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SOME FOSSIL WOODS FROM THE TERTIARY OF KACHCHH, WESTERN INDIA

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ABSTRACT

Fossil woods resembling the modern genera *Dipterocarpus* Gaertn. f., *Sterculia* Linn., *Terminalia* Linn. and a species of *Palmoxylon* Schenk are described from the probable Pliocene (Kankawati Series) beds of district Kachchh, Gujarat. They represent the families Dipterocarpaceae, Sterculiaceae, Combretaceae and Palmae respectively. The modern comparable forms of the fossil species indicate a more humid climate at the time of deposition contrary to the present day arid conditions in Kachchh.

Key-words — Xylotomy, *Dipterocarpoxylon*, *Sterculinium*, *Terminalioxylon*, *Palmoxylon*, Pliocene?, Kachchh (India).

सारांश

पश्चिमी भारत में कच्छ के तृतीयक कल्प से कुछ अवशेष काष्ठाश्म – जसवन्तसिंह गुलेरिया

गुजरात में कच्छ जनपद के सम्भवतः अतिनूतन युगीन (कन्कावती श्रेणी) संस्तरों से वर्तमान वंशों – डिप्टेरोकार्पस गेयर्टन० एँफ०, स्टरकुलिआ लिन्नियस, टर्मिनेलिया लिन्नियस तथा पाल्मॉक्सीलॉन् शैंक की एक जाति से मिलते-जुलते काष्ठाश्मों का वर्णन किया गया है। ये क्रमशः डिप्टेरोकार्पेसी, स्टरकुलिएसी, कॉम्ब्रीटेसी एवं पाल्मी कुलों का निरूपण करते हैं। इन काष्ठाश्मों के वर्तमान तुलनीय प्रारूप कच्छ की वर्तमान शुष्क परिस्थितियों के विपरीत निक्षेपण के समय अधिक आर्द्र जलवायु का होना इंगित करते हैं।

INTRODUCTION

LAKHANPAL and Guleria (1981) have recently summarized the work done till then onthe Tertiary flora of Kachchh. The present paper is a further addition to the knowledge of the megaflora of this area. The material of this paper comes from two localities — Dhaneti and Mothala. The former is situated about 24 km east of Bhuj and the latter about 66 km WWS of Bhuj (Map 1). Both the localities are easily accessible by road from Bhuj. The woods are found buried in the soil as well as strewn in a considerable area in both the localities. The preservation of material is fairly good. These fossil woods have been derived from the base of the Kankawati Series, the age of which is considered to be probable Pliocene (Biswas & Raju, 1973).

SYSTEMATIC DESCRIPTION

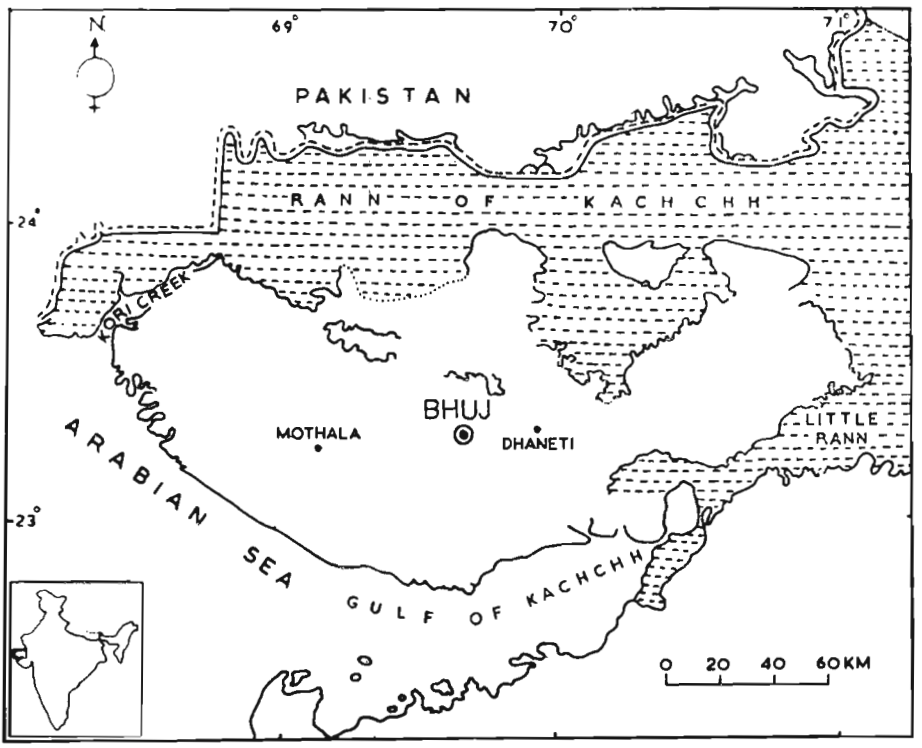
FAMILY — DIPTEROCARPACEAE

Genus — *Dipterocarpoxylon* Holden emend. Den Berger, 1927

Dipterocarpoxylon malavii Ghosh & Ghosh, 1959

Pl. 1, figs 1-4

In 1959, Ghosh and Ghosh briefly described a fossil dipterocarpaceous wood, *Dipterocarpoxylon malavii*, from the Pliocene beds of Mothala, district Kachchh. However, no attempt was made by them to find out the nearest modern equivalent of the fossil and also did not give any diagnosis for this species. In the present investigation a few woods were recognized as belonging to the genus *Dipterocarpus*. On critical exami-



MAP 1 — Map of Kachchh showing the fossil localities.

nation of their thin sections, two of them have been identified as *Dipterocarpoxylon malavii*. They exhibit more anatomical details and variations which were not mentioned earlier by Ghosh and Ghosh (1959). Therefore, it is considered necessary to give a detailed account of *D. malavii* before comparing it with the modern species of *Dipterocarpus*.

Topography — Wood diffuse - porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary, evenly distributed, 5-7 vessels per sq mm; tyloses abundant, completely plugging the vessels together with gummy material (Pl. 1, figs 1, 2). *Tracheids* sparse, intermingled with paratracheal parenchyma round the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, intermingled with vasicentric tracheids, forming 1-2 cells wide sheath round the vessels, sometimes aliform; apotracheal parenchyma diffuse or diffuse-in-aggregate and also associated with vertical gum canals (Pl. 1, fig. 2) frequently extending laterally, uniting with those of neighbouring gum canals, forming 3-8 (mostly 3-4) seriate bands. *Xylem rays* fine to moderately broad, 1-7 seriate (frequently 3-5), about 6-8 rays per mm; ray tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells, 3-13 cells or 30-400 μm high, 16-32 μm wide; multiseriate rays heterocellular, consisting of procumbent cells in the median portion and 1- several uniseriate marginal rows of upright cells (Pl. 1, figs 3, 4), 10-60 cells or 120-1600 μm high (most of the rays less than 1000 μm high), up to 208 μm wide; sheath cells occasionally present. *Fibre tracheids* aligned in radial rows between two consecutive rays. *Gum canals* frequent, vertical, diffuse, mostly solitary or in pairs, often up to 4, rarely 5, enclosed by parenchyma (Pl. 1, fig. 2); 3-4 gum canals per sq mm.

Elements — Vessels oval to elliptical in cross section, t.d. 80-240 μm (average 190

μm), r.d. 112-350 μm, thin-walled; vessel-members 180-440 μm with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, vestured. *Tracheidal cells* oval or flattened, 20-40 μm in diameter. *Parenchyma cells* circular, oval, elliptic to polygonal in cross section, 8-36 μm in diameter. Upright *ray cells* 32-60 μm in tangential height, 20-40 μm in radial length; procumbent cells 4-20 μm in tangential height, 40-60 μm in radial length. *Fibre tracheids* circular, oval to polygonal in cross section, 4-12 μm in diameter, non-septate, thick-walled, wall thickness 4-6 μm; pits about 4 μm in diameter, bordered. *Gum canals* circular to oval, t.d. 40-120 μm, r.d. 40-140 μm.

