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FOSSIL DICOTYLEDONOUS WOODS FROM THE TERTIARY OF BLUE NILE VALLEY, ETHIOPIA

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ABSTRACT

Six species belonging to five dicotyledonous families have been described here from a collection of petrified woods made from the Tertiary (Mio-Pliocene) pyroclastic deposits of the basalt on the southern side of Canon in Blue Nile Valley. They are *Mammeoxylon lanneoides* Lemoigne emend. of Guttiferae, *Cassinium ethiopicum* sp. nov. of Leguminosae, *Sapotoxylon multiporosum* sp. nov. of Sapotaceae, *Stereospermoxylon eoacuminatissimum* gen. et sp. nov., *S. grambasti* sp. nov. of Bignoniaceae and *Vitexoxylon africanum* sp. nov. of Verbenaceae.

Key-words — Xylotomy, Dicotyledonous fossil woods, Blue Nile Valley, Mio-Pliocene, Ethiopia.

सारॉंश

इथोपिया में ब्लू नाइल घाटी के तृतीयक युग से द्विबीजपत्रीय काष्ठाश्म – उत्तम प्रकाश, नीलाम्बर अवस्थी एवं वाई० लैमोयने

ब्लू नाइल घाटी में केनन के दक्षिणी भाग से तृतीयक युगीन (मध्यनूतन-आदिनूतन) बासाल्ट के ज्वलखंडाश्मी निक्षेपों से एकत्रित अश्मीभूत काष्ठों के एक संग्रह से पाँच द्विबीजपत्रीय कुलों की छः जातियों का वर्णन किया गया है। ये गट्टीफ़ेरी की मेॅमिऑक्सीलॉन् लेन्नॉयडिस लैमोयने संशोधित, लैगूमिनोसी की केसीनियम् इथिओपिकम् नव जाति, सैपोटेसी की सैपोटॉक्सीलॉन् मल्टीपोरोसम् नव जाति, बिग्नोनिएसी की स्टीरिओस्पर्माक्सीलॉन् इओ-ऍक्यूमिनेटिसिमम् नव प्रजाति व नव जाति, स्टी० ग्रामबस्ताई नव जाति तथा वर्बीनेसी कुल की वाइटॅक्सोक्सी-लॉन् ऑफ्रीकेनम् नव जाति हैं।

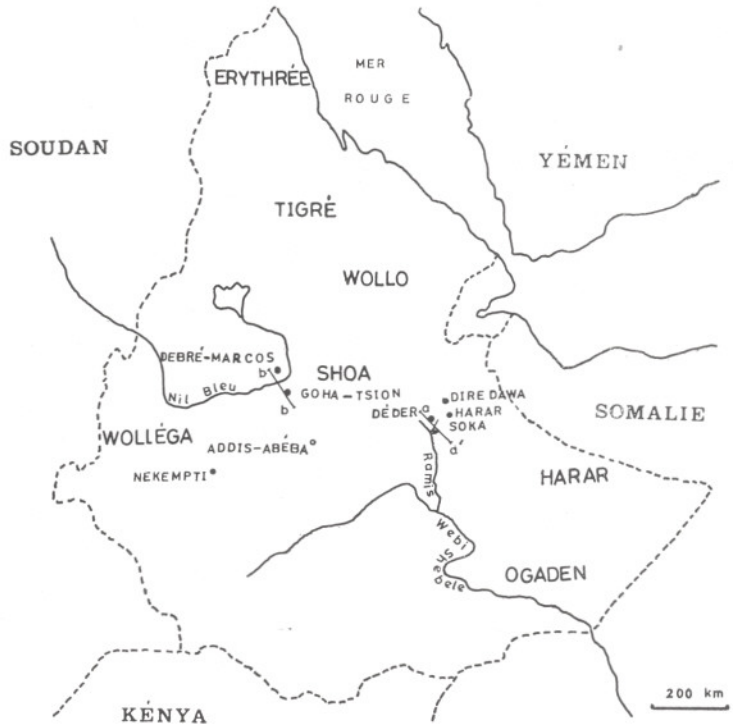
INTRODUCTION

A FEW years ago, one of us (Y. Lemoigne) made a large collection of fossil angiopsermic woods from the pyroclastic deposits of the basalt on the southern side of Canon between the village Goha-Tsion and the bridge over the Blue Nile River in Ethiopia. This locality is about 200 km north-west of Addis-Abéba along the road to Debré-Marcos in the province of Shoa (Map 1). The stratigraphical sequence (Text-fig. 1) of the rocks seen in a section of the Canon overlooking the bridge on the Blue Nile River is described below:

11 — Basalt and pyroclastic deposits - - - - 250 m
- a — Prismatic basalt - - - - 70 m.
- b — Pyroclastic deposits: Yellow ashes with angiospermic fossil woods - - - - 35 m.
- c — Vesiculous basalt, with pyroclastic intercalations containing angiosperm fossil woods and leaf-impressions - - - - 140 m.

10 — Sandstones and shales (Upper Sandstone Formation) - - - - 15 m.
- a — Yellow sandstones.
- b — Red and green shales.

9 — Limestone and marls (Antalo Formation) - - - - 300-350 m.



TEXT-FIG. 1 — Map of Ethiopia showing the location of Goha-Tsion Village and the nearby Blue Nile River.

a — Recifal limestones - - - - 20 m.
b — Alternating limestone and grey marl beds - - - 120 m.
c — Calcareous marls - - - - 80 m.
d — Marls and yellow and red shales with interbedded calcareous sandstones - - - - 100 m.

8 — Shales with interbedded sandstones and gypsum beds in the lower part - - - - 190 m.

7 — Brown gypsum with intercalation of dolomitic limestone beds in the upper part, and of marl or sandstone beds in the lower part - - - - 220 m.

6 — Variegated shales and sandstones - - - - - - - 100 m.
a — Red and green shales containing crystals of gypsum.
b — Red and pink sandstone beds.
c — Green shales
d — Shale and sandstone beds.

5 — Fine-grained sandstones (siltstone) - - - - 40 m (upper part of Oldigrat Sandstone Formation).

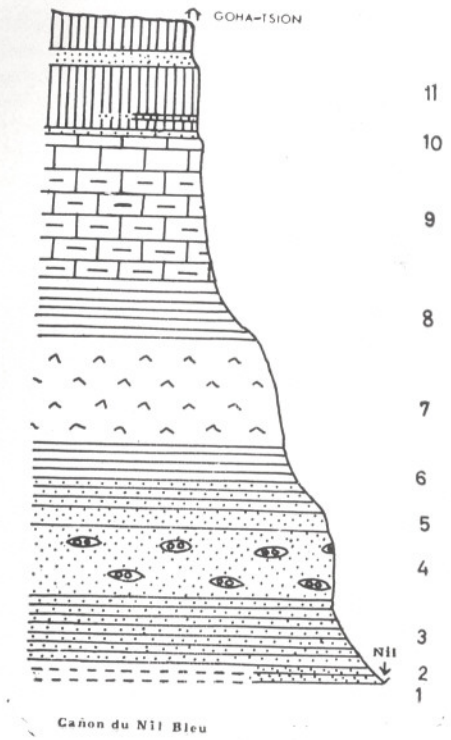
4 — Sandstones and conglomerates (middle part of Oldigrat Sandstone Formation). Red or pink sandstones often with cross beddings; silicified woods in conglomerates showing Araucarian structure - - - - 150 m.

3 — Sandstones and shales - - - - 120 m.

2 — White sandstone (with plant impressions) - - - - more than 40 m.

1 — Precambrian rocks (not visible near the bridge, but visible near the confluence between Mugher and Blue Nile).

The volcanic deposits (Bed no. 11), which represent the upper part of the Blue Nile rock sequence, contain the angiospermic leaf-impressions and silicified woods. The leaf-impressions are confined to the lower part of this deposit and are preserved in the pyroclastic intercalations, while fossil woods occur abundantly in different pyroclastic beds of the basalt (Bed nos. 11 b & c). Although more than 200 specimens of fossil woods were collected, only a few



TEXT-FIG. 2 — A section of the Canon near the bridge on the Blue Nile River.

are well-preserved and could be worked out. The ones included in this paper show resemblance with the modern woods of *Mammea* of Guttiferae, *Cassia* of Leguminosae, *Stereospermum*, *Kigelia* and *Markhamia* of Bignoniaceae, *Vitex* of Verbenaceae and those of the family Sapotaceae. These are described here as *Mammeoxylon lanneoides* Lemoigne (1978), *Cassinium ethiopicum* sp. nov., *Sapotoxylon multiporosum* sp. nov., *Stereospermoxylon eoacuminatissimum* gen. et sp. nov., *S. grambasti* sp. nov. and *Vitexoxylon africanum* sp. nov.

Although a rich assemblage of plants has recently been worked out from the Tertiary volcanic deposits of Welkite (Lemoigne & Beauchamp, 1972), Dire Dawa (Beauchamp & Lemoigne, 1973), Debre-Libanos (Beauchamp, Lemoigne & Petrescu, 1973), Mush Valley, Molale, Debre-Sina, and Wondo (Lemoigne, Beauchamp & Samuel, 1974) and Omo Valley (Dechamps, 1976; Lemoigne, 1978), the present study on the fossil woods of Blue Nile Valley forms the first record of the Tertiary plant remains from this region of Ethiopia. The age of the pyroclastic deposits embedding the petrified woods is most porbably Mio-Pliocene as is also evident from the close resemblance of fossil forms with those of the living taxa.

SYSTEMATIC DESCRIPTION

FAMILY — GUTTIFERAE

Genus — *Mammeoxylon* Lemoigne, 1978 emend.

1. *Mammeoxylon lanneoides* Lemoigne, 1978

Pl. 1, figs 1, 3, 5, 6

In 1978, Lemoigne described *Mammeoxylon lanneoides* from the Tertiary of Omo Basin in Ethiopia showing its affinity with the extant genus *Mammea* of the family Guttiferae. In the present collection of woods we found another wood which shows closest resemblance with *Mammea*, especially with an African species, *M. africana*. From its detailed anatomical features it is apparent that our specimen belongs to *Mammeoxylon lanneoides*, although there is no mention about the presence of vasicentric tracheids and bordered pits in the fibres of fossil wood described by Lemoigne (1978) which are characteristics of *Mammea*. Besides, the gum canals have not been illustrated by its author. Therefore, it is deemed necessary to give here a well-illustrated account and emended diagnosis of *Mammeoxylon lanneoides* based on the present specimen.

Topography — Wood diffuse-porous. *Growth rings* indistinct. *Vessels* exclusively solitary, medium to large, showing slight tendency towards oblique arrangement along radial lines (Pl. 1, fig. 1), about 6-15 vessels per sq mm; tyloses present. *Vasicentric tracheids* present, intermingled with paratracheal parenchyma. *Parenchyma* paratracheal and apotracheal (Pl. 1, fig. 1); paratracheal parenchyma scanty, only a few cells associated with the vessels, occasionally forming incomplete sheath round the vessels, intermingled with vasicentric tracheids; apotracheal parenchyma diffuse to diffuse in-aggregate (Pl. 1, fig. 1), occasionally forming short, uniseriate lines. *Xylem rays* fine, 1-3 (mostly 1-2) seriate, those containing

horizontal gum canals 4-5 seriate (Pl. 1, fig. 3), about 4-42 cells in height and 6-12 per mm; ray tissue heterogeneous; uniseriate rays quite frequent, mostly composed wholly of upright cells; biseriate and triseriate rays heterocellular, consisting of one to several marginal rows of upright cells at both the ends and procumbent cells through the median portion (Pl. 1, figs 3, 5); end to end ray fusion often seen. *Tracheids* aligned in radial rows between the two consecutive xylem rays. *Gum canals* horizontal, occurring in broader rays (Pl. 1, fig. 3).

Elements — *Vessels* circular to oval (Pl. 1, fig. 1), t.d. 105-280 μm, r.d. 105-300 μm, walls 8-12 μm thick; perforations simple, nearly horizontal to oblique; vessel members up to 400 μm in length. *Vasicentric tracheids* 16-34 μm in diameter, length almost same as of fibres; pits arranged in two rows, 2-4 μm in diameter, with circular or slit-like orifices. *Parenchyma cells* circular to tangentially elongated, 24-52 μm in diameter. *Ray cells* both upright and procumbent; upright cells (Pl. 1, fig. 5), 40-120 μm in tangential height and 28-60 μm in radial length; procumbent cells 16-32 μm in tangential height and 40-160 μm in radial length. *Fibre-tracheids* thick-walled, angular, mostly hexagonal, 12-32 μm in diameter, nonseptate; pits bordered (Pl. 1, fig. 6), about 2-4 μm in diameter, with slit-like orifices. *Gum canals* oval (Pl. 1, fig. 3), 80-240 μm in diameter.

The genus *Mammea* is distributed in the tropical regions of the world. One species is found in tropical America, West Indies; one in Africa, 20 in Madagascar, and 27 species in Indo-Malayan and Pacific regions (Willis, 1973, p. 709). *Mammea africana* Sabine, the nearest modern equivalent of the present fossil, is found in tropical Africa, in Sierra Leone, Angola and Belgian Congo.

Emended Generic Diagnosis

Mammeoxylon Lemoigne, 1978 emend.

Wood diffuse porous. *Growth rings* indistinct. *Vessels* small to large, exclusively solitary, showing slight tendency towards oblique arrangement in radial lines, tylosed; perforations simple, plates nearly horizontal to oblique. *Vasicentric tracheids* forming sheath around the vessels; pits bordered, arranged in vertical rows. *Parenchyma* mostly apotracheal, diffuse or diffuse-in-aggregate, sometimes forming short uniseriate lines, occasionally paratracheal, intermingled with vasicentric tracheids. *Xylem rays* 1-5 seriate, broader rays with horizontal gum canals; ray tissue heterogeneous. *Fibre-tracheids* angular or hexagonal, thick-walled, nonseptate; pits bordered. *Gum canals* horizontal, occurring in multiseriate rays.

Emended Specific Diagnosis

Mammeoxylon lanneoides Lemoigne, 1978

Wood diffuse-porous. *Growth rings* indistinct. *Vessels* medium to large, exclusively solitary, rarely tending to arrange in oblique radial lines, t.d. 105-280 μm, r.d. 105-300 μm, 6-15 vessels per sq mm; tyloses present; perforations simple, nearly horizontal to oblique. *Vasicentric tracheids* forming a sheath of 1-2 cells around the vessels; pits leading to vessels bordered, arranged in vertical rows, 2-4 μm in diameter with slit-like orifices. *Parenchyma* apotracheal, diffuse or diffuse-in-aggregate, occasionally forming uniseriate lines, 9-12 lines per mm; paratracheal parenchyma occasionally present, intermingled with vasicentric tracheids. *Xylem rays* 1-3 (mostly 1-2) seriate, those containing horizontal gum canals 4-5 seriate, 4-42 cells in height; ray tissue heterogeneous; uniseriate rays frequent, mostly homocellular, composed wholly of upright cells; multiseriate rays heterocellular, consisting of one to several marginal rows of upright cells and rest procumbent cells. *Fibre tracheids* angular or hexagonal, thick-walled, nonseptate; pits bordered, 2-4 μm in diameter with slit-like orifices. *Gum canals* horizontal, occurring in broader rays, oval, 80-240 μm in diameter.

Specimen — NB6/2, Palaeobotany Laboratory, Lyon University, France.

Family — Leguminosae

Genus — *Cassinium* Prakash, 1975

2. *Cassinium ethiopicum* sp. nov.

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

Topography — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to

medium-sized, solitary and in radial multiples of 2-5 (mostly 2-3), evenly distributed (Pl. 1, fig. 7), about 15-30 vessels per sq mm; tyloses absent. *Parenchyma* paratracheal, banded, bands regular and somewhat wavy, completely enclosing the vessels, sometimes anastomosing or bifurcating and joining with those of adjacent vessels (Pl. 1, fig. 7), 3-6 (mostly 3-4) seriate, about 4-6 bands per mm. *Xylem rays* 1-4 seriate (Pl. 1, fig. 8), 5-27 cells in height and 7-12 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 1, fig. 9). *Fibres* aligned nearly in radial lines between the two consecutive rays.

Elements — Vessels circular or oval (Pl. 1, fig. 7), those of radial multiples slightly flattened at places of contact, t.d. 30-160 μm, r.d. 25-155 μm, walls 6-10 μm; perforations simple, nearly horizontal to oblique; vessel members 100-375 μm in length; intervessel pits medium to large, 6-10 μm in diameter, alternate, bordered, vestured, with lenticular apertures (Pl. 2, fig. 10); vessel-parenchyma and vessel-ray pits slightly bigger than intervessel pits. *Parenchyma cells* circular, 20-40 μm in diameter; crystalliferous strands abundant, divided into several locules containing solitary crystals. *Ray cells* procumbent, 12-20 μm in tangential height, 24-100 μm in radial length. *Fibres* semi-libriform, thick-walled, nonseptate, nearly circular, 8-20 μm in diameter.

Affinities — The most important features of the fossil wood are: vessels small to mostly medium, solitary and in radial multiples, intervessel pits vestured; parenchyma paratracheal, banded; rays 1-4 seriate, homocellular and fibres nonseptate. These features collectively show its resemblance with the modern woods of *Cynometra* and *Cassia* of the family Leguminosae. However, considering all other anatomical details *Cynometra* can be differentiated from it. One of the important differences is that in *Cynometra* the xylem rays are heterocellular, consisting of 1-2 marginal rows of upright cells, whereas in the present fossil the xylem rays are homocellular consisting only of procumbent cells.

Detailed comparative study of the fossil was made with the thin sections of a number of species of *Cassia*, viz., *Cassia alata* L., *C. aubrevillei* Pellegr., *C. auriculata* L., *C. fistula* L., *C. grandis* L., *C. javanica* L., *C. laevigata* Willd., *C. marginata* Roxb., *C. montana* Heyne, *C. nodosa* Buch-Ham. ex Roxb., *C. siamea* Lam. and *S. timoriensis* D. C. Besides examining the thin sections, it was also compared with the published description and figures of a few other species of *Cassia*. Of these, *Cassia aubrevillei* shows similarity with our fossil. However, the present fossil slightly differs from it in having comparatively thinner parenchyma bands and smaller vessels.

Fossil woods resembling the modern woods of *Cassia* are placed under the genus *Cassinium* Prakash (1975). So far six species of *Cassinium* are known from the Neogene rocks of India (see Awasthi, 1979, p. 160). Of these, *Cassinium borooahii* (Prakash) Prakash (= *Cassioxylon borooahii* Prakash, 1966) shows gross resemblance with the present fossil particularly in having banded parenchyma. However, there are some significant differences in their anatomical features which differentiate them from one another. In *Cassinium borooahii* the vessels are medium to large (t.d. 150-320 μm; r.d. 180-405 μm) and 2-4 per sq mm, and the parenchyma bands are relatively broader, i.e. more than 4-8 cells in width, whereas in the present fossil the vessels are small to medium-sized (t.d. 30-160 μm; r.d. 25-155 μm) and about 15-30 per sq mm, and the parenchyma bands are about 3-6 (mostly 3-4) cells in width.

In view of its closest similarity with the woods of *Cassia*, the present fossil is placed under the genus *Cassinium* Prakash. Since it is different from all the species of *Cassinium*, it is named as *Cassinium ethiopicum* sp. nov.

The genus *Cassia* consists of 500-600 species distributed in tropical and warm temperate regions excluding Europe (Willis, 1973, p. 211). About 26 species are found in tropical Africa. *Cassia aubrevillei* Pellegr., with which the present fossil shows closest resemblance, grows in patches in the dense forests of Ivory Coast and Central Congo (Normand, 1950, p. 125).

Specific Diagnosis

Cassinium ethiopicum sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, solitary and in radial multiples of 2-5 (mostly 2-3),

about 15-30 vessels per sq mm.; vessel-members about 100-375 μm in height; intervessel pits medium to large, 6-10 μm in diameter, vestured, alternate with lenticular apertures. *Parenchyma* paratracheal, banded, bands regular and somewhat wavy, seldom bifurcating and joining with those of adjacent vessels, 3-6 (mostly 3-4) seriate, about 4-6 bands per mm; parenchyma strands crystalliferous. *Xylem rays* 1-4 seriate, about 4-27 cells in height, 7-12 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells. *Fibres* semilibriform, thick-walled, nonseptate, small, about 8-20 μm in diameter.

Holotype — NB5, Palaeobotany Laboratory, Lyon University, France.

FAMILY — SAPOTACEAE

Genus — *Sapotoxylon* Felix, 1882

3. *Sapotoxylon multiporosum* sp. nov.

Pl. 2, figs 11-15

Topography — Wood diffuse-porous. *Growth rings* not clearly seen. *Vessels* small to medium-sized, mostly small, solitary and mostly in radial multiples of 2-10, occasionally up to 18, exhibiting short chain-like structures, characteristically grouped together in oblique radial lines (Pl. 2, figs 12, 13) forming zig zag flame-like pattern, about 60-120 vessels per sq mm; tyloses present, thick-walled, vessels also filled with whitish crystalliferous contents. *Vasicentric tracheids* occurring in the immediate vicinity of vessels and vessel groups (Pl. 2, fig. 13). *Parenchyma* paratracheal and apotracheal, the former scanty, only a few cells associated with the vessels, intermingled with vasicentric tracheids, while the latter forming more or less loose, wavy as well as straight, regular lines, 1-3 (mostly 1-2) seriate in width (Pl. 2, fig. 13), about 8-12 lines per mm. *Xylem rays* fine, 1-2 seriate (Pl. 2, fig. 14), 7-45 cells in height and 18-22 rays per mm; ray tissue heterogeneous, rays heterocellular, consisting of procumbent cells through the median portion and one-several uniseriate marginal rows of upright cells at both the ends (Pl. 2, figs 14, 15). *Fibres* aligned in radial rows between two consecutive rays.

Elements — Vessels circular to oval, those in multiples flattened at places of contact, t.d. 48-100 μm, r.d. 32-120 μm; perforations simple; vessel members truncate or attenuately tailed, usually short, 60-440 μm in length; intervessel pits small to medium, 4-6 μm in diameter, crowded, alternate with small, circular apertures (Pl. 2, fig. 11); pits leading to contiguous vasicentric tracheids almost similar to intervessel pits; pit leading to ray cells slightly bigger than intervessel pits. *Vasicentric tracheids* slightly bigger than fibres, usually with 2 rows of bordered pits. *Parenchyma cells* angular or rounded in cross section, 20-28 μm in diameter, infiltration dark. *Ray cells* upright and procumbent; upright cells 64-100 μm in tangential height, 24-40 μm in radial length; procumbent cells 8-24 μm in tangential height, 40-160 μm in radial length. *Fibres* libriform, thick-walled, nonseptate, angular in cross section, small with narrow constricted lumen, about 8-12 μm in diameter; pits not seen.

Affinities — The above features of the fossil clearly show that it is a sapotaceous wood. The family Sapotaceae, on the whole, is quite homogeneous in wood structure. There is hardly any characteristic feature in the woods which can be of diagnostic value in the generic distinction. However, they can be distinguished only in certain cases when all the characters of the woods are taken into consideration collectively. After examining the available thin sections of modern woods as well as published description and illustrations of quite a number of woods of this family (Desch, 1954, pp. 538-558; Kribs, 1959, pp. 146-151, figs 309-314, 458-464; Lecomte, 1926, pls 63-64; Metcalfe & Chalk, 1950, pp. 875-877, fig. 201; Moll & Janssonius, 1920, pp. 353-412, figs 259-262; Normand, 1960, pp. 305-320, pls 131-142; Pearson & Brown 1932, pp. 663-688, figs 217-225), it was found that the fossil shows general resemblance with some species of *Mimusops*, *Manilkara*, *Payena*, *Bequaertiodendron* (= *Neoboivinella*) and *Pachystela*.

Manilkara and *Mimusops* exhibit some significant variations with regard to the size and arrangement of the vessels, the type of parenchyma and rays. The size of vessels varies from small to large, arranged in loose to compact groups along oblique radial lines; the parenchyma lines are 1-3 seriate, close or

slightly widely spaced; the rays are 1-2 or up to 4-seriate. In the present fossil the vessels are mostly small, with majority of vessels being less than 100 μm in diameter, arranged in groups as well as along oblique radial lines; the parenchyma lines are 1-3 seriate and closely spaced, and the rays are only 1-2 seriate. From this it is evident that the possibility of being either *Manilkara* or *Mimusops* as its modern equivalent can not be ruled out. In the nature and distribution of vessels and parenchyma and in the width of rays, it is also somewhat similar to those of *Payena*. However, the vessels in *Payena* are slightly bigger than those of the fossil. In the type and distribution of vessels and parenchyma, the fossil also shows resemblance with *Bequartiodendron glomeruliflora* Aubr. (= *Neoboivinella glomeruliflora* Aubr.) and *Pachystela brevipes* Baill. (Normand, 1960, p. 309, pls 136, 137). However, the former differs from the fossil in having slightly smaller vessels (i.e. the diameter being less than 100 μm), while the latter differs in having rays up to 4-seriate. Since the fossil exhibits all the anatomical characters of the family Sapotaceae, it is assigned to the genus *Sapotoxylon* Felix (1882).

So far eight species of fossil woods of the family Sapotaceae are known. These are *Sapotoxylon taeniatum* (Felix, 1882) from Bavaria in south-east Germany, *Manilkaroxylon diluviale* (Hofmann, 1948) from the Quaternary deposits of South America, *Manilkaroxylon crystallophora* and *Palaeosideroxylon flammula* (Grambast-Fessard, 1968) from the Upper Miocene of Castellane in south-east France, *Siderinium deomaliense* Prakash & Awasthi (1970) from the Mio-Pliocene of Deomali, Arunachal Pradesh, *Manilkaroxylon bohemicum* and *Sapotoxylon pacltovae* (Prakash, Brezinova & Awasthi, 1974) from the Tertiary of South Bohemia, Crechoslovaka, *Chrysophylloxylon indicum* Awasthi (1977) from the Mio-Pliocene beds, near Pondicherry, India and *Madhucoxylon cacharense* Prakash & Tripathi (1977) from the Tipam Series, near Hailakandi, Assam. All these species are quite different from the present fossil wood.

In *Sapotoxylon taeniatum* the vessels are slightly bigger (diameter 180 μm), rays 2-3 seriate and parenchyma lines 3-celled or even broader. The vessels in *Palaeosideroxylon flammula* are very much crowded and grouped forming dendritic pattern, and the parenchyma lines are 2-3 seriate and widely spaced. In *Manilkara crystallophora* the rays are 1-4 seriate with swollen and crystalliferous upright cells, and the vessels are arranged in distinct radial lines without forming zig-zag or flame-like pattern. Similarly, in *Siderinium deomaliense* and *Madhucoxylon cacharense*, the vessels are in radial lines without forming zig-zag pattern and the parenchyma is diffuse or in uniseriate lines. In *Manilkaroxylon bohemicum* the vessels are mostly large (t.d. 50-290 μm, r.d. 50-310 μm) and the rays are 1-3 seriate. The frequency of the vessels in *Sapotoxylon pacltovae* is very less (2-4 vessels per sq mm) and their size ranges between 75 to 200 μm in diameter, and the apotracheal parenchyma lines are uniseriate only. In *Chrysophylloxylon indicum* the vessels are large and the xylem rays are 1-4 seriate, whereas in the present Ethiopian fossil wood the vessels are mostly smaller (t.d. 48-100 μm, r.d. 32-120 μm), arranged in long radial multiples forming zig-zag pattern, the xylem rays are 1-2 seriate and the parenchyma is scanty paratracheal and in regular lines of 1-3 (mostly 1-2) cells in width. Thus it is seen that the present fossil is quite different from all the above species. It is, therefore, described as a new species of *Sapotoxylon* Felix, *Sapotoxylon multiporosum* sp. nov.

Specific Diagnosis

Sapotoxylon multiporosum sp. nov.

Wood diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, mostly small, t.d. 48-100 μm, r.d. 32-120 μm, solitary and mostly in radial multiples of 2-10, occasionally up to 18, characteristically grouped in oblique radial lines, 60-120 vessels per sq mm; perforations simple; intervessel pits alternate, crowded, small to medium, 4-6 μm in diameter, with circular apertures; tyloses present, thick-walled. *Vasicentric tracheids* few, associated with vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma having only a few cells associated with vessels; apotracheal parenchyma forming 1-3 (mostly 1-2) seriate, almost regular, straight or wavy lines, about 8-12 lines

per mm. *Xylem rays* fine, 1-2 seriate, about 7-45 cells in height and 18-22 per mm; ray tissue heterogeneous, rays heterocellular, consisting of procumbent cells through the median portion and one to several marginal rows of upright cells at both the ends. *Fibres* libriform, thick-walled with narrow constricted lumen, nonseptate, angular, small, 8-20 μm in diameter.

Holotype — NB9-Palaeobotany Laboratory, Lyon University, France.

FAMILY — BIGNONIACEAE

Genus — *Stereospermoxylon* gen. nov.

4. *Stereospermoxylon eoacuminatissimum* sp. nov.

Pl. 2, figs 16, 17; Pl. 3, figs 18-20

Topography — Wood diffuse-porous to semi-ring porous (Pl. 2, fig. 16). *Growth rings* present, delineated by relatively bigger vessels at the beginning of annual rings (Pl. 2, figs 16, 17). *Vessels* medium to large, a few small, those occurring at the beginning of annual rings bigger in size (Pl. 2, figs 16, 17), arranged in a tangential rows and gradually grading into smaller vessels towards the close of rings, solitary and in radial multiples of 2-4 (mostly 3), rarely up to 6, sometimes in double rows, evenly distributed, about 6-10 vessels per sq mm; tyloses not seen. *Parenchyma* paratracheal, vasicentric to aliform and confluent, enclosing vessels and vessel groups laterally and obliquely, or joining with those of neighbouring vessels (Pl. 2, fig. 17); parenchyma encircling bigger vessels of early wood forming undulating lines or narrow confluent bands (Pl. 2, figs 16, 17). *Xylem rays* 1-4 seriate (Pl. 3, fig. 18), about 5-30 cells in height and 5-7 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 3, fig. 19). *Fibres* arranged in radial rows between two consecutive rays.

Elements — Vessels circular to oval (Pl. 2, fig. 17), t.d. 50-320 μm, walls 8-12 μm; perforations simple, horizontal to oblique; vessel members short, 60-375 μm in lenght; intervessel pits medium, 6-8 μm in diameter, alternate, bordered with circular to lenticular apertures (Pl. 3, fig. 20); vessel parenchyma and vessel-ray pits slightly bigger than intervessel pits; yellowish infiltration present. *Parenchyma cells* 3-4 per strand, angular, mostly hexagonal, radially elongated in cross section. *Ray cells* procumbent, 16-24 μm in tangential height, 40-180 μm in radial length. *Fibres* semilibriform, thick-walled, small, angular and 8-24 μm in diameter.

Affinities — The important features of the present fossil are: wood diffuse-porous to nearly semi-ring porous; vessels mostly medium to large, solitary as well as in radial multiples; parenchyma paratracheal, aliform to confluent; rays 1-4 seriate, homocellular, composed of procumbent cells and fibres moderately thick-walled and nonseptate. These features obviously suggest its affinities with the modern woods of Bignoniaceae. In the family Bignoniaceae, *Stereospermum*, *Kigelia* and *Markhamia* exhibit almost similar xylotomical features as present in our fossil wood. A number of thin sections of the woods of these genera were examined and the description and figures of *Stereospermum sauveolens* DC., *S. xylocarpum* Benth. et Hook. f. (Pearson & Brown, 1932, pp. 770-780, figs 246-248), *S. fimbriatum* DC. (Desch, 1957, pp. 50, 51, pl. 9, fig. 1), *S. neuranthemum* Kurz (Metcalfe & Chalk, 1950, pp. 1005-1009, fig. 236H), *S. acuminatissimum* K. Schum, *Kigelia africana* Benth. and *Markhamia lutea* K. Schum. (Normand, 1960, pp. 300-354, pls 156, 157) were consulted. Although it is difficult to find out the exact modern equivalent of the present fossil, but considering the nature and distribution of vessels, parenchyma and rays, the fossil appears to be more closer to *Stereospermum*, particularly with an African species — *Stereospermum acuminatissimum*. It has also been found that in most of the cases the woods of some of the species of *Stereospermum*, *Kigelia* and *Markhamia* are so similar that they cannot be differentiated anatomically. Therefore, for naming the fossil woods resembling woods of *Stereospermum*, *Kigelia* and *Markhamia* which cannot be differentiated easily from each other, a new genus *Stereospermoxylon* is created. Since the present fossil shows similarity with those of *Stereospermum*, *Markhamia* and *Kigelia* in general and comes somewhat closer to *Stereospermum acuminatissimum*, it is placed under the genus *Stereospermoxylon* and

named as *Stereospermoxylon eoacuminatissimum* sp. nov.

The genus *Stereospermum* Cham. consists of 24 species, distributed in tropical Africa and Asia (Willis, 1973, p. 1103). About 11 species are found in tropical Africa, (Thiselton-Dyer, 1906, pp. 517-570). *Stereospermum acuminatissimum* K. Schum. is found in East Africa, Lagos and Cameroons.

Generic Diagnosis

Stereospermoxylon gen. nov.

Wood diffuse-porous to occasionally semi-ring porous. *Growth rings* present, delineated by bigger vessels, parenchyma lines and thick-walled fibres. *Vessels* small to large, solitary as well as in radial multiples; tyloses absent; perforations simple; vessel members short to medium in length; intervessel pits medium to large, bordered, alternate, with lenticular apertures. *Parenchyma* paratracheal, vasicentric, aliform to confluent, extending laterally joining with those of adjacent vessels; lines of parenchyma also present at the growth rings. *Xylem rays* fine to moderately broad, mostly 1-4 seriate; ray tissue homogeneous; rays mostly homocellular, consisting of procumbent cells. *Fibres* semi-libriform, moderately thick-walled, nonseptate.

Genotype — Stereospermoxylon eoacuminatissimum sp. nov.

Specific Diagnosis

Stereospermoxylon eoacuminatissimum sp. nov.

Wood diffuse-porous to semi-ring porous. *Growth rings* present, delineated by bigger vessels at the beginning and grading into smaller vessels at the close of the annual rings, t.d. 50-250 μm, r.d. 50-320 μm, solitary and in radial multiples of 2-4, about 6-10 vessels per sq mm; vessel members short to medium in length; intervessel pits medium to large, about 6-8 μm, alternate, bordered with lenticular apertures. *Parenchyma* paratracheal, aliform to confluent, extending laterally and obliquely joining with those of the adjacent vessels; narrow lines or bands of parenchyma present at the inception of growth rings encircling the bigger vessels. *Xylem rays* 1-4 seriate, up to 50 cells in height, and 5-7 rays per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells only. *Fibres* semilibriform, moderately thick-walled, nonseptate, angular, small, 8-24 μm in diameter.

Holotype — NB 11, Palaeobotany Laboratory, Lyon University, France.

5. *Stereospermoxylon grambasti* sp. nov.

Pl. 3, figs 21, 23, 24

Topography — Wood diffuse - porous. *Growth rings* present, delineated by slightly bigger vessels, thin apotracheal parenchyma lines which merge with confluent bands and thick-walled fibres (Pl. 3, fig. 24). *Vessels* small to large, solitary and in radial multiples of 2-8 (mostly 2-3), seldom in double rows, sometimes very small and in clusters associated with bigger vessels, evenly distributed, about 10-20 vessels per sq mm; tyloses not seen. *Parenchyma* paratracheal and apotracheal, paratracheal vasicentric, aliform to confluent, extending side ways and joining with those of adjacent vessels, sometimes showing tendency to form somewhat longer, straight, interrupted, tangential, anastomosing bands joining several vessels (Pl. 3, fig. 24); apotracheal parenchyma in fine lines of 2-3 cells wide, occurring at the inception of annual rings merging with aliform confluent lines or bands. *Xylem rays* 3-4 seriate (Pl. 3, fig. 21), 6-40 cells in height and 5-7 rays per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only. *Fibres* aligned in radial rows between two consecutive rays.

Elements — Vessels circular to oval (Pl. 3, fig. 24), t.d. and r.d. about 30-3000 μm, mostly 160-250 μm, thin-walled, walls 4-8 μm; perforations simple, nearly horizontal; vessel members short, 90-450 μm in length; intervessel pits small to medium, 6-8 μm in diameter, circular, alternate, bordered with lenticular to circular apertures; vessel-parenchyma and vessel-ray pits almost similar to intervessel pits. *Parenchyma cells* 3-4 per strand, oval to angular and radially elongated in cross section, those occurring in the immediate vicinity of vessels peripherally flattened, 20-48 μm in diameter. *Ray cells* procumbent, 16-24 μm in tangential height and 40-200 μm in radial length.

Fibres nonlibriform to semilibriform, moderately thick-walled, nonseptate, small, circular to angular in cross section and 8-20 μm in diameter.

Affinities — The anatomical characters of this fossil wood indicate its resemblance with *Markhamia lutea* (Normand, 1960, p. 353, pl. 157) and *Stereospermum* spp. in the nature and distribution of vessels, parenchyma and rays. The characteristic features of the fossil, viz., the presence of distinct parenchyma lines and clusters of small vessels often associated with bigger vessels, are also seen in *Markhamia lutea* and a few species of *Stereospermum*. Hence the present fossil is placed in the genus *Stereospermoxylon*.

In spite of a close resemblance between *Stereospermoxylon eoacuminatissimum* and the present fossil specimen, particularly in the nature and distribution of vessels, parenchyma fibres and length and width of rays, there is a marked difference between the two. The former is a distinctly semiring porous while the latter is diffuse-porous. Another difference is that in the latter clusters of small vessels associated with bigger vessels are commonly present which are very rarely seen in the former. Such differences have also been noticed among the various species of *Stereospermum* and other Bignoniaceous woods. In view of this the present fossil wood is named as *Stereospermoxylon grambasti* sp. nov., after the late Professor L. Grambast of the University of Montepellier, France.

Specific Diagnosis

Stereospermoxylon grambasti sp. nov.

Wood diffuse-porous. *Growth rings* present, delineated by slightly bigger vessels and thin apotracheal parenchyma lines which merge with aliform-confluent bands, and thick-walled fibres. *Vessels* small to large, solitary and in radial multiples of 2-8, mostly 2-3, sometimes in double rows or in small clusters associated with bigger vessels, circular to oval in cross section, t.d. and r.d. 30-300 μm; vessel members short 90-450 μm in length; intervessel pits bordered, alternate, 6-8 μm in diameter with lenticular to circular apertures. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma vasicentric, aliform to confluent, extending laterally joining with those of adjacent vessels or vessel groups; apotracheal parenchyma terminal or initial, occurring at the inception of annual rings merging with aliform-confluent lines or bands, about 2-3 cells wide. *Xylem rays* 3-4 seriate and about 6-40 cells in height; ray tissue homogeneous, rays homocellular, consisting of procumbent cells. *Fibres* non-libriform to semilibriform, moderately thick-walled, nonseptate, small, circular or angular and 8-20 μm in diameter.

Holotype — NB12, Palaeobotany Laboratory, Lyon University, France.

Family — Verbenaceae

Genus — *Vitexoxylon* Ingle emend. Prakash & Tripathi, 1974 =(Syn. *Vitexoxylon* Lemoigne, 1978)

6. *Vitexoxylon africanum* sp. nov.

Pl. 4, figs 26-30

Topography — Wood diffuse-porous. *Growth rings* present, delimited by thin lines of apotracheal parenchyma (Pl. 4, figs 26, 28). *Vessels* mostly medium to large, solitary and in radial multiples of 2-5, mostly 2-3 (Pl. 4, figs 26, 27), rarely up to 9, sometimes in double rows, about 5-7 vessels per sq mm; tyloses and whitish infiltration present (Pl. 4, fig. 27). *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming narrow, uniseriate or incomplete sheath around the vessels (Pl. 4, fig. 27); apotracheal parenchyma in narrow 1-2 seriate lines at the beginning of growth rings (Pl. 4, figs 26, 27). *Xylem rays* 1-3 (mostly 2-3) seriate (Pl. 4, fig 29), 6-40 cells in height, about 7-10 rays per mm; ray tissue heterogeneous; rays homocellular to heterocellular (Pl. 4, fig. 30), the former consisting of procumbent cells only while the latter composed of procumbent cells in the middle and 1-2 marginal rows of upright cells at one or both the ends. *Fibres* aligned in radial rows between two consecutive rays.

Elements — Vessels circular to oval (Pl. 4, fig. 27), t.d. 120-360 μm, r.d. 60-400 μm, walls 8-10 μm in thickness; perforations simple, nearly horizontal to oblique; vessel members usually short, about 300-600 μm in length, intervessel pits 6-8 μm in diameter, alternate, with lenticular to circular apertures (Pl. 4, fig. 22); vessel-parenchyma and vessel-

ray pits slightly bigger than intervessel pits. *Parenchyma cells* circular or angular, those occurring in the immediate vicinity of vessels peripherally flattened, about 24-40 μm in diameter. *Ray cells* upright and procumbent (Pl. 4, fig. 30); upright cells 40-72 μm in tangential height, 24-40 μm in radial length; procumbent cells 1-28 μm in tangential height, 40-80 μm in radial length; cells occasionally crystalliferous. *Fibres* nonlibriform, moderately thick-walled, septate, angular to squarish in shape and 8-24 μm in diameter.

Affinities — The important features of this fossil wood are: vessels medium to large, solitary and in radial multiples, parenchyma vasicentric and apotracheal delimiting the growth rings; rays 1-3 seriate and heterogeneous; fibres septate and moderately thick-walled. These features collectively indicate the affinities of the fossil with the modern woods of the family Verbenaceae. Among the woods of various genera of this family consulted for comparison, *Vitex limonifolia* Wall. shows close resemblance with the present fossil. This study included the examination of thin sections of modern woods of *Vitex altissima* L., *V. canescens* Kurz, *V. glabrata* R. Br., *V. guameri* Greenman, *V. heterophylla* Roxb., *V. leucoxylon* L., *V. limonifolia* Wall., *V. negundo* L., *V. pachyphylla* Baker, *V. parviflora* A. Juss., *V. peduncularis* Wall. and *V. pubescens* Vahl. The fossil wood was also compared with the published description and figures of most of the above species as well as a few others (Desch, 1954, p. 628; Kanehira, 1924, pp. 44, 45; Kribs, 1959, pp. 161, 162, figs 473-475; Lecomte, 1926, pl. 65; Metcalfe & Chalk, 1950, pp. 1036, 1037, fig 248B, H; Normand, 1960, pl. 154; Pearson & Brown, 1932, pp. 805-811 figs 253-255).

So far only two species of fossil woods of *Vitex* are known from India and abroad. These are *Vitexoxylon miocenicum* Prakash & Tripathi (1974) from the Tipam sandstones near Hailakandi, Assam and *Vitecoxylon aethiopicum* Lemoigne (1978) from the region of Welkite in Ethiopia. Besides, Ingle (1972) described a fossil wood as *Vitexoxylon indicum* from the Deccan Intertrappean beds of Madhya Pradesh. But according to Prakash and Tripathi (1974, p. 310) it does not appear to belong to the genus *Vitex*.

Although the above species resemble the present fossil wood in gross structures, they also differ from it particularly in the absence of apotracheal parenchyma lines at the growth rings. Such parenchyma is not necessarily present in all the species of modern *Vitex*. When it is absent, the growth rings are delimited by thick-walled fibres and bigger vessels. *Vitexoxylon* (= *Vitecoxylon*) *aethiopicum* further differs from our fossil wood in having diffuse parenchyma, nonseptate fibres and smaller vessels (solitary pores 175 μm in diameter). Similarly, *Vitexoxylon miocenicum* is also distinct from this fossil in having broader, 1-6 seriate xylem rays and in the absence of terminal parenchyma. Thus, it is evident that the present fossil wood is quite different from the above species. It is, therefore, named as *Vitexoxylon africanum* sp. nov.

The genus *Vitex* consists of 250 species, distributed in tropical and temperate regions (Willis, 1973, p. 1214). About 58 species are known to occur in tropical Africa (Thiselton-Dyer, 1900, pp. 315-331).

Specific Diagnosis

Vitexoxylon africanum sp. nov.

Wood diffuse-porous. *Growth rings* delimited by thin lines of apotracheal parenchyma. *Vessels* medium to large, solitary and in radial multiples of 2-5, rarely up to 9, sometimes in double rows, t.d. 120-360 μm, r.d. 60-400 μm, about 5-7 vessels per sq mm; perforations simple; vessel members medium to short, about 300-500 μm in length and tylosed; intervessel pits 6-8 μm in diameter, alternate, with lenticular to circular orifices. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric, forming narrow, usually 1-seriate, complete or incomplete sheath round the vessels; apotracheal parenchyma 1-2 seriate lines at the beginning of growth rings. *Xylem rays* 1-3 (mostly 2-3) seriate, about 6-40 cells in height; ray tissue heterogeneous, rays homocellular to heterocellular, consisting either of procumbent cells only or procumbent cells in the centre with 1-3 marginal rows of upright cells at one or both the ends. *Fibres* angular to squarish in cross section, nonlibriform, moderately thick-walled, septate, about 8-24 μm in diameter.

Holotype — NB 15, Palaeobotany Laboratory, Lyon University, France.

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EXPLANATION OF PLATES

PLATE 1

Mammeoxylon lanneoides Lemoigne emend.

1. Cross section showing nature and distribution of vessels and parenchyma. × 30.

Mammea africana

2. Cross section showing vessels and parenchyma similar to that of the fossil shown in fig. 2. × 30.

Mammeoxylon lanneoides Lemoigne emend.

3. Tangential longitudinal section showing xylem rays and horizontal gum canal. × 90.

Mammea africana

4. Tangential longitudinal section showing xylem rays and horizontal gum canal as in fossil shown in fig. 4. × 90.

Mammeoxylon lanneoides Lemoigne emend.

5. Radial longitudinal section showing heterocellular xylem rays. × 90.
6. Fibre-tracheids. × 400.

Cassinium ethiopicum sp. nov.

7. Cross section showing nature and distribution of vessels and parenchyma. × 30.
8. Tangential longitudinal section showing xylem rays. × 60.
9. Radial longitudinal section showing homocellular xylem rays. × 90.

PLATE 2

Cassinium ethiopicum sp. nov.

10. Intervessel pitting. × 400.

Sapotoxylon multiporosum sp. nov.

11. Intervessel pitting. × 400.

Sapotoxylon multiporosum sp. nov.

12. Cross section showing nature and distribution of vessels. × 30.
13. Cross section magnified to show the apotracheal parenchyma bands and the arrangement of vessels. × 90.
14. Tangential longitudinal section showing xylem rays. × 90.
15. Radial longitudinal section showing heterocellular xylem rays. × 90.

Stereospermoxylon eoacuminatissimum gen. et sp. nov.

16. Cross section under low magnification showing nature and distribution of vessels and growth rings. × 7.
17. Cross section magnified to show vessels and parenchyma. × 30.

PLATE 3

Stereospermoxylon eoacuminatissimum gen. et sp. nov.

18. Tangential longitudinal section showing rays. × 90.
19. Radial longitudinal section showing homocellular rays. × 90.
20. Intervessel pitting. × 400.

Stereospermoxylon grambasti sp. nov.

21. Tangential longitudinal section showing rays. × 90.

Stereospermum sp.

22. Tangential longitudinal section showing rays similar to fossil as shown in fig. 25. × 90.

Stereospermoxylon grambasti sp. nov.

23. Cross section showing vessel and parenchyma distribution. × 7.
24. Cross section magnified showing distribution of vessels and parenchyma. × 30.

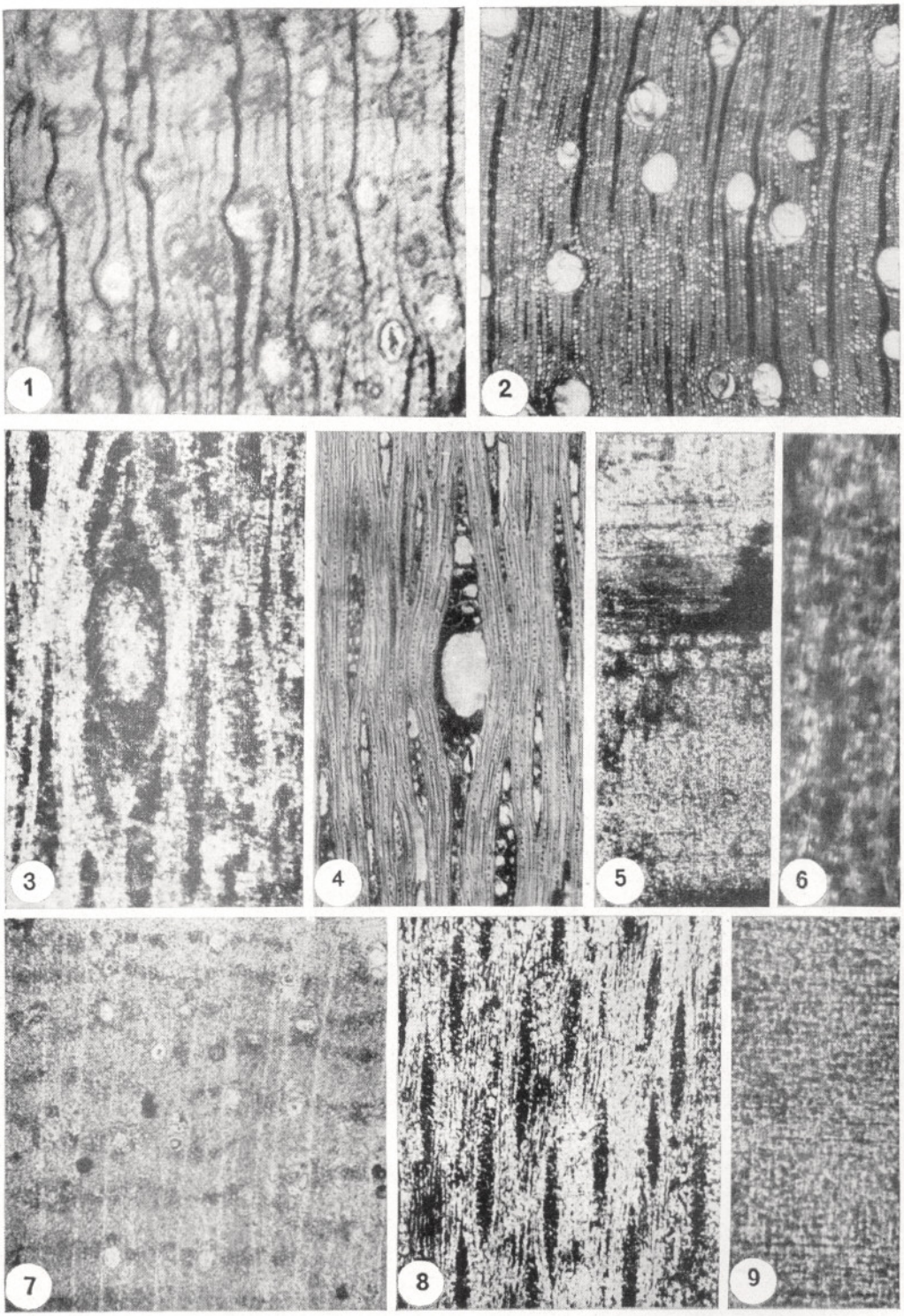
Stereospermum sp.

25. Cross section showing vessels and parenchyma similar in nature and distribution to fossil shown in fig. 23. × 90.

PLATE 4

Vitexoxylon africanum sp. nov.

26. Cross section showing nature and distribution of vessels. × 7.
27. Cross section magnified to show vessels and paratracheal and terminal parenchyma. × 30.
28. Intervessel pitting. × 400.
29. Tangential longitudinal section showing xylem rays. × 90.
30. Radial longitudinal section showing heterocellular rays. × 90.



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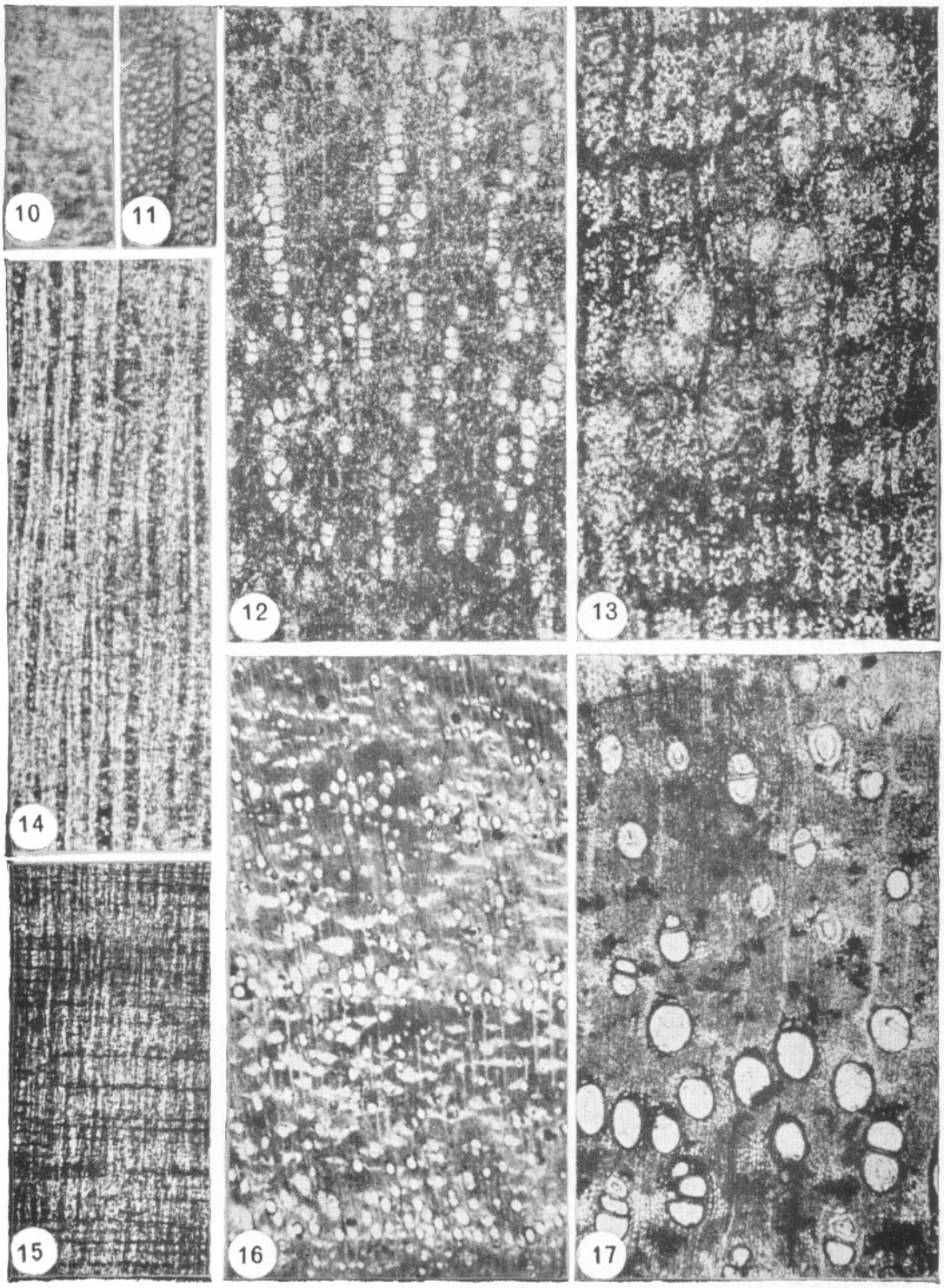

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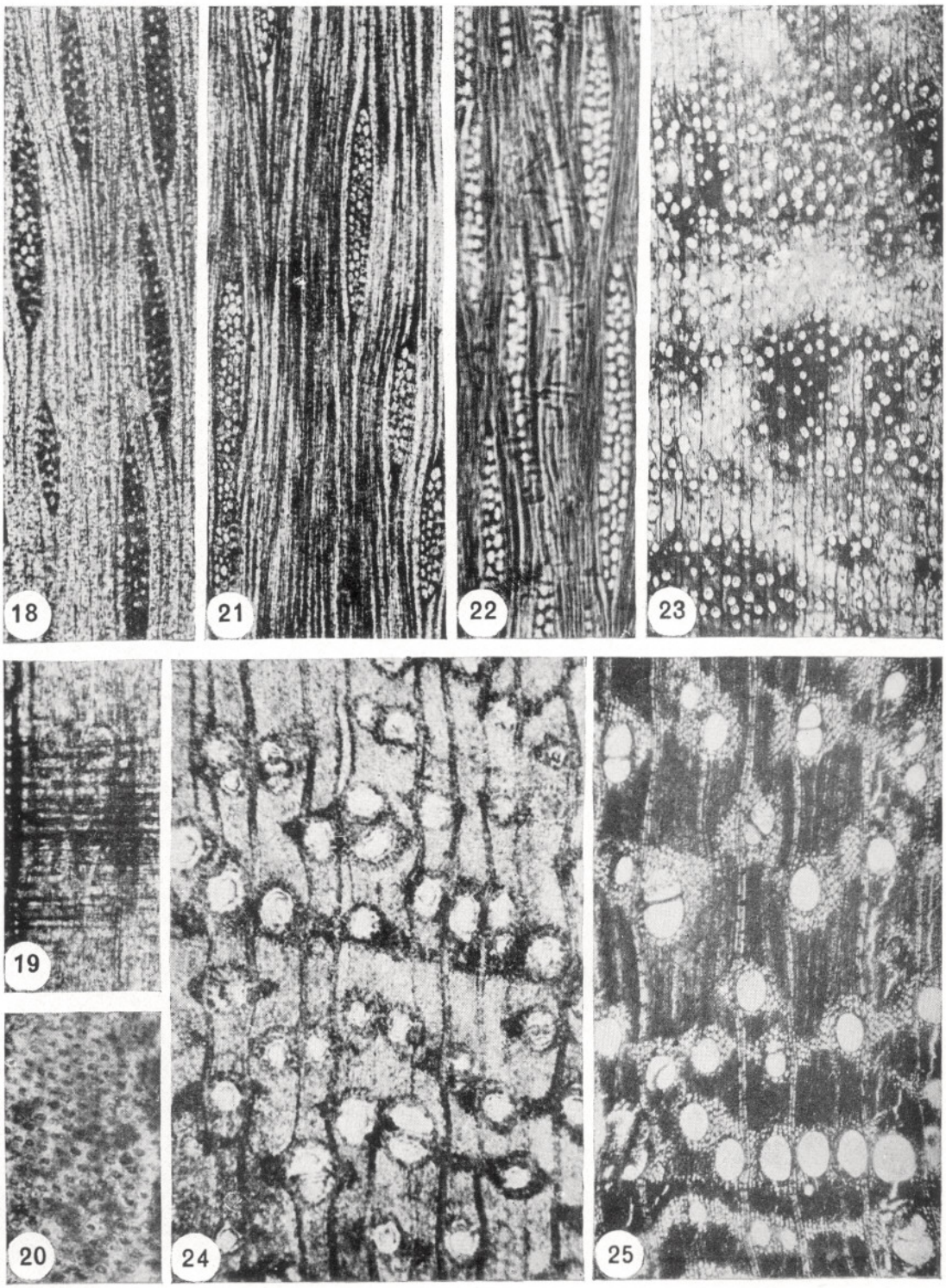

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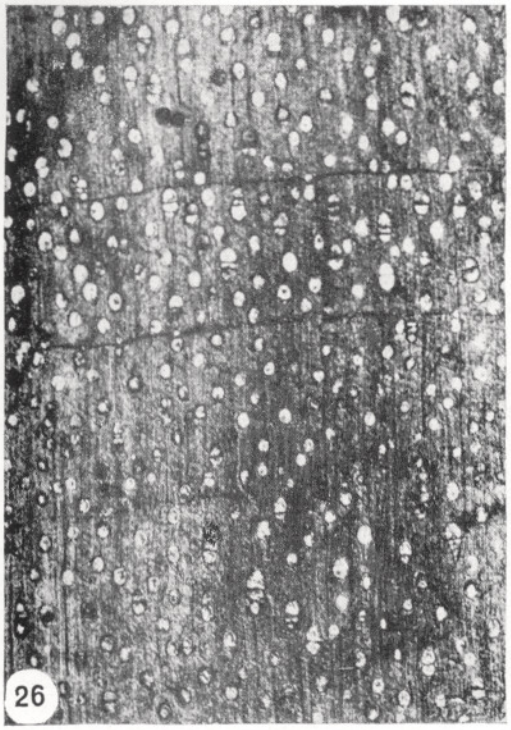

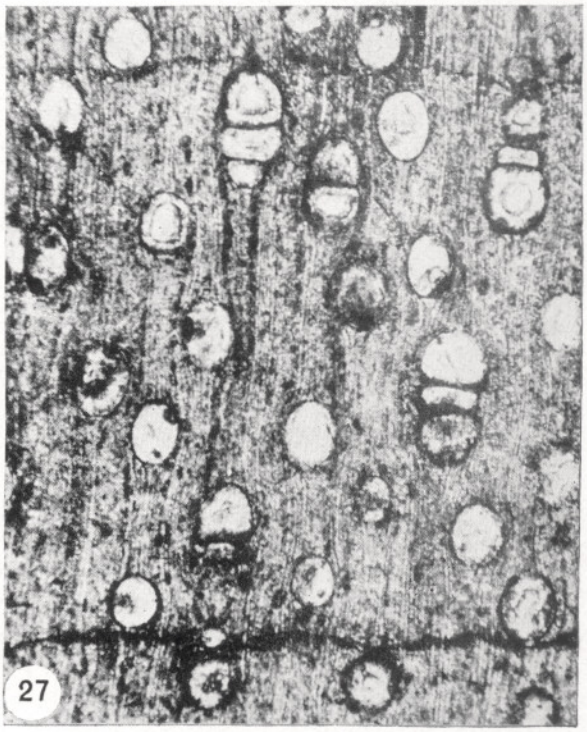

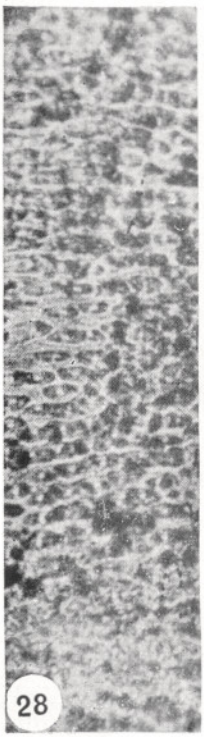

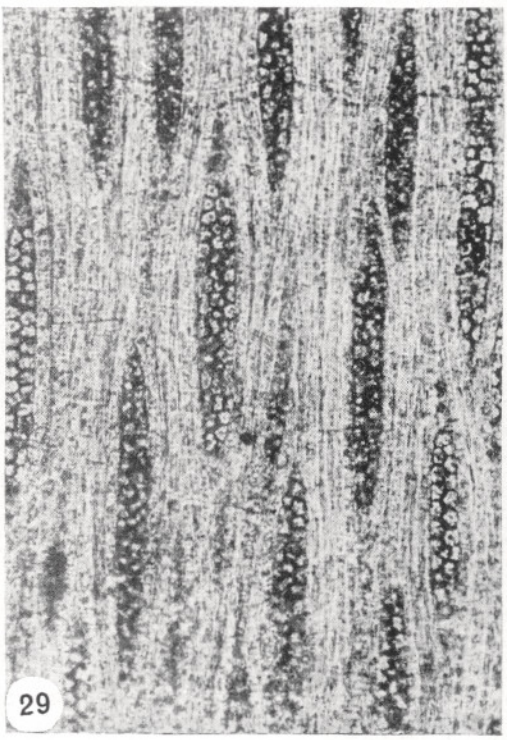

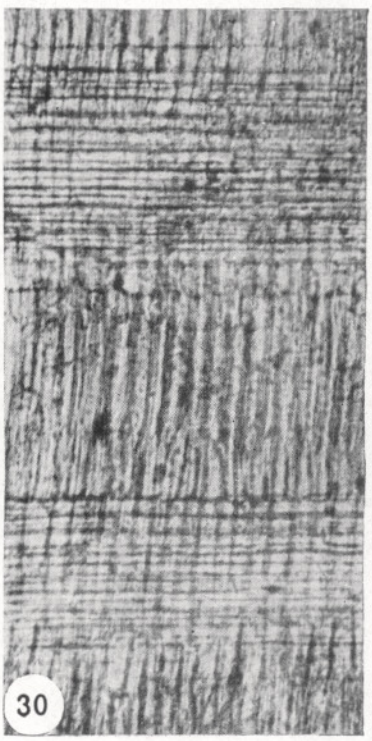

PLATE 4