CYCLANTHODENDRON REMAINS FROM THE DECCAN INTERTRAPPEAN BEDS OF MADHYA PRADESH, INDIA

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ABSTRACT

Small, sometimes large remains of *Cyclanthodendron*, viz., roots, rhizomes, stems, leaf-sheaths and leaves either in organic connection or dispersed have been described from time to time from the Deccan Intertrappean Series of Madhya Pradesh, India by various workers. Fruits with peduncle are being described here for the first time. These attached fruits closely resemble dispersed fruits known as *Tricoccites trigonum*. The fruit peduncle anatomically is identical with the stem of *Cyclanthodendron sahnii*. Affinities with living members of the families Cyclanthaceae, Palmae, Pandanaceae and Araceae are discussed in detail and possible relationships have been indicated. From the new evidence adduced here it becomes quite clear that the fossil fruit or for that matter even the stem of *Cyclanthodendron* can not be accommodated in any living family of the angiosperms.

INTRODUCTION

RODE (1933) described a silicified fossil as *Palmoxylon sahnii*. He regarded that this was probably a palm inflorescence axis. Later, Sahni and Surange (1944a, 1944b) reported that Rode's specimen was not an inflorescence axis of a palm but a vegetative stem of Cyclanthaceae. Sahni and Surange (1944) therefore gave a new name to this plant and called it *Cyclanthodendron sahnii* (Rode) Sahni & Surange (*P. sahnii* Rode). The specimen recovered by these authors was the basal part of the plant consisting of rhizome with many roots attached and basal region of several stems. The leaf of this plant was discovered from the same locality later by Sahni and Surange (1950, 1953).

In 1933, Rode reported fruits with three seeds from the Intertrappean beds of Mohgaon Kalan and suggested the name *Tricoccites* to them under the mistaken belief that they showed affinity with the modern genus *Tricoccus* (Euphorbiaceae). Later, Sahni and Rode (1937) on reinvestigation came to the conclusion that the whole organisation of the fruit suggests close affinity with palms. In 1950, Shukla reported a long axis of *Tricoccites* fruits. Mahabale (1950) reported two pieces of axis from Mohgaon Kalan which on close scrutiny according to him showed close resemblance with the floral axis of *Carludovica*, a member of the Cyclanthaceae.

Chitaley in 1956, described well-preserved specimens of *Tricoccites trigonum* Rode in detail. She noticed that leaf-sheaths similar to those of *Cyclanthodendron sahnii* occur in close association with these fruits. Because of very close proximity of the sheaths which are known to be an integral part of *Cyclanthodendron* and their presence very near *Tricoccites* fruits, Chitaley thought that *Tricoccites* could be the fruit of *Cyclanthodendron*, although this could not be established beyond doubt as no organic connection between these two structures could be shown by her.

Ramanujam (1959) described the stem and leaf-sheath of *Cyclanthodendron* in great detail. His specimens probably represent the upper part of the stem. He described certain interesting features of this plant which had escaped the notice of Sahni and Surange (1953). Ramanujam also furnished evidence to show a close resemblance between the leaf sheaths of *Tricoccites* and *Cyclanthodendron*.

In our collection we have numerous specimens of *Cyclanthodendron*, some of these are stems with sheathing leaf-sheaths, while a few are without them. Only one axis with well-preserved fruits has been found by us so far (Trivedi & Verma, 1972). Transverse sections of this specimen very distinctly show a few fruits attached to their peduncle and protecting leaf-sheaths. Numerous dispersed fruits of *Tricoccites* have also been examined by us. These are without any

subtending axis but are generally well-preserved and contain three well-developed seeds. Sometimes two seeds are well-developed while the third one is small and less developed. Occasionally, there may be only two seeds in the fruit with no trace of the third seed.

Neither the peduncle nor the fruit of *Cyclanthodendron* have been known so far, they are, therefore, being described here in detail. The peduncle, anatomically is indistinguishable from the stem of *Cyclanthodendron* and therefore, there is no doubt of its being a part of this taxon.

MATERIAL AND METHODS

We undertook four field trips over a period of five years to collect numerous specimens of *Cyclanthodendron* from Mohgaon Kalan, a village in Chhindwara District, Madhya Pradesh, India. Remains of *Cyclanthodendron* are fairly common in Intertrappean beds, which are exposed there. Some of the specimens are about 30-40 cm long and 5 cm in diameter while others are 5-10 cm long and 0·5 to 1·5 cm in diameter. Only a single incomplete axis with fruits, 10 cm long and 1·5 cm in diameter, has been found by us. On this axis a few fruits are arranged on one side, unfortunately only one seed in the fruit can be seen, the other seed(s) which probably were present, as appears likely from the specimen, have disappeared because of weathering. Dispersed fruits of *Tricoccites* are quite frequently met with. Many fruits without attachment to any axis with usually three, rarely two seeds have been collected and examined. Specimens of *Cyclanthodendron* stems collected by us generally show good preservation.

For studying the fossil material usual method of sectioning was adapted. Sometimes serial sections were also made. For detailed anatomical studies transverse as well as longitudinal sections were prepared. In most sections stain was not used because the preservation is excellent. In a few sections of fruits, stains (haematoxylin & safranin) have been used.

