laterally flattened, disaccate-striate pollen, 80×44 μm; central body distinct, finely intrareticulate, body ends appearing to be truncate. Sulcus 12 μm wide.

Remarks — *S. decorus* is characterised by rhomboidal body with truncate ends. The real nature of body in this specimen is not discernible due to lateral flattening and thus a provisional assignment to this species has been made.

Striatopodocarpites venustus Bharadwaj & Salujha, 1965

Pl. 3, fig. 18

Holotype — Bharadwaj & Salujha, 1965; pl. 2, fig. 37.

Description — Diploxylonoid pollen 62×109 μm with vertically oval distinct body, exine intrareticulate, striations simple, 7 in number, distal sulcus 15 μm wide; no lunar folds along zones of attachment.

Striatopodocarpites magnificus Bharadwaj & Salujha, 1964

Pl. 1, fig. 3

Holotype — Bharadwaj & Salujha, 1964; pl. 10, fig. 143.

Description — Diploxylonoid grains 68 × 108 μm. Central body distinct, subcircular, 40 × 60 μm, 8-10 striations, simple; exine intramicroreticulate.

Striatopodocarpites tiwarii Bharadwaj & Dwivedi, 1981

Pl. 3, fig. 22

Holotype — Tiwari, 1965; pl. 7, fig. 151.

Description — Diploxylonoid, subcircularly oval grain, 85 × 67 μm. Central body big, well-defined, 50 × 56 μm. Oval with round ends. 6 horizontal striations present. Exine of body intramicroreticulate. Distal sulcus narrow. Sacci narrow, meeting laterally to form distinct notch, mediumly intrareticulate.

Genus — *Striatites* Pant emend. Bharadwaj, 1962

Type Species — *Striatites sewardii* (Virkki) Pant, 1955.

Striatites communis Bharadwaj & Salujha, 1964

Pl. 4, fig. 25

Holotype — Bharadwaj & Salujha, 1964, pl. 7, fig. 105.

Description — Diploxylonoid, 120 × 78 μm. Central body circular, 53 μm without marginal ridge, not very thick. Horizontal striations 9, vertical partition absent, sulcus 10 μm wide straight. Sacci spherical, big, medium-sized with intrareticulate structure.

Striatites varius Kar, 1968

Pl. 4, fig. 21

Holotype — Kar, 1968, pl. 2, fig. 55.

Description — Disaccate, diploxylonoid, central body circular dense, 35 μm microverrucose; striations horizontal, no vertical partition, distal sulcus narrow; sacci finely intrareticulate.

Striatites gopadensis Srivastava, 1970

Pl. 4, fig. 28

Holotype — Srivastava, 1970; pl. 1, fig. 13.

Description — Bisaccate, diploxylonoid, 84 × 42 μm. Central body dense, 35 μm in size, distinct, equatorial rim present; horizontal striations 5, no vertical partitions, exine of the body finely microverrucose; distal sulcus narrow, straight, sacci bigger than the body, laterally close to each other, finely intrareticulate.

Striatites sp.

Pl. 3, fig. 4

Description — Haploxylonoid, bisaccate grain. Central body vertically oval with well-defined equatorial rim, 60 × 40 μm horizontal striations 8, no vertical partitions, sulcus 8 μm wide, slightly convex; sacci smaller than the body, medium-sized intrareticulate.

Remarks — No other species is known in this genus with equatorial rim on the body and haploxylonoid construction of the sacci.

Genus — *Verticipollenites* Bharadwaj, 1962

Type Species — *Verticipollenites secretus* Bharadwaj, 1962.

Verticipollenites oblongus Bharadwaj, 1962

Pl. 4, fig. 29

Holotype — Bharadwaj, 1962; pl. 13, fig. 150.

Description — Disaccate, diploxylonoid, 84 × 48 μm; central body vertically oval, 20 × 17 μm, thick, micro-intrareticulate; horizontal striations 6, vertical partitions few. Sacci big, spherical, pitcher-shaped, leaving distally 10 μm wide free-area, finely intrareticulate.

Remarks — The specimens described by Bharadwaj (1962) possess more vertical partitions than the present specimen. However, in other characters the latter resembles the holotype.

Genus — *Lunatisporites* Leschik, 1955 emend. Bharadwaj, 1974

Type Species — *Lunatisporites acutus* Leschik, 1955.

Lunatisporites ovatus (Goubin) Maheshwari & Banerji, 1975

Pl. 4, fig. 11

Holotype — Goubin, 1965, pl. 2, fig. 2.

Description — Disaccate, haploxylonoid, 80 μm. Central body broadly oval, distinct.

40 μm, exine intramicroreticulate; taenie 7, with irregular spaces in between each other. Sulcus 10-15 μm wide, zone of saccus attachment accompanied by lunar folds. Sacci finely intrareticulate.

Genus — *Chordasporites* Klaus, 1960

Type Species — *Chordasporites singulichorda* Klaus, 1960.

Chordasporites sp.

Pl. 4, fig. 27

Description — Bilateral, nonstriate-disaccate grain. Central body horizontally oval, thin, distinct, proximally bearing a 5 μm wide, straight chord-like strip, entering at both ends in sacci. Body exine finely intrareticulate. Sacci ear-lobe-shaped, more or less equal to the central body, intrareticulate with fine muri and meshes, distally inclined only up to 5 μm entering central body outline; laterally widely apart.

Genus — *Staphlosporonites* Sheffy & Dilcher, 1971

Type Species — *Staphlosporonites conoidens* Sheffy & Dilcher, 1971.

Staphlosporonites allomorphus Sheffy & Dilcher, 1971

Pl. 5, figs 42, 52

Description — Multicellular, oblong body with irregular cell size and orientation; septa 1 μm thick, surface psilate. Cell wall 1 μm thick; one cell at the narrow end usually elongated.

Remarks — These are fungal cells resembling the modern genus *Alternaria* (Pirozynski, 1976).

Genus — *Veryhachium* Denuff, 1954 emend. Downie & Sarjeant, 1963

Type Species — *Veryhachium trisulcum* (Denuff) Denuff, 1954.

Veryhachium sp.

Pl. 5, fig. 32

Description — Vesicle triangular lenticular, the corners drawn out into three appendages, one broken, second one half, third one bifurcated at tip. Appendages open into vesicle cavity; wall smooth or with minor sculpture.

Genus— *Micrhystridium* Deflandre, 1937 emend. Sarjeant, 1963

Type Species — *Micrhystridium inconspicum* Deflandre, 1937.

Micrhystridium balmei Sarjeant, 1971

Pl. 5, fig. 44

Holotype — *Micrhystridium balmei* Sarjeant, 1971.

Description — Vesicle 20 μm sphaeroidal to broadly ovoidal bearing 1-1.5 μm long, thin spines with broader bases. Opening as a bent, cryptosuture seen in the form of a fold.

A number of alete sporomorphs having unorganised germinal aperture and with or without ornamentation have been found. These are described here as ' types '.

TYPE 1

Pl. 5, figs 47, 48, 49

Description — Small subcircular to ovoidal body, usually with one or two longitudinal folds; size 15-17 μm. Exine dark thick, beset with 1 μm high verrucae all over the body.

TYPE 2

Pl. 5, figs 45, 46

Description — Subcircular to triangular, 17-19 μm in size. Exine beset with 0.5-1 μm verrucae all over the body; folds generally forming a triangular area. Cryptopore circular distinct in most of the specimens, situated on the reverse side of the folds.

TYPE 3

Pl. 5, figs 34, 35, 50, 51, 53, 54

Description — Circular, 12-20 μm in diameter; exine one or many layered, 1-4 μm thick, psilate, internally finely structured, infragranulose. In some specimens cryptosuture seen as a splitting zone.

Type 4

Pl. 5, figs 40, 41

Description — Circular dark brown miospore, 36 μm, including process. Equatorially 4 μm wide, dark, thick zone present; ornamentation 2-4 μm long, flat, thin 4 μm wide squarish papillate covering the surface and projecting on the equator as a 'corona'. Germinal mark not seen.

CHITINOZOA

The Chitinozoa are being assigned only to the comparable generic placement; the detailed work will only be taken after the collection of several more specimens. However, the significance of their record is obvious in these hitherto known nonfossiliferous strata.

Genus — *Chonochitina* Eisenack, 1931 restr. 1955

Type Species — *Chonochitina claviformis* Eisenack, 1931.

Chonochitina sp.

