

TEXT-FIGS. 2-4 — *Calophylloxylon indicum* gen. et sp. nov. — 2. Xylem rays as seen in the tangential longitudinal section; a — uniseriate homocellular, b & c — uniseriate heterocellular, d & e — biseriata heterocellular. $\times 215$. 3. Vessel-tracheid pits. $\times 350$. 4. Fibres in cross-section. $\times 350$.

FIG. 5), paratracheal, forming 1-2 cells wide sheath around the vessels. *Parenchyma* visible to the naked eye in cross-section, apotracheal, banded (PL. 1, FIG. 1; PL. 2, FIG. 5; TEXT-FIG. 1), continuous or broken into short bands (PL. 1, FIG. 1), slightly wavy, ending abruptly, interrupted by the xylem rays, irregularly spaced, mostly wide apart, 0-2 per mm.; each

parenchyma band 2-7 (mostly 3-5) cells wide. *Xylem rays* not visible to the naked eye, visible with the help of hand lens in cross-section, very fine (PL. 1, FIG. 1; PL. 2, FIG. 5), 12-28 μ wide, close (PL. 1, FIG. 1; TEXT-FIG. 1), 16-20 rays per mm., mostly uniseriate (PL. 1, FIG. 3; TEXT-FIG. 2 a-c), occasionally biseriata due to paired cells at some places in the median portion

(TEXT-FIG. 1 d & e); ray tissue heterogeneous; rays heterocellular, consisting of procumbent cells in the median portion and 1-2 marginal rows of upright cells at both the ends (PL. 1, FIG. 3; PL. 2, FIG. 6; TEXT-FIG. 2 b-e), 2-30 (sometimes up to 40) cells in height; those of 2 cells in height homocellular, composed of upright cells (TEXT-FIG. 2 a). *Fibres* aligned in radial rows between two consecutive xylem rays (TEXT-FIG. 4).

ELEMENTS: *Vessels* thin-walled, 5-6 μ in thickness, circular to oval (PL. 1, FIG. 1; PL. 2, FIG. 5), t. d. 60-210 μ , r. d. 75-255 μ ; vessel-members short to medium, 225-630 μ in length with truncate ends; perforations simple; pits leading to contiguous tracheids (vessel-tracheid pits) arranged in vertical rows (TEXT-FIG. 3), circular to oval (TEXT-FIG. 3), bordered, small, 4-6 μ in diameter, aperture minute, circular or slit-like; vessels filled with crystalliferous contents. *Tracheid* cells circular to oval or angled in cross-section, t. d. 20-32 μ , r. d. 20-24 μ , nearly as long as fibres; pits present in vertical rows of 1-2, similar to vessel-tracheid pits. *Parenchyma* cells round to oval in cross-section, t. d. 16-28 μ , r. d. 16-36 μ , 40-142 μ in length; infiltration dark; crystalliferous parenchyma strands not seen. Upright *Ray cells* 20-60 μ in tangential height, 16-32 μ in radial length; procumbent cells 16-24 μ in tangential height, 60-100 μ in radial length; infiltration dark. *Fibres* non-septate, non-gelatinous, thin to moderately thick-walled (TEXT-FIG. 4), oval to angular or hexagonal (TEXT-FIG. 4), sometimes tangentially flattened (TEXT-FIG. 4), t. d. 12-24 μ , r. d. 12-20 μ ; walls 2-4 μ in thickness; interfibre pits not seen.

DISCUSSION

Comparison with the modern woods — The fossil wood is characterized by the solitary vessels which are arranged in oblique radial lines. According to Metcalfe & Chalk (1950) this character is met with in some genera of the following families as listed below:

1. Guttiferae (Calophylloideae) — *Calophyllum* and *Mesua*.
2. Quinaceae — *Touroulia*.
3. Hypericaceae — *Psorospermum* and *Vismia*.
4. Rosaceae (Chrysobalanoideae) — almost all genera.

5. Myrtaceae — *Eucalyptus*.

6. Casuarinaceae — *Casuarina*.

7. Fagaceae — *Castanea*, *Castanopsis*, etc.

However, taking into consideration the other important anatomical features, namely (1) diffuse-porous wood, (2) paratracheal tracheids, (3) widely spaced apotracheal tangential parenchyma bands of 2-7 cells width, (4) very fine 1-2 (mostly 1) seriate heterogeneous xylem rays, (5) non-septate fibres — the fossil wood closely resembles the wood of *Calophyllum* of the family Guttiferae (BRAZIER & FRANKLIN, 1961; CHOWDHURY & GHOSH, 1958; KRIBS, 1959; LECOMTE, 1925; METCALFE & CHALK, 1950; MOLL & JANSSONIUS, 1906; PEARSON & BROWN, 1932). It also resembles *Mesua* in the above features but differs from it in having thin to moderately thick-walled fibres and widely spaced parenchyma bands, whereas in *Mesua* the fibres are highly thick-walled, so much so that the lumen is hardly visible even under high magnification; moreover, the parenchyma bands are comparatively more closely spaced.

