ON A NEW PETRIFIED PALM WOOD FROM MOHGAON KALAN AREA

VIMALA K. MENON (Miss)*
Department of Botany, University of Lucknow

ABSTRACT

A petrified palm stem M 115 with roots attached to has been described in detail. A comparison is made with *Palmoxylon sclerodermum* Sahni, *P. surangei* Lakhanpal and *P. kraeuselii* Rao & Menon, all with attached roots. The stem and root structure vary in all these and M 115 cannot be definitely referred to any of these species. The structure and organization of the fibrovascular bundles and ground tissue in M 115 however, is very similar to those of a petrified palm petiole, *Palmocaulon raoi* Menon, also from Mohgaon Kalan area. Because of its close resemblance with *Palmocaulon raoi*, M 115 is designated *Palmoxylon raoi*. It is not unlikely that the two represent the petiole and the stem of the same species of a fossil palm.

INTRODUCTION

THE specimen described in this paper, M 115 is a fragment of petrified palm wood collected from Mohgaon Kalan area of the Deccan Intertrappean series. M 115 is a small portion of a stem, dark brown in colour, about 3 cm. long and 5·5 cm. broad, with a root zone attached to it (PL. 1, FIG. 1). Transverse sections show that the stem part is smaller than the root part and is made up of cortical, dermal and sub-dermal zones (PL. 1, FIG. 1) as in the other palm woods. The central zone is not preserved in this fossil stem. The root region possesses smaller as well as medium sized roots which are crowded together and cut in different planes. There are no leaf-traces found in the specimen.

The detailed anatomical structures of the wood are not clear as such, due to the extreme silicification of the tissues. It has, however, been possible to show up the structures clearly by staining the sections in aqueous safranin or gentian violet. Safranin proved most useful in this case. The lignified tissues took up the stain very nicely. The parenchyma parts of the roots are slightly stained, so that it is very easy to distinguish the tissues from each other.

ANATOMY OF THE ROOT

Cross-section of the wood show a root region about 3·7 cm. broad, compactly packed with 1 to 2 mm. thick roots usually deformed and pressed in various forms by crowding although some of them do retain their circular form (PL. 1, FIG. 1).

Epidermis — The outer most layer is not at all satisfactorily preserved.

Hypodermis — Below the epidermis can be seen a composite layer which evidenty is the hypodermis (TEXT-FIG. 1; PL. 1, FIG. 2). It consists of only two zones, the outler one of two or three layers of thin-walled parenchymatous cells without any cell contents and the inner one of two or three layers of thick walled cells. According to Mahabale and Udwadia (1960) the hypodermis consists of three zones, the outer one filled with a dark substance the tannin, the middle one with thin walled cells and the inner one having thick lignified cells with no cell contents. They point out that *Nypa fructicans* is an exception to this, in which the outer zone is parenchymatous without any cell contents or tannin. The hypodermis in the fossil described here is two zoned and looks in transverse section just like that of *Nypa fruticans* figured by Mahabale and Udwadia (1960).

Cortex — Below the hypodermis lies the cortex having three parts, the outer, middle and inner which can be very easily recognized (PL. 1, FIG. 2). The outer cortex consists of one or two layers of thin walled parenchymatous cells (TEXT-FIG. 2; PL. 1 FIG. 2). The lacunar middle cortex shows spaces which are separated from each other by irregular vertical diaphragms of short, thin walled parenchymatous cells. The air spaces are in a single radiating series separated from each other by thin, radially extended diaphragm, as in many palms of

*Present address: Centre of Advanced Study in Botany, University of Madras, Madras.

swampy situations, e.g. *Raphia* and *Nypa* (TOMLINSON, 1961). The parenchyma cells in the diaphragms are also radially arranged and are mostly one celled in thickness, some times 2 or 3 celled also (TEXT-FIG. 2; PL. 1, FIG. 2). The middle cortex is about 0·47-0·61 mm. thick and consists of some scattered cells with black contents of indeterminable nature (TEXT-FIG. 2; PL. 1, FIG. 2). The inner cortex is made up of 1-3 layers of parenchymatous cells. They lie outside the endodermis.

Endodermis — Next to the cortical region on the inner side, is a layer of rectangular cells with thick lateral and inner walls, constituting the endodermis (TEXT-FIG. 3; PL. 2, FIG. 3). The pericycle is single layered (TEXT-FIG.3; PL. 2 FIG. 3).

Stele — There are 8 to 12 exarch xylem bundles present in the root. In each bundle two or three xylem elements are placed end to end or in a V-shaped manner (TEXT-FIG. 2; PL. 2, FIG. 3). The disorganized phloem patches are seen in between the xylem bundles. The metaxylem elements are surrounded on their inner and lateral sides by thick walled cells of the conjunctive parenchyma. In the parenchymatous pith region of some roots there are one or two xylem elements, each surrounded by thick walled cells (PL. 2, FIG. 3). They may be the medullary bundles as reported by Mahabale and Udwadia (1960) in certain palm roots.