Pl. 6, figs 60, 65

Description — The specimens illustrated here being somewhat variable in shape; test almost conical, constricted, forming oral tube; basal margins rounded, base convex. Oral tube varying in shape. Maximum diameter near base 90-110 μm, total length 145-150 μm. Body-wall laevigate.

cf. *Chonochitina* sp.

Pl. 6, fig. 69

Description — Test elongated, conical, maximum diameter near the base 54 μm, length 166 μm. On the body-wall scars seen, may be remnants of the appendages.

Genus — *Cyathochitina* Eisenack, 1955

Type Species — *Cyathochitina campanulaeformis* (Eisenack) Eisenack, 1955.

Cyathochitina sp.

Pl. 6, fig. 67

Description — Test slightly constricted exhibiting the emergence of oral tube. Basal margin conico-flat measuring 116 μm in width, base flat. Total length 160 μm. Body-wall showing no appendages.

Genus — *Ancyrochitina* Eisenack, 1955

Type Species — *Ancyrochitina ancyrea* (Eisenack) Eisenack, 1955.

Ancyrochitina sp.

Pl. 6, fig. 62

Description — Conical chamber differentiable from cylindrical neck, basal margin slightly convex, basal diameter 130 μm. Total length 146 μm. Spines on side walls of the chamber simple or multifurcate.

Genus — *Angochitina* Eisenack, 1931

Type Species — *Angochitina echinata* Eisenack, 1931.

Angochitina sp.

Pl. 6, figs 56, 59

Description — Test cylindro-conoid in shape, measuring 75-85 μm in diameter, total length being 108-116 μm. Spines are present all over the test, variable in shape and size.

Genus — *Rhabdochitina* Eisenack, 1931

Type Species — *Rhabdochitina magna* Eisenack, 1931.

Rhabdochitina sp.

Pl. 6, fig. 58

Description — Test cylindro-conical, base weakly conical measuring 100×238 μm. Basal scars on body-wall apparent.

Genus — *Lagenochitina* Eisenack, 1931

Type Species — *Lagenochitina baltica* Eisenack, 1931.

Lagenochitina sp.

Pl. 6, figs 61, 68

Description — In the specimens illustrated, the test is large, damaged at apex; basal margin rounded, base slightly convex; maximum diameter near base 76-90 μm. Total length from 114-130 μm. Body wall laevigate.

cf. *Lagenochitina* sp.

Pl. 6, fig. 64

Description — Specimen showing clear differentiation of the test into a chamber and the oral tube. Basal margin of the chamber rounded, base convex, maximum diameter at base 70 μm and the total length 210 μm. Body wall smooth.

Genus — *Desmochitina* Eisenack emend. Eisenack, 1962

Type Species — *Desmochitina nodosa* Eisenack, 1931.

cf. *Desmochitina* sp.

Pl. 6, figs 55, 57, 63, 66

Remarks — Illustrated specimens are variable in their overall shape. Tests are sub-spherical, maximum diameter of these discs varying from 50 to 150 μm and the total length 50-200 μm.

QUALITATIVE COMPOSITION OF MIOFLORAL ASSEMBLAGE

The quantitative determination of the assemblage could not be done because of the paucity of miospore specimens. However, in a fairly good number of specimens the morphographic characters are clearly discernible which have made the specific identifications possible. The palynomorphs, thus, identified are significant enough to be considered as characteristic for each assemblage delimited here. For qualitative assessment, the general pattern of occurrence has been considered to evaluate the situation (also see Text-fig. 2).

1. *Malari Group* — No sample analysed.
2. *Sumna Group* — No yield of miospores except in two samples (34, 33) from the Muth Formation, where some chitinozoans have been found in which the forms *Chonochitina*, *Desmochitina*, *Lagenochitina*, *Rhabdochitina* are significant.

The forms recorded in this paper are quite widely-ranging at generic level, and since no specific-level identifications have been attempted here, the precise dating is not being proposed in this work. However, the important forms diagnostic of the Devonian age are present in these samples — a supporting evidence of the conventional view regarding the age of Muth Formation.

3. *Rawalibagar Group*:

(i) *Kuling Shale* (*Formation*) — The Kuling Shale is the oldest horizon which has yielded miospore in the present study. The fossil yielding sample nos. are 393, 392, 391, 389, 387, 386 and 385. Thus, in addition to the samples which yielded in the earlier work (Tiwari *et al.*, 1980), the sample nos. 391, 392 and 393 have also been found to contain miospores during the present study. The species identified are:

Callumispora fungosa, *Lophotriletes* sp., *Hennellysporites diversiformis*, *Lundbladispora* sp., *Verrucosisporites* sp., *Densipollenites indicus*, *Parasaccites diffusus*, *P. distinctus*, *P. bilateralis*, *P.* sp. cf. *P. radiaplicatus*, *Scheuringipollenites tentulus*, *Alisporites parvus*, *A. tenuicorpus*, *A.* sp., *Faunipollenites* sp., *Crescentipollenites ampulus*, *C. hirsutus*, *C. fuscus*, *C.* sp., *Striatopodocarpites rotundus*, *S. venustus*, *S.* sp. cf. *S. decorus*, *S. magnificus*, *Striatites* sp., *Luevigatosporites* sp., *Pilasporites plurigenus*.

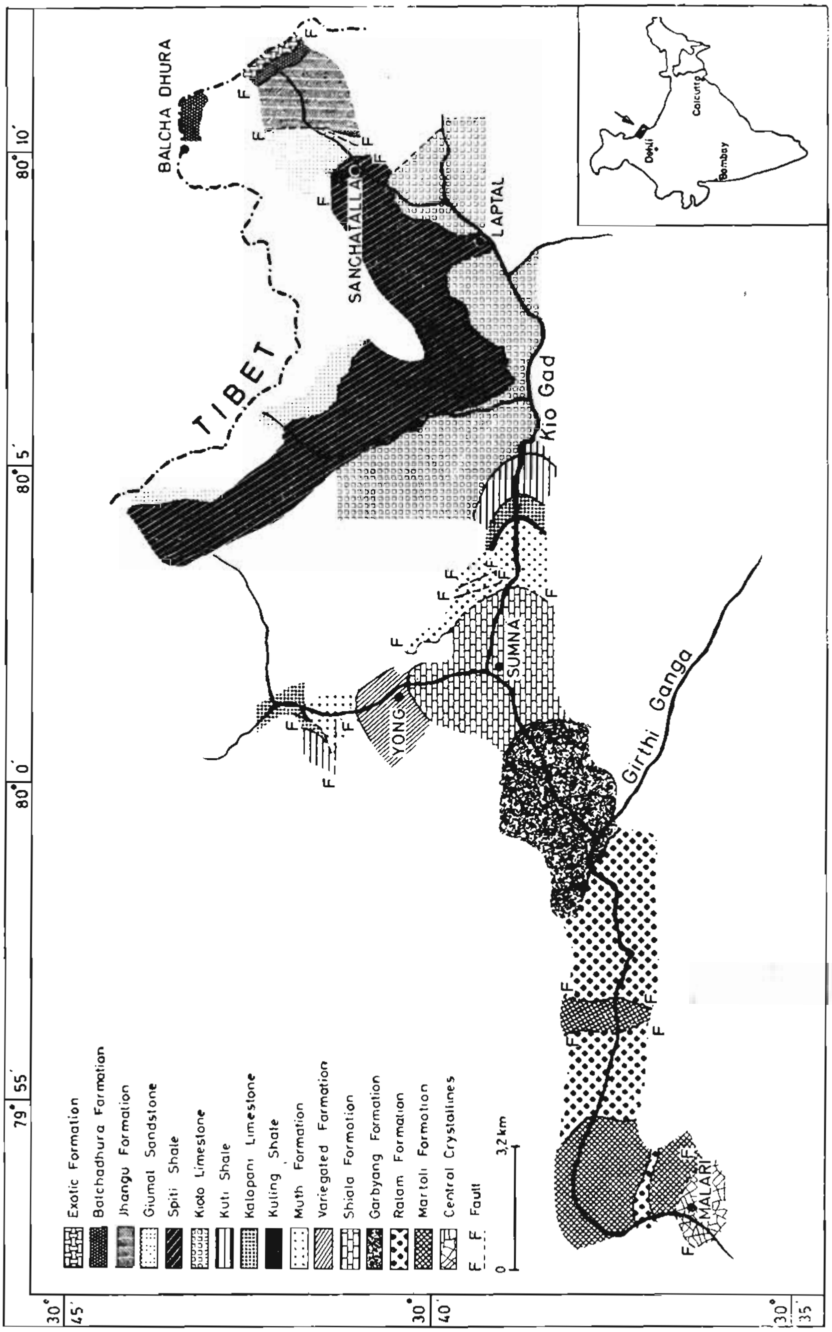
Spores Alete Types — 1, 2, 3, 4

A perusal of the distribution of different species through the Kuling Shale (Table 1) clearly indicates that the older samples — 393 and 392, are prominently represented by alete types and fern spores. This assemblage represents a typical condition prior to the encroachment of the land by thick vegetation in this region. Some of the alete types also suggest a marine shallow water conditions during the advent of Kuling Shale deposition.