In order to find out which of the modern species comes nearest to the fossil wood, thin sections of the woods of a number of *Calophyllum* spp., viz. *Calophyllum amoenum* Wall., *C. blancoi* Pl. & Tr., *C. brazilense* Camb., *C. costatum* F. M. Bailey, *C. inophyllum* L., *C. kunstleri* King, *C. obliquinervium* Wall., *C. polyanthum* Wall., *C. pulcherrimum* Merr., *C. (spectabile) sculattri* (Willd.) Burm. F., *C. tomentosum* Wight, *C. wallichianum* Pl. & Tr., *C. (wightianum) apetalum* (Wall.) Willd., *Calophyllum* sp. (Java), *Calophyllum* sp. (Kuala-Lumpur), *Calophyllum* sp. (Sandakan), *Calophyllum* sp. (Singapore) were examined. Besides, published descriptions and figures of *Calophyllum haskarlii* Teysm. et Binn. ex Planch. et Triana, *C. venulosum* Zoll. (MOLL & JANSSONIUS, 1906) and *C. saigonense* Pierre (LECOMTE, 1925) were also consulted. This study has revealed that the nearest approach of the fossil wood is with the wood structure of *Calophyllum wightianum* Wall. There is close resemblance in all the anatomical features between *C. wightianum* and the fossil except a little difference in the size of the vessels, which is slightly smaller in the fossil wood than in *C. wightianum* (PL. 1, FIGS. 1 & 2).

Comparison with the fossil species — So far a number of fossil guttiferous woods are known from India and abroad. From

outside India they are *Symphonioxylon stefaninii* and *S. sccc-gurensis* (CHIARUGI, 1933) from the Cretaceous of Somali, Africa; *Guttiferoxylon fareghense* and *G. symphonioides* (KRÄUSEL, 1939) from the Tertiary of Egypt; *G. platonoides* and *G. compactum* (SCHÖNFELD, 1947) from the Tertiary of Colombia, South America; *G. garcinioides* (HOFMANN, 1944) and *G. prambachense* (HOFMANN, 1952) from the Tertiary of Austria and *G. saharianum* (BOUREAU, 1952) from the Algerian Tertiary. However, none of these woods resembles the present fossil wood. From India, the known fossil woods of Guttiferae are, *Kayeoxylon assanicum* (CHOWDHURY & TANDAN, 1949) from the Tertiary of Assam; *Guttiferoxylon indicum* (RAMANUJAM, 1960) from the Tertiary of South India and *Mesuoxylon arcotense* (LAKHANPAL & AWASTHI, 1964) also from the Tertiary of South India. But the present wood belongs to *Calophyllum*, while none of the previously described Indian species shows affinities with this genus.

It is important to mention here that the occurrence of Guttiferae has been reported from many localities of the Indian Tertiary. Besides the fossil woods mentioned above, impressions of leaves of *Mesua* and *Calophyllum* and fruits comparable with those of Guttiferae in general have been described by Lakhanpal & Bose (1951); also LAKHANPAL, 1964) from the Fuller's earth bed (Eocene) at Kapurdi near Barmer in Rajasthan. Jain (1964) has described a petrified fruit, *Indocarpa intertrappea*, referred to Guttiferae, from the Deccan Intertrappean beds of Mohgaon Kalan, district Chhindwara in Madhya Pradesh.

Because of its close resemblance with the wood structure of *Calophyllum*, the fossil wood has been named *Calophylloxylon* gen. nov. Its specific name, *C. indicum* sp. nov., refers to its occurrence in the Tertiary of India.

Present Distribution of Calophyllum — This genus includes about 80 species (WILLIS, 1957) of trees widely distributed in the Tropics of both hemispheres. Most of the species occur in Tropical Asia and East Indies but none in Africa except in the Island of Madagascar (GREENE, 1932). Of nearly a dozen species indigeneous to the Indian region (India, Burma, E. Pakistan, Ceylon and the Andamans), five species are found in India proper, distributed in

eastern and southern parts of the country. In South India 4 species occur, viz., *Calophyllum inophyllum* Linn., *C. tomentosum* Wight, *C. wightianum* Wall. and *C. trapezifolium* Thw. Of these the closest to our fossil, *C. wightianum*, is found in the Western Ghats from North Kanara to Travancore, on the banks of rivers and in the evergreen forests (CHOWDHURY & GHOSH, 1958; PEARSON & BROWN, 1932).