DESCRIPTION

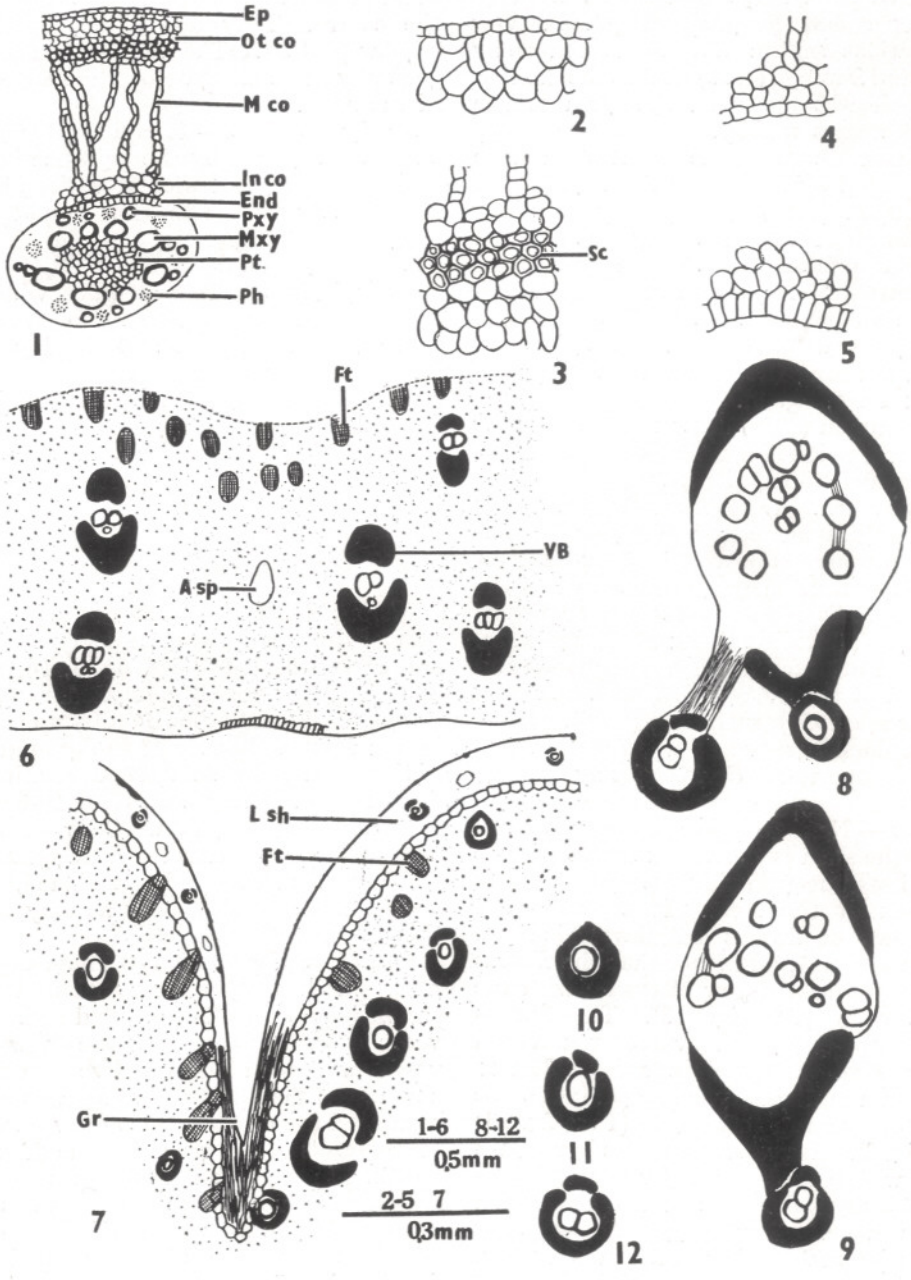
Sahni and Surange (1953) and Ramanujam (1959) have described the root, stem and leaf-sheath in great detail. However, we have observed a few hitherto unnoticed structures as we had access to a large number of specimens. We have laid stress particularly on the features observed by us.

Root — There are many specimens in our collection in which roots are attached at their basal ends. Such structures were probably underground rhizomes, as the aerial stems are devoid of roots. Many small rootlets as well as mature roots can be clearly seen in transverse sections of these specimens (Pl. 1, fig. 1).

Smaller roots are very well-preserved, but not the larger ones. In transverse section, roots show small vascular cylinder and wide cortex (Text-fig. 1). Epiblema is well-preserved and consists of radially flattened parenchymatous cells (Text-fig. 2). The cortex can be divided into three distinct zones, i.e. outer, middle and inner. Below the epiblema, are present two or three layers of parenchyma which is loosely arranged, this layer is followed by 3 to 5 cells deep sclerenchyma (Text-figs. 1-3). Below the sclerenchymatous layer, 2-3 layers thick parenchyma is again present (Text-figs. 3-4). These three layers constitute the outer cortex. Below this layer occur numerous air spaces, separated mostly by single or rarely more cell wide parenchymatous partitions, constituting the middle cortex (Text-figs. 1, 3). The inner cortex is two or three cells deep and is entirely parenchymatous. Endodermal cells are clearly visible but pericycle could not be observed in any section (Text-fig. 4). The xylem and phloem elements alternate with one another and are embedded in sclerenchymatous tissue (Text-fig. 1). The metaxylem consists of a single large vessel present towards the centre while one or two smaller protoxylem vessels occur towards the endodermis. Phloem is not well-preserved. Pith is solid and sclerenchymatous. The root described here is similar to the one already described by Sahni and Surange (1953).

Rhizome & Stem — The rhizomatous part of the plant is flattened. It bears numerous adventitious roots at its base and is devoid of leaf-sheath. Only one specimen of this kind has been found by us. Anatomically there is no difference between the structure and form of vascular bundles of rhizome and stem.

For detailed anatomical studies of the aerial stem we cut and examined numerous



TEXT-FIGS. 1-12 — **1,** cross section of root showing lacunose cortex and stele. **2,** few cells of epidermis and parenchymatous cells of the outer cortex of root. **3,** few cells of parenchyma and sclerenchyma of the outer cortex of root. **4,** few cells of endodermis and inner cortical cells of root. **5,** cells of lower epidermis and parenchyma cells of leaf. **6,** a part of leaf showing fibrous and vascular bundles. **7,** a part of peduncle showing notch region, leaf-sheath and epidermal cells. **8-12,** different kinds of vascular bundles found in the stem (8-9, lobed bundles; 10-12, small diminutive bundles).

Ep, epidermis; **Ot co,** outer cortex; **M co,** middle cortex; **I co,** Inner cortex; **End,** endodermis; **Pxy,** protoxylem; **Mxy,** metaxylem; **Pt,** pith; **Ph,** phloem; **Sc,** sclerenchymatous cells; **Ft,** fibrous bundles (elongated); **VB,** vascular bundle; **A sp,** air space; **Gr,** groove (notch); **L sh,** leaf-sheath.

specimens of various dimensions both in transverse and longitudinal planes. Our observations confirm the statement made by Sahni and Surange (1953) that as the number of leaf-sheaths increases, the girth of the stem decreases rapidly.

Epidermal cells of the aerial stem were not reported by Sahni and Surange (1953). Ramanujam (1959) subsequently described them as thick-walled, closely packed and somewhat prismatic, either empty or with dark contents. He, however, does not mention the presence of cuticle. In the present investigation we have observed a regular thin cuticle, covering the epidermal cells (Text-fig. 20; Pl. 1, fig. 3).

Ramanujam (1959) described the presence of a notch, a little higher up on the stem of his specimen; though it was not reported in type specimen. We have not noticed any notch in the stems either young or old examined by us. However, a very distinct notch is present in the peduncle where the epidermal cells can also be clearly seen to be dipping in (Text-figs. 7, 19; Pl. 2, figs. 6, 8). This kind of notch has not been noticed in the stem of the living Cyclanthaceae either by Surange (1950) or Harling (1958). However, a dorsal groove between lamina and petiole is reported in *Carludovica* by Surange (1950).