The next assemblage represented by sample nos. 391, 389 and 387 is comparable with the early Upper Permian of the Peninsular India in having striate-disaccate pollen and the trilete forms. Above to this, the sample nos. 386 and 385 have a well diversified mioflora having some typical form, such as *Densipollenites*, *Crescentipollenites*, *Lundbladispora*, indicating a late Permian affinity.

The above account clearly indicates that the early Permian assemblage has not been recovered from this Kuling Shale Formation.

(ii) *Kalapani Limestone* — It includes the productive sample no. 363; the preservation



TEXT-FIG. 3 — Geological map of Tethyan Himalaya in Malla Johar area on which the present study is based.

is poor and there is lack of diversity in forms, mainly the aletes and fungal microspores having been encountered. The palynomorphs identified are: *Densoisporites playfordii*, *Lophotriletes minimus*, *Apiculatisporis* sp., *Thymospora* sp. and *Alisporites* (indeterminate). A great diversity has been observed among the alete forms having sculptured exine. These have been informally designated as 'Types'. However, the species *Staplinisporites allomorphus* and [illegible] *babaei* could be identified.

The rarity of specimens does not permit to comment upon the composition of this assemblage in detail but, as such, *Densoisporites playfordii* is found in the Lower Triassic mioflora of Peninsular India (Bharadwaj, Tiwari & Anand Prakash, 1979). A change at this level (Kuling/Kalapani Limestone) of deposition is, however, evident. The ornamented alete forms are significant in indicating the brackish water condition of deposition at this level. Thus, the beginning of Triassic exhibits an environmental change of the set up in this region.

(iii) *Kuti Shale* — Five samples have yielded from this bed, out of them two samples (372 & 379) exhibit a rich assemblage comprising *Densoisporites playfordii*, *Lundbladispora* sp., *Ovalipollenites pollax*, *Alisporites parvus*, *A. opii*, *A. tenuicorpus*, *A.* sp., *Klausipollenites schaubergeri*, *Cuneatisporites radialis*, *Faunipollenites varius*, *F.* sp., *Scheuringipollenites maximus*, *S. tentulus*, *Pinuspollenites* sp., *Platysaccus fuscus*, *Ibisporites diplosaccus*, *Striatopodocarpites communis*, *S. rotundus*, *S. tiwarii*, *S.* sp. cf. *S. decorus*, *Striatites communis*, *S. gopadensis*, *Verticipollenites oblongus*, *Chordasporites* sp., *Guttulapollenites hannonicus*, *Lunatisporites pellucidus*, *L. ovatus*, *Rhizomaspora* sp., *Pretricolpipollenites bharadwajii*, *Veryhachium* sp., and Alete types — 1, 2, 3, 4.

This diversified mioflora suddenly declines in samples 380, 382 and 91 — the younger samples in the sequence, where only a few fungal spores along with a nonstriate-disaccate pollen have been found. This reflects a change in the sedimentary environmental condition at these junctures.

(iv) *Passage Formation* — From this bed only two samples (Sample nos. 96 & 103) have yielded ill-preserved specimens. In sample no. 96, several taxa, viz., *Verrucosisporites* sp., *Tetraporina* sp., *Alisporites parvus*, *Cuneatisporites radialis*, *Platysaccus fuscus*, *Striatopodocarpites magnificus*, *Klausipollenites schaubergeri* have been encountered. Sample no. 103 does not contain any miospore except the alete ones. This assemblage, however, is not rich, and therefore, detailed comparison is not being attempted.

(v) *Kioto Limestone* — Sample nos. 109, 110, 116 and 117 have shown the presence of the taxa *Callumispora fungosa*, *Lophotriletes* sp., *Lundbladispora warti*, *L.* sp., *Goubinispora* sp. cf. *G. morondavensis*, *Klausipollenites schaubergeri*, *Alisporites parvus*, *A.* sp., *Striatopodocarpites* sp., *Lunatisporites diffusus* and Alete Types — 1, 2, 3, 4 from this bed.

The samples in this horizon, viz., nos. 109, 110, 116 and 117 exhibit the presence of a good assemblage. The drastic decline in the representation of striate-disaccate genera and a fair occurrence of monosaccate (referable to *Goubinispora*) and disaccate non-striate distinguish this association of taxa from the older one. In sample no. 117 again the mioflora has impoverished.

4. *Sangcha Malla Group* — The uppermost rock unit of Malla Johar Supergroup extends in age from Oxfordian to Upper Cretaceous. The different formations in it are: Spiti Shale, Giumal Sandstone, Jhangu and Balcha Dhura formations.

(i) *Spiti Shale* — The yielding samples are 1, 2, 3, 5, 6, 7, 8 and 10. The specimens are represented by three species of *Callialasporites* — *C. dampieri*, *C. monoalasporus* and *C. trilobatus*. The other identified species are: *Verrucosisporites* sp., *Platysaccus* sp., *Crescentipollenites amplus*, *Striatopodocarpites* sp. and *Lunatisporites ovatus*.

These pollen yielding samples are from the lower part of Spiti Shale which is considered to be of Oxfordian age on the basis of forams and ammonoids (see Jai Krishna *et al.*, 1982). The Spiti Shale assemblage of miospore is, thus, characterised by the presence of *Callialasporites* which is an indicator of its being of Jurassic age. However, the continuation in the occurrence of the striate and taeniate-disaccate, although meagre is interesting in this horizon. There is a chance of recycling also as far as these older elements are concerned.

(ii) *Giumal Sandstone* — No samples were analysed in the present study. However, dinoflagellate cysts (Jain *et al.*, 1978) and radiolarian microfauna (Garg *et al.*, 1980) assemblages are known.

It is thus concluded that the present study brings out the following sequential position of miofloral distribution and pattern of changes through the succession.

The record of Chitinozoa from a few samples of Muth Quartzite Formation is very significant in view of the absence of any other microfossils recovered from here. The Devonian age has been indicated by these organisms, although more detailed data is needed for finer dating.

The Kuling Shale is dated to be Late Permian in age supported by the recovered mioflora. Its younger part (sample nos. 385 & 386) is of late Upper Permian.

In Kalapani Limestone, the miospores are recorded for the first time, but the rarity of the forms does not permit detailed comparisons. However, the miofloral change is evident as the Cavate triletes appear and the ornamented aletes qualify the assemblage for a marine environment.

During the present study, the Kuti Shale samples have yielded a fairly well-diversified mioflora (compare — Tiwari *et al.*, 1980). The presence of *Densoisporites*, *Lundbladispora*, *Klausipollenites* and *Lunatisporites* shows late Lower Triassic affinities, while the genera *Densipollenites*, *Alisporites* (?*Nidhipollenites*), *Pretricolpipollenites* even may suggest Middle Triassic affinity. Because of the absence of any well-dated Noric mioflora from Indian Peninsula, no precise comparisons could be attempted. But it could be assertively said on the basis of evidences we have at present, that the mioflora has an older affinity than the Noric level.

The Passage Zone assemblage did not show anything special to distinguish it from the underlying Kuti Shale. The paucity of microfossils is the main reason for this situation. The Kioto Limestone had some elements, viz., *Goubinispora*, to indicate its younger position in comparison to the underlying formations and thus indicates a Middle Triassic affinity vis-a-vis the Peninsular assemblages. However, its Rhaetic age is still not reflected by the mioflora it contains (Heim & Gansser, 1939; Tiwari *et al.*, 1980).

The Spiti Shale mioflora could not exhibit the details of pollen-spore contents, and due to the presence of *Callialasporites* a Jurassic age is indicated, in general. However, concurrently with this study Jain *et al.* (in press) have recovered following taxa from sample L-27, 200 m above the ferrugenous oolite and suggested early Upper Tithonian age.