Affinities

A large number of thin sections of the woods of *Dipterocarpus* were examined and published description and figures of many other species were also consulted (Chowdhury & Ghosh, 1958; Desch, 1941, 1957; Kribs, 1959; Lecomte, 1926; Moll & Janssonius, 1906; Pearson & Brown, 1932; Reyes, 1938). From this survey it was found that the present wood shows close similarity with that of *Dipterocarpus dyeri* Pierre ex De Laness.

Dipterocarpus is rather a large genus with 76 species, distributed in Sri Lanka and India to W. Malaysia and Bali (Willis, 1973, p. 376). *D. dyeri* Pierre ex De Laness is a large tree and occurs in Burma, Indo-China, Thailand and Malay Peninsula (Chowdhury & Ghosh, 1958, p. 115).

Specific Diagnosis

Dipterocarpoxylon malavii Ghosh & Ghosh, 1959

Topography — Wood diffuse - porous. *Growth rings* absent. *Vessels* small to large (mostly medium), t.d. 80-240 μm (average 190 μm), r.d. 112-350 μm, exclusively solitary, 5-7 vessels per sq mm; perforations simple; pits leading to contiguous tracheids vestured; tyloses abundant. *Tracheids* intermingled with paratracheal parenchyma forming sheath round the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, intermingled with vasicentric tracheids forming 1-2 cells wide sheaths round the vessels, sometimes aliform; apotracheal parenchyma diffuse or diffuse-in-aggregate, and also associated with vertical gum canals forming 3-8 (usually 3-4) seriate bands. *Xylem rays* 1-7 (frequently 3-5) seriate or 16-208 μm wide, 10-60 cells or 120-1600 μm high (most of the rays less than 1000 μm); ray tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright and procumbent cells, 3-13 cells or 30-400 μm high; multiseriate rays heterocellular, consisting of procumbent cells and 1- several uniseriate marginal rows of upright cells at both the ends; sheath cells occasionally present. *Fibre tracheids* non-septate, 4-12 μm in diameter, thick-walled, wall thickness 4-6 μm; pits small, bordered. *Gum canals* frequent, diffuse, solitary or in pairs and often in tangential groups of 4-5; t.d. 40-120 μm, r.d. 40-140 μm.

Specimen — B.S.I.P. Museum no. 36003.

Localities — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road and Mothala about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Dipterocarpoxylon pondicherriense Awasthi, 1974a

Pl. 1, fig. 5; Pl. 2, fig. 8

This species is represented by two pieces of well-preserved secondary wood measuring 6-8 cm in length and 2.5-4.0 cm in diameter.

Topography — Wood diffuse - porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary (Pl. 1, fig. 5), evenly distributed, t.d. 96-240 μm (average 160 μm), r.d. 160-360 μm, 6-7 vessels per sq mm; tyloses not seen, gummy material occasionally filled in the vessels; vessel-members 240-440 μm in length with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, vestured. *Tracheids* sparse, intermingled with paratracheal parenchyma forming narrow sheath round the vessels; tracheidal cells oval or slightly flattened, 16-40 μm in diameter,

Parenchyma paratracheal and apotracheal; paratracheal parenchyma relatively sparse, intermingled with vasicentric tracheids forming narrow sheath round the vessels; apotracheal parenchyma associated with vertical gum canals (Pl. 1, fig. 5), frequently extending laterally uniting with those of neighbouring gum canals, forming short bands of 3-6 cells wide; diffuse cells occasionally present; parenchyma cells oval to polygonal in cross section, 15-28 μm in diameter. *Xylem rays* fine to moderately broad, 1-6 (mostly 4-5) seriate, 12-75 cells or 325-1920 μm high, up to 120 μm wide, 5-7 rays per mm; rays tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells, 3-12 cells or 128-320 μm high, 20-28 μm wide; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1- several marginal rows of upright cells at one or both the ends (Pl. 2, fig. 8), sheath cells occasionally present. *Fibre tracheids* aligned in radial rows, circular or oval to polygonal in cross section, 8-16 μm in diameter, non-septate, thick-walled, wall thickness 4-6 μm; pits about 4 μm, bordered. *Gum canals* abundant, diffuse, enclosed by parenchyma, rarely solitary, sometimes in pairs and usually in tangential rows of 3-11 canals; t.d. 64-144 μm, r.d. 96-160 μm; about 4-7 per sq mm (Pl. 1, fig. 5).

Affinities

The above mentioned characters of the fossil indicate that it is a *Dipterocarpus* Gaertn. f. wood. Out of 23 species of *Dipterocarpoxylon* known so far from India and abroad (Awasthi, 1974a, b, 1980; Prakash, 1975, 1978, 1981; Lemoigne, 1978; Ghosh & Roy, 1979; Trivedi & Ahuja, 1980) the present fossil shows closest similarity in all its anatomical characters with *Dipterocarpoxylon pondicherriense* Awasthi (1974a) described from the Cuddalore Series near Pondicherry. The only difference between the two is that the frequency of gum canals seems to be relatively more in the present fossil than in *D. pondicherriense*. However, seeing the range of variation of this character in the living *Dipterocarpus indicus* Bedd. (with which *Dipterocarpoxylon pondicherriense* has been compared) the present fossil is being placed under *Dipterocarpoxylon pondicherriense*.

Dipterocarpus indicus Bedd. is a lofty tree up to 40 m high, distributed in the evergreen forests of Western Ghats from North Kanara southwards, Malabar and Travancore. It is common in South Kanara at the foot-hills and at an elevation up to 900 m especially in South Travancore.

Specimen — B.S.I.P. Museum no. 36004.

Locality — Mothala, about 66 km WWS of Bhuj, on the Bhuj Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Family — Sterculiaceae

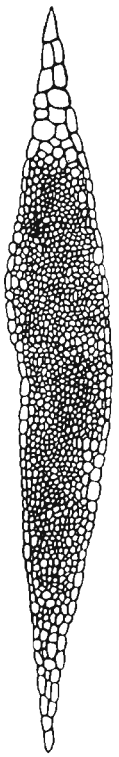
Genus — *Sterculinium* gen. nov.

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

Pl. 2, figs 6, 7, 9, 10; Text-fig. 1

This species is represented by half a dozen pieces of petrified wood. The biggest is 23 cm long and 13.5 cm in diameter. The preservation is fairly good.

Topography — *Wood* diffuse-porous (Pl. 2, figs 6, 7). *Growth rings* not clearly seen, delimited by somewhat denser and narrow late wood fibres. *Vessels* visible to naked eye in cross section as dots, medium to large, solitary or in multiples of 2, rarely 3-4, evenly distributed, about 1-2 vessels per sq mm; tyloses not seen, vessels often filled with gummy material. *Parenchyma* abundant, both paratracheal and apotracheal; paratracheal parenchyma sparse, forming narrow sheath of 1-3 cells round the vessels; apotracheal parenchyma forming regular tangential bands, about 4-6 bands per mm, each 4-7 cells in width (Pl. 2, fig. 7). *Xylem rays* of two sizes, broad and narrow (Pl. 2, fig. 9); narrow rays few, 1-4 (mostly 1-2) seriate or 20-60 μm broad, short, 5-14 cells or 100-400 μm in height, homocellular to heterocellular, consisting of upright and procumbent cells; broad rays mostly spindle-shaped, up to 25 seriate or 560 μm in width and 25-90 cells or 800-3420 μm (average 1280 μm) in height, cells in the median portion of broad rays sometimes disorganized; ray tissue heterogeneous, rays heterocellular, consisting of upright cells at one



TEXT-FIG. 1 — *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov. Tangential longitudinal view of a ray showing procumbent, upright and sheath cells, × 100.

or both the ends and procumbent cells in the median portion; sheath cells present (Text-fig. 1). *Fibres* poorly preserved, in broad conspicuous alternating bands, almost as broad as parenchyma bands (Pl. 2, figs 6, 7). *Gum canals* present at some places, aligned in regular tangential rows (Pl. 2, fig. 6), often confluent, 1-2 rows per cm.

