Fossil Palms

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Living palms are familiar plants to all who grow them and are a characteristic feature of many parts of the tropics. That palms have a long history in time is not always recognized. It is the object of this article to illustrate some of the fossil palms found in the United States, correlating structure of stems, roots, and leaves with those seen in living palms, the anatomy of which has been reviewed and evaluated by Tomlinson in his volume on Palmae in Anatomy of the Monocotyledons (1).

Palms first definitely appeared in the Upper Cretaceous rocks, some 63-90 million years ago by the geologic time scale of Kulp (2). A fossil which has been called *Palmoxylon cliffwoodensis* dating from that period has been found in the Magothy formation of New Jersey where today no palm lives (3). Delevoryas (4, p. 173) mentions that palm-like leaf impressions from France (the *Propalmophyllum* of Lignier) were reported in 1907 as dating from the Jurassic period (135-181 million years ago). If truly a palm, this stands as evidence for the presence of flowering plants at that early date. However, going back still further, the discovery of a palm-like leaf imprint in sandstone was reported and illustrated in color by Ladd and Brown (5) and by Brown (6) from the Triassic period (181-230 million years ago). This ancient fossil leaf was found by Dr. G. Edward Lewis near Placerville, Colorado, in the vicinity of the San Miguel River. Several months later, Dr. Brown and Dr. Lewis explored the area where the first imprint had been found. Six more imprints were uncovered and taken back to the Smithsonian Institution. Delevoryas (4, p. 172) mentions that the discovery was "one of the most significant finds in recent times" although with incomplete evidence it should be classified only as palm-like. Ladd and Brown also illustrated in color the cross-section of a fossil palm trunk of a later era found on Antigua in the West Indies. It has a light yellow-brown color similar to much of the fossil palm wood found in Southern California.

Arnold (7, p. 341) places most of the fossil palms in North America along with rocks of the Eocene epoch (36-58 million years ago). There was a shifting or migration of palms southward due to climatic changes at the end of the Eocene which continued into the Pliocene (1-13 million years ago). Thus the occurrence of palms in the fossil record has served more or less as an indicator of the prevailing climate of the past. Noé (8), La Motte (9) and Mahabalé (10) give many references on fossil palms.

There are several important areas from which material of fossil palms has been obtained. One of the most famous is the extensive region along the coastal plain of the United States bordering the Gulf of Mexico, where rocks containing what is known as the Wilcox flora were laid down in lower Eocene times. These beds contained many fossils including *Chamaedorea*-like species. At about the same time, the Raton flora existed in northern New Mexico and southern Colorado. Knowlton (11, p. 180) includes a photograph of a leaf impression of a *Sabal*-like palm from this flora. From a succeeding middle Eocene flora, the Claiborne which extended from Alabama to Texas, Berry (12, p. 51) described several palms based on leaf structure—one suggestive of *Thrinax,* and two feather-leaved species called *Bactrites* and *Geonomites* from their resemblance to modern *Bactris* and *Geonoma.* Still later in time, from the upper Eocene Jackson flora of Texas, fossil fruits of a date-like palm were found. Chaney (13, p. 11) published a photograph of a large bed composed of layers of fossil palm leaves from the Clarno shale of Oregon, also of Eocene age. Most of