Alisporites grandis (Cookson) Dettmann, 1963; *Alisporites* sp. A; *Appendicisporites* sp. A; *Callialasporites monoalasporus* Dev, 1961; *C. trilobatus* Dev, 1961; *Cicatricosisporites autraliensis* (Cookson) Potonié, 1956; *Concavissimisporites kutchensis* Venkatachala, 1969; *Contignisporites multimuratus* Dettmann, 1963; *Couperisporites vangaurdensis* Pocock, 1962; *C. jurassicus* Pocock, 1971; *Densoisporites velatus* (Weyland & Krieger) Krasnova, 1961; *D.* sp. cf. *D. playfordii* (Balme) Dettmann, 1983; *Heliosporites* sp. A; *Laricoidites* sp. A; *Lycopodiumsporites* sp. A; *Podocarpidites multisinus* (Bolkhovitina) Pocock, 1962; *Todisporites minor* Couper, 1953.

Absence of mioflora in sediments below Kuling Shale is attributed to the poor preservation and paucity of suitable lithology. The absence of mioflora in the Cretaceous part of the sequence is related to deepening of the basin when deposition took place mostly in the continental slope and land-derived flora was not easily coming.

FLORA OF TETHYAN HIMALAYA WITH REFERENCE TO INDIAN PLATE BOUNDARY

In the context of plate tectonics, the concept regarding the extent of Indian shield (Peninsular India) and its relationship with Himalayan area have changed considerably during the last few years. The northern extent of the Indian plate is still debatable. It is generally believed that Himalaya is the result of collision of the Indian plate with the Asian Plate, and the collision might have taken place along the Indus-suture-zone (Gansser, 1966; Lefort, 1975). A greater Indian plate has been envisaged by many workers which might have extended up to Tien Shan mountains (Crawford, 1974; Kaila & Narain, 1976).

In this model, the earlier concept of a Central Crystalline Ridge (Central Himalaya) to separate the Gondwanaland elements of the Indian shield lying in the south from the Angara land elements in the north, loses its significance. The palaeobotanical data from the Himalayan and Tibet, though meagre, clearly show that the sediments of Tethyan zone as well as southern Tibet exhibit Gondwana affinities (Hsü, 1978; Tiwari *et al.*, 1980; Ganeshan & Bose, 1982).

From the Tethyan Himalayan region Tiwari *et al.* (1980) reported the preliminary results of palyno-assemblage and their studies of Tethyan sediments of Malla Johar area, for the first time showed the Gondwanic affinities of the flora of these sediments. The reasons for Gondwanic affiliations of Malla Johar area put forward by Tiwari *et al.* (1980) were not properly understood by Maheshwari (1982), and some of them were even misinterpreted and or altered for convenience. Maheshwari (1982), probably unaware of the distributional pattern of *Klausipollenites*, doubted its occurrence in Malla Johar without giving any valid reasons for his conclusion. Further, he misquoted Tiwari *et al.* (1980), as saying it (i.e. *Klausipollenites*) to be an indicator of Gondwana affinity.

The present more detailed and comprehensive study has further supported the previous observations regarding the occurrence of the genus *Klausipollenites*. It has been further observed that in the finer details of the exine, the Himalayan taxa are more akin to the Indian Peninsular forms rather than those found in the European sediments (*pers. obs.* Tiwari). It is to be noted that the presence of *Striatopodocarpites* is confirmed which was doubted by Maheshwari (1982) ignorantly. This Gondwanic affinity is further substantiated in the present study by fairly diversified pollen and spore assemblages in the Kuling Shale, the Kalapani Limestone, the Kuti Shale and the Kioto Limestone which makes the present succession. In this context, some of the important findings on palaeobotany and palynology from Himalayan region are being analysed briefly as under:

The palynostratigraphic studies done by Balme (1970) from West Pakistan provide one of the most important data for comparison, because of its systematic morphotaxonomic treatment as well as good preservation of spores and pollen — a rare thing in the Himalayan sediments.

Balme (1970) has studied the Permian and Triassic sediments of Surghar Range and Salt Range, Pakistan (Text-fig. 3, I). He has concluded a Gondwana affiliation for this assemblage in general, but at the same time identified a few northern elements too in the Pakistan mioflora. However, during the last 14 years — after the publication of Balme's work, a substantial new data from India on Permian and Triassic has appeared (Maheshwari & Banerjee, 1975; Bharadwaj, Tiwari & Anand Prakash, 1979; Tiwari & Rana, 1980, 1981) which clearly reveals the presence of almost all the forms in the Indian Peninsular Permian-Triassic sediments which are enlisted by Balme (1970) to be exclusively European or local elements for the Salt Range mioflora. Thus, as it stands now, the Salt Range and Surghar miofloras are akin to the Indian Peninsular miofloras of the same age and show a Gondwanic affiliation rather than the northern one.

In north-western Himalaya (Text-fig. 3, II) the megaflora from the Aishmuqam Formation (Upper Devonian), Syringothyris Limestone and Fenestella Shale Formation (Lower Carboniferous), and Nishatbagh and Mammal formations (Lower Permian) described by Singh *et al.* (1982) shows a mixed tendency having both Gondwanic and the northern elements. Since no Devonian or Carboniferous megaflora (or microflora) is known from the Indian Peninsular region, a detailed comparison of this type is yet to be attempted. Moreover, as the miospores are showing differences after detailed studies, the megafossils may also reveal some characteristic features of their own on further critical study. The basic differences between the European and Gondwanic morphography have yet to be evaluated with respect to the finer details of fossils.

A mioflora from the early Permian sediments (Boulder Slate sequence of the Lower Bijni Tectonic unit, Garhwal Syncline) of Garhwal, Lesser Himalayas (Text-fig. 3, III) has been recovered by Gupta and Visscher (1980); it contains *Callumispora* (*Leiotriletes*), *Parasaccites*, *Plicatipollenites*, *Potonieisporites*, *Crucisaccites*, and striate-disaccate pollen. This composition clearly resembles the early Permian (Talchir) assemblages of the Peninsular India.

In the western and central Himalayas, no other detailed record of plant microfossils is available for comparison. However, recently Ganesan and Bose (1982) have described a megaflora from Lingshi Basin, Nepal (Text-fig. 3, VI) which resembles the plant assemblages known from the Upper

Gondwana of Satpura and Kachchh in having *Pachypteris* sp. cf. *P. indica*, *Ptilophyllum acutifolium*, *Elatocladus jabalpurensis*, *Pagiophyllum*, *Coniferocaulon* sp. cf. *C. rajmahalense*. The Lingshi Basin is a part of Tethyan belt of Higher Himalaya in Nepal and its affiliation with the Indian Peninsula is interesting.

In Bhutan Himalayas, Pande, Hochuli and Gansser (1987) have dated the Barsong formation of eastern Bhutan to be of Jurassic age on the basis of palynological fossils. The formation represents a rare Mesozoic deposit between the Tethyan and the Lesser Himalayan facies. Besides the dinoflagellates, Chitinozoa, and microform, the miospore genera *Punctatisporites*, *Deltoidospora* and *Alisporites* have been illustrated. Similar forms are known from all over the world during Mesozoic time. However, unless detailed structure and organization of the palynofossils are known, nothing definite could be ascertained regarding its affiliation on the basis of this poorly represented assemblage. Therefore, in the present context, only it could be remarked that in the assemblage presently studied from the Malla Johar area contains comparable forms which are present in the Kioto Limestone (Early Jurassic) also.

Another recent report on the occurrence of Lower Permian miospores from Bhutan Himalaya is by Banerjee and Dasgupta (1983) who recovered the mioflora from coal exposures in western part of Deothang. It contains *Scheuringipollenites*, *Striatites*, *Faunipollenites*, *Callumispora*, *Horriditriletes*, etc. showing an affinity with the Barakar miofloras of the Peninsular India—particularly that of the Damodar Basin.

From the north- north-eastern portion of Himalayan belt, Hsü (1978) has deduced interesting conclusions on the basis of megafossils studies. He has established the relationship between the *Glossopteris* flora from the Qubu Formation of southern Tibet (Text-fig. 3, V) and that of the main Indian Peninsula (particularly with the Raniganj Formation of Damodar Basin). He indicates the presence of *Glossopteris communis*, *G. indica*, *Sphenophyllum speciosum*, *Raniganjia qubuensis*, etc. in the Qubu Formation. This flora has no affinities with the *Gigantopteris* flora of northern Tibet, although the two localities are only 600 km away from each other.

On detailed study the plant species found by Hsü might show some differences from the Indian Peninsular species but the generic affiliation seems to be akin with the Indian Gondwana since no taxon of northern hemisphere has been identified in these assemblages. This work supports the extension of the northern limits of the Indian plate up to the southern part of Tibet (Hsü 1978).