In the smaller roots the middle cortex is not lacunar so that the cells of the three zones of the cortex are rectangular and are compactly arranged (PL. 2, FIG. 4). In slightly older roots the parenchymatous cells of the cortex are larger and become lacunar. In still older roots the air-spaces are fully formed (PL. 1, FIG. 2). In all roots scattered cells with black contents are seen in the cortex (TEXT-FIG. 2; PL. 1, FIG. 2).

Figure 5 on plate 2 shows a big root, in the cortex of which is seen a smaller well preserved root with a thin, undifferentiated cortex (PL. 2, FIG. 6). It is difficult to say whether this is a case of an old root dividing, or a stage in the production of branched lateral roots as quoted by Tomlinson (1961, p. 47).

ANATOMY OF THE STEM

The stem region consists of cortical, dermal and sub-dermal zones (PL. 1, FIG. 1). The epidermal layer of the stem is not clear.

Cortical zone— It is about 1 cm. broad and made up of fibrovascular bundles and roots (PL. 1, FIG. 1), which are no doubt endogenous as in all palms. Their horizontal passage to the cortex can be seen in Figure 1 (PL. 1). The irregularly distributed fibrovascular bundles of the cortex consist of both dorsal and ventral sclerenchymatous sheaths (TEXT-FIG 4). They are more or less equally developed and are separated by the ground tissue. Sometimes both the sclerenchyma are joined together forming a complete sheath (TEXT-FIG. 5). Some bundles are placed very closely showing a tendency for lateral fusion (TEXT-FIG- 6). The presence of the roots in between the fibrovascular bundles does not permit a correct count of the frequency of the bundles in the cortex. The F/v ratio of the bundles is 0·47/1-0.9/1 and their diameter is 0·18-0·63 mm. Although the phloem is not preserved, its position is seen on the dorsal side of the bundle. The ventrally placed xylem elements vary in number from bundles to bundle and are arranged more or less in a