GENERIC DIAGNOSIS

Calophylloxylon gen. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* small to large, forming vessel lines along the grain, normally solitary, characteristically arranged in oblique radial lines, circular to oval in cross-section, vessel-members small to large; perforations simple; pits leading to contiguous tracheids small, bordered with minute, circular or slit-like aperture; usually tylosed. *Tracheids* paratracheal. *Parenchyma* apotracheal, in concentric tangential bands, continuous or broken, often widely spaced. *Xylem rays* fine, 1-2 seriate, ray tissue heterogeneous. *Fibres* non-septate, thin to thick-walled.

Genotype — *Calophylloxylon indicum* sp. nov.

SPECIFIC DIAGNOSIS

Calophylloxylon indicum sp. nov.

Wood diffuse-porous. *Growth rings* absent. *Vessels* medium to large (mostly medium) in size, exclusively solitary, arranged in oblique radial lines, circular to oval in cross-section, t. d. 60-210 μ , r. d. 75-225 μ ; vessel-members 250-630 μ in length with truncate ends; perforations simple; pits leading to contiguous tracheids small, 4-6 μ in diameter, bordered with minute, circular to slit-like aperture; tyloses thin walled. *Tracheids* paratracheal, 1-3 (mostly 1-2) cells wide sheath around the vessels, pits similar to vessel-tracheid pits. *Parenchyma* apotracheal, tangential bands of 2-7 (mostly 3-5) cells wide, usually widely spaced, bands continuous as well as short, broken, slightly wavy, ending abruptly, 0-2 bands per mm. *Xylem rays* very fine, 12-26 μ wide, close, 16-20 rays per mm., uniseriate, occasionally biseriate due to

paired cells in the median portion; ray tissue heterogeneous; rays heterocellular, consisting of mostly 1-2 marginal rows of upright cells and procumbent cells in the median portion; 2-30 (sometimes up to 40) cells in height. *Fibres* aligned in radial rows, oval or polygonal (mostly hexagonal), somewhat tangentially flattened at some places, non-septate, thin to moderately thick-walled, walls 2-4 μ in thickness.

Holotype — B.S.I.P. Museum No. 33072.

Locality — Between Murattandichavadi, Tiruchitambalam (Thiruchitrabalam) and Pattanur, about 10 kilometers W.N.W. of Pondicherry, South Arcot district, Madras.

Horizon — Cuddalore Series.

Age — Middle Tertiary.

II. *Calophylloxyton cuddaloreense* sp. nov.

Pls. 2-3, Figs. 7-14; Text-figs. 5-8

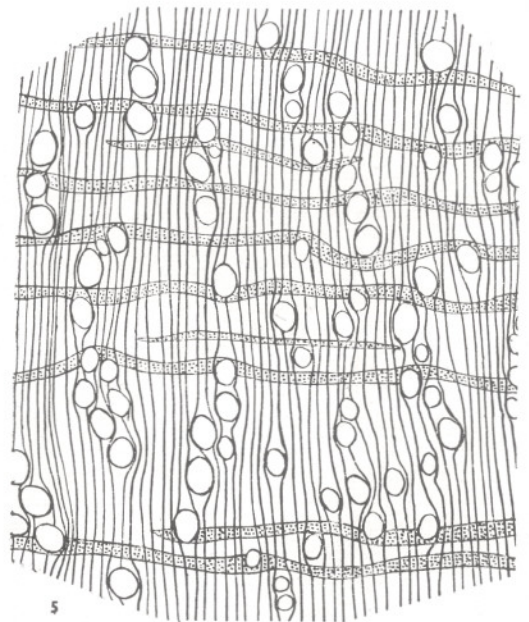
DESCRIPTION

The present species is based on a big piece of silicified secondary wood measuring about 80 cm. in length and 20 cm. in diameter. The colour of the cut surface is dirty white and at some places blotched with orange patches. The preservation is fairly good.