GEOLOGIC TIME SCALE

after Kulp (2) and others

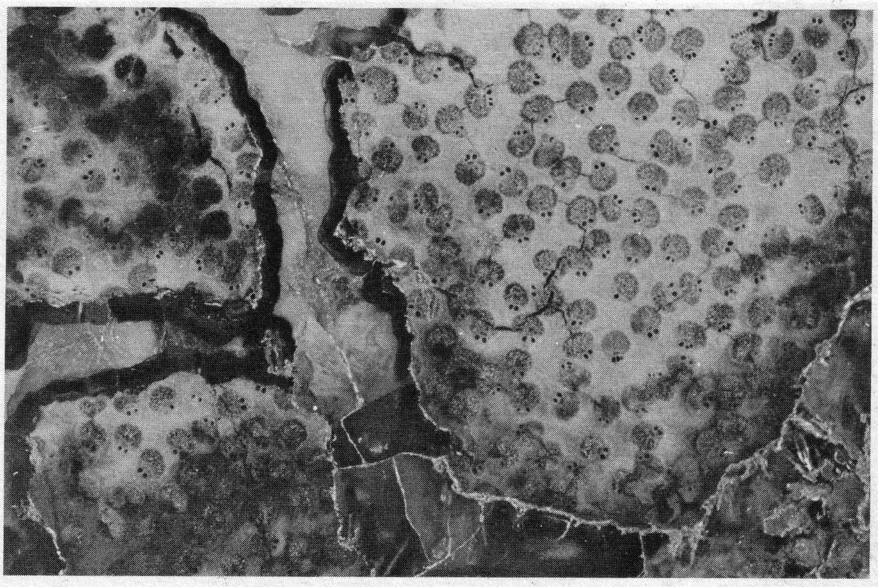
ERA		PERIOD	MILLIONS OF YEARS BEGINNING & END OF PERIOD	MILLIONS OF YEARS DURATION	POSITION OF FOSSIL PALMS IN GEOLOGIC TIME SCALE *PALMS IN AUTHOR'S COLLECTION
CENOZOIC	QUATERNARY	RECENT	0 - 0.01 (10,000 yrs)	0.01	
		PLEISTOCENE	0.01 - 1.0±	1	VERO, FLORIDA
	TERTIARY	PLIOCENE upper lower	1 - 13	12	*RICARDO BEDS (LAST CHANCE CANYON) CALIFORNIA COPIAH COUNTY, MISSISSIPPI *ROSAMOND, CALIF. (NEAR MOHAVE)
		MIOCENE upper middle lower	13 - 25	12	JAPAN (TERTIARY) EPOCH NOT KNOWN *BARSTOW BEDS (MULE CANYON) CALIF. *TEHACHAPI, CALIF. (HORSE CANYON) *LAGRANGE, FAYETTE COUNTY, TEXAS
		OLIGOCENE	25 - 36	11	ANTIGUA, WEST INDIES ? OLIGOCENE SUB-DIVISION NOT KNOWN
		EOCENE	36 - 58	22	*FARSON, WYOMING (EDEN-VALLEY) *NEPHI, UTAH *SIERRA COUNTY, NEW MEXICO
		upper	36 - 45	9	CLARNO, OREGON, FOSSIL LEAVES JACKSON-FLORA - GULF COAST REGION BRAZOS CO. TEXAS. NIPA-LIKE FRUITS
		middle	45 - 52	7	CLAIBORNE-FLORA - GULF COAST REGION
		lower	52 - 58	6	RATON-FLORA NORTHERN NEW MEXICO WILCOX FLORA GULF COAST REGION NIPA-LIKE FRUITS GRANADA CO. MISS.
		PALEOCENE	57 - 63	5	*NORTH CAROLINA BRAZIL. NIPA-LIKE FOSSIL FRUITS
MESOZOIC		CRETACEOUS upper lower	63 - 90 90 - 135	27 45	FOSSIL PALMS FIRST APPEAR IN UPPER CRET. PERIOD (MAGOTHY FORMATION) N.J. TURONIAN OF FRANCE
		JURASSIC	135 - 181	46	PALM-LIKE LEAF IMPRINTS PROPALMOPHYLLUM OF LIGNIER (FRANCE)
		TRIASSIC	181 - 230	49	PALM-LIKE LEAF IMPRINTS (COLORADO)
PALEOZOIC		PERMIAN PENNSYLVANIAN MISSISSIPPIAN DEVONIAN SILURIAN ORDOVICIAN CAMBRIAN	230 - 280 280 - 320 320 - 345 345 - 405 405 - 425 425 - 500 500 - 600	50 40 25 60 20 75 100	NO EVIDENCE OF PALMS OR PALM-LIKE STRUCTURES BELOW THE TRIASSIC PERIOD
PRECAMBRIAN		INCLUDES THE OLDEST BASEMENT ROCKS FROM THE TIME OF ORIGIN OF THE EARTH UP TO THE LOWER CAMBRIAN PERIOD	600 - 3600+	3000+	

the fossil palms of Wyoming occur in rocks of the same age.