Zhaosheng (1980) worked out the middle and upper Triassic miofloras from Ruishui River, Hauting County in Gansu Province of China. Although they have reported some similar forms as have been known from the Triassic of India, the compositions of the assemblages are not comparable. The Ruishui River miofloras have more pteridophytic spores than the Indian counterparts. Besides, a number of new taxa are also present in the former. The detailed comparison needs more data from this region. Yet it can be concluded that no similarity of components exists between the Chinese assemblage under discussion and that of the Malla Johar when same age equivalents are taken into account.

In the far east from Arunachal Pradesh Himalaya, Srivastava and Dutta (1977) while studying the sediments of Garu-Gensi road section, Siang District (Text-fig. 3, VII), have discovered miofloras divisible into two zones, one consisting of *Parasaccites*, *Plicatipollenites*, *Rugasaccites*, *Virkkipollenites*, *Stellapollenites*, *Potonieisporites* and *Illinites* and the other having *Callumispora*, *Indotriradites*, *Microbaculispora*, *Crucisaccites*, etc. as the characteristic miospore genera. These assemblages are similar to the early Lower Gondwana miofloras of the Peninsular India. The genera *Potonieisporites*, *Limitisporites* and *Illinites*, although do occur in the European Permo-Carboniferous succession, have specific differentiation in details of exine structure, etc. from their northern counterparts and hence considered here to be characteristic of the Gondwanic assemblage.

These results are further substantiated by the study of same horizon by T. Singh (1979) who on the basis of palynology has established the close relationship of these sediments with the Lower Permian rocks of Indian Peninsula as well as other Gondwanic continents.

DISCUSSION AND CONCLUSIONS

The foregoing account clearly reveals that the miofloras of Tethys Himalaya have affinity with Indian Shield miofloras of respective age. The similarity with the European forms is only apparent and not the real. This conclusion has been drawn after detailed morphographic study of European as well as Indian specimens. However, some genera cannot be distinguished on such regionalism and their presence in northern as well as southern hemisphere cannot be denied, but the totality of the assemblage determines the affinity of regional floras.

Thus, the megafossils as well as microfossils of the Permian and Triassic sediments in the Tethyan zone of the Himalaya exhibit Indian Peninsular affinity — of course, with some local elements of their own. This regional character is in any way not more in degree than the differences recorded in any two floral regions (e.g. Damodar and South Rewa Gondwana Basins) within the Peninsula. The distribution of important assemblages has been depicted in Text-fig. 3. This gives general floral boundaries for Indian plate. Indeed more detailed work is needed for precise delimitation of such floral boundaries, and more so in the Tibetan side of the Himalaya. The Tethyan Himalaya has caught the attention of the palaeopalynologists although the bad preservation and paucity of specimen remains the main hurdle; determined improvement in techniques may usher into better data.

It is, therefore, imperative to arrive at the conclusion on the basis of present study as well as the earlier evidences that the Indian Peninsular area, Tethyan Himalaya and the Southern Tibet belong to the same miofloral province, i.e. the Gondwana. It is apparent that at least up to the Indus Suture Zone the Indian Gondwana plate extended. It may be mentioned that the Indian Shield itself extended up to the southern limit of Tethyan zone, as visualized by Singh (1976, 1979). More data is needed from northern Tibet, before detailed comparison of mioflora of north and south of Indus Suture Zone can be done in order to decide the northern limit of larger Indian plate which some of the workers conceive as extending up to Tien Shan mountains (Crawford, 1974).

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EXPLANATION OF PLATES

(All figures unless otherwise stated are × 750)

Plate 1

1. *Callumispora fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari, 1977; Film no. 26/29; Lab slide no. 110/1, slide no. BSIP 6095 × 350.
2. *Parasaccites diffusus* Tiwari, 1965; Film no. 28/6; Lab slide no. 385/2, slide no. BSIP 6976 × 500.
3. *Striatopodocarpites magnificus* Bharadwaj & Salujha, 1964, Film no. 30/11; Lab slide no. 386/3, slide no. BSIP 6087.
4. *Striatites* sp. Film no. 30/8, Lab slide no. 387/4; slide no. BSIP 6986.
5. *Klausipollenites schaubergeri* Potonié & Klaus) Jansonius, 1962 Film no. 51/1; Lab slide no. 372/1, slide no. BSIP 6979.
6. *Densoisporites playfordii* (Balme) Dettmann, 1963; Film no. 52/5; Lab slide no. 372/2, slide no. BSIP 6980.
7. *Verrucosisporites* sp. Film no. 29/1, Spiti Shale 1; slide no. BSIP 6057.
8. *Parasaccites distinctus* Tiwari, 1965, Film no. 28/11; Lab slide no. 385/4; slide no. BSIP 6188 × 500.

Plate 2

9. *Callialasporites trilobatus* (Dev, 1961; Film no. 29/26; Lab slide no. Spiti shale/10, slide no. BSIP 6981.
10. *Callialasporites monoalasporus* Dev, 1961, Film no. 29/9; Lab slide no. Spiti shale/2, slide no. BSIP 6982.
11. *Callialasporites dampieri* Dev, 1961, Film no. 29/17; Lab slide no. Spiti shale/6, slide no. BSIP 6100.
12. *Guttulapollenites hannonicus* Goubin, 1965, Film no. 31/29, Lab slide no. 372/1; slide no. BSIP 6977. × 500.
13. *Alisporites* sp. cf. *A. opii* Daugherty, 1941; Film no. 57/20; Lab slide no. T-7/51 slide no. BSIP 6984.
14. *Densipollenites pellis* Segroves, 1969; Film no. 51/34, Lab slide no. 372/1, slide no. BSIP 6950.
15. *Densipollenites densus* Bharadwaj & Srivastava 1969; Film no. 28/15; Lab slide no. 386/2; slide no. BSIP 5086.

Plate 3

16. *Parasaccites bilateralis* Tiwari, 1965; Film no. 28/7; Lab slide no. 385/3; slide no. BSIP 6976.
17. *Crescentipollenites amplus* (Balme & Hennelly) Tiwari & Rana, 1980 Film no. 28/11; Lab slide no. 386/4; slide no. BSIP 6085.
18. *Striatopodocarpites magnificus* Bharadwaj & Salujha, 1965. Film no. 28/8; Lab slide no. 386/4; slide no. BSIP 6088.

19. *[illegible]* (Tiwari) Tiwari, 1973; Film no. 51/15; Lab slide no. 372/1; slide no. BSIP 6979.
20. *Crescentipollenites* sp.; Film no. 28/12; Lab slide no. 386/4; slide no. BSIP 6988.
21. *Striatopodocarpites* sp. cf. *S. decorus* Bharadwaj & Salujha, 1964; Film no. 30/10; Lab slide no. 387/5; slide no. BSIP 6997.
22. *Striatopodocarpites* *[illegible]* Bharadwaj & Dwivedi, 1981; Film no. 52/6; Lab slide no. 372/2; slide no. BSIP 6980.
23. *Striatopodocarpites* *[illegible]* (Maheshwari) Bharadwaj & Dwivedi, 1981; Film no. 25/4; Lab slide no. 355/3; slide no. BSIP 6976.

PLATE 4

24. *Striatites* *[illegible]* Kar, 1968; Film no. 52/12; Lab slide no. 372/2; slide no. BSIP 6980.
25. *Striatites* *[illegible]* Bharadwaj & Salujha, 1964; Film no. 52/28; Lab slide no. 379/1; slide no. BSIP 6990.
26. *Guttulapollenites* sp. cf. *G.* *[illegible]* (Goubin) Tiwari & Rana, 1981; Film no. 27/28; Lab slide no. 109/2; slide no. BSIP 6964 × 500.
27. *Chordasporites* sp.; Film no. 51/25; Lab slide no. 372/1; slide no. BSIP 6978.
28. *Striatites* *[illegible]* Srivastava, 1970; Film no. 52/11; Lab slide no. 372/2; slide no. BSIP 6980.
29. *Verticipollenites* *[illegible]* Bharadwaj, 1962; Film no. 51/14; Lab slide no. 179/2; slide no. BSIP 6983.
30. *Corisaccites* *[illegible]* Leschik, 1955; Film no. 55/10; Lab slide no. 179/2; slide no. BSIP 6987.
31. *Lunatisporites* *[illegible]* (Goubin) Maheshwari & Banerji, 1975; Film no. 53/16; Lab slide no. T-3/2; slide no. BSIP 6991.