Cortex — Next to epidermis on the inner side of the stem is the cortex which is wide at the base but gradually decreases towards the apex of the stem. It consists of 1 to 4 rows of fibrous bundles which are arranged in such a manner that the fibrous bundles of the first row alternate with the next 2 rows (Text-fig. 13). The fibrous bundles are elongated, oval or round and vary in size. Many air cavities 0·85-1 × 0·5-0·6 mm in diameter, arranged in a circle are also present in this region (Text-fig. 13; Pl. 1, fig. 2). Many small bundles having 1-2 vessels with both dorsal and ventral sclerenchymatous sheaths are commonly met with in this zone. Few bigger fibrovascular bundles (normal ones) with 2-4 metaxylems, 1-2 protoxylem vessels and with both dorsal and ventral sclerenchymatous sheaths also occur here.

Dermal Zone — This is rather narrow and is demarcated from the cortex by the presence of numerous crowded vascular bundles (Text-fig. 13; Pl. 2, fig. 7). Smaller bundles occur at the periphery, but gradually the size of bundles increases as one proceeds towards the centre. They are arranged in fairly regular pattern. The vascular bundles are generally more elongate on the radial plane of the stem.

Subdermal Zone — It is also narrow and can be recognized by the presence of small as well as large bundles of various shapes. These occur mixed in the ground tissue, irregularly arranged and are not as closely packed as in the dermal zone.

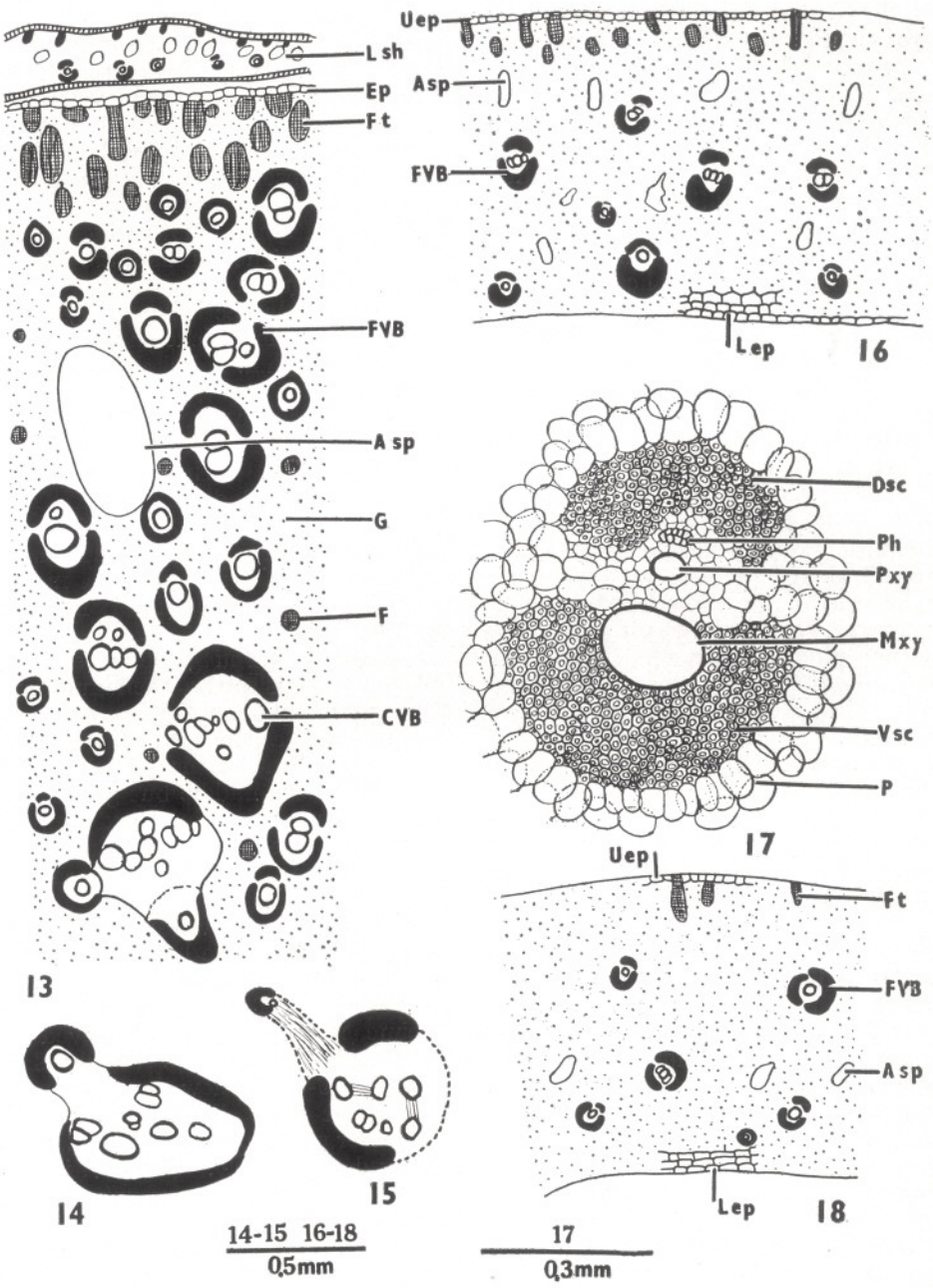
Central Zone — This is quite wide with large, lobed bundles, as also numerous smaller, normal fibrovascular bundles. These bundles are irregularly distributed in the parenchymatous ground tissue. Diminutive bundles after separating from lobed bundles with a single small vessel, also occur in this zone. All the vascular bundles are irregularly distributed.

STRUCTURE OF BUNDLES

Fibrous Bundles — Occur in the peripheral part of the stem, peduncle, leaf-sheath, leaf and fruit wall (Text-figs. 6, 13, 16, 18, 19, 25). They are mostly elongated, rarely oval or round. Small fibrous bundles up to 30 μm in diameter also occur in the ground tissue of the stem, peduncle and leaf-sheath (Text-figs. 13, 19). They consist of 10-60 fibres and have no stegmata. Cells of fibrous bundles are of somewhat hexagonal shape and have thick walls and small lumen, though sometimes their walls may be only slightly thickened.

Small Vascular Bundles — These are numerous, small, irregularly distributed in the stem, peduncle, leaf-sheath and leaf. These vascular bundles have only one or two small vessels with both dorsal and ventral sclerenchymatous sheaths, the two sheaths may be separated from each other by few parenchymatous cells of the ground tissue (Text-figs. 10-12). In these bundles it has been observed that ventral sclerenchyma is more developed and covers about 3/4 of the bundle, while the dorsal one is less developed (Text-figs. 11-12). Stegmata are absent. Average size of the vascular bundles is 220-250 × 200-250 μm in diameter.

Normal Vascular Bundles — Present mostly in the cortical region of the stem and leaf-sheath. These bundles have two to four metaxylem and a few protoxylem vessels with dorsal and ventral sclerenchymatous



TEXT-FIGS. 13-18 — **13,** a part of stem in cross section showing leaf-sheath, fibrous and vascular bundles. **14-15,** lobed vascular bundles of stem. **16,** a part of leaf-sheath in cross section at the middle region. **17,** normal vascular bundle enlarged showing cellular details. **18,** a part of the leaf-sheath in cross section at the marginal region showing distribution of vascular bundles and air spaces.