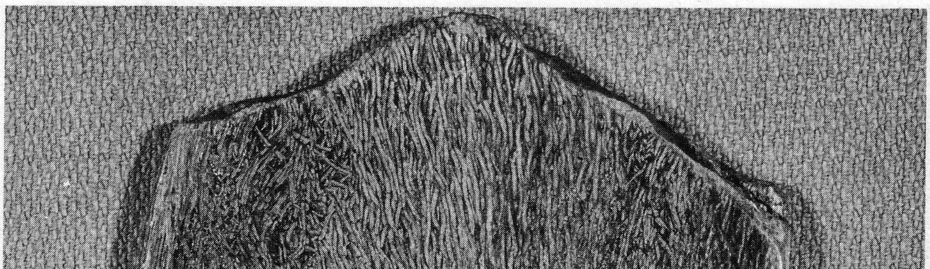
Fossil palms in Texas are found in rocks from both the Miocene and Eocene epochs, those from Fayette County being of Miocene age. In California, the Tehachapi flora of the present western Mohave Desert region was laid down in the Middle Miocene (about 18 million years ago) while the Barstow beds, which include the Mule Canyon area north of Yermo, are of upper Miocene age (15 million years ago) and the Ricardo beds of Southern California, which occur in the Last Chance Canyon area, are of lower Pliocene age. Axelrod (14) described fossil palms of Pliocene age from Palmdale, California. An imprint of a *Sabal*-like leaf with a costapalmate blade was revealed during the process of road building near Castaic in Los Angeles County and is illustrated by Hertrich (15, p. 4). From Japan on the islands of Hokkaido and Kyushu, Kryshtofovich (16) has described *Sabal*-like palm leaf impressions. In Europe, during the Eocene epoch, *Sabal*-like palms grew in England, France and southern Russia and also appear in the Pliocene rocks of the Rhone Valley. Eocene beds of England occur in two separate basins, the Hampshire and the London. Fossil fruits of the tropical palm *Nypa* (*Nipa*) have been found in the old delta mud or clay which lies below London. It is also exposed in the cliffs of eastern Kent County and the Isle of Sheppey located at the mouth of the Thames River. Reid and Chandler (17) and Chandler (18) have made extensive studies on the flora of the London clay in which fossil *Nypa* structures have been found. Geologically this important palm has existed since the Cretaceous period. At the present time *Nypa* is restricted to parts of southeast Asia and some of the South Pacific Islands. Fossil *Nypa* fruits of Eocene age have also been found in Belgium, Borneo, France, India and Russia. Some of these structures have also been found in beds of Miocene age in India. Fossil pollen grains have been reported from Borneo in beds of Cretaceous age. In the United States *Nypa*-like fossil fruits have been found (Berry 19, p. 176) in the Wilcox (Eocene) flora, Granada formation, Granada County, Mississippi. From Texas Berry (12, p. 150) reported similar fruits found in the Eocene Fayette formation near Wellborn, Brazos County. Also from the Paleocene of Brazil, fossil fruits of *Nypa* have been reported by Dolianiti (20) in 1955. These structures can drift for long distances with the ocean currents. The oceanic paths of migration are discussed by Corner (21, pp. 249-252). He also suggests the possibility that the *Nypa* - like fruits found in southern U.S.A. may be from tropical American palms other than *Nypa*.

One of the most informative descriptions of how plants became fossils is given by Arnold (7, p. 14-40). Compressions, casts and petrifications (permineralization) are the most important methods by which fossilization is effected. Of the monocotyledonous plant forms, the petrified (silicified) palms are among the best preserved. Many factors are involved in the petrification process. One important factor for setting the stage for petrification is the rapid submergence of the trunk and roots in a body of water where oxygen is absent. Another important factor is deposition in the water of finely divided sediments such as clay, mud, sand and volcanic ash.