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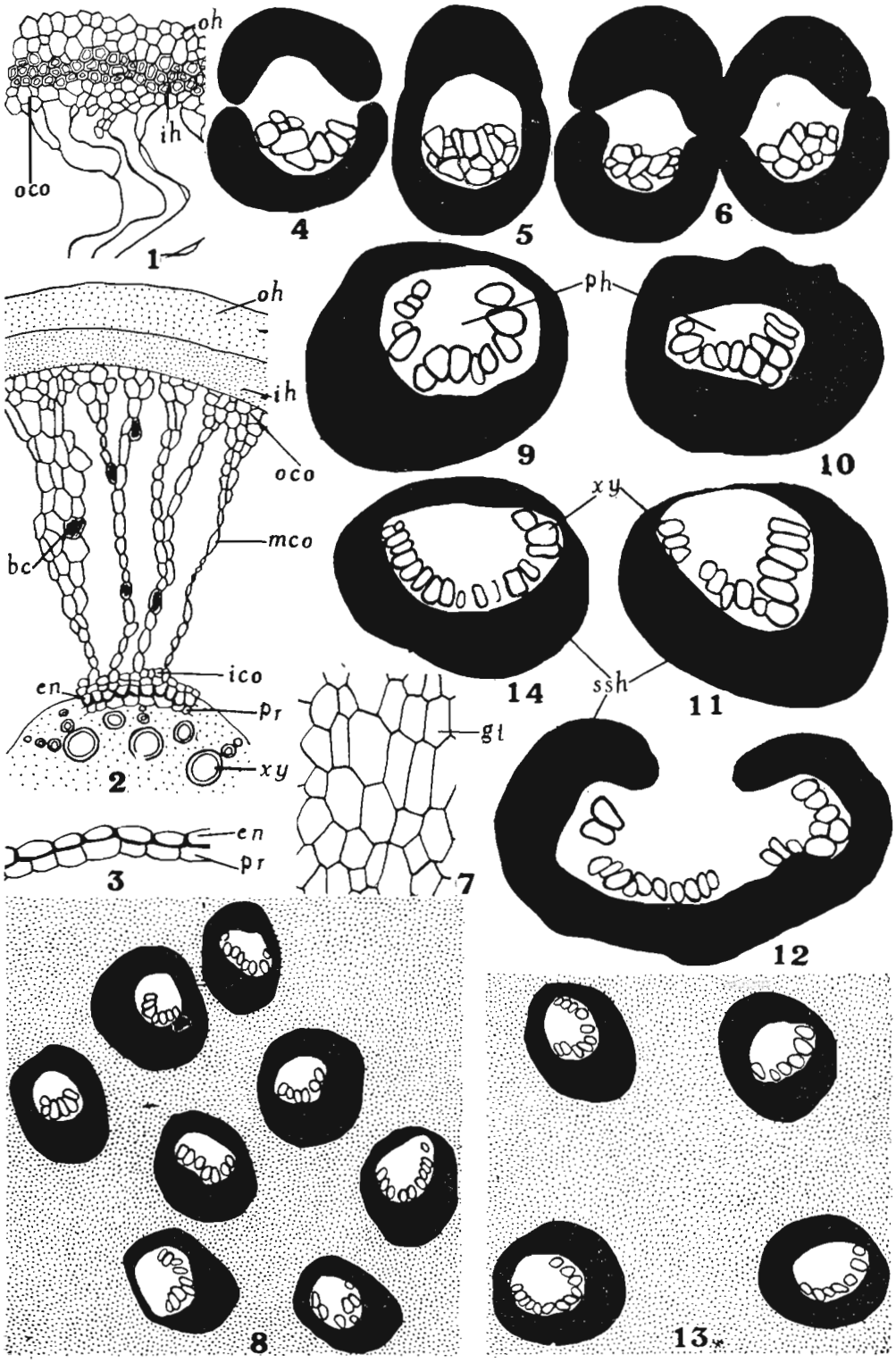
TEXT-FIGS. 1-14 — 1. A portion of the root in transverse section showing the outer and inner hypodermis. × 75. 2. Transverse section of a portion of the root showing the detailed structure. × 75. 3. A portion of the endodermis and pericycle enlarged. × 365. 4. One fibrovascular bundle from the cortex enlarged showing the two sclerenchyma sheath and the xylem elements. × 75. 5. One fibrovascular bundle from the cortex having a complete sclerenchyma sheath surrounding a group of xylem elements. × 75. 6. Fibrovascular bundles from the cortex showing lateral fusion. × 75. 7. A portion of the ground tissue from the cortex in transverse section. × 75. 8. The distribution of the fibrovascular bundles in the dermal zone. × 37·5. 9-11. Fibrovascular bundles from the dermal zone showing the complete sclerenchyma sheath and xylem elements. ×75. 12. One fused bundle from the dermal zone with the broken sclerenchyma at one side. × 75. 13. Distribution of fibrovascular bundles in subdermal zone. × 37·5. 14. One fibrovascular bundle from the sub-dermal zone enlarged. × 75. (*bc* = black content; *en* = endodermis; *gt* = ground tissue; *ico* = inner cortex; *ih* = inner hypodermis; *mco* = middle cortex; *oco* = outer cortex; *oh* = outer hypodermis; *ph* = phloem; *pr* = pericycle; *ssh* = sclerenchyma sheath; *xy* = xylem).



TEXT-FIGS. 1-14

crescentic manner (TEXT-FIG. 4) or sometimes in a compact group (TEXT-FIG. 5). The ground parenchyma is not fully preserved but at places can be seen to be composed of rectangular or slightly elongated cells (TEXT-FIG. 7).

Dermal zone — It is 0·8 cm. broad. There is a distinct layer separating the dermal zone from the cortical zone (PL. 1; FIG. 1). The cells of this, however, are not clear under the microscope. In fact a similar layer separates the cortical zone from the root region (PL. 1, FIG. 1). The distribution of the fibrovascular bundles is regular and closely packed (TEXT-FIG. 8) and their frequency is 120 to 130 per cm^2. They are rounded to oval in shape (TEXT-FIG. 9; PL. 2, FIG. 7). A fibrovascular bundle of this zone consists of xylem, phloem and a sclerenchymatous sheath completely surrounding the vascular elements (TEXT-FIG. 9). The sheath is narrow on the dorsal side and broad on the ventral side. The F/v ratio of the bundles is 0·37/1-1·1/1 and their diameter is 0·35-0·73 mm. In a few bundles the sclerenchymatous sheath is more or less uniform on all sides (TEXT-FIG. 10). But in some other bundles the dorsal sheath is either very thin or sometimes absent (TEXT-FIG. 11). Unlike those of the cortical bundles, the bundle sheaths here are always united together and are never separated by the ground parenchyma. The vascular tissues, however, are similar to those of the cortical bundles. No parenchyma is clear on the ventral side of the bundles or in between the xylem elements. Smaller bundles are seen scattered here and there in between the bigger ones. Bigger bundles with smaller bundles attached on their dorsal side are found in this zone (PL. 2, FIG. 8). There are some bundles which are unusually broad with sclerenchyma all round except on one side and xylem vessels also in two different arcs. These may be fused bundles which have been laterally compressed during preservation with the sclerenchyma broken on one side (TEXT-FIG. 12). The outer-most cells of the sheath — probably stegmata — contain some black deposit. The ground tissue cells surrounding the fibrovascular bundles look like radiating parenchyma. There is no tabular parenchyma around the fibrovascular bundles. Fibrous bundles are also completely absent. The grouned tissue is not nicely preserved. But at places it appears to be compact, thin walled, parenchymatous, with mostly angular cells.