L sh, leaf-sheath; **Ep,** epidermis; **Ft,** fibrous bundles (elongated); **FVB,** fibrovascular bundles; **A sp,** air space; **G,** ground tissue; **F,** small fibrous bundles; **CVB,** lobed and compound bundles; **U ep,** upper epidermis; **L ep,** lower epidermis; **D Sc,** dorsal sclerenchyma; **Ph,** phloem; **Pxy,** protoxylem; Mxy, metaxylem; **V sc,** ventral sclerenchyma; **P,** parenchyma.

sheaths, the latter is slightly more developed. The two sheaths are separated from each other by parenchymatous ground tissue (Text-fig. 17; Pl. 3, fig. 13). Such bundles are common in the leaf-sheath also. Stegmata (or silica cells) are absent though they have been reported in the vascular bundles of the type specimen by Sahni and Surange (1953). What appears to be stegmata are actually thin-walled cells without in any way being associated with silica (c.f. silica cells).

Fused Vascular Bundles — These bundles occur in the cortical region of the stem. It has been found that generally two adjacent bundles fuse laterally, rarely, however, they may fuse end to end, i.e. the ventral sclerenchymatous sheath of one bundle may fuse with the dorsal sclerenchymatous sheath of the other bundle (Pl. 1, fig. 4). Sometimes three bundles may also fuse but here fusion takes place along the ventral sclerenchymatous sheaths of the three bundles (Pl. 2, fig. 9); in living genera of Cyclanthaceae they fuse by their phloems (Surange, 1950), while here they fuse by their xylems. The bundles measure 0·7-0·9 mm in length and 0·3-0·4 mm in width.

Lobed Bundles — Commonly occur in the central zone of stem and peduncle (Text-fig. 13). They are more numerous at the base of the stem, gradually becoming more scarce and more widely spaced towards the apex. Nothing is known about their origin. Lobed bundles are characterized by the presence of 4-8 xylem vessels which are arranged in a semi-circle and with dorsal and ventral sclerenchymatous well-developed sheaths (Text-figs. 14-15). Large lobed bundles produce small subsidiary or additional bundles by branching (Text-figs. 8-9, 14-15; Pls. 1, 2, figs. 5, 10). The subsidiary bundles also have distinct dorsal and ventral sclerenchymatous sheaths or sometimes these two form a continuous ring enclosing one or two metaxylem vessels. They remain attached to the parent bundles for some distance and then get separated (Text-figs. 9, 15; Pl. 1, fig. 5). These run parallel to the parent bundles for some distance but later assume an independent course and may be seen to be irregularly distributed within the stem. Lobed bundles measure 0·8-1 mm in length and 0·5-0·6 mm in width.

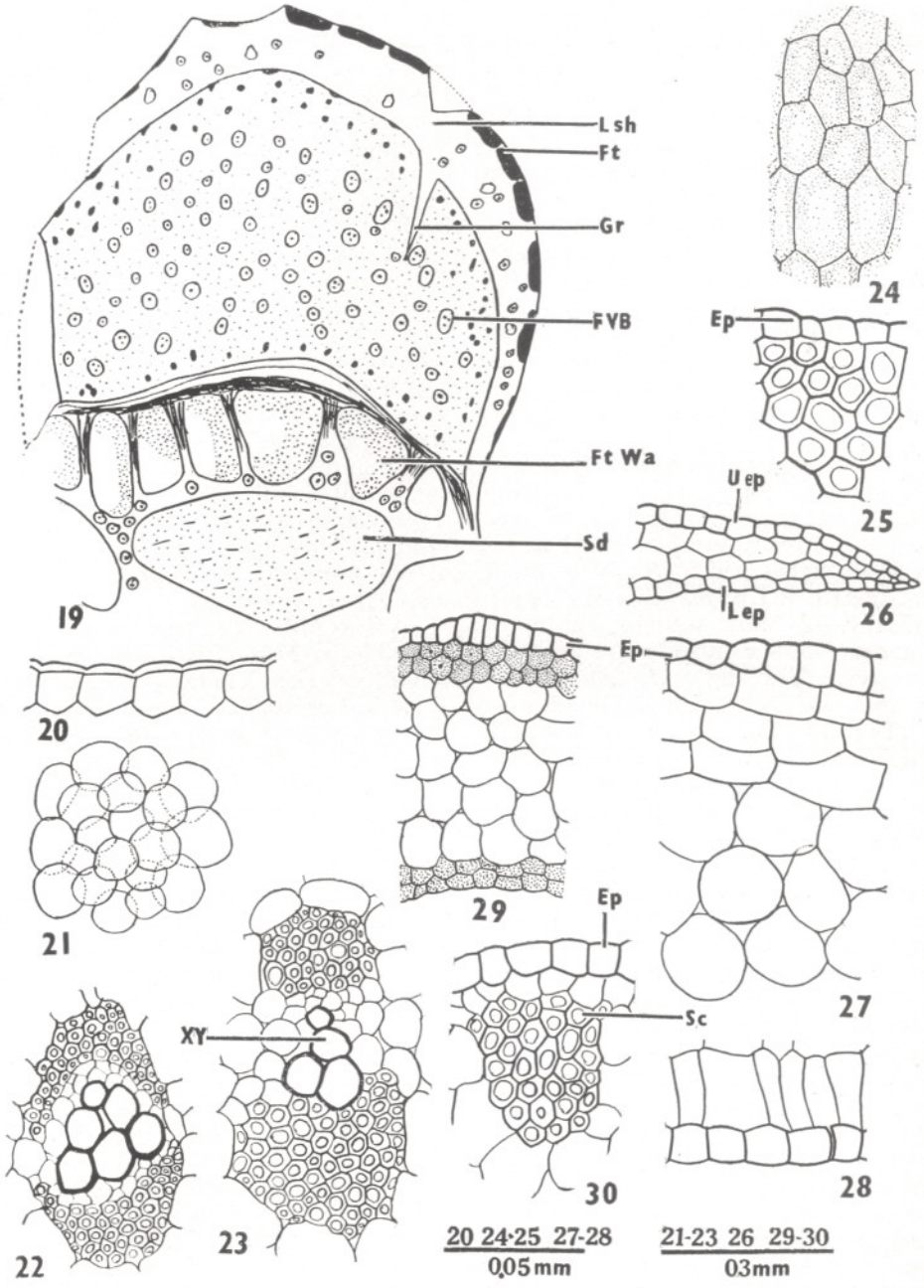
Diminutive Vascular Bundles — These are small and occur exclusively in the central part of the stem. To understand the origin of these bundles serial sections starting from base to the top of the fossil stems were cut. It appears that at any given level in the stem the frequency of diminutive bundle is proportional to that of the lobed bundles. Thus it has been observed that as the number of lobed bundles decreases from base to apex the same pattern is followed by the diminutive bundles. The bundles are 140-150 × 140-160 μm in diameter.