Elements — Vessels mostly oval or flattened due to compression, walls 4-13 μm thick, t.d. 132-286 μm (average 250 μm), r.d. 118-308 μm; vessel members 200-400 μm in height with horizontal to slightly oblique ends; perforations simple, intervessel pits medium, hexagonal or polygonal in outline, 4-8 μm in diameter, crowded, alternate, bordered, aperture round-elliptical to linear (Pl. 2, fig. 10). *Parenchyma cells* four per strand, thin-walled, 20-30 μm in diameter, 40-90 μm in height, strands storied; crystals present. Procumbent *rays cells* variable in shape, vertical height 8-20 μm, radial length could not be measured, vertical height of upright cells 24-44 μm, radial length could not be measured. *Fibres* rectangular to polygonal in cross section, 12-20 μm in diameter, non-libriform to libriform. thin to thick-walled, wall 3-6 μm thick, non-septate; interfibre pits not seen. *Gum canals* r.d. 208-400 μm, t.d. variable and more than r.d. due to flattening.

AFFINITIES

The important characters of the fossil are: wood diffuse porous; vessels medium to large; parenchyma banded, bands alternating regularly with the fibre bands, parenchyma strands storied; rays of two types, narrow and broad, narrow rays 1-4 (mostly 1-2) seriate, broad rays up to 25 cells wide with sheath cells, ray tissue heterogeneous; fibres non-libriform to libriform, non-septate; gum canals at some places or in tangential rows.

Among these, the presence of banded parenchyma and broad and tall rays with sheath cells are the most important features of the present fossil. From a general survey of the dicotyledonous woods it has been found that similar type of parenchyma and rays are found in the following genera:

1. Bombacaceae — *Catostemma*
2. Boraginaceae — *Cordia*
3. Leguminosae — *Butea*, *Erythrina*
4. Moraceae — *Ficus*
5. Sterculiaceae — *Argyrodendron*, *Cola*, *Eriobroma*, *Firmiana* (inclusive *Erythropsis*), *Pterygota*, *Sterculia*

The genus *Catostemma* of Bombacaceae shows general similarity with the fossil. However, it differs in the vessels arrangement and paratracheal nature of the parenchyma bands (Chattaway, 1937, p. 361). Further, the rays are 4-10 cells wide as compared to much broad rays in the fossil. Fibres are commonly storied and extremely thick in *Catostemma* (Metcalfe & Chalk, 1950, pp. 238-240). Similarly some of the species of *Cordia*, *Butea*, *Erythrina* and *Ficus* show resemblance with the fossil. However, sheath cells are rare in the comparable species of these genera. *Butea* and *Erythrina* further differ in having vestured pits. In addition, gum canals are absent in *Butea*, *Erythrina* and *Ficus*. Of the family Sterculiaceae *Argyrodendron*, *Firmiana* (inclusive

Erythropsis) and *Pterygota* which are very close to the fossil, also differ from it in having storied fibres (Metcalfe & Chalk, 1950, p. 248). The gum canals are absent in *Cola* and *Eriobroma*. Evidently the fossil resembles in all its anatomical characters with the wood of *Sterculia*.

On the basis of wood anatomy Chattaway (1937, p. 358) divided the species of *Sterculia* into two groups, viz., *Sterculia* A and *Sterculia* B. The *Sterculia* A group comprises Sterculias with metatracheal parenchyma predominantly in lines of one cell width and *Sterculia* B group includes Sterculias with metatracheal parenchyma and paratracheal parenchyma often indistinguishable, predominantly in broad bands of 3-4 cells wide. Thus, the present fossil belongs to *Sterculia* B group of Chattaway.

Out of a large number of species of *Sterculia* having banded parenchyma, *Sterculia alata* Roxb., *S. coccinea* Roxb., *S. colorata* Roxb., *S. fulgens* Wall., *S. oblonga* Mast., *S. populifolia* Roxb., and *S. rhinopetala* K. Schum show apparently similar anatomical characters as present in the fossil. Among these, the rays are much narrower, 1-6 cells wide in *S. populifolia* while in *S. alata* the rays are comparatively shorter and not as broad as in the fossil. Fibres as well as parenchyma bands are relatively wider in *S. colorata*. Further, the gum canals are absent in these three species. However, they are present in *S. coccinea* and *S. fulgens* in tangential rows. *S. fulgens* shows close similarity with the fossil in most of the characters, but differs in having diffuse-aggregate parenchyma. Further, the fibre bands are occasionally double the width of parenchyma bands. Thus, *S. coccinea*, *S. oblonga* and *S. rhinopetala* shows nearest possible similarity with the fossil.

Some of the fossil woods which were earlier identified as *Nicolia aegyptiaca* (Unger, 1859; Chiarugi, 1933), *Nicolia giarabubensis* (Chiarugi, 1929) and *Nicolia oweni* (Schenk, 1883; Schuster, 1910) were reinvestigated by Kräusel (1939). He thought that they belong to *Sterculia* and accordingly constituted a new genus *Sterculioxylon* to accommodate these fossil woods which were placed by him under two new species, viz., *Sterculioxylon aegyptiacum* (Unger) and *Sterculioxylon giarabubense* (Chiarugi). From the work of Chattaway (1937), Metcalfe and Chalk (1950), Pearson and Brown (1932) and the study of thin sections of the modern woods of *Sterculia*, it is apparent that the genus *Sterculioxylon* of Kräusel does not show the characters of *Sterculia* wood. The most important differences are in the parenchyma and rays. The paratracheal parenchyma in the type species (*Sterculioxylon aegyptiacum*) is aliform to confluent and the apotracheal bands are irregular and distantly placed (see Kräusel, 1939, pl. 18, figs 3-6; pl. 19, figs 1-7; text-fig. 23), whereas in the modern wood of *Sterculia* paratracheal parenchyma is vasicentric and not distinctly aliform or confluent. Besides, the banded parenchyma is more or less regular and is relatively closely spaced. The rays in *Sterculioxylon aegyptiacum* are homogeneous and 1-7 seriate wide as compared to distinctly heterogeneous and much broader rays in *Sterculia*. Boureau (1949) and Boureau and Louvet (1975) have pointed out the resemblance of *Sterculioxylon aegyptiacum* with the wood of *Detarium* of Leguminosae. Lalitha and Prakash (1980) have also endorsed this view as it shows strong resemblance with the wood of *Copaifera-Detarium-Sindora*, which are anatomically inseparable.