The complex petrification process has been studied by Arnold (22), Darrah (23) and Barghoorn (24, 25). They have produced much evidence indicating that the fundamental basic process

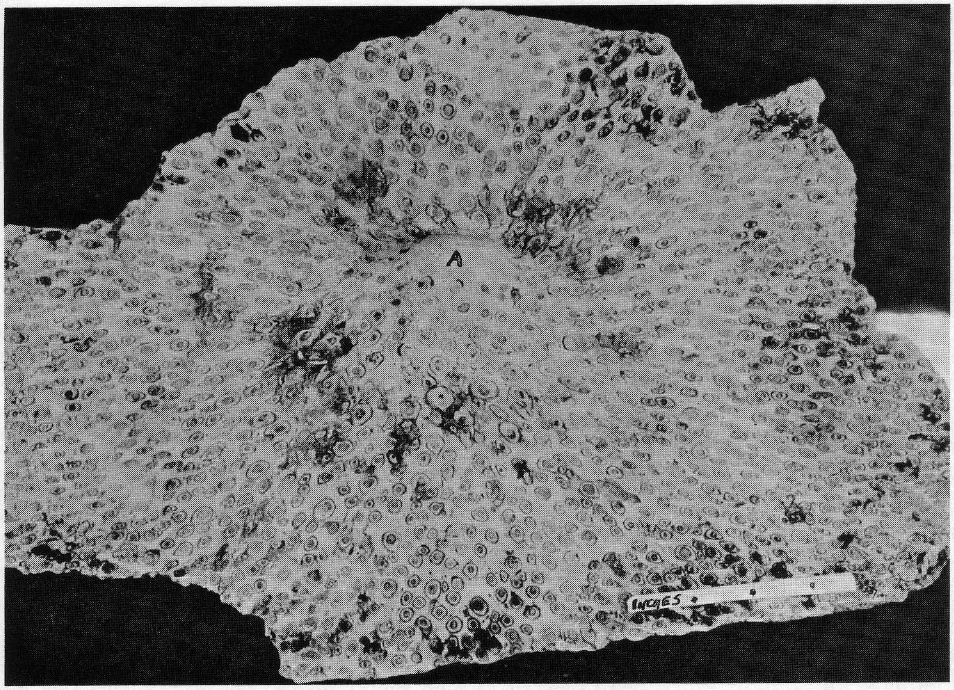


1. Fossil palm, Tehachapi, Kern Co., Calif. Photograph enlarged 3×. Two xylem vessels, occasionally three, in each vascular bundle stand out like ink dots. With the use of a 4× or 10× lens some bundles show groups of phloem structures between the xylem vessels and the large fibrous bundle sheath "cap", also agatized septa dividing the palm structure into islands.



2. Fossil palm, Horse Canyon, Kern Co. California. Longitudinal section showing the intricate interwoven appearance of the vascular bundles.

is chiefly one of infiltration, rather than the "molecule by molecule" replacement of the plant structure by mineral substances. The nature of the process can be shown in preparations using a highly carbonaceous black Wyoming



3. Fossil root mass, Mule Canyon, Yermo, California. The central area at (A) devoid of root structures, has typical vascular bundles and represents the lowermost portion of the stem. The opposite or upper side of the specimen shows stem structure with vascular bundles and a narrow rim showing roots.

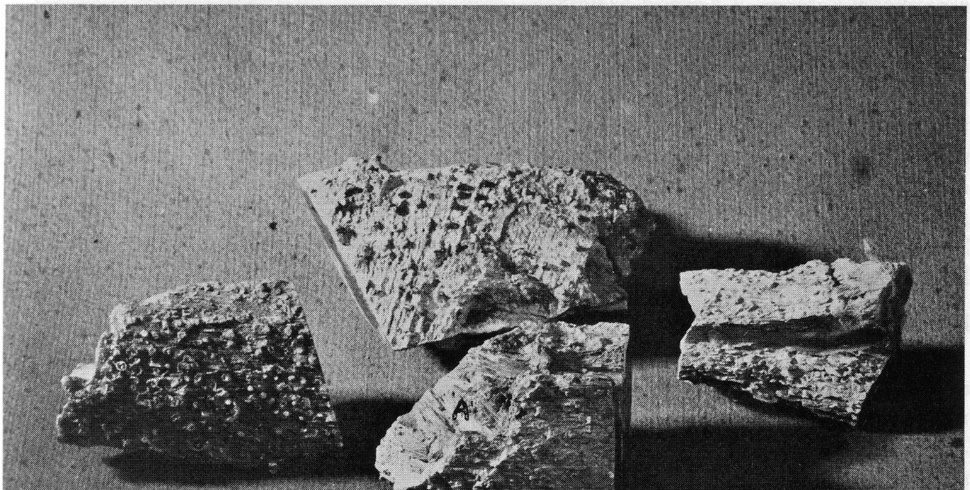
fossil palm. Microtome sections and "peel" preparations were made following the techniques described by Darrah (26), Joy, Willis and Lacey (27) and Kummel and Raup (28). The silica was removed with hydrofluoric acid, leaving a residual organic carbonaceous framework which outlines the cellular pattern of the fossil structure. This material represents the degradation products of cellulose, hemi-cellulose and lignin, of which the original woody structure of the plant cell walls is chiefly composed. The complex structure of lignin has recently been reviewed by Brown (29). Figures 15 and 16 compare the peel preparation with a standard thin section, both methods showing a similar carbonaceous framework.