In longitudinal sections metaxylem vessels show scalariform thickenings while protoxylem vessels show spiral thickenings (Pl. 3, fig. 14).

Ground tissue of the stem is parenchymatous. Cells are oval or round and are loosely arranged with intercellular spaces (Text-fig. 21). Radiating parenchymatous cells have been observed all round the compound bundles. These cells have also been observed around the metaxylem vessels in some bundles (Pl. 1, fig. 5; Pl. 2, fig. 10).

Leaf-sheath — Young aerial stems generally have leaf-sheaths, their number, however, gradually increases as one proceeds upwards, thus at the apex of the stem there may be 4-6 leaf-sheaths. Each leaf-sheath is widest at the middle but gradually thins out towards the margins (Text-figs. 16, 18). Atleast two leaf-sheaths structurally similar to those of the stem, have also been observed around the peduncle.

Both, upper and lower epidermal cells can be clearly seen. The lower epidermal cells are transversely flattened, stomata have not been observed (Text-figs. 16, 18). In some specimens, it has also been observed that the lower epidermal cells are radially elongated (Text-figs. 5-6). Below the upper epidermis are present more than one row of fibrous bundles or plates of sclerenchyma, which are arranged alternately. Air cavities as well as vascular bundles are irregularly arranged. The vascular bundles in the middle part of the leaf-sheath are larger, longer than broad and gradually diminish in size towards the margins. The structure of the vascular bundles occurring here is similar to the cortical bundles of the stem. Fibrous bundles do not occur near the margins. In smaller bundles, as also in larger bundles, ventral sclerenchyma is more developed. The two sheaths are separated by parenchymatous cells. The ground tissue of the leaf-sheath



TEXT-FIGS. 19-30 — **19,** fossil peduncle in cross section showing fruit attachment. **20,** few cells of epidermis enlarged and showing cuticular layer. **21,** few cells of ground tissue showing loosely arranged cells. **22,** vascular bundle of fruit wall. **23,** vascular bundle of leaf. **24,** endosperm cells of fruit. **25,** epidermis and fibrous bundle of leaf. **26,** margin of leaf showing complete absence of vascular bundles. **27,** upper epidermis and few parenchymatous cells of leaf. **28,** lower epidermis of leaf. **29,** seed coat showing different layers. **30,** outer epicarp and fibrous bundle of fruit.

L sh, leaf-sheath; **Ft,** fibrous bundles; **Gr,** groove (notch); **FVB,** fibrovascular bundles; **Ft Wa,** fruit wall; **Sd,** seed; **Xy,** xylem; **Ep,** epidermis; **U ep,** upper epidermis; **L ep,** lower epidermis; **Sc,** sclerenchymatous cells.

is made up of loosely arranged parenchymatous cells some of which are filled up with dark contents. Many small fibrous bundles, round or hexagonal in shape, also occur scattered in the ground tissue. Stegmata are altogether absent both from fibrous part of the vascular bundles and also from fibrous bundles.

Sahni and Surange (1953) stated that there are two definite rows of air cavities and also the arrangement of vascular bundles in the leaf-sheaths is regular. Ramanujam (1959) on the other hand observed that the air cavities and vascular bundles are irregularly arranged. Our observations based on large number of specimens support the latter view.

Leaf — Of a large collection of *Cyclanthodendron* stems examined by us, we found only a few cherts which bore leaf impressions. On sectioning, these blocks revealed leaves cut in various planes which closely resemble the leaf-sheath of *Cyclanthodendron sahnii*, anatomically. In cross sections, the upper epidermis and a few hypodermal cells are well-preserved (Text-figs. 27, 28) and are clearly seen alongwith fibrous bundles or plates (Text-fig. 25). Lower epidermis is quite distinct, its cells are broad (Text-fig. 28). The vascular bundles have xylem, phloem and two well-developed sclerenchymatous sheaths (Text-fig. 23). Leaves show distinct crest and furrow regions. 2-3 vascular bundles occur in crest region and there are no air cavities, while in the furrow region there is a single air cavity and a large vascular bundle. This type of arrangement is found in the thicker part of the lamina. At the margins there is only one row of smaller bundles. Few smaller bundles with one or two xylem vessels are present at the lower side of the lamina, above the lower epidermis. The structure of the vascular bundles is similar to those found in the leaf-sheath. The remaining portion of the leaf has parenchymatous cells which are loosely arranged, some of the cells are filled up with dark contents. The leaf cut at the middle in transverse plane is identical in some characters with the one already described by Sahni and Surange (1953). In some sections marginal portion of the leaf is clearly seen from where the vascular bundles are completely absent (Text-fig. 26).

Peduncle — A small piece of peduncle measuring 15 cm long bearing a few fruits was sectioned transversely. In cross section, the peduncle shows radially elongated epidermal cells (Text-fig. 19; Pl. 2, fig. 6). A thin layer of cuticle lining the epidermis on the out side can be clearly seen. Stomata have not been observed in any section. At one place there is a prominent notch or furrow similar to that of the stem described by Ramanujam (1959). Fibrous bundles of various shape and size, closely packed, are found in the peripheral zone.

A few cells layer below the epidermis can be seen a narrow dermal zone in the peduncle also, it is as distinct here as in the stem. Vascular bundles of central region are bigger than those of the dermal region but are structurally similar to those of the stem. Sometimes two of them may fuse to form a compound bundle (Text-fig. 19). Air cavities are absent from the cortical region of the peduncle unlike the stem. Ground tissue of the peduncle is parenchymatous with intercellular spaces.

Fruit — Although large number of fruits referable to *Tricoccites trigonum* have been found, yet their affinities are in doubt. A fructification and an axis presumably both belonging to the same plant were described by Chitaley (1956) but organic connection between the two could not be established by her. Previous to the present investigation, fruits have been reported either singly or in groups but none have been found attached to their axes. There is only one incomplete specimen in our collection which shows a few fruits actually attached to their peduncle. On sectioning of this specimen, it has been found that the peduncle (fruit axis) closely resembles the stem known as *Cyclanthodendron* so much so that anatomically the two are indistinguishable from each other. Fruits borne on this peduncle show very close affinity with *Tricoccites trigonum*. The fruits are closely packed. The peduncle bearing the fruits is enclosed by leaf-sheaths, this can be best seen in transverse section (Text-fig. 19; Pl. 2, fig. 6).