Sub-dermal zone — It measures about 1·5 cm. in breadth. The fibrovascular bundles are distributed widely and are more or less irregular in orientation (TEXT-FIG. 13). The bundles of this zone are mostly oblique and badly preserved. So the structural details could not be studied thoroughly. But from some of the better preserved bundles it could be made out that the organization, size and shape of the vascular bundles are of the same type as that of the dermal bundles (TEXT-FIG. 14). Their frequency is 44 to 55 per cm.^{2}, F/v ratio is 0·56/1-0·9/1 and diameter is 0·26-0·67 mm. The ground tissue also is similar to that of the dermal zone.

Longitudinal sections of the specimen show scalariform pitting of the xylem elements and also the annular and helical (PL. 2, FIG. 9) thickenings exactly like those figured and described by Esau (1962, p. 227-228).

DISCUSSION

A careful study of the specimen, M 115, shows that a comparison with other species of *Palmoxylon* known from India (RAO & MENON, 1963) is not possible on the basis of the frequency, F/v ratio, diameter and disposition of the sclerenchyma, of the fibrovascular bundles. The species of *Palmoxylon* with which it can bear a slight comparison because of the association of roots are *Palmoxylon sclerodermum* (SAHNI 1943, 1964; SHUKLA, 1946), *P. surangei*, (LAKHANPAL, 1955) and *P. kraeuselii* (RAO & MENON, 1965) (TABLE 1). Out of this a closer comparison is only possible with *P. sclerodermum*. One specimen of *P. sclerodermum* described by Sahni (1943) did not bear roots. Another specimen of the same species described by Shukla (1946) showed some roots attached to the stem as in my specimen. Roots of *P. sclerodermum* are big and have (i) an outer cortex made up of fibres, (ii) a compact peripheral portion of the inner cortex with scattered cells containing black contents of indeterminable nature, (iii) a lacunar middle cortex, (iv) the inner layer of the cortex which is a single layered endodermis, (v) a pericycle of one or two layers, (vi) 24 xylem arcs with phloem paches in between them, and lastly,

(vii) the sclerenchymatous pith. But in my specimen the roots are smaller and have their hypodermis divisible into an outer thin walled zone and an inner thick walled zone. The cortex is also divisible into three zones, the outer 2-3 cells deep, the middle lacunar and the inner 1-4 cells deep. The cells in all these three zones are thin walled. Some black contents are seen in a few scattered cells of the diaphragm of the middle cortex in my specimen. These are exactly like those found in the periphery of the middle cortex of *P. sclerodermum*. Further, the cells of the endodermis are thickened on their inner and lateral walls. The pericycle is single layered and the xylem arcs number 8-12 only. In addition to this, the stem structure, the frequency, distribution and nature of the fibrovascular bundles therein, the disposition of sclerenchyma, all these differ in the two cases (TABLE 1). The complete sclerenchymatous sheath surrounding the vascular bundles of the stem in M 115, is another special feature that distinguishes it from all the other petrified palm stems from India.

P. surangei Lakhanpal (1955) and also *P. kraeuselii* Rao & Menon, both with attached roots from the same locality, show a three zoned cortex as in M 115. In all other respects they differ from M 115 (*see* TABLE 1).

The roots of *Cyclanthodendron sahnii* (SAHNI & SURANGE, 1944, 1953; RAMANUJAM, 1959) are very similar to those of M 115 but the structure of the stem and its vascular bundles are different. Further my specimen shows all palm characters and is evidently a palm, while *C. sahnii* is referred to the *Cyclanthaceae*, and even this appears doubtful. In view of this a comparison with *C. sahnii* is not tenable and the similarity in root structure may perhaps be explained as a parallel development.

Yet another palm remains with which M 115 stands comparison is a small petrified palm wood regarded as a petiole and referred to the genus *Palmocaulon* and designated *Palmocaulon raoi* (MENON, 1964). This specimen is only 1·8 inches in diameter and has 2 zones and shows other features which suggest that it is more a petiole rather than a stem. But the fibrovascular bundles of this bear a very close resemblance to the fibrovascular bundles of the specimen described in this paper not only in their form, but also in the arrangement of xylem vessels and disposition of the phloem and sclerenchyma (*see* TABLE 1). A rather characteristic feature that brings the above-mentioned stem and petiole together is the presence in both of a complete ring of sclerenchyma in each vascular bundle.