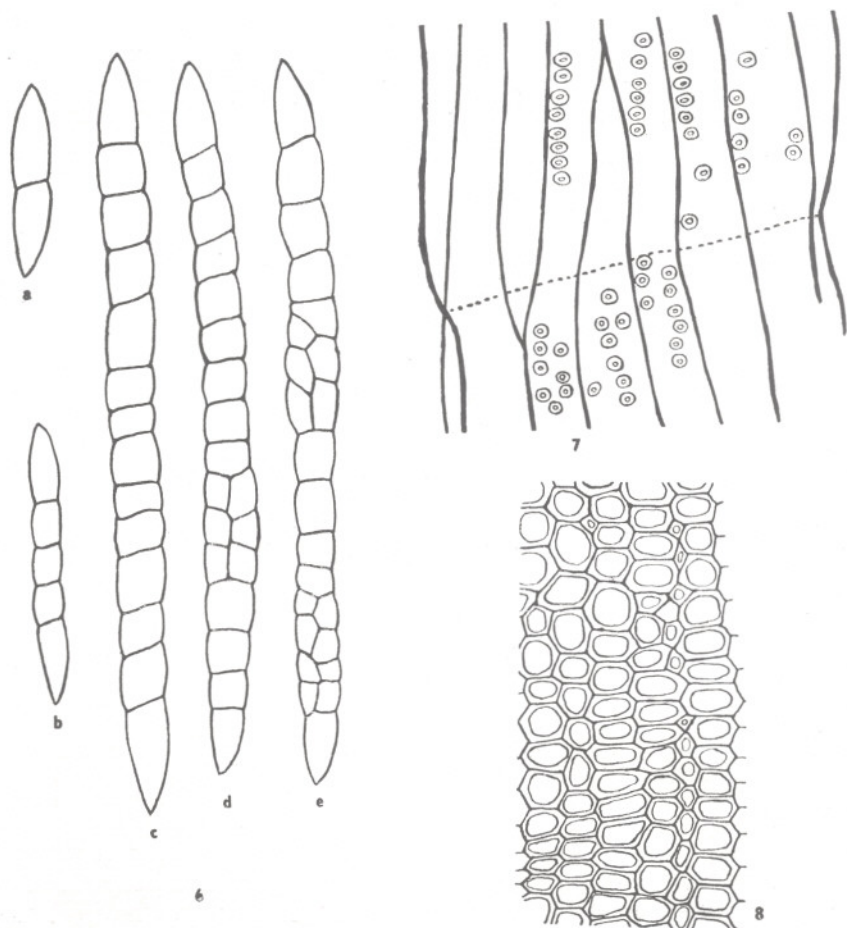
TOPOGRAPHY: Wood diffuse-porous (PL. 3, FIG. 10). *Growth rings* not seen. *Vessels* clearly visible to the naked eye, usually moderately large to extremely large, sometimes a few also small to medium, forming prominent vessel lines along the grains, almost exclusively solitary (PL. 2, FIG. 7; PL. 3, FIG. 10; TEXT-FIG. 5), arranged in oblique radial lines, and in groups (PL. 2, FIG. 7; PL. 3, FIG. 10), 2-5 vessels per sq. mm.; tyloses present, thin-walled (PL. 3, FIG. 10). *Tracheids* paratracheal, forming 1-3 (mostly 2-3) cells wide sheath around the vessels, sometimes occurring abundantly within the vessel groups forming an extensive tract (PL. 2, FIG. 7; PL. 3, FIG. 10). *Parenchyma* visible to the naked eye, apotracheal (PL. 3, FIG. 10), in concentric tangential bands of 2-9 (mostly 2-5) cells wide, bands continuous (PL. 3, FIG. 10; TEXT-FIG. 5) and also broken into short bands (TEXT-FIG. 5), slightly wavy, ending abruptly, interrupted by xylem rays. 1-4 bands per mm. *Xylem rays* not visible to the naked eye, visible in cross-section with

the hand lens, very fine (PL. 2, FIG. 7; PL. 3, FIG. 10), 10-32 μ wide, closely spaced, 12-20 rays per mm., uniseriate (PL. 3, FIG. 13; TEXT-FIG. 6 a-c), occasionally biseriate due to paired cells in the median portion (PL. 3, FIG. 13; TEXT-FIG. 6 d, e); ray tissue heterogeneous; rays heterocellular, consisting of mostly 1-2 marginal rows of upright cells and procumbent cells in the median portion (PL. 2, FIG. 8; TEXT-FIG. 6 b-e), 2-30 cells and 105-675 μ in height, those 2 cells in height homocellular, composed of upright cells (TEXT-FIG. 6 a). *Fibres* aligned in radial rows between two consecutive rays (TEXT-FIG. 8).

ELEMENTS: *Vessels* thin-walled, walls 4-6 μ in thickness, circular to oval in cross-section (PL. 2, FIG. 7; PL. 3, FIG. 9); maximum t. d. of large vessels 330 μ , r. d. 435 μ ; minimum t. d. of small vessels 60 μ , r. d. 75 μ ; vessel-members 225-660 μ in length with truncate ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows (TEXT-FIG. 7), 6 μ in diameter, bordered, circular to oval, (TEXT-FIG. 7) with small, circular to slit-like apertures; vessels filled with crystalliferous contents. *Tracheid* cells circular to oval in cross-section, 16-28 μ in diameter,



TEXT-FIG. 5 — *Calophylloxyton cuddaloreense* sp. nov. Cross-section showing vessels, parenchyma and rays. $\times 14$.