The fruits are sessile, somewhat rounded in cross section, only a single loculus with a single seed can be seen (Text-fig. 19; Pl. 2, fig. 6). The fruit is obviously incomplete but there are indications that probably it had more than one loculus. The fruit consists of three distinct walls, viz., outer, middle and inner (Pl. 3, figs. 11,12). Outer (epicarp) is thin-walled parenchymatous, below this

TABLE 1 — COMPARATIVE ACCOUNT OF THREE SEEDED AND ONE SEEDED FRUITS

CHARACTERS	THREE SEEDED FRUITS	ONE SEEDED FRUITS (found attached to the peduncle)
Size of the fruit	3 × 3 mm	1·5 × 1 mm in diameter
Fruit wall		
a—Outer layer (epicarp)	One layered, parenchymatous	One layered parenchymatous
Hypodermis	2-3 layered parenchymatous, with fibrous bundles	1-2 layered parenchymatous with fibrous bundles
b—Middle layer (mesocarp)	With large air spaces separated by thick septa having vascular bundles	With many air spaces separated by parenchymatous septa, having vascular bundles
Size of air spaces	0·3 × 0·3 mm	0·2 × 0·25 mm in diameter
c—Inner layer (endocarp)	Fibrous with few vascular bundles, us. 4 to 6 layers thick	Fibrous with few vascular bundles, us. 4 to 5 layers thick
Seed		
Number of seeds	Three, well-developed, equal in size	Incomplete specimen, only one seen (others not seen in the attached axis)
Size of seeds	1 × 1 mm	0·9 × 0·3 mm in diameter
Thickness of seed coat	0·25 mm thick	0·15 to 0·2 mm thick
Epidermal layer	Single layer parenchymatous	One layer thick parenchymatous
Middle layer	5 to 7 layers thick parenchymatous slightly thickened walls with dark contents	3 to 6 layered parenchymatous with dark contents
Inner layer	Several layers thick parenchymatous with granular contents	Several layers thick parenchymatous with dark contents
size of the vascular bundles	0·25-0·3 × 0·2 - 0·35 mm	0·2-0·22 × 0·21-0·3 mm

layer are fibrous bundles (Text-fig. 30). The middle (mesocarp) region has numerous air chambers which run along the entire outer circumference of the fruit. The partitions dividing the air chambers are 2 or more cells wide, parenchymatous, with many bundles which have only a few vessels. The inner (endocarp) consists of many fibrous as well as fibrovascular bundles.

The single seed has distinct seed coat, whose thickness is 0·15 mm. The seed coat has three distinct layers, viz., outer, middle and inner. The outer epidermis is single layered with elongated parenchymatous cells. The middle one consists of 4-8 layers of parenchymatous cells with dense contents. The inner membrane has parenchymatous cells whose thickness varies in different specimens. The cells of this layer have dark contents (Text-fig. 29). Below this layer are a few cells in groups, these probably represent the endosperm (Text-fig. 24).

Remarks on Tricoccites Fruit — Tricoccites fruits have three well-developed seeds with a thick wall provided with numerous air chambers. A detailed account of the fruit wall and structure of seed of *Tricoccites trigonum* shows that these as well as the fruit and seed found attached to the peduncle of *Cyclanthodendron* structurally resemble each other rather closely (Table 1).

Size of the fruit, thickness of the fruit wall and number and size of the seeds varies considerably in different specimens. Many fruits in our collection show only two seeds. Anatomically these specimens are identical with three seeded fruits. We have also noticed that in many sections two seeds are well-developed while the third one remains under developed or is small.

DISCUSSION AND COMPARISON

The fossils described here bear comparison with the arborescent monocotyledonous families like Palmae, Pandanaceae, some members of Cyclanthaceae and Araceae. A detailed comparison, however, rules out any close affinity with any living or fossil taxon amongst the monocotyledons.

Palms and pandans are by and large arborescent and woody in nature whereas Cyclanthaceae and Araceae are predominantly herbaceous. *Cyclanthodendron* was woody as

the structure of the stem clearly shows and probably it was not as tall as majority of present day palms.

The fossil stem genus *Cyclanthodendron* has unique vegetative anatomy, it has five kinds of bundles in its rhizome, stem and as now shown in its peduncle, viz., fibrous bundles, diminutive, lobed, compound and normal vascular bundles. Compound bundles formed by fusion of two or more normal bundles occur in rhizomes of living Cyclanthaceae. This character is also shared by two other families, viz., Pandanaceae and Araceae. In the living members of Cyclanthaceae, the vascular bundles of the stem have either dorsal or ventral sclerenchymatous sheath, rarely both may be absent. In the fossil stem on the other hand vascular bundles have both these invariably present and these are well-developed though the ventral one is more developed. Furthermore, the structure and formation of compound vascular bundles in the families Pandanaceae, Araceae and Cyclanthaceae differs markedly from the fossil, *Cyclanthodendron* (vide supra).

Living palms like *Wallichia disticta, Hyphaene thebiaca, Phoenix reclinata, Calyptocalyx spicatus, Licuala spinosa, L. peltata, Cyrtostachys* sp. and *Dictyosperma* sp. have compound vascular bundles which are formed in various ways but in these as also in Pandanaceae and Araceae only two vascular bundles fuse with each other whereas in the fossils sometimes more than two vascular bundles may fuse with each other to form a compound vascular bundle.

Lobed bundles like those of *Cyclanthodendron* are not found in any monocotyledon — living or fossil.

Chitaley (1956) failed to establish any organic connection between the leaf-sheath and the fruit of *Tricoccites*. But the peduncle with a few fruits embedded in it and enclosed by sheathing leaves described here is structurally and anatomically very similar to the stem and leaf-sheaths of *Cyclanthodendron*. Further, a distinct notch has been observed in the fossil peduncle, this notch is similar to the one that occurs in the aerial stem of *Cyclanthodendron* Ramanujam (1959). It is unfortunate that only an incomplete part of the fruiting axis has been found by us. The fruit shows a single seed — other seed(s), that may have been present have disappeared during fossilization. The fruit wall and seed of the fossil closely resemble corresponding structures of *Tricoccites*.

In Cyclanthaceae, the fruit wall may be aerenchymatous but the size of seed is smaller than in *Cyclanthodendron*. The number of seeds per fruit here may vary from 1-3 while in Cyclanthaceae their number is fairly numerous. In Palmae, Pandanaceae and Araceae there is no aerenchyma in the fruit. In Cyclanthaceae the fruits are arranged around a central fleshy axis towards periphery while in fossil the fruits are embedded in the axis but placed towards the centre of the peduncle.

Systematic Status — Families — Cyclanthaceae, Palmae, Pandanaceae and Araceae are placed close together by Bentham and Hooker (1862-83), Wettstein (1911) but Engler (1887) places the family Pandanaceae near Typhaceae and Potamogetonaceae away from Palmae, Araceae, etc. These families have certain common anatomical characters which have been described by Surange (1950), Tomlinson (1961) and Tomlinson and Zimmermann (1967). According to Hallier (Lotsy, 1911, p. 863) Pandanaceae and Palmaceae evolved from Cyclanthaceae. According to Surange (1950, p. 205) the two subfamilies of Cyclanthaceae, viz., Cyclantheae and Carludoviceae are similar to Pandanaceae and Palmaceae respectively. According to Harling (1958, p. 89) Cyclanthaceae evolved from the protocyclanthaceous stock.