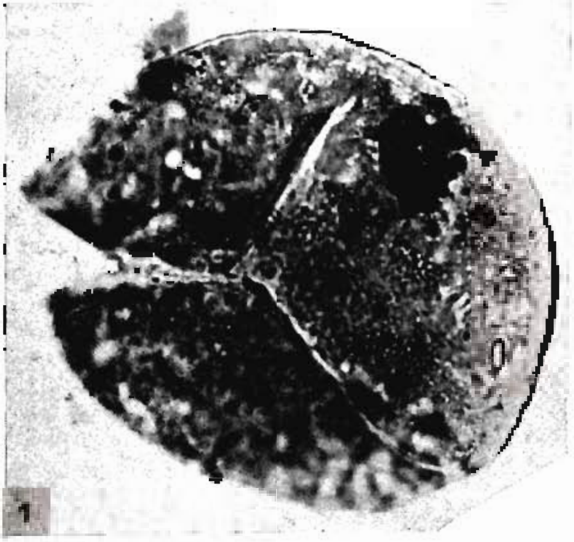
PLATE 5

32. *Veryhachium* Deunff, 1954; Film no. 55/8; Lab slide no. 372/2; slide no. BSIP 6980.
33-38. Indeterminate; Film no. 51/31; Lab slide no. 372/1; slide no. BSIP 6979. Film no. 52/10; Lab slide no. T-3/4; slide no. BSIP 6994. Film no. 27/25; Lab slide no. 109/1; slide no. BSIP 6995. Film no. 57/11; Lab slide no. T-2/4, 11/5 — 108; slide no. BSIP 6994. Film no. 27/15; Lab slide no. 109/5; slide no. BSIP 6991.
39, 50, 51, 53, 54. Type-1; Film nos. 54/21, 54/1, 54/20, 54/6, 51/16, 54/1; Lab slide nos. 393/1, 363/1, 391/1, 361/2, 373/1, 363/2; slide nos. BSIP 6988, 6997, 6988, 6993, 6979, 6993.
40, 41. Type-4; Film no. 51/21, 22; Lab slide no. 363/1; slide no. BSIP 6993.
42, 52. *[illegible]* Sheffy & Dilcher, 1971; Film nos. 51/15, 34; Lab slide no. 363/1; slide no. BSIP 6993.
43. *Pilasporites plurigenus* Balme & Hennelly, 1956; Film no. 26/11; Lab slide no. 191/4; slide no. BSIP 6996.
44. *Micrhystridium* *[illegible]* Sargeant, 1971; Film no. 54/4; Lab slide no. 363/2; slide no. BSIP 6993.
45, 46. Type-2; Film nos. 54/16, 51/10; Lab slide nos. 363/2, 372/3; Slide no. BSIP 6993, 6980.
47-49. Type-3; Film nos. 53/26, 27, 54/2; Lab slide nos. 353/1, 363/2; slide nos. BSIP 6992, 6993.

PLATE 6

(All figures are × 400)

55, 57, 64, 66. cf. *Desmochitina* Eisenack, 1931; Film nos. 107/12, 15, 17, 19; Lab slide nos. 33/2, 35/5, 34/1, 33/1; slide no. BSIP 8005.
56, 59. *Angochitina* Eisenack, 1931; Film nos. 107/10, 9; Lab slide no. 34/1; slide no. BSIP 8004.
58. *Rhabdochitina* Eisenack, 1931; Film no. 107/34; Lab slide no. 34/2; slide no. BSIP 8005.
60, 65. *Conochitina* Eisenack, 1931; Film nos. 107/21, 20; Lab slide no. 13/1; slide no. BSIP 8006.
61, 63. *Lagenochitina* Eisenack, 1931; Film nos. 107/17, 13; Lab slide nos. 35/5, 34/1; slide no. BSIP 8005 and 8004.
62. *Ancyrochitina* Eisenack, 1955; Film no. 107/6; Lab slide no. 34/1; slide no. BSIP 8004.
68. cf. *Lagenochitina* Eisenack, 1931; Film no. 107/29; Lab slide no. 30/2; slide no. BSIP 8005.
67. *Cyathochitina* Eisenack, 1955; Film no. 107/35; Lab slide no. 13/2; slide no. BSIP 8005.
69. cf. *Conochitina* Eisenack, 1931; Film no. 107/7; Lab slide no. 34/4; slide no. BSIP 8004.



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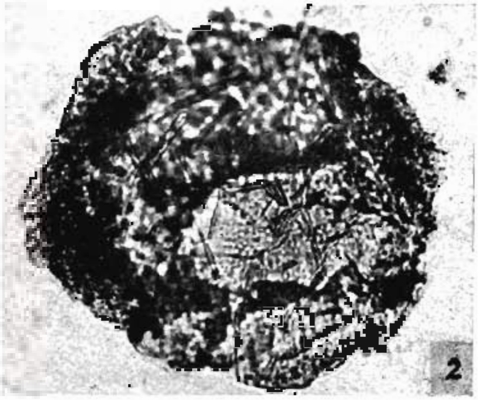

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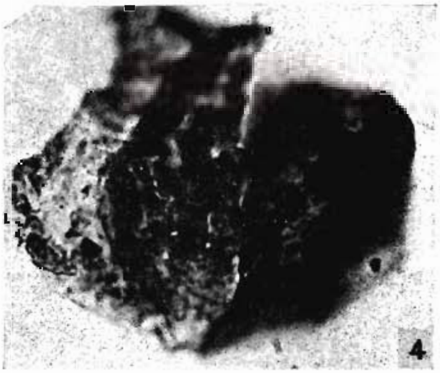

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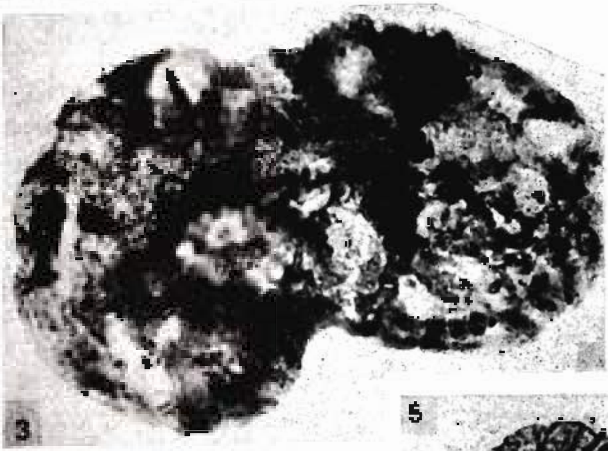

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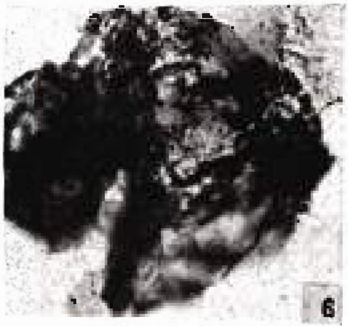

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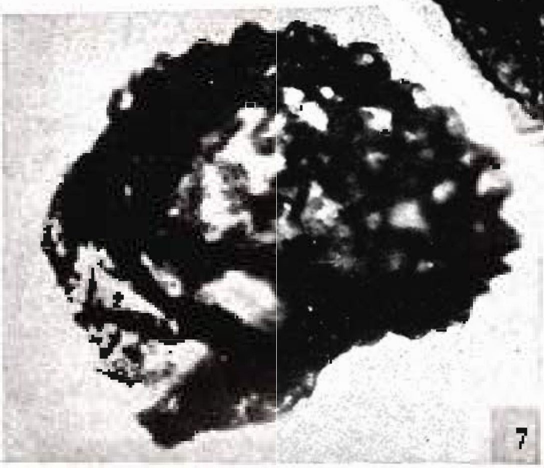

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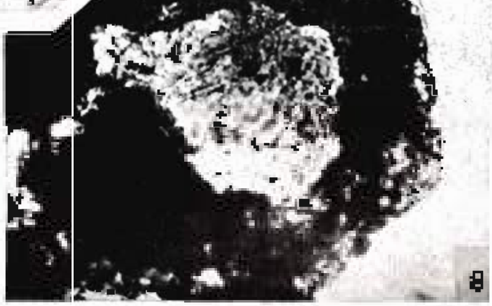