TEXT-FIGS. 6-8 — *Calophylloxyton cuddalorensis* sp. nov. — 6. Xylem rays as seen in the tangential longitudinal section; a — uniseriate homocellular, b & c — uniseriate heterocellular, d & e — biseriate heterocellular. $\times 215$. 7. Vessel-tracheid pits. $\times 350$. 8. Fibres in cross-section. $\times 350$.

nearly as long as fibres; walls thin, about 2μ in thickness; pits similar to vessel-tracheid pits. *Parenchyma cells* round to oval in cross-section, t. d. $16-26 \mu$, r. d. $16-32 \mu$; infiltration dark (PL. 3, FIG. 10); crystalliferous parenchyma strands not seen. Procumbent *Ray cells* circular to oval in tangential section (PL. 3, FIG. 13; TEXT-FIG. 6), $12-24 \mu$ in tangential height, $40-84 \mu$ in radial length; upright cells $40-60 \mu$ in tangential height, $20-32 \mu$ in radial length; infiltration dark. *Fibres* oval to polygonal (hexagonal), somewhat tangentially flattened (TEXT-FIG. 8), t. d. $8-24 \mu$, r. d. $8-20 \mu$, nonseptate, thin to moderately thick-walled (TEXT-FIG. 8), walls $2-3 \mu$ in thickness; pits not seen.

DISCUSSION

The fossil wood shows the following important anatomical features that are of diagnostic value: (1) Wood diffuse-porous; (2) Vessels large, exclusively solitary, arranged in oblique radial lines; (3) Tracheids paratracheal; (4) Parenchyma apotracheal, bands of 2-9 cells width; (5) Xylem rays 1-2 (mostly 1) seriate, heterogeneous; (6) Fibres nonseptate.

A combination of all these features is met with in the genus *Calophyllum* L. as discussed earlier in the preceding pages. Hence the present wood has also been placed under the genus *Calophylloxyton*.

Of the woods of modern species of *Calophyllum* studied (see preceding pages) the present fossil closely resembles *Calophyllum inophyllum* and *C. tomentosum*. In the shape, size and arrangement of vessels it resembles *C. tomentosum* (PL. 3, FIG. 12) while in the number of parenchyma bands and their distribution it matches *C. inophyllum* (PL. 3, FIG. 11). Other characters are nearly common in both the species. Thus in some features it resembles *C. tomentosum* while in others *C. inophyllum*.

The only known fossil wood of the modern genus *Calophyllum* is *Calophylloxylon indicum* gen. et sp. nov., described in the preceding pages. The present wood differs from it in having usually large to very large vessels which show a tendency to be arranged in groups, though generally they are orientated in oblique radial lines. Moreover, the parenchyma bands are comparatively more closely placed in the present wood than in *C. indicum*.

From these differences it is quite evident that the present wood is distinct from *C. indicum*; and hence it has been assigned to a different species, *Calophylloxylon cuddaloreense*, named after the Cuddalore Series.

The modern species *Calophyllum tomentosum* is a large tree found in South India where it is common on the Mulamune Ghats in South Kanara and in the ever-green forests of the Western Ghat from North Kanara to Travancore. It is common in the forests near Gairroppa falls, associated with *Eugenia* (now *Syzygium*) *kanarensis* and Dipterocarps and also in Tillichery Ghats (PEARSON & BROWN, 1932). The other species, *C. inophyllum*, is a moderate sized tree found along the coast above high water marks and in mangrove forests of Burma, down the Western coast of India from Konkan southwards, and along the Orissa coast. It is also common in Tenasserim and in the Andamans (PEARSON & BROWN, 1932).

SPECIFIC DIAGNOSIS

Calophylloxylon cuddaloreense sp. nov.

Wood diffuse-porous. Growth rings absent. Vessels usually moderately large,

sometimes small to medium, forming prominent vessel lines along the grains, almost exclusively solitary, arranged in oblique radial lines and in groups, circular to oval in cross-section, maximum t. d. of large vessels 330 μ , r. d. 435 μ ; minimum t. d. of small vessels 60 μ , r. d. 75 μ ; vessel-members truncate, 225-660 μ in length; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, small, 4-6 μ in diameter, circular to oval, bordered, with small, circular or slit-like aperture; tyloses thin-walled. Tracheids paratracheal, forming 1-3 (mostly 2-3) cells wide sheath around the vessels, sometimes occurring abundantly within the vessel groups; cells circular to oval, 16-28 μ in diameter; pits similar to vessel-tracheid pits. Parenchyma apotracheal, in concentric tangential bands of 2-9 (mostly 2-5) cells width, bands continuous and also broken into short ones, slightly wavy, 1-3 bands per mm. Xylem rays very fine, 10-32 μ wide, close, 12-20 rays per mm., uniseriate, occasionally biseriate at some places in the median portion; ray tissue heterogeneous; rays heterocellular, consisting of procumbent cells in the median portion and 1-2 marginal rows of upright cells, 3-30 cells and 105-675 μ in height. Fibres aligned in radial rows, oval or polygonal (mostly hexagonal), somewhat tangentially flattened at some places, non-septate, thin to moderately thick-walled, walls 2-3 μ in thickness.