From the evidence presented here it can be safely presumed that inspite of *Cyclanthodendron* showing some affinities with the families Cyclanthaceae and Palmae it can not be kept within them as it has some characters in which it differs markedly from both these, viz., in the occurrence of lobed vascular bundles which pinch off small diminutive bundles, well-developed but unequal sclerenchymatous dorsal and ventral sheaths in vascular bundles, a fleshy peduncle with embedded fruits and aerenchymatous wall. The structure of vascular bundles in the Pandanaceae is quite different from the fossil hence any affinity with this family is also ruled out. Moreover, the fruit also differs markedly in the two. These characters lead one to believe that *Cyclanthodendron* can not be kept within families Cyclanthaceae, Palmae, Pandanaceae or Araceae. It will be best therefore to keep it under a separate family of its own.

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EXPLANATION OF PLATES

PLATE 1

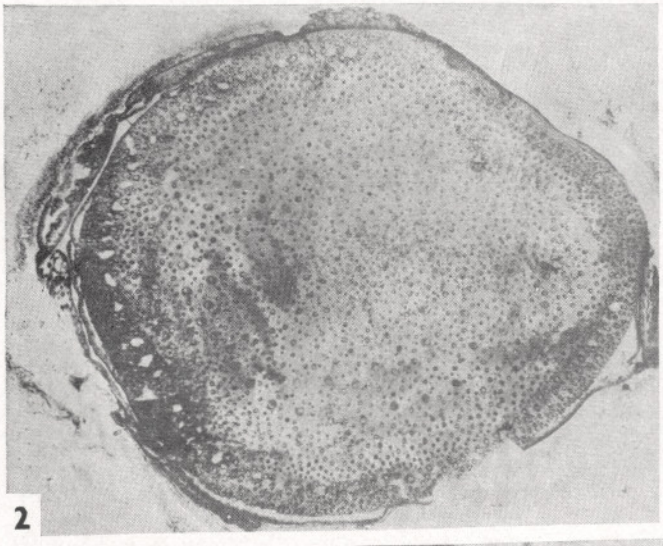
1. Cross section of rhizomatous part showing roots. × 2.
2. Cross section of stem showing leaf-sheath, peripheral air spaces and vascular bundles. × nat. size.
3. A part of stem in cross section showing epidermal cells and fibrous bundles. × 65.
4. Two bundles showing fusion. × 65.
5. A lobed vascular bundle, showing two diminutive vascular bundles. × 60.

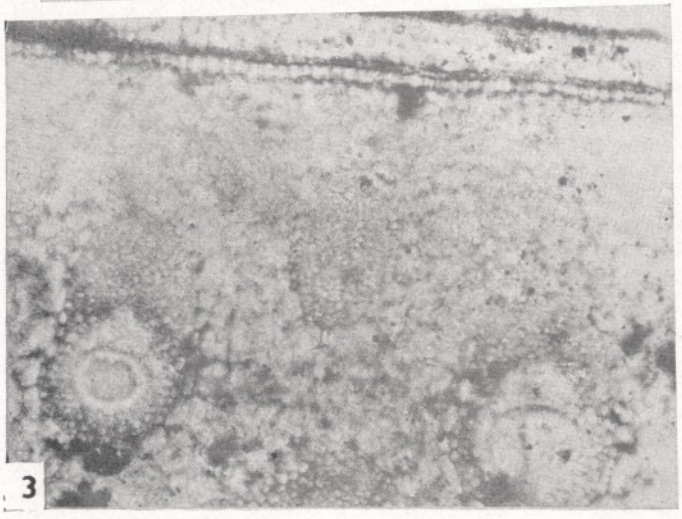
PLATE 2

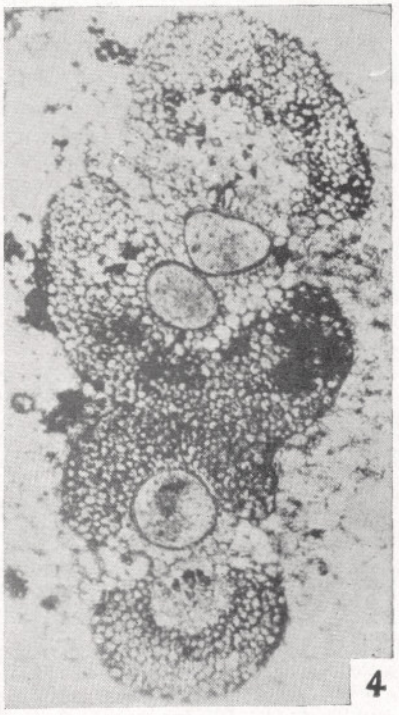
6. Cross section of peduncle showing attached fruit and its wall. × 2.
7. A part of cross section of stem showing crowded bundles at the periphery. × 20.
8. Notch region of the peduncle enlarged showing fibrous bundles. × 35.
9. Three vascular bundles, showing fusion (compound vascular bundle). × 55.
10. Lobed vascular bundles showing at one end diminutive bundle. × 45.

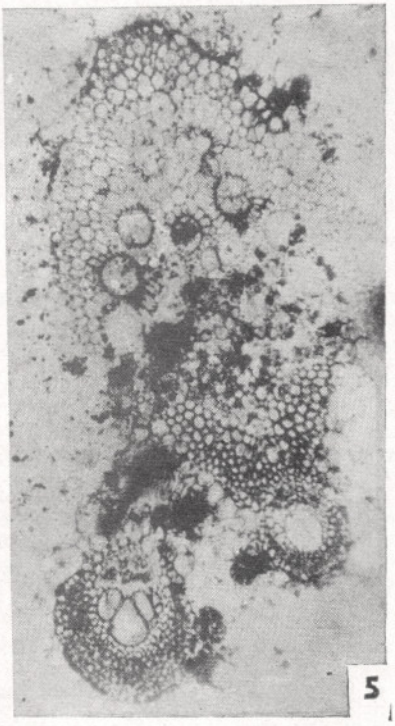
PLATE 3

11. Cross section of a fruit showing two seeds. ×2.
12. Fruit in cross section showing three seeds and leaf-sheath all round. × 2.
13. Normal vascular bundle enlarged showing both dorsal and ventral sclerenchymatous sheaths. × 70.
14. A vessel in L.S. showing spiral thickening. × 120.