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PLATE 1


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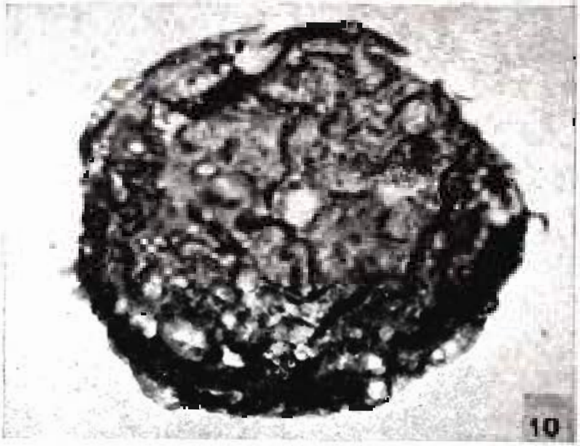
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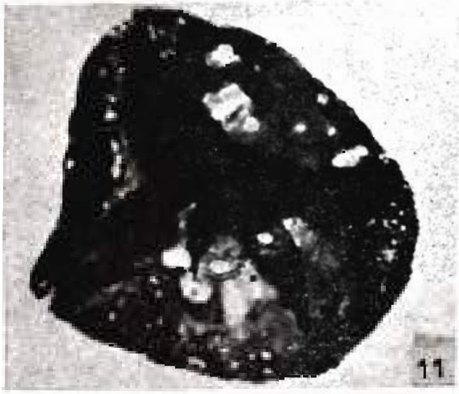
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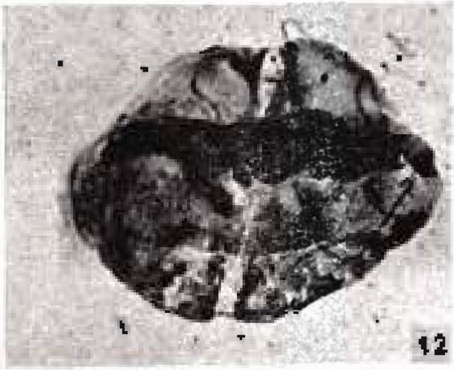
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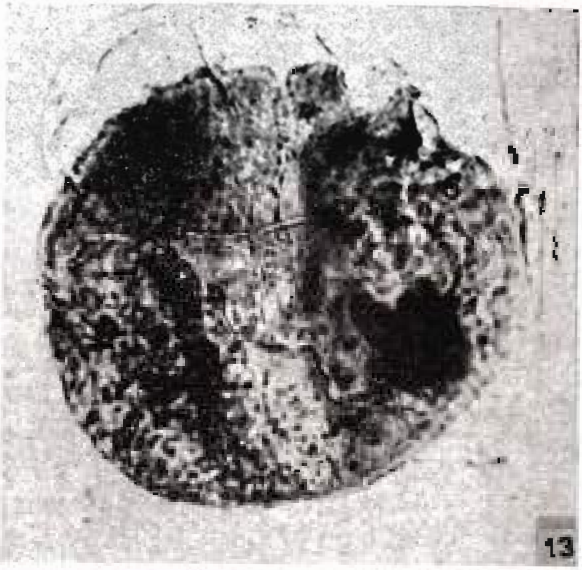
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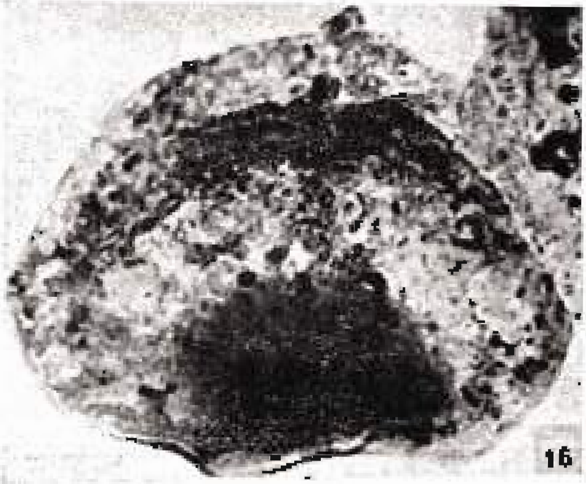
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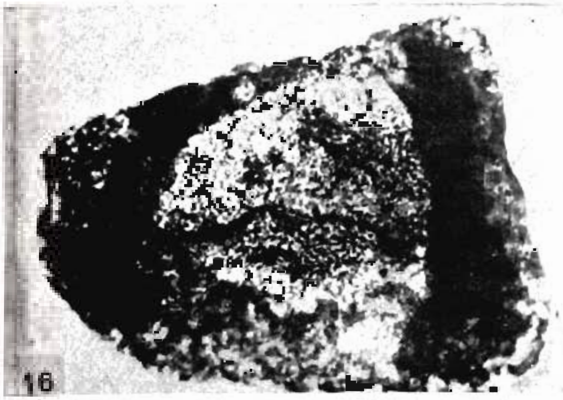
PLATE 2



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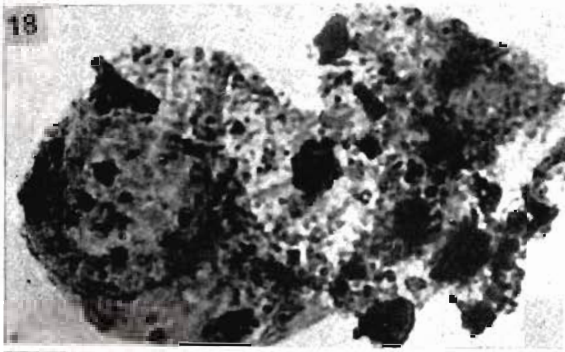

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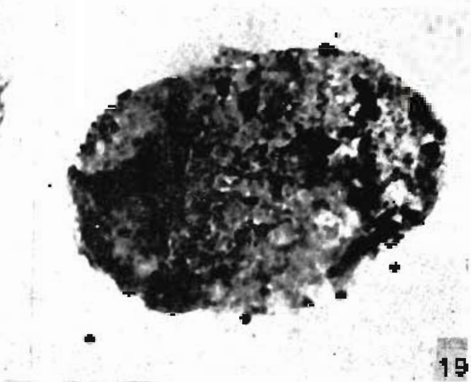

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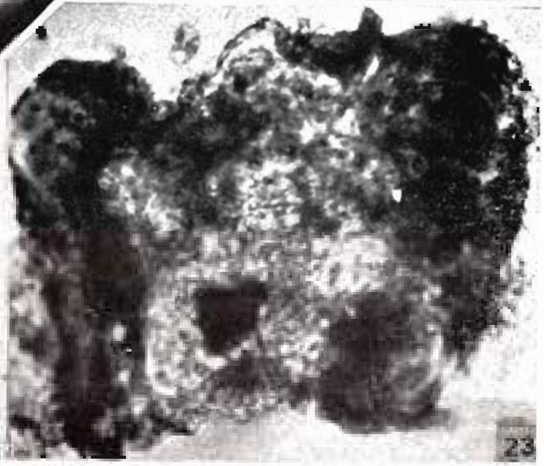

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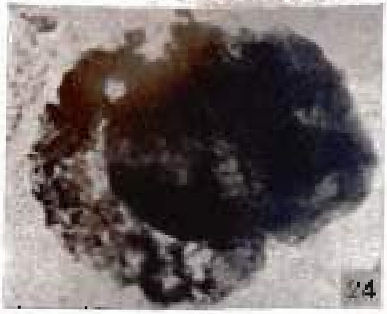

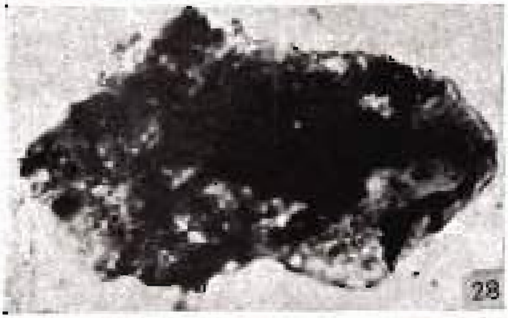

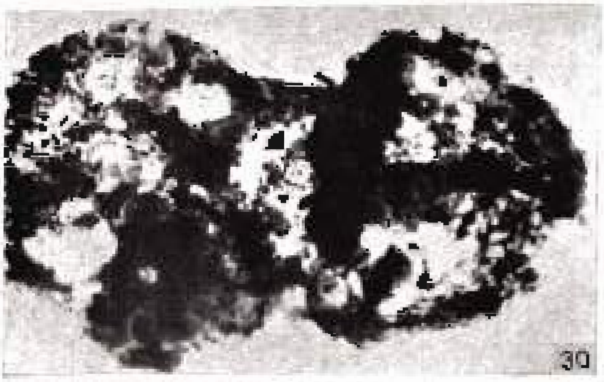

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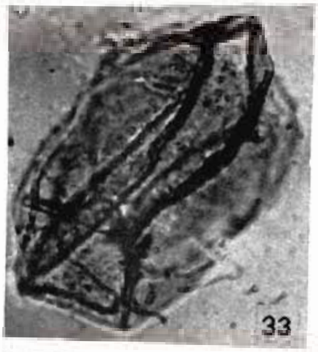
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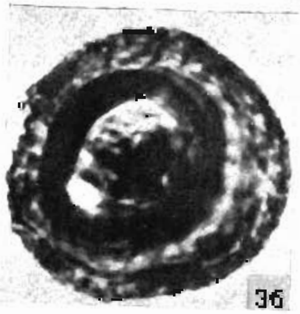
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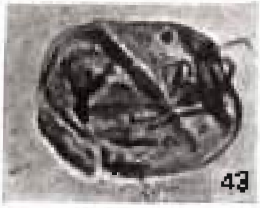
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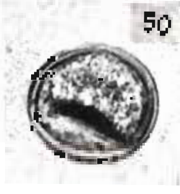
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PLATE 5