In view of these similarities one cannot overlook the possibility of my specimen being the stem on which possibly the petiole *P. raoi* was borne. In spite of the similarities of the fibrovascular bundles, there are differences in the frequency and F/v ratio of the bundles in the two species, which of course could be explained as due to the two different organs in which the bundles occur. In view of this and also the fact that the present specimen is definitely a palm stem and does not agree fully with any of the known species of Palmoxylons, I refer it to a new species, *Palmoxylon raoi*. I also feel that these two species, *Palmoxylon raoi* and *Palmocaulon raoi* are best kept separate till such a time as their relationship is established fully, in addition to the similarity of their vascular bundles as is seen now.

Roots of M 115 in transverse section resemble in all respects the roots of *Nypa fruticans* (MAHABALE & UDWADIA, 1960), but differ from it in having 8-12 protoxylem points instead of 24. Nevertheless, the presence of *Rhizopalmoxylon indicum* Sahni (MAHABALE & UDWADIA, 1960), a root comparable to *Nypa*, in the same beds is suggestive. Another fruit described by Chitaley (1960) from the same locality is also referred to the genus *Nypa*. At the same time one should not overlook the possibility that these anatomical similarities may not necessarily indicate any natural affinities but may be the result of the common environmental factors.

My specimen cannot be compared with the foreign species of *Palmoxylon* bearing roots and described under the names *P. iriarteum* (STENZEL, 1904, PL. 24), *Rhizo-Palmoxylon glaeseli* and *R. bohlenianum* (GOTHAN, 1942, PL. 1, 2) *Palmoxylon rutherfordi* (STOCKMAN & WILLIERS, 1943, PL. 7) and *Palmoxylon maedae* (OGURA, 1952, PL. 1) in any important characters.

The specimen M 115 can further be placed under the section *Cocos-like* palms, according to the combined scheme of Von Mohl (1845, 1849) and Stenzel (1904) because of the similar structure and more or less similar

TABLE 1

CHARACTERS	*Palmoxylon sclerodermum* (Sahni 1943 & Shukla 1946)	*Palmoxylon surangei* (Lakhanpal 1955)	*Palmoxylon kräuselii* (Rao & Menon, in press)	M 115 (Menon)	*Palmocaulon raoi* (Menon 1964)
ROOT					
Epidermis	Not clear	Not clear	Somewhat thick walled	Not clear	...
Hypodermis	...	...	Outer—Thin walled 2-4 layers Inner—Thick walled 2-3 layers	Outer—Thin walled 2-3 layers Inner—Thick walled 2-3 layers	...
Cortex	Outer—Thick walled Middle—Peripheral compact, with scattered cells containing black contents, other portion loose with air-spaces	Outer—Thick walled dark coloured cells, loose with air cavities, fibrous bundles present Inner-Compact cells	Outer—Thin walled compact cells Middle—Loose, large airspaces, separated by parenchymatours layers Inner-Compact thin walled cells	Outer—Thin walled Middle—Loose with large airspaces, scattered cells with black contents Inner-Compact parenchymatous cells	...
Endodermis	Single layered with casparian strips	Single layered	Single layered	Single layered with thickened lateral and inner walls	...
Pericycle	1-2 layered, thin walled cells	2 layered, thin walled cells	One layered	One layered, thin walled cells	...
Xylem bundles	24, 3-4 vessels end to end	22 arches of xylem	26-33 arches, 2-3 vessels end to end	8-12, 2 to 3 end to end I-shaped or V-shaped	
Pith	Sclerenchymatous	Parenchymatous with medullary bundles	Thin walled parenchymatous	Parenchymatous, sometimes sclerenchymatous	*PETIOLE*