Collecting Fossils

Apart from providing material for the study of detailed structure, one of the incentives for collecting petrified wood (chiefly stems and roots) is the wide variation in color and pattern in the polished sections. Most palm wood is a yellow brown, some is multicolored with red, black, green and blue, in fact every imaginable color combination. In general, however, palm woods are not as colorful as the diffusely agatized silicified *Araucarioxylon arizonicum* of the Petrified Forest National Monument of Arizona, or the Utah Cycadeoids. Certain of the fossil palms show exceptionally well preserved vascular bundle and ground tissue. Naumann (30) has described the variation in color found in palm wood from Fayette County, Texas, and especially has given a detailed account of searching for fossil palms in that region.

Only a few specimens have been il-

4. Semi-cast of black Wyoming fossil palm shows trunk rings (leaf base scars) in the surface layers of the stem, also vertical fissures in the spaces between the rings. The interior consists of sandstone and black areas containing crystallized and carbonaceous remnants of the vascular bundles and ground tissue.



5. Wyoming fossil palm with spiny stems shows numerous bases of spines which had been broken off close to the stem either before or after petrification. At (A) the stem structure had been disrupted by some severe mechanical force before petrification had taken place.

lustrated in this article to demonstrate the variety of fossils one may encounter. Choice specimens are not easy to find today since most material near the surface has already been taken by private collectors. Most of the material has been collected in Southern California, Utah and Wyoming. Other locations from which fossil palm specimens have been obtained are Arizona, Baja California (Mexico), Louisiana, Mississippi, southern Nevada, North Carolina, southwest Oklahoma and Texas. The Arizona fossil wood came from a mine 50 miles north of Wickenburg, and contained visible yellow areas of radioactive material, probably carnotite. The specimens from Searchlight, Nevada have been thought by some to be petrified Joshua Tree. Wyoming has furnished the greatest variety of fossil palm material, most of it being in rocks of Eocene age from the Eden Valley area near Farson, Wyoming. The material includes stems with bark-like outer structures showing leaf base rings and longitudinal fissures, adventitious roots, branch-like structures, cane-like stems, spiny stems, underground root masses and specimens which are suggestive of damage by insects and fungi. Some examples of these structures follow.