Interestingly, Sheikh and Kolhe (1980) also instituted the genus *Sterculioxylon* while describing a fossil wood (*Sterculioxylon baradense* gen. et sp. nov.) from the Deccan Intertrappean beds of Mahurzari, near Nagpur. They have not mentioned about any earlier known species of *Sterculioxylon*. This, unfortunately, indicates their complete ignorance about the previous records of *Sterculioxylon*. They emphasized that their fossil shows close similarity with the family Sterculiaceae showing very close resemblance with the genus *Sterculia* of Chattaway's Subgroup B. A careful examination of the photographs and the accompanied description as given by the authors rules out the possibility of *Sterculioxylon baradense* being a wood belonging to *Sterculia* of Subgroup B of Chattaway for the following reasons: (i) though the author's claim the regular formation of parenchyma bands, they are not visible in the photographs, (ii) rays are homogeneous and 1-6 seriate broad in the fossil in contrast to markedly heterogeneous and much broader rays with sheath cells in *Sterculia*, (iii) there is no mention of the parenchyma strands whether storied or

TABLE 1 — *STERCULIOXYLON* SPECIES

No.	Name	Vessel Size	Parenchyma	Xylem Rays	Gum Canals	Age and Distribution
1.	*Sterculioxylon aegyptiacum* (Ung.) Kräusel (1939), Boureau (149)	T.D. 100-240 μm R.D. 100-430 μm	Paratracheal and metatracheal; aliform, confluent and banded	1-7 seriate, homogeneous	Present	Tertiary of Egypt; Post Eocene of Tibesti in Sahara; Tertiary of Ethiopia
2.	*S. giarabubense* (Chiarugi) Kräusel (1939)	—	Paratracheal and metatracheal; aliform, confluent and banded	1-5 seriate, homogeneous	Present	Lower Oligocene to Lower Miocene of North Africa
3.	*S. rhenanum* Müller-Stoll & H. (1949)	T.D. 100-200 μm R.D. 150-300 μm	Paratracheal and metatracheal; vasicentric to aliform, confluent and banded	1-15 seriate, at best weakly heterogeneous	—	Eocene, South-west Germany
4.	*Sterculioxylon* sp. Hofmann (1952)	—	Paratracheal abundant aliform; apotracheal parenchyma forming tangential bands at considerable distance and 6-7 (14) cells wide	4-9 seriate, heterogeneous	—	Upper Miocene to Lower Pliocene, Austria
5.	*S. freulonii* Boureau (1957)	T.D. 120-200 μm R.D. 200-300 μm	Concentric bands of parenchyma sometimes with aliform types	1-6 seriate, heterogeneous	Present	Post Eocene, Libya
6.	*Sterculioxylon* sp.? Greguss (1969)	Diameter 60-90 μm	Vasicentric and terminal	1-2 seriate, homogeneous	—	Oligocene, Dorog, Hungary
7.	*S. foetidense* Prakash (1973)	T.D. 160-400 μm R.D. 240-480 μm	Paratracheal in narrow sheaths around vessels; apotracheal predominantly diffuse to diffuse-in-aggregate, irregular broken or in continuous uniseriate lines	1-8 seriate, heterogeneous	—	Tertiary, Burma
8.	*S. dattai* Prakash & Tripathi (1974)	T.D. 72-310 μm R.D. 96-348 μm	Paratracheal parenchyma vasicentric, 1-4 (mostly 1-2) cells thick around the vessels; apotracheal parenchyma abundant in fine, 1-2 cells thick lines, sometimes occurring as solitary cells, also around the gum ducts, sometimes forming tangential bands 1-6 (mostly 3-4) cells thick	1-10 seriate, heterogeneous	Present	Upper Miocene, Assam, India

— *Contd.*

TABLE 1 — *STERCULIOXYLON* SPECIES — *Contd.*

No.	Name	Vessel Size	Parenchyma	Xylem Rays	Gum Canals	Age and Distribution
9.	*S. kalagarhense* Trivedi & Ahuja (1978)	T.D. 132-286 μm R.D. 118-308 μm	Paratracheal parenchyma vasicentric forming narrow to thick sheath around some of the vessels; apotracheal parenchyma in the form of regular bands	1-16 seriate, heterogeneous	Present	Mio-Pliocene, Kalagarh, Uttar Pradesh, India
10.	*S. deccanensis* Lakhanpal *et al.* (1978)	T.D. 60-120 μm R.D. 70-180 μm	As in *S. foetidense*	1-10 seriate, heterogeneous	—	? Early Eocene, Mandla District, Madhya Pradesh, India
11.	*S. shahpurensis* Bande & Prakash (1980,1983)	T.D. 45-255 μm R.D. 60-360 μm	Paratracheal parenchyma 1-2 seriate, vasicentric; apotracheal parenchyma diffuse-in-aggregate forming 1-2 seriate, tangential lines	1-22 seriate, heterocellular	—	Early Tertiary, Shahpura, Mandla District, Madhya Pradesh, India
12.	*S. pondicherriense* Awasthi (1981)	T.D. 100-280 μm R.D. 50-250 μm	Paratracheal, banded, bands broad, 3-12 cells wide	Up to 25 seriate, heterogeneous	—	Mio-Pliocene, Pondicherry, India
13.	*S. baradense* gen. et sp. nov. Sheikh & Kolhe (1980)	T.D. 135 μm	Paratracheal vasicentric forming 2-3 layers around each vessel, and confluent forming regular bands between adjacent vessels	1-6 seriate, homogeneous	—	? Uppermost Cretaceous, Mahurzari (Barad), Nagpur District, Maharashtra, India
14.	*S. varmahii* Lakhanpal *et al.* (1981)	T.D. 120-225 μm R.D. 210-345 μm	Aliform, confluent to mostly banded; bands completely or incompletely enclosing the vessels, regular or irregular, 5-16 cells wide	1-11 seriate, homo-heterocellular	—	Mio-Pliocene, Arunachal Pradesh, India
15.	*Sterculioxylon* sp. cf. *S. shahpurensis* Bande & Prakash (1983)	—	As in *S. shahpurensis*	1-40 seriate, heterogeneous	—	Early Tertiary, Shahpura, Mandla District, Madhya Pradesh, India

non-storied which in the case of *Sterculia* are distinctly storied, and (iv) the fibres are storied in the fossil which are, however, non-storied in the Subgroup B of *Sterculia*.

From the foregoing discussion it is clear that both the *Sterculioxylon* (Kräusel, 1939; Sheikh & Kolhe, 1980) fail to represent the wood characters of *Sterculia*. Therefore, the fossil woods showing the characters of *Sterculia* cannot be placed under them. Hence, a new generic name *Sterculinium* is proposed for *Sterculia* and *Sterculia*-like fossil woods (which includes *Brachychiton, Cola, Eriobroma & Pterocymbium*; *Firmiana, Erythropsis, Pterygota* in part*, etc). The genus *Sterculinium* consists of two types of woods. The first type includes *Pterocymbium* and those species of *Sterculia* and *Brachychiton* which possess parenchyma predominantly in lines one cell wide. The second type includes *Cola, Eriobroma Firmiana, Erythropsis, Pterygota* and those species of *Sterculia* which possess predominantly broad bands of parenchyma. So far 15 species of *Sterculioxylon* have been described (see Table 1). Out of them, the following belong to *Sterculia* and they are now named as *Sterculinium freulonii* (Boureau) comb. nov., *Sterculinium foetidense* (Prakash) comb. nov., *Sterculinium dattai* (Prakash & Tripathi, comb. nov., *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov., *Sterculinium deccanensis* (Lakhanpal *et al.*) comb. nov., *Sterculinium shahpurensis* (Bande & Prakash) comb. nov., *Sterculinium pondicherriense* (Awasthi) comb. nov., *Sterculinium varmahii* (Lakhanpal *et al.*) comb. nov. and *Sterculinium* sp. cf. *S. shahpuraensis* (Bande & Prakash) comb. nov. The remaining species need reinvestigation for their true affinities.

The genus *Sterculia* Linn. consists of 300 species (Willis, 1973, p. 1103) distributed throughout the tropics and reaches its best development in tropical Asia (Pearson & Brown, 1932, p. 145). Of the three comparable species, *Sterculia coccinea* is found in the eastern Himalayas ascending up to 900 m in Bhutan, Sikkim and Assam Hills and in Burma extending southwards to Tennasserim (Chowdhury & Ghosh, 1958, p. 214). The other two, *S. oblonga* and *S. rhinopetala* are confined to tropical forests of Africa.

*As some of the species of *Sterculia* have been transferred to *Firmiana* and *Pterygota* (Chowdhury & Ghosh, 1958, pp. 211, 212, 214, 275).

Generic Diagnosis

Sterculinium gen. nov.