TABLE 1 *Contd.*

STEM

Distribution of vascular bundles in different zones	CO — Regular D — Regular SD — Regular C — Irregular	CO — Regular D — Regular SD — Regular C — Irregular	CO — ... D — Regular SD — Regular	CO — Irregular D — Regular SD — Irregular C — ...	PZ — Regular C — Irregular
Frequency of the fibrovascular bundles per cm.[2]	Sahni / Shukla D — 108 / 105 SD — 65 / 85 C — ... / 70	D — 90-95 SD — 45-50 C — 25	D — ... SD — 50-55	CO — ... D — 120-130 SD — 44-55 C — ...	PZ — 250-350 C — 135-150
F/v ratio of the fibrovascular bundles	Sahni / Shukla D — 10/1-15/1 / 9/1-18/1 SD — 15/1-25/1 / 20/1 C — ... / 23/1	D — 9/2 SD — 5/1-6/1 C — 4/1	D — 0·2/1-1·1/1 SD — 0·4/1-1/1	CO — 0·47/1-0·9/1 D — 0·37/1-1·1/1 SD — 0·56/1-0·9/1 C — ...	PZ — 1·5/1-4·7/1 C — 0·6/1-2·9/1
Diameter of the fibrovascular bundles in mm.	Sahni / Shukla D — 0·3-0·5 / 0·4 SD — 1 / 1 C — ... / 1	D — 1-0·5 SD — 0·95-0·65 C — 0·95-0·8	D — 0·18-0·3 SD — 0·27-0·4	CO — 0·18-0·63 D — 0·35-0·73 SD — 0·26-0·67 C — ...	PZ — 0·29-0·91 C — 0·23-0·8
Sclerenchyma of the fibrovascular bundles	Dsc — Bigger, cordate base Vsc — Smaller, only in leaf trace bundles	Dsc — Bigger, cordate base Vsc — Smaller, only in the leaf-trace bundles	Dsc — Present, smaller than the vascular part Vsc — Absent	A *sheath surrounding* the vascular elements. Ventral side of the sheath many times bigger than dorsal	A complete sheath around the vascular element. Ventral part of sclerenchyma will be always bigger than dorsal
Xylem vessels	D — Single SD — 2 side by side C — 2 side by side	D — 2-3 side by side SD — 2-3 side by side C — 2-4 side by side	D — One SD — 2-3 side by side	Xylem vessels large in number, arranged in a crescentic manner	Xylem vessels larger in number, arranged in a crescentic manner
Fibrous bundles	Present	Present	Present	Absent	Absent
Stegmata	Present	Present	Present ?	Present	Absent
Ground tissue	Compact, thin-walled isodiametric cells	Compact, thin-walled cells	Elongated, thin-walled, loose cells	Compact, thin-walled, angular cells	Compact, thin-walled, angular cells

Note:
C — Central Zone
CO — Cortical Zone
D — Dermal Zone
Dsc — Dorsal sclerenchyma
PZ — Peripheral Zone
SD — Sub-dermal Zone
Vsc — Ventral sclerenchyma

size of the outer and inner fibrovascular bundles.

DIAGNOSIS

Palmoxylon raoi is a petrified fossil palm stem with roots attached to it.

Root — 1 to 2 mm. thick; outer hypodermis thin walled, inner lignified; outer cortex thin walled, middle cortex large with air spaces, inner cortex thin walled; endodermis single layered, inner and lateral walls lignified; pericycle one celled; xylem bundles 8-12, phloem in between xylem bundles; pith usually thin walled, sometimes sclerenchymatous.

Stem — Cortical zone — Irregularly orientated fibrovascular bundles, both dorsal and ventral sclerenchyma well developed, separated, xylem vessels grouped or crescentic F/v ratio 0·47/1-0·9/1, diameter 0·18-0·63 mm., ground parenchyma thin walled, cells rectangular to elongated.

Dermal zone — Fibrovascular bundles regular, closely placed, frequency 120-130/cm.^{2}, F/v ratio 0·37/1-1·1/1, diameter 0·35-0·73 mm., xylem vessels arranged in crescentic manner, complete sclerenchymatous sheath around the vascular elements, mostly bigger on the ventral side, sometimes equal on all sides, fibrous bundles absent, stegmata present, ground parenchyma same as in cortex.

Subdermal zone — Irregularly orientated scattered fibrovascular bundles, frequency 44-55/cm.^{2}, F/v ratio 0·56/1-0·9/1, diameter 0·26-0·67 mm., bundle organization as in dermal zone, no fibrous bundles, stegmata present, ground tissue as in cortex.

Locality — Mohgaon Kalan, Chhindwara district, Madhya Pradesh.

Age — ? Eocene.

Type specimen — M 115 (kept in the department of botany, University of Lucknow).