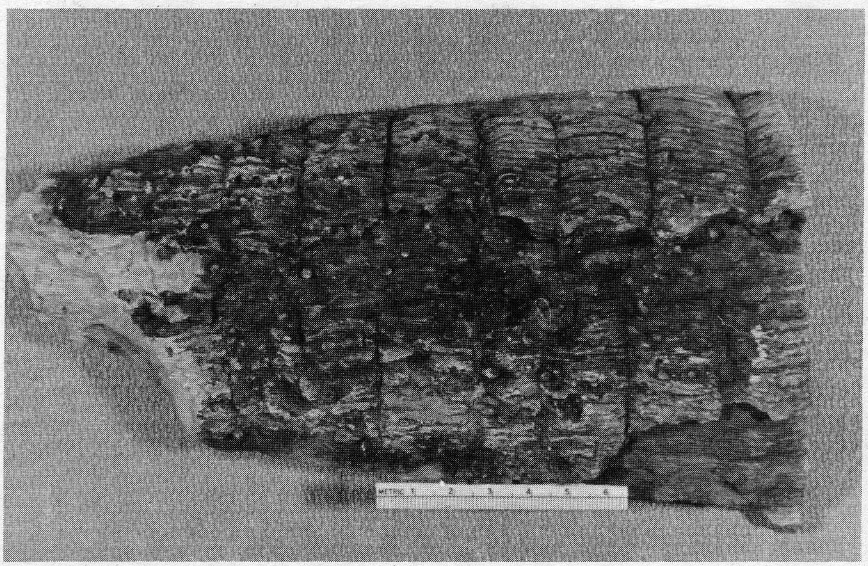
Fossil Palms with Adventitious Roots

Some of the Wyoming stems show an overlying layer of adventitious roots up to 1½ inches in thickness (Fig. 7). The outer surface of the adventitious root mass is covered with a bark-like layer up to 0.15 inches in thickness. In the outer layer, some specimens show well-defined rings of leaf scar origin. It is interesting that this outermost layer covering a thick layer of roots resembles closely the bark-like outer surface layers of many of the Wyoming specimens which do not have adventitious roots. The junction of the inner surface of the adventitious root mass and the cortex of the stem shows some of the roots lying at right angles to the cortex and entering the ground tissue for a distance of about a millimeter. In two specimens the adventitious roots were unequally distributed, some areas having a layer of matted roots up to 1 inch in thickness, whereas on adjacent areas of the same specimen, the roots do not form a thick layer but show single closely spaced short spine-like structures perpendicular to the stem. In some places, two or three of these spines are conjoined and capped by a bark-like silicified structure. The spines show a root structure and their appearance is somewhat suggestive of the root-spines seen on stems of living *Cryosophila.*

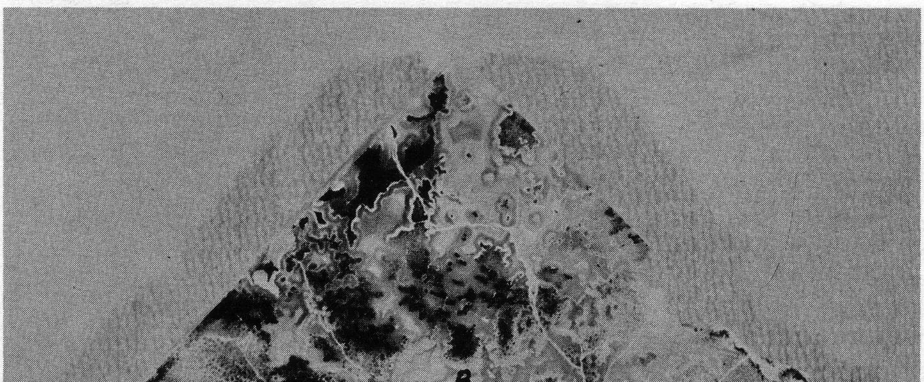
Cane-like Stems

Many fossil palm stems are thick but some are slender and cane-like, resembling those of such modern genera as *Chrysalidocarpus* or *Geonoma.* In Wyoming, cane-like fossils are found in a small valley about one mile across at its greatest width in Sublette Co., near the Big Sandy Reservoir north of the town of Farson. The floor of the valley is covered with sage brush and surrounded by rolling hills about 300 feet high. The matrix which held some of the stems appears to be composed chiefly of limestone which dissolves in hydrochloric acid leaving a small silicate residue soluble in hydrofluoric acid. Most of the cane-like specimens are found free from their matrix.