Holotype — B. S. I. P. Museum No. 33073.

Locality — Between Murattandichavadi and Kasippalayam, about 10 kilometers W. N. W. of Pondicherry, South Arcot District, Madras.

Horizon — Cuddalore Series.

Age — Middle Tertiary.

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EXPLANATION OF PLATES

PLATE 1

Calophylloxyton indicum gen. et sp. nov.

1. Cross-section of the fossil wood showing type and distribution of vessels, parenchyma and rays. $\times 15$.

2. Cross-section of *Calophyllum wightianum* showing similar type and distribution of vessels, parenchyma and rays. $\times 15$.

3. Tangential section of the fossil wood showing rays. $\times 125$.

4. Tangential section of *Calophyllum wightianum* showing similar type of rays. $\times 125$.

PLATE 2

Calophylloxyton indicum gen. et. sp. nov.

5. Cross-section of the fossil magnified to show apotracheal parenchyma band and paratracheal tracheids. $\times 70$.

6. Radial section of the fossil showing heterocellular rays. $\times 125$.

Calophylloxyton cuddaloreense sp. nov.

7. Cross-section of the fossil magnified to show the vessels in group and paratracheal tracheids. $\times 70$.

8. Radial section of the fossil showing heterocellular rays. $\times 125$.

9. Cross-section of the fossil wood showing fibres with wide lumina. $\times 550$.

PLATE 3

Calophylloxyton cuddaloreense sp. nov.

10. Cross-section of the fossil showing type and distribution of vessels, parenchyma and rays. $\times 15$.

11. Cross-section of *Calophyllum inophyllum* showing similar type and distribution of vessels, parenchyma and rays. $\times 14$.

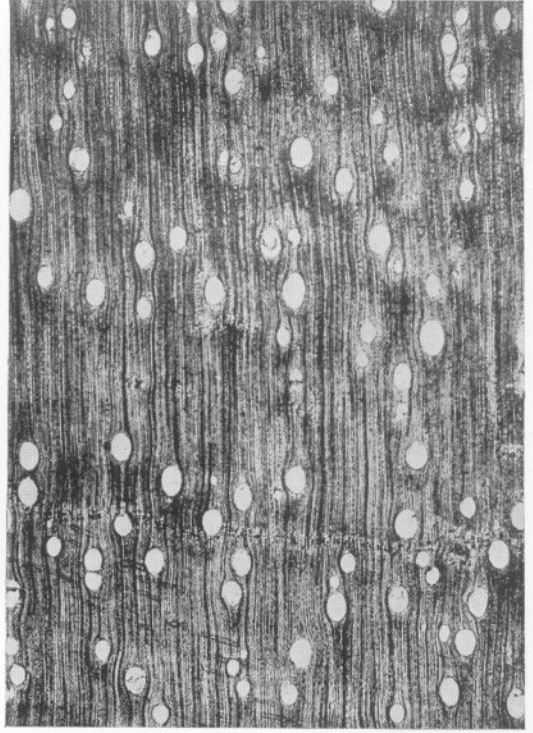
12. Cross-section of *Calophyllum tomentosum* showing the vessels similar to the fossil in size and arrangement. $\times 15$.

13. Tangential section of the fossil showing rays. $\times 125$.

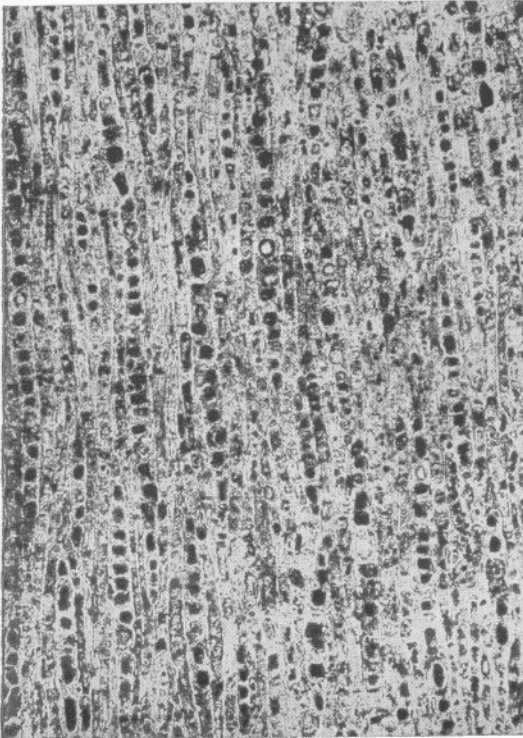
14. Tangential section of *Calophyllum inophyllum* showing similar rays. $\times 125$.