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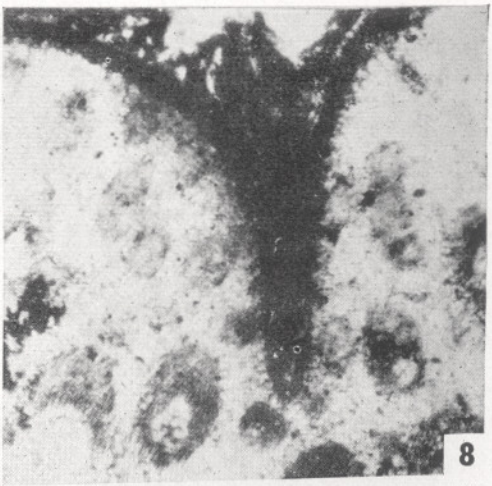
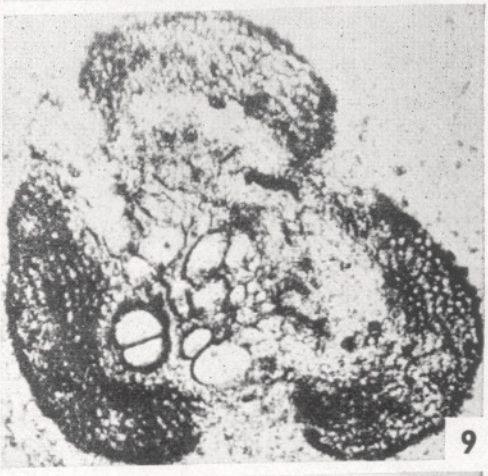
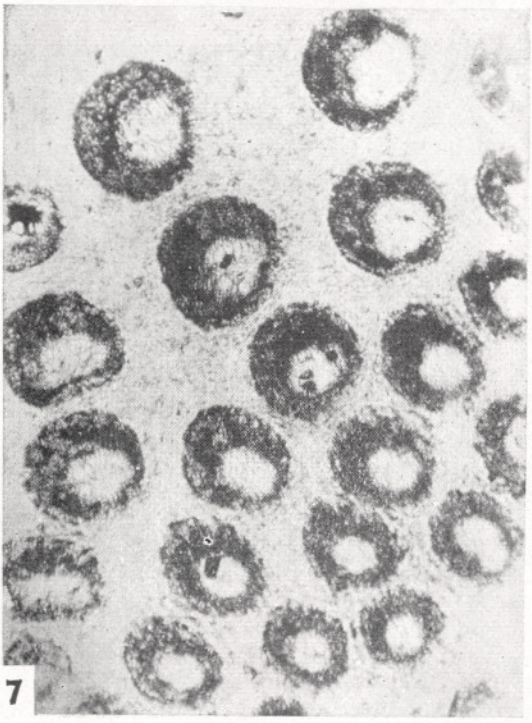






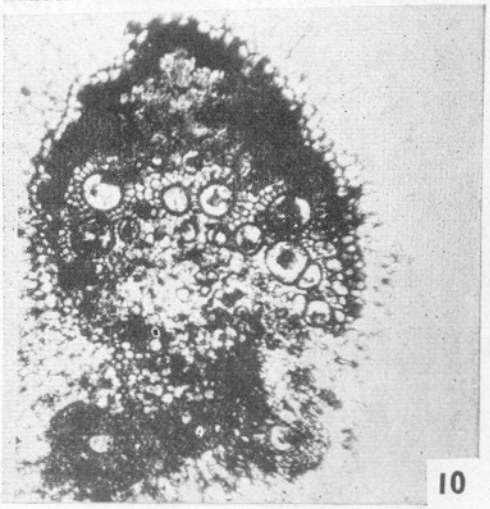
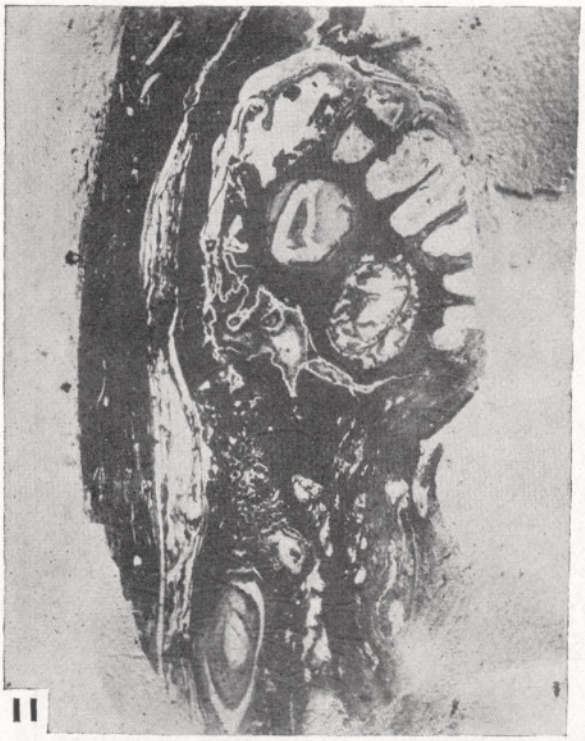
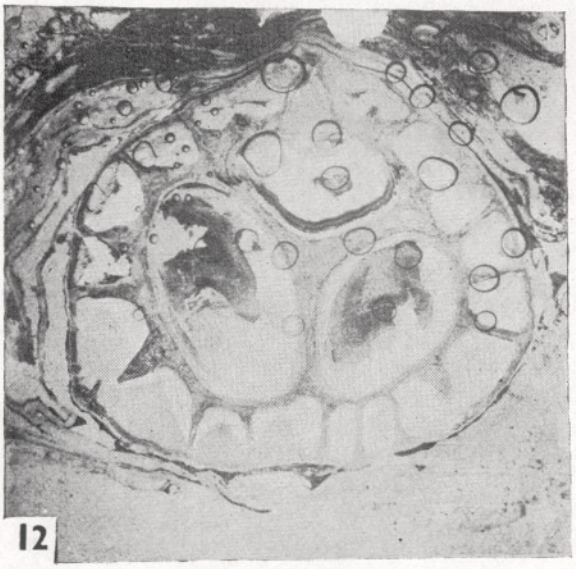


PLATE 2





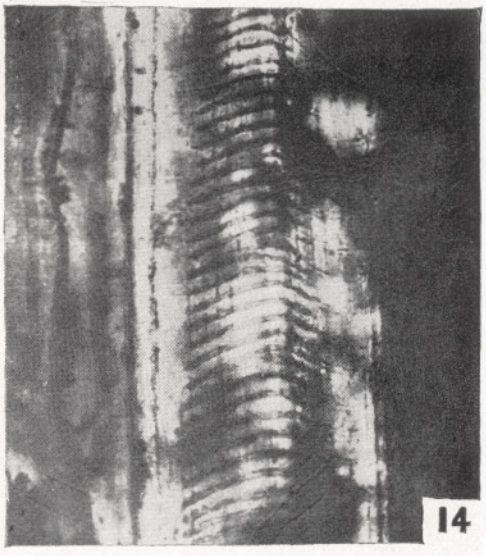


PLATE 3