Wood diffuse-porous. *Growth rings* indistinct, sometimes demarcated by thin bands of terminal parenchyma. *Vessels* mostly medium to large, solitary and in small radial multiples; perforations simple; intervessel pits alternate, bordered; tyloses sometimes present. *Parenchyma* abundant; apotracheal, paratracheal and terminal; paratracheal in narrow sheaths around the vessels and apotracheal predominantly in lines one cell wide or apotracheal and paratracheal parenchyma often indistinguishable, predominantly in broad bands, three to four cells wide; strands usually of two cells in the scattered cells and uniseriate bands, usually of four, sometimes eight cells in the broad bands; distinctly storied. *Xylem rays* often of two distinct sizes, larger one usually more than 10 cells wide; markedly heterogeneous with two to several marginal rows of upright cells and sheath cells; small rays storied when sufficiently numerous; crystals usually present in rays or parenchyma or both. *Fibres* non-libriform to libriform, non-septate; storied (*Sterculia* A) as well as non-storied (*Sterculia* B). *Intercellular canals* may or may not present.

Genotype — *Sterculinium kalagarhense* (Trivedi & Ahuja) comb. nov.

Specific Diagnosis

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

Growth rings not clearly seen. *Vessels* medium to large, t.d. 132-286 μm (average 250 μm), r.d. 118-308 μm, solitary or in multiples of 2, rarely up to 3-4, 1-2 per sq mm; tyloses absent; perforations simple; intervessel pits medium, 4-8 μm in diameter, alternate, bordered, hexagonal to polygonal in outline, aperture round-elliptic to linear. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma forming narrow sheaths of 1-3 cells round the vessels; apotracheal parenchyma in regular bands,

bands 4-7 cells wide; parenchyma strand storied. *Xylem rays* narrow and broad, narrow rays 1-4 (mostly 1-2) seriate or 20-60 μm broad, short, 5-14 cells or 100-400 μm in height, homocellular to heterocellular, sparse; broad rays mostly spindle-shaped, up to 25 seriate or 560 μm wide, 25-90 cells or 800 to 3420 μm (average 1280 μm) in height, consisting of procumbent and upright cells at one or both ends; sheath cells present. *Fibres* in regular alternating bands of almost same width as of parenchyma bands, non-libriform to libriform, non-septate. *Gum canals* present at some places; in tangential rows; r.d. 208-400 μm, t.d. variable and more than r.d. due to flattening.

Holotype — S-23, Botany Department, Lucknow University, Lucknow.

Specimen — B.S.I.P. Museum no. 36005.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Family — Combretaceae

Genus — *Terminalioxylon* Schönfeld, 1947

Terminalioxylon felixii Ramanujam, 1956

Pl. 3, figs 11, 12

This species is represented by a well-preserved piece of silicified wood 8 cm long and 4 cm in diameter.

Topography — *Wood* diffuse-porous (Pl. 3, fig. 11). *Growth rings* distinct, demarcated by narrow lines of parenchyma and small vessels (Pl. 3, fig. 11). *Vessels* small to large (mostly medium), t.d. 60-240 μm, r.d. 144-340 μm, mostly solitary or in radial multiples of 2-4, evenly distributed, 5-7 vessels per sq mm; tyloses present; vessels sometimes filled with dark contents (Pl. 3, fig. 11); vessel members 120-400 μm in height with truncated ends; perforations simple; intervessel pits small, alternate, oval to elliptic, about 4 μm in diameter, vestured. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform (Pl. 3, fig. 11), sometimes confluent when vessels are closely placed; apotracheal parenchyma aggregate and forming narrow lines of 1-3 cells wide at the growth rings; parenchyma cells oval to slightly elliptic in cross section, 16-28 μm in diameter, thin-walled, crystalliferous strands occasionally present with several chambers containing solitary crystals. *Xylem rays* fine, uniseriate, occasionally with paired cells (Pl. 3, fig. 12), 12-40 μm wide, 5-21 cells or 120-520 μm high; 14-16 rays per mm; ray tissue homogeneous to weakly heterogeneous, rays homocellular to weakly heterocellular consisting of procumbent cells with single marginal row of upright or squarish cells at one or both the ends (Pl. 3, fig. 12). *Fibres* aligned in radial rows, oval to polygonal in cross section, 8-16 μm in diameter, thick-walled, wall thickness about 4 μm, nonseptate; interfibre pits not seen.

Affinities

The above characters indicate that the present fossil belongs to the genus *Terminalia* Linn. of the family Combretaceae.

The genus *Terminalioxylon* was established by Schönfeld in 1947 for the fossil woods of *Terminalia*. Mädel-Angeliewa and Müller-Stoll (1973) emended the diagnosis of the genus *Terminalioxylon* Schönfeld and merged the *Anogeissusoxylon* Navale (1964) and *Anogeissusoxylon* Louvet (1965) in it. Later, Prakash (1979, p. 54) disagreeing with the contention of Mädel-Angeliewa and Müller-Stoll again separated the genus *Anogeissusoxylon* Navale for the fossil woods of *Anogeissus* and *Terminalioxylon* Schönfeld for the fossil woods of all species of *Terminalia*. The genus *Terminalioxylon* is used here in its original sense as proposed by Schönfeld.

A large number of fossil woods have been described under the genus *Terminalioxylon* from India and abroad and 30 species have been listed by the author (1978). Recently, five more species, viz., *T. pachitanensis* Sukieman (1977), *T. doubingeri*, *Terminalioxylon* sp. Lemoigne (1978), *T. palaeomanni* Prakash (1981), *T. varkalaensis* Awasthi & Ahuja (1982) have been added to this list. Out of them, *Terminalioxylon felixii* Ramanujam (1956) appears almost identical to the present specimen in all the features except for minor variations in the number of vessels per sq mm. Hence, it is placed under the same species. *Terminalia arjuna* Bedd. and *T. tomentosa* W. & A. with which the present fossil resembles most, are large trees. *T. arjuna* is distributed throughout the greater

part of India from Avadh southwards usually along the banks of rivers and streams, ravines and dry water courses and occurs in southern, western and central India, Bihar, Orissa, parts of Maharashtra, Tamil Nadu and Sri Lanka. *T. tomentosa* is very common and probably the most widely distributed of all the important forest trees of India. It occurs in the sub-Himalayan regions from the Punjab eastwards to Goalpara in Assam, ascending up to 1200 m elevation and throughout the greater part of the Peninsula except the arid zones of Rajasthan.

Specimen — B.S.I.P. Museum no. 36006.

Locality — Mothala, about 66 km WWS of Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll, 1973

Pl. 3, figs 13, 14

In 1968, Prakash and Dayal described briefly a fossil wood of *Terminalia* from Kachchh, indicating its affinities with *Terminalia tomentosa* Wight & Arn. About its geological age they considered it to have been derived from the Deccan Intertrappean beds situated near Ratnal Railway Station on Gandhidham-Bhuj branch line of Western Railway. Since it was a stray piece and the Intertrappean beds are nowhere around, it seems plausible that the fossil was brought to this place somehow by some agency from the Pliocene beds of Kankawati Series exposed nearby from where identical specimens were also collected. These are being described here in detail.