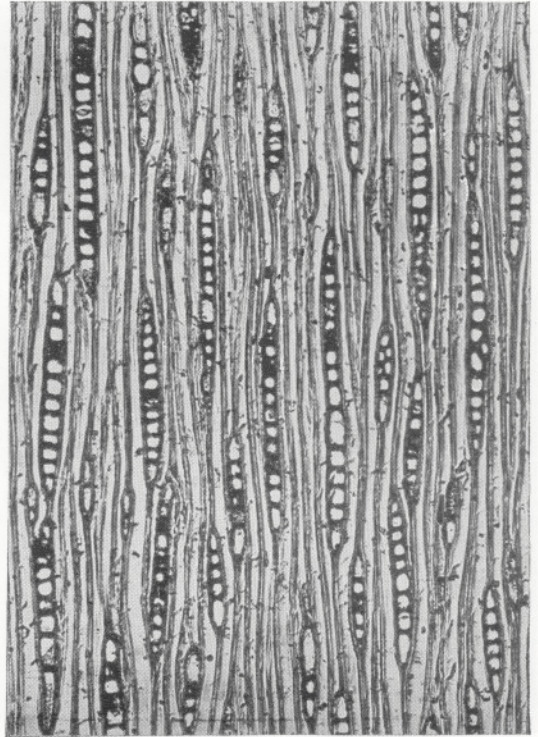
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2



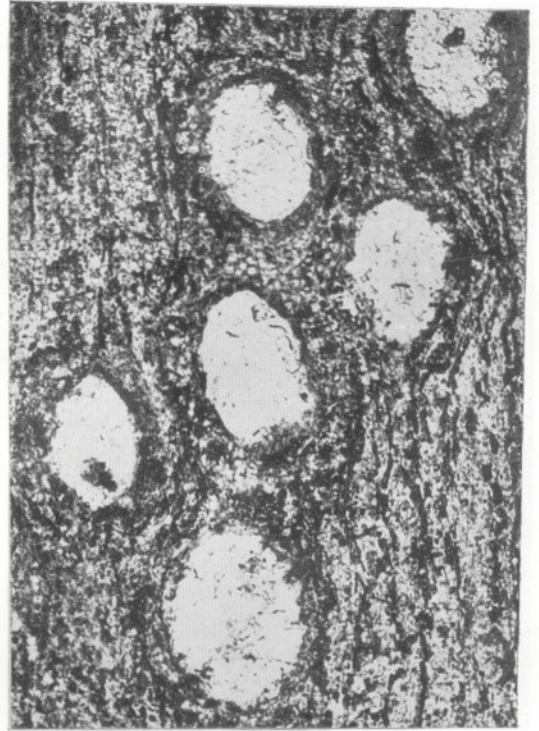
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4