ACKNOWLEDGEMENTS

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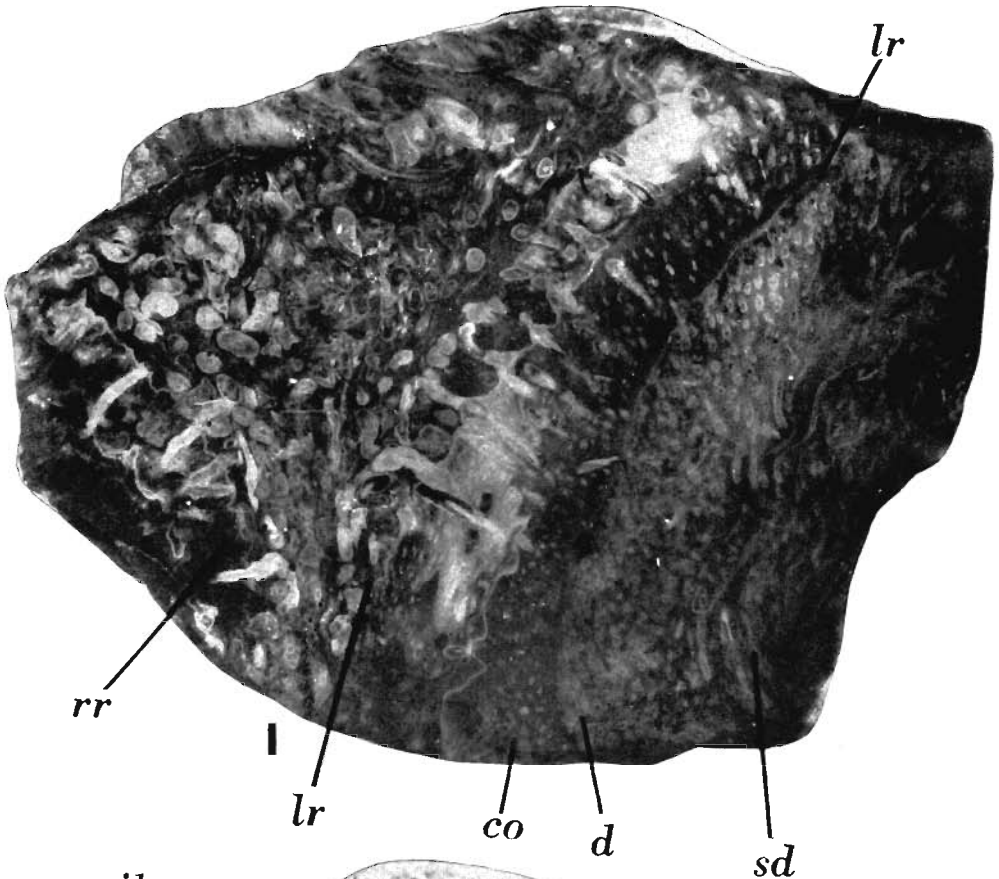

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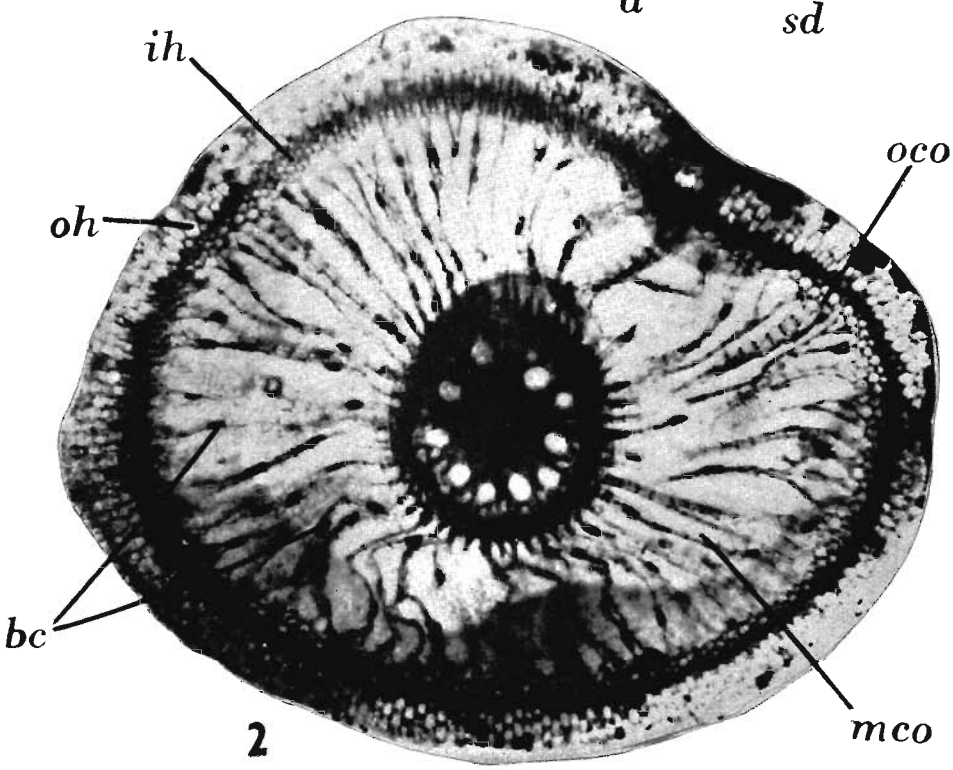