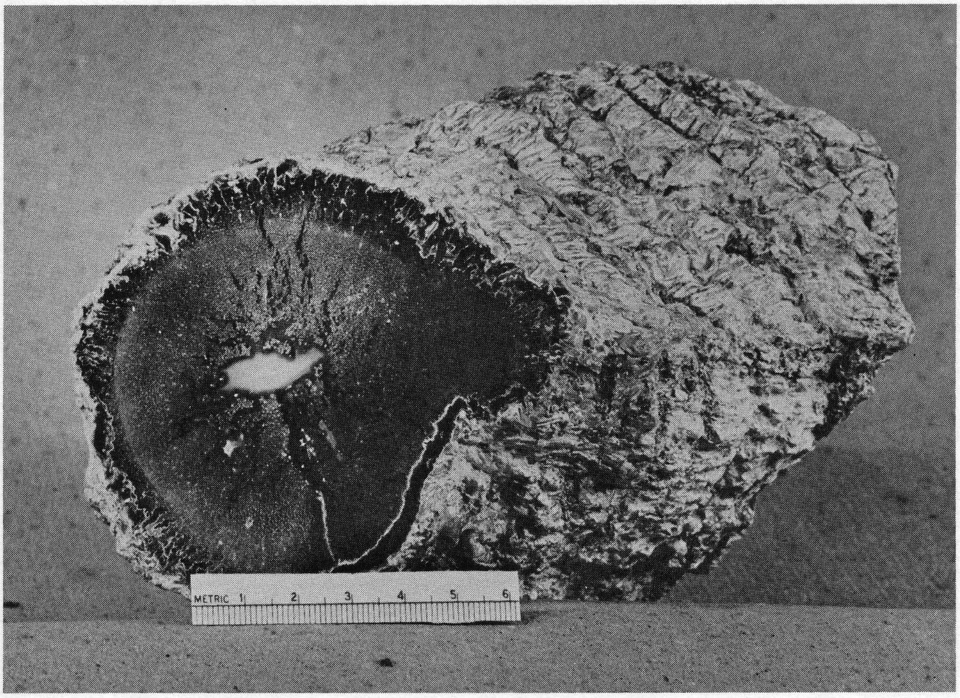
One of the external molds where the stem had fallen out of the matrix shows plainly the outlines of rings (leaf base scars) on the trunk (Fig. 10). A few specimens are black due to a high content of carbonaceous material. The stems are mostly short sections though some are up to 12 inches in length and



6. Wyoming fossil palm with spiny stems shows numerous short spines scattered throughout the spaces between the trunk rings.



7. Wyoming fossil palm with thick zone of adventitious roots. (A) cortical zone of stem. (B) central zone of stem agatized in a variegated fashion. (C) zone of adventitious roots. (D) deposits of fossil algae.



8. Wyoming black fossil palm with central area of white agate formation. The stem is covered by a thick layer of adventitious roots, also an overlying bark-like surface layer showing trunk rings. The spaces between the rings show a gray to white surface layer marked by roughly parallel vertical fissures.

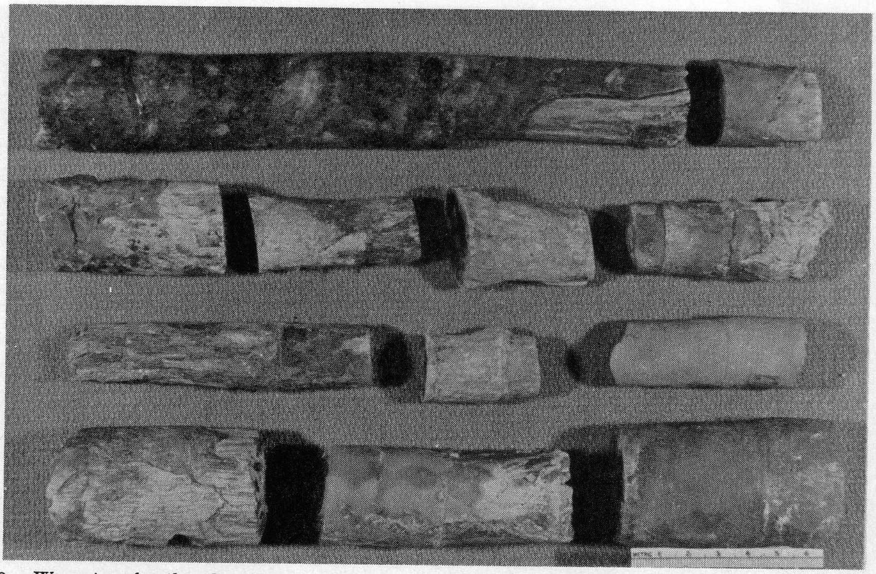
$1\frac{1}{2}$ inches in diameter. An occasional stem with attached roots has been found When the ends are polished some of them show glistening quartz crystals lining cavities; others have jet black areas and foci of blue agate. The broken ends are roughly perpendicular to the long axis. Why they break up or fracture in this particular manner is not easily explained. Visitors have asked this question of the park naturalists in the Petrified Forest National Monument of Arizona (31). They see the huge petrified logs with the ends looking as though they had been sawed by man, instead of having been broken by the mechanical forces of nature. One explanation given is that shock waves caused by earthquakes initiate rhythmic vibrations which caused more or less regularly spaced breaking up of the trunks.

Spiny Stems