Topography — *Wood* diffuse-porous (Pl. 3, fig. 13). *Growth rings* distinctly marked, demarcated by narrow lines of parenchyma and small vessels (Pl. 3, fig. 13). *Vessels* small to medium (mostly medium), t.d. 60-200 μm (average 120 μm), r.d. 90-270 μm, mostly solitary or in multiples of 2-4, evenly distributed, 6-10 vessels per sq mm; tyloses present; vessels occasionally filled with dark contents and crystals (Pl. 3, fig. 13); vessel-members 160-448 μm in height with truncated ends; perforations simple; intervessel pits alternate, oval to elliptic, sometimes coalescent, about 2-4 μm in diameter, vestured. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform and confluent (mostly aliform); apotracheal parenchyma forming narrow lines at the growth rings, 1-3 cells wide (Pl. 3, fig. 13); parenchyma cells round, oval to elliptic, 16-28 μm in diameter, thin-walled, crystalliferous strands occasionally present with several chambers containing solitary crystals. *Xylem rays* fine, 1-2 seriate, mostly uniseriate, occasionally with paired cells, 12-28 μm wide, 3-29 (mostly 11-15) cells or 40-480 μm high, 10-14 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular (Pl. 3, fig. 14), consisting of procumbent cells or with one row of marginal upright or squarish cell at one or both the ends. Upright *ray cells* 20-28 μm in vertical height, procumbent cells 12-20 μm in vertical height, radial lengths could not be measured. *Fibres* oval to polygonal in cross section, thick-walled, walls about 4 μm thick, 8-16 μm in diameter, occasionally septate; interfibre pits not seen.

Affinities

All the above characters collectively indicate that the fossil belongs to the genus *Terminalia* Linn. On comparing it with a large number of woods of *Terminalia* species it was found that there is a close agreement between the fossil and modern wood of *Terminalia tomentosa* W. & A. in all the characters (Ramesh Rao & Purkayastha, 1972, p. 200).

Mädel-Angeliewa and Müller-Stoll (1973) instituted a new species of *Terminalioxylon*, viz., *Terminalioxylon burmense* to include the fossil woods referred to *Terminalia tomentosa* W. & A. by Chowdhury and Tandon (1964), Prakash (1966) and Prakash and Dayal (1968). Later, an illustrated account of the same was given by Kramer (1974) from the south-east Asia. Except for a few minor differences which are of variable nature, the present specimens show closest resemblance with *Terminalioxylon burmense*. Hence, they are placed under the same species.

Specimens — B.S.I.P. Museum no. 36007.

Locality — Dhaneti, about 24 km east of Bhuj, on the Bhuj-Bhachau Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

FAMILY — PALMAE

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon kachchhensis sp. nov.

Pl. 3, figs 15, 16; Pl. 4, figs 17-21

The material consists of a single piece of fairly well-preserved petrified stem measuring 11 cm in length and 6.7 cm in diameter (Pl. 3, fig. 15). The cortical, dermal and the central zones are lacking and only the subdermal zone is present as indicated by the spacing and orientation of the fibrovascular bundles in the specimen.

Topography — Fibrovascular bundles obovate, orbicular, reniform and rarely ovate in shape (Pl. 4, figs 17, 19), usually regularly oriented, fairly distantly placed without touching the neighbouring bundles, 28-52 (average 40) bundles per sq cm; t.d. 0.75-1.4 (average 1.0) μm; r.d. 1.2-1.5 μm; f/v ratio varies from 5-10/1; sclerenchyma surrounded by 1-2 (3) layers of thin-walled more or less flattened cells of tabular parenchyma (Pl. 4, figs 20, 21); radiating parenchyma also present; dorsal sclerenchyma cap reniform or cordate type, auricular lobes rounded at their ends; ventral sclerenchyma cap not seen; sclerenchyma tissue highly disintegrated and impregnated by silica; the xylem consists of 1-3 (mostly 1-2) vessels, excluded, vessels filled with dark contents, annular thickenings seen in vessels; xylem parenchyma occasionally preserved; phloem between the xylem and median sinus almost disorganized except in a few fibrovascular bundles where it is seen as patch of badly preserved tissue; median sinus generally rounded or angular; stegmata present in the fibrous part of the fibrovascular bundles. *Leaf-trace bundles* present. The *ground parenchyma* consists of oval, polygonal and elongated (mostly elongated) cells, thin-walled, occasionally relatively thick-walled, forming radial plate-like structure (Pl. 3, fig. 16; Pl. 4, figs 18, 21), almost compact, occasionally small intercellular spaces present; crystals present between the neighbouring fibrovascular bundles in the ground parenchyma. *Fibre bundles* absent.

Discussion — The fossil palm stems have been assigned to the artificial genus *Palmoxylon* Schenk (1882). Though attempts have been made to resolve the fossil palms into their natural genera on the basis of the xylotomical characters by Schoute (1912), Kaul (1935, 1938), and Mahabale (1958, 1966), nevertheless it has not been possible so far to evolve a natural system of classification for them. Obviously, in the absence of natural system of classification various artificial classifications have been followed. Here, the artificial scheme adopted by Sahni (1943) (which is in fact a synthesis of classifications of Mohl, 1845 & Stenzel, 1904) is being followed. According to it the present fossil falls under two subgroups, viz., Cordata and Reniformia. In the absence of dermal and central regions in the present fossil it is difficult to decide that to which of the subgroups the present fossil exactly belongs.

Comparison with fossil Palmoxyla — A very large number of *Palmoxylon* species are known from India and abroad. A comprehensive list of these has been given by Prakash & Boureau (1968) and Prakash (1974). In addition, a few more species have been described afterwards. However, the following Indian species, viz., *Palmoxylon blanfordi* Schenk (1882), *P. chhindwarense* Prakash (1960), *P. compactum* Sahni (1964), *P. cordatum* Trivedi & Surange (1969), *P. cribriforme* Sahni (1964), *P. deccanense* Sahni (1964), *P. indicum* Sahni (1964), *P. khalsa* Sahni (1964), *P. puratanum* Ramanujam (1958), *P. rewahense* Sahni (1964), *P. sagari* Sahni (1964), *P. scotti* (Menon) Dayal & Menon (1965), *P. sinosum* Sahni (1964), *P. splendidum* Trivedi & Chandra (1971), *P. sundaram* var. *vidarbhai* Rao & Menon (1964), and *P. wadiai* Sahni (1964) with reniform or cordate type of dorsal sclerenchyma cap, more or less compact ground parenchyma and without fibre bundles, show apparent similarity with the present fossil. Besides *P. libycum* Stenzel (1904), *P. cottae* (*partschii*) (Unger) Stenzel (1904) and *P. tenue* Stenzel (1904) show some resemblance with the present fossil.

Palmoxylon blanfordi is based on central region hence, it cannot be compared with the present fossil which represents the subdermal region. In *P. chhindwarense*, *P. puratanum*, *P. scotti*, *P. splendidum* and *P. sundaram* var. *vidarbhai* fibrovascular bundles are much more and f/v ratio is much less in the corresponding region, whereas in *P. indicum* and *P. sagari* the fibrovascular bundles and f/v ratio is much less. In *P.*

compactum, *P. cribriforme*, *P. rewahense*, *P. sinuosum*, the ground parenchyma is of different type. In *P. wadiai*, the ground parenchyma is much more lacunar and somewhat stellate type and f/v ratio is much less. Fibrovascular bundles are also relatively less and moreover diminutive fibrovascular bundles are present in *P. wadiai*. *P. khalsa* differs in having usually 3-4 vessels as compared to 1-2 in the present fossil. *P. deccanense* and *P. cordatum* show better resemblance, however, the tabular parenchyma is absent and vessels are frequently in groups of 3-10 in addition to 2 main vessels in the former. The latter differs in relatively lesser f/v ratio. Similarly, *P. libycum*, *P. partschii* and *P. tenue* also differ from the present fossil in one or more characters.

Thus the present fossil is quite different from all the known species of *Palmoxylon* and therefore a new name, *P. kachchhensis* is assigned to it.

Specific Diagnosis

Palmoxylon kachchhensis sp. nov.