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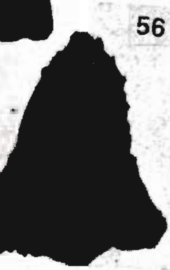
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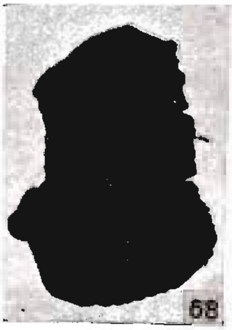
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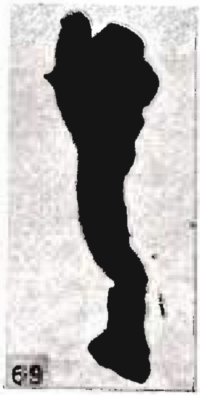
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PLATE 6

The Palaeobotanist, **32**(3): 368-369, 1984.

CARNOCONITES RAJMAHALENSIS (WIELAND) COMB. NOV. FROM THE JURASSIC OF RAJMAHAL HILLS, INDIA

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ABSTRACT

Excepting the mode of preservation the specimen of *Williamsonia*(?) *rajmahalensis* Wieland and those of *Carnoconites laxum* Srivastava have been found to be similar. Therefore, the specimens described by various authors as *Carnoconites laxum* Srivastava are being named as *Carnoconites rajmahalensis* (Wieland) comb. nov.

Key-words — *Carnoconites*, *Williamsonia*, Rajmahal Hills, Jurassic (India).

साराँश

राजमहल पहाड़ियों (भारत) के जूराई कल्प से कार्नोकोनाइटिस राजमहलेन्सिस (वीलैंड) नव संयोजन –
महेन्द्रनाथ बोस, पंकज कुमार पाल एवं टॉम मैक्सवेल हेरिस

परिरक्षण के ढंग को छोड़कर विलियमसोनिया? राजमहलेन्सिस वीलैंड तथा कार्नोकोनाइटिस लैक्सम् श्रीवास्तव के प्रादर्श आपस में एक सदृश प्रेक्षित किए गये हैं। अतएव कार्नोकोनाइटिस लैक्सम् श्रीवास्तव के नाम से विभिन्न लेखकों द्वारा वर्णित प्रादर्शों को इस शोध-पत्र में कार्नोकोनाइटिस राजमहलेन्सिस (वीलैंड) नव संयोजन से नामांकित किया गया है।

WHILE working on various organs belonging to the *Pentoxylon* plant we had the occasion to examine the specimen described by Feistmantel (1877, pl. 39, figs 5, 5a, 5b) as "*Inflorescence or Fructification of Cycadeous plants*" from Murrero (now known as Mandro), Rajmahal Hills, Bihar. The specimen was later on described by Wieland (1911) as *Williamsonia*(?) *rajmahalensis*. In all its available features this specimen agrees with the petrified specimens of *Carnoconites laxum* Srivastava described by Srivastava (1944, 1946), Sahni (1948) and Vishnu-Mittre (1953). However, the mode of preservation of Feistmantel's specimen is different. Besides Feistmantel's specimen (Fig. 1), similarly preserved specimens have also been collected from two other Jurassic localities of the Rajmahal Hills, viz., Onthea (Fig. 2) and Sakrigalighat (Bose, 1959, pl. 3, figs 8, 9). We are convinced that Feistmantel's specimen, described by Wieland (1911) as *Williamsonia*(?) *rajmahalensis*, and the petrified specimens described by various authors as *Carnoconites laxum* Srivastava belong to the same species. Thus, according to Article 55.1 of the International Code of Botanical Nomenclature, *Carnoconites laxum* Srivastava should now be known as *Carnoconites rajmahalensis* (Wieland).

Carnoconites **Srivastava, 1944**

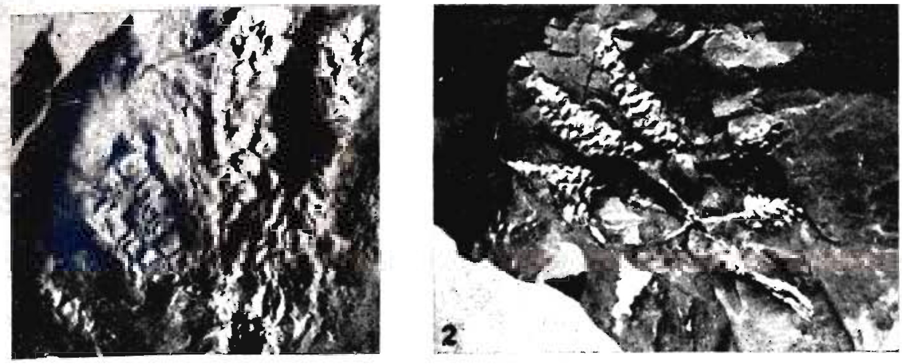
Carnoconites rajmahalensis (Wieland) comb. nov.

Basionym:

1911 *Williamsonia*(?) *rajmahalensis* Wieland, *Amer. J. Sci.*, **32**, p. 461, fig. 17D.

Synonyms:

1877 "*Inflorescence or Fructification of Cycadeous plants*" Feistmantel, *Mem. geol. Surv. India Palaeont. indica*, Ser. 2, **1** (2), p. 79, pl. 39, figs 5, 5a, 5b.



FIGURES 1, 2 — *Carnoconites rajmahalensis* (Wieland) comb. nov. **1**, Holotype, from Mandro, G.S.I. no. 4514, × 2; **2**, specimen from Onthea, B.S.I.P. no. 35699, × 1.

1919 *Haitingeria rajmahalensis* (Wieland) Krasser, *Denkschr. Akad. Wiss. Wien. Math. — Naturwiss, Kl.*, **97**, pp. 3, 16, fig. 10.

1928 *Strobilites pascoei* Sahni, *Mem. geol. Surv. India Palaeont. indica*, n. Ser. **11**, p. 42, pl. 6, figs 98-100.

1944 *Carnoconites laxum* Srivastava, *Proc. natn. Acad. Sci. India*, **14** (1), p. 75, pl. 2, fig. 13.

1946 *Carnoconites laxum* Srivastava, *Proc. natn. Acad. Sci. India*, **15** (6), p. 207, pl. 8, figs 75-78.

1948 *Carnoconites laxum* Srivastava: Sahni, *Bot. Gaz.*, **110** (1), p. 73, figs 30-33, 44.

1953 *Carnoconites laxum* Srivastava: Vishnu-Mittre, *Palaeobotanist*, **2**, p. 83, pl. 5, fig. 1.

1959 *Carnoconites laxum* Srivastava: Bose, *Palaeobotanist*, **7** (1), pl. 3, figs 8, 9.

1974 *Carnoconites laxum* Srivastava: Rao, p. 207, in K. R. Surange *et al.* (eds) — *Aspects & Appraisal of Indian Palaeobotany*.

Holotype — Specimen no. 4514 of the Geological Survey of India, Calcutta (Feistmantel, 1877, pl. 39, figs 5, 5a, 5b).

Occurrence — Mandro (Murrero: *locus typicus*), Sakrigalighat and Nipania of the Rajmahal Hills, Bihar, India.

Horizon & Age — Rajmahal Formation; Upper Jurassic.

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VISHNU-MITTRE (1953). A male flower of the Pentoxyleae with remarks on the structure of the female cones of the group. *Palaeobotanist*, **2**: 75-84.

WIELAND, G. R. (1911). On the *Williamsonia* tribe. *Amer. J. Sci.*, **32**: 433-476.