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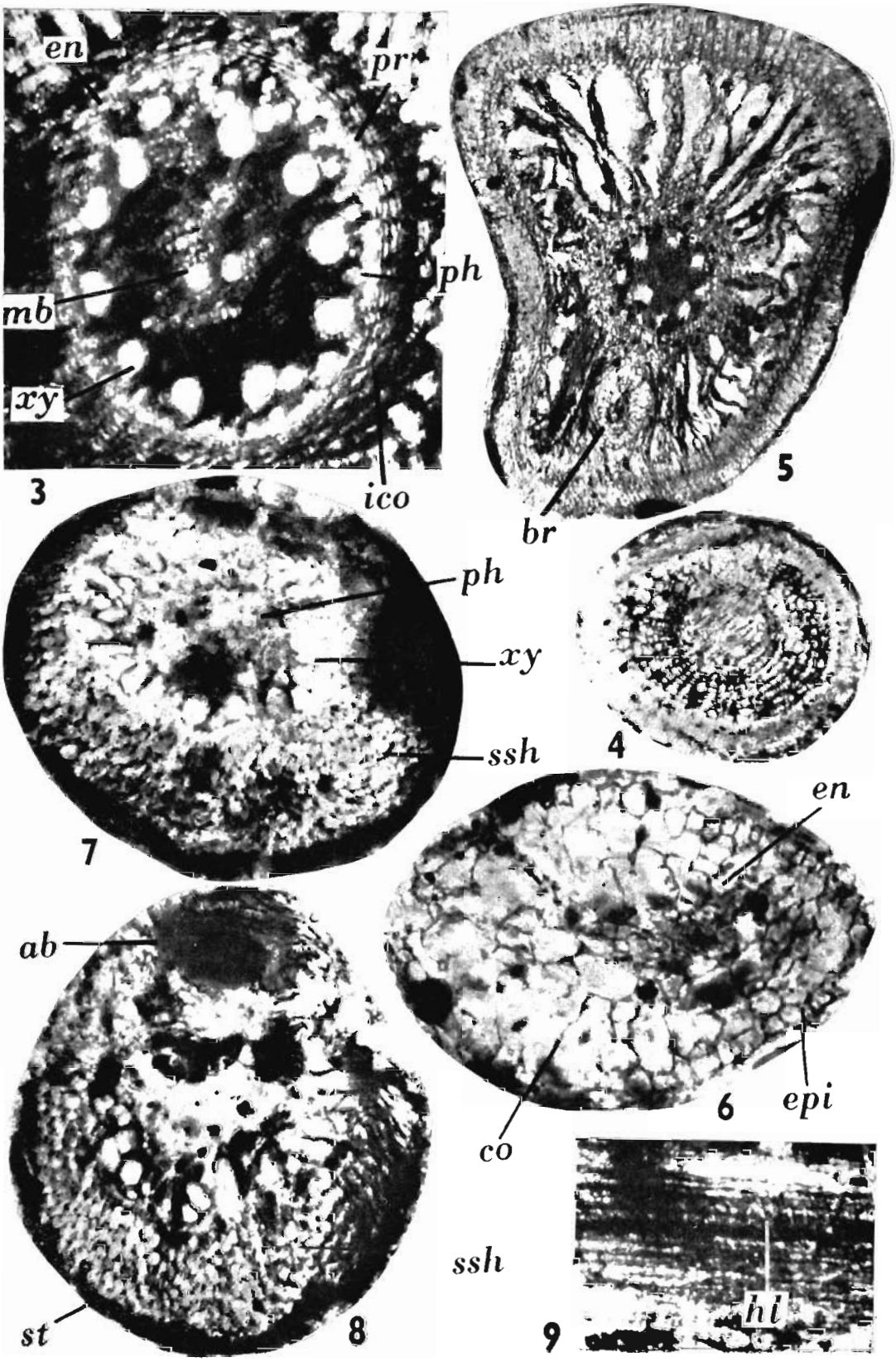
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EXPLANATION OF PLATES

PLATE 1

1. Transverse section of the fossil wood showing the root region and the different zones of the stem region clearly. × 1·9.
2. One root enlarged showing all the parts clearly. × 8·9 — (*bc* = black content; *co* = cortex; *d* = dermal zone; *ih* = inner hypodermis; *lr* = layer; *mco* = middle cortex; *oco* = outer cortex; *oh* = outer hypodermis; *rr* = root region; *sd* = subdermal zone.)

PLATE 2

3. The stellar portion of a root enlarged showing the medullary bundles and other tissues. × 112·7.
4. A small root in transverse section showing the compactly packed parenchymatous cells in the cortex. × 44.
5. A root section showing one small branched root attached in the cortex of the big one. × 55·7.
6. Branched root enlarged. × 294·5.
7. One fibrovascular bundle from the dermal zone enlarged. × 113·6.
8. A lobed bundle showing the attachment of a small bundle on the dorsal side of the big bundle. × 95.
9. Longitudinal section of the fossil wood showing helical thickening of the xylem vessels. × 57. (*ab* = attached bundle; *br* = branched root; *co* = cortex; *en* = endodermis; *epi* = epidermis; *hl* = helical thickening; *ico* = inner cortex; *mb* = medullary bundle; *ph* = phloem; *pr* = pericycle; *ssh* = sclerenchyma sheath; *st* = stegmata; *xy* = xylem.)