Fibrovascular bundles obovate, orbicular, reniform, rarely ovate, fairly distantly placed without touching the neighbouring bundles; t.d. 0.75-1.4 (average 1.0) μm; r.d. 1.2-1.5 μm; 28-52 (average 40) bundles per sq cm; f/v ratio 5-10/1; dorsal sclerenchyma cap reniform or cordate type; xylem consists of 1-3 (mostly 1-2) vessels; stegmata present; ventral sclerenchyma cap and fibre bundles absent; tabular and radiating parenchyma present. *Leaf-trace bundles* present. *Ground parenchyma* consists of oval, polygonal and elongated (mostly elongated) cells, mostly thin-walled; occasionally relatively thick-walled forming radial plate-like structure between the neighbouring fibrovascular bundles; ground tissue almost compact occasionally with small intercellular spaces; crystals present in the ground parenchyma.

Holotype — B.S.I.P. Museum no. 36008.

Locality — Mothala, about 66 WWS from Bhuj, on the Bhuj-Naliya Road, Kachchh District, Gujarat.

Horizon — Kankawati Series.

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EXPLANATION OF PLATES

PLATE 1

Dipterocarpoxyoln malavii Ghosh & Ghosh, 1959

1. Cross section at low magnification showing the distribution of vessels, gum canals and xylem rays. × 7. Slide no. 6619.
2. Cross section magnified to show the nature and distribution of vessels, gum canals, xylem rays and parenchyma. × 50. Slide no. 6619.
3. Tangential longitudinal section showing the type and distribution of xylem rays. × 60. Slide no. 6620.
4. Radial longitudinal section showing heterocellular xylem rays. × 140. Slide no. 6621.

Dipterocarpoxylon pondicherriense Awasthi, 1974

5. Cross section at low magnification showing the distribution of vessels, gum canals, xylem rays and parenchyma. × 7. Slide no. 6622,

PLATE 2

Sterculinium kalagarhense (Trivedi & Ahuja) comb. nov.

6. Cross section showing the nature and distribution of vessels, gum canals, xylem rays and parenchyma. × 10. Slide no. 6624.
7. A portion of cross section magnified to show the nature and distribution of vessels, parenchyma and xylem rays. × 30. Slide no. 6624.
9. Tangential longitudinal section showing uniseriate to multiseriate rays and storied parenchyma strands. × 50. Slide no. 6625.
10. Intervessel pits. × 600. Slide no. 6625.

Dipterocarpoxylon pondicherriense Awasthi, 1974

8. Tangential longitudinal section showing the type and distribution of xylem rays. × 60. Slide no. 6623.

PLATE 3

Terminalioxylon felixii Ramanujam, 1956

11. Cross section at low magnification showing the distribution of vessels, parenchyma, rays and growth rings. × 15. Slide no. 6626.
12. Tangential longitudinal section showing the nature and distribution of rays. × 120. Slide no. 6627.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll, 1973

13. Cross section at low magnification showing growth rings and nature and distribution of vessels, parenchyma and rays. × 15. Slide no. 6628.
14. Tangential longitudinal section showing the nature and distribution of xylem rays. × 120. Slide no. 6629.

Palmoxylon kachchhensis sp. nov.

15. Cross section of the specimen, slightly enlarged than natural size.
16. Magnified cross section showing the nature of ground tissue. × 35. Slide no. 6630.

PLATE 4

Palmoxylon kachchhensis sp. nov.

17. Cross section of the outer zone showing the size, shape, orientation and general distribution of the fibrovascular bundles. × 8. Slide no. 6630.
18. Magnified cross section showing relatively thick-walled radial plate-like structure. × 30. Slide no. 6630.
19. Cross section of inner zone showing the size, shape, orientation and general distribution of the fibrovascular bundles. × 8. Slide no. 6630.
20. A fibrovascular bundle from the inner zone with tabular parenchyma. × 30. Slide no. 6630.
21. Magnified cross section of the inner zone showing the type and orientation of the fibrovascular bundles and the ground tissue. × 20. Slide no. 6630.

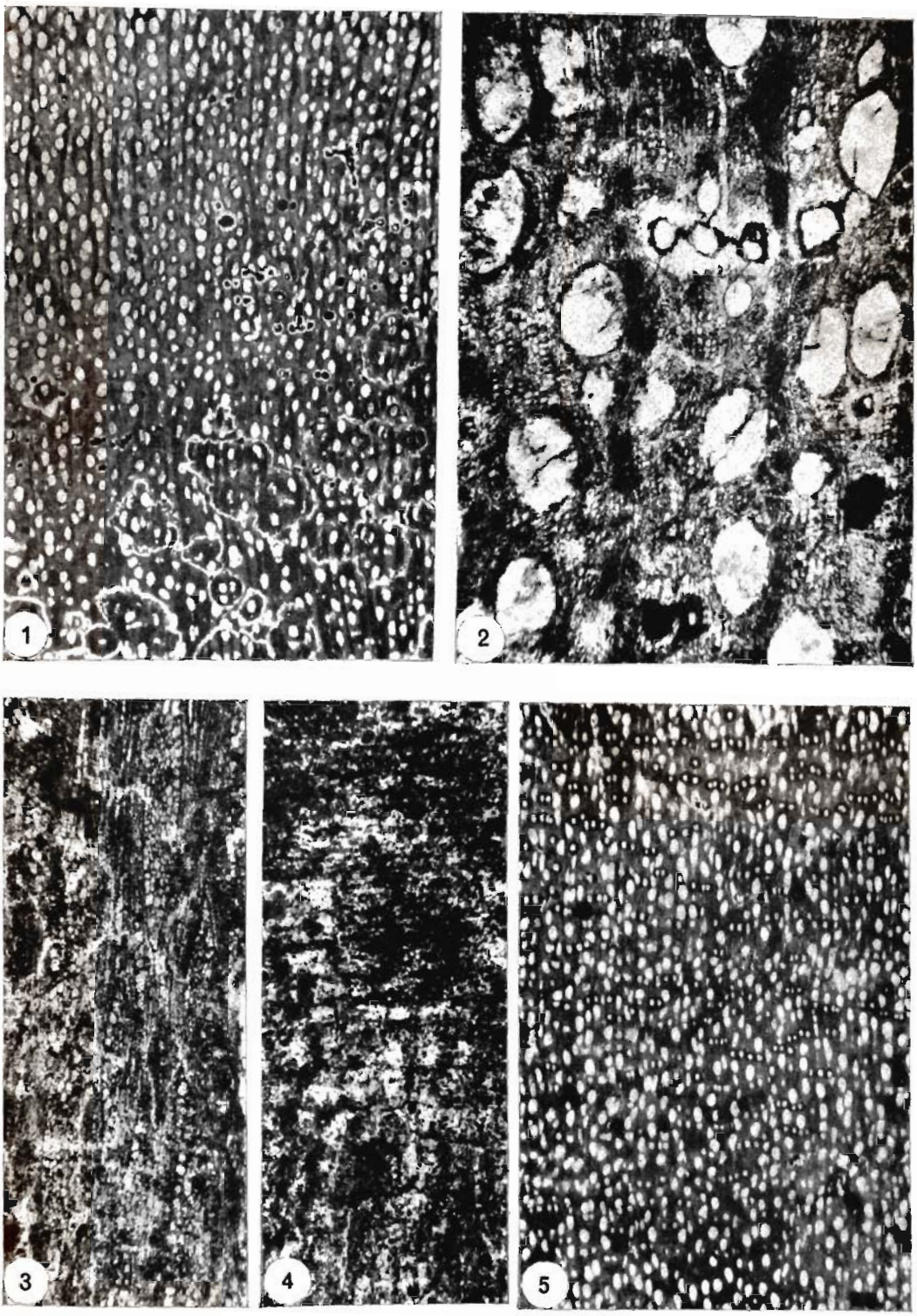
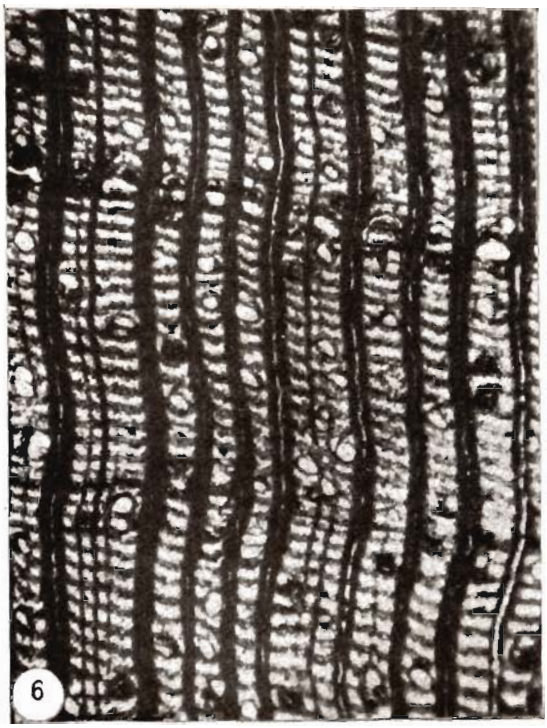
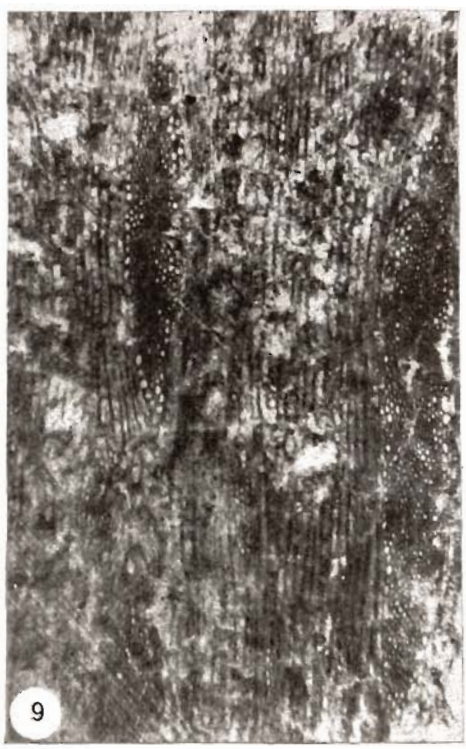


PLATE 1





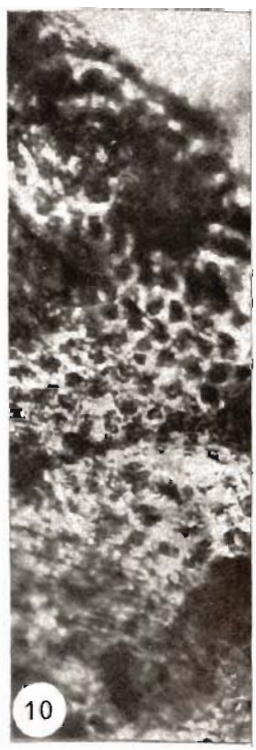
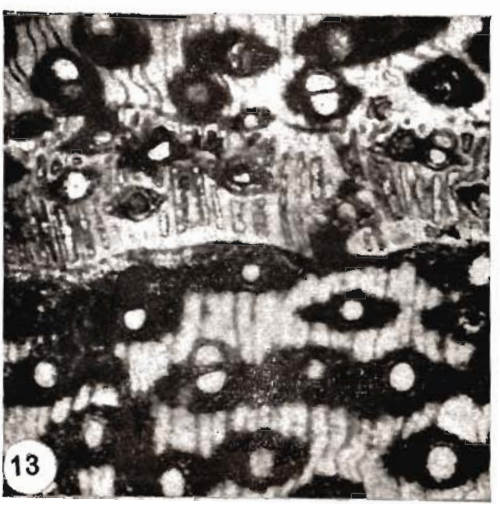
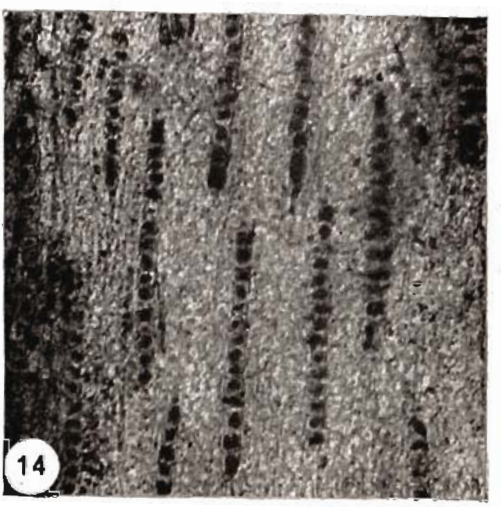
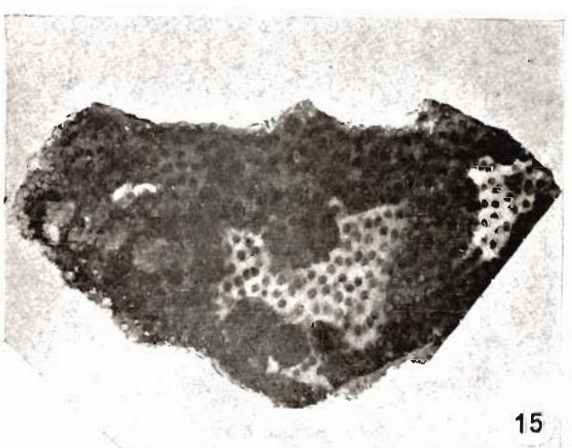


PLATE 2







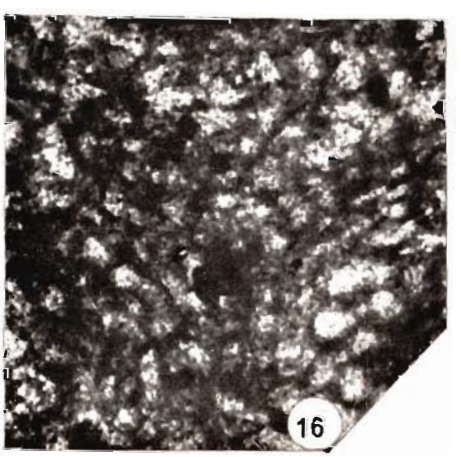
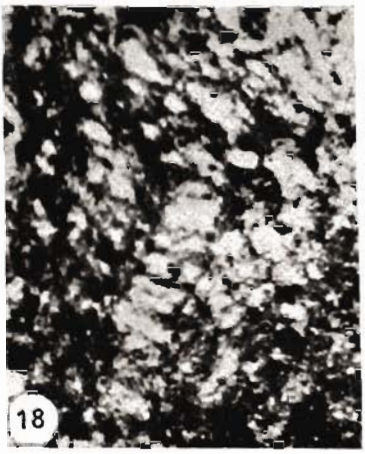


PLATE 3



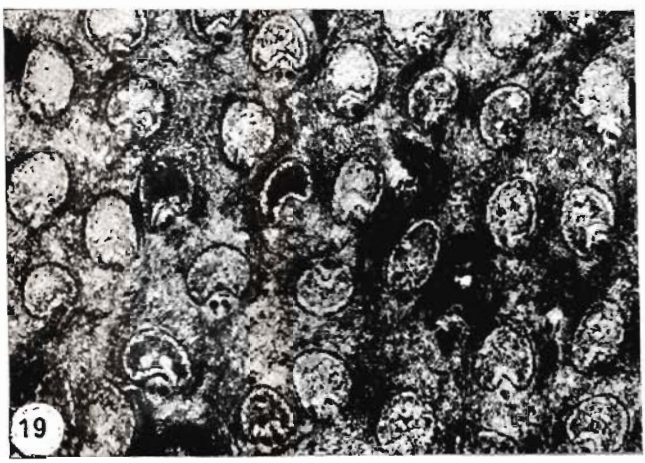


PLATE 4