5



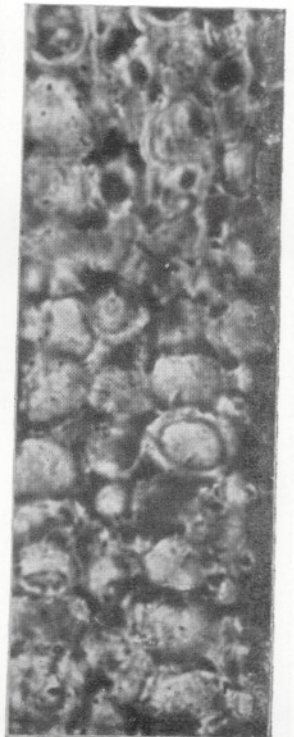
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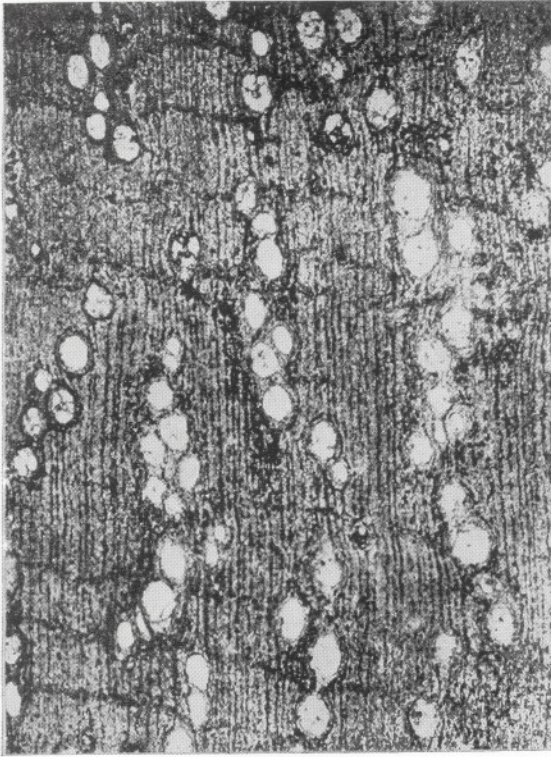
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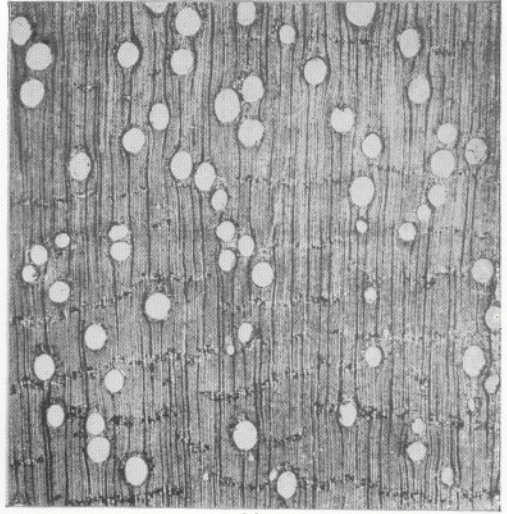
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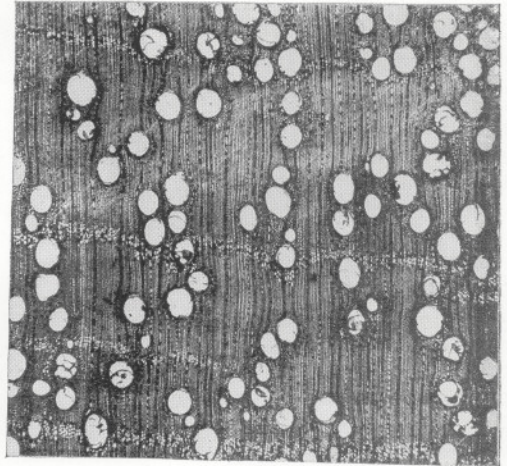
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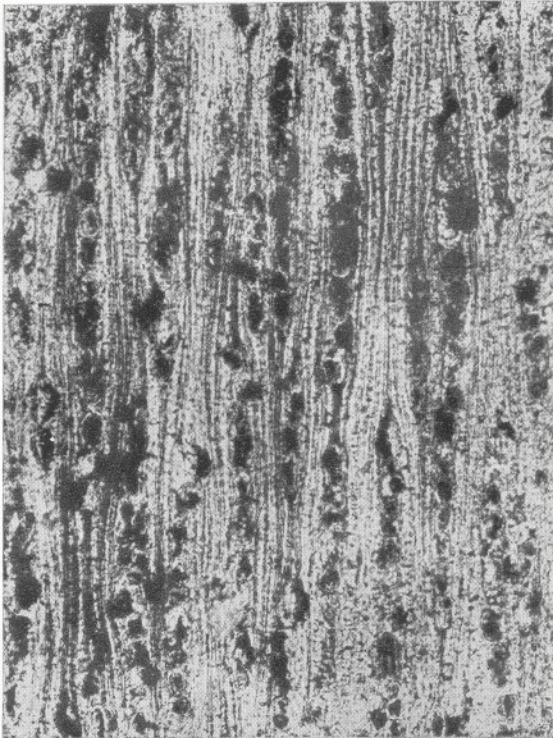
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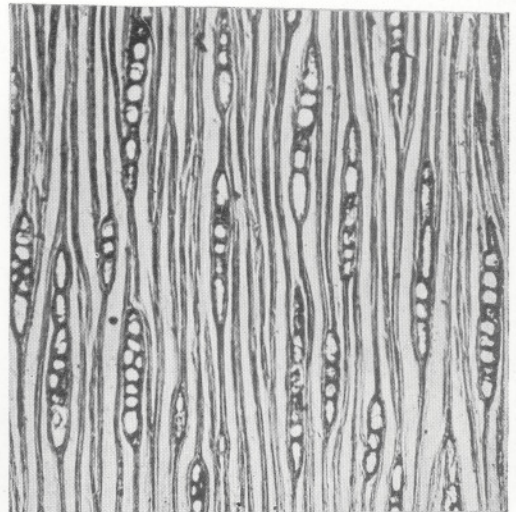
11



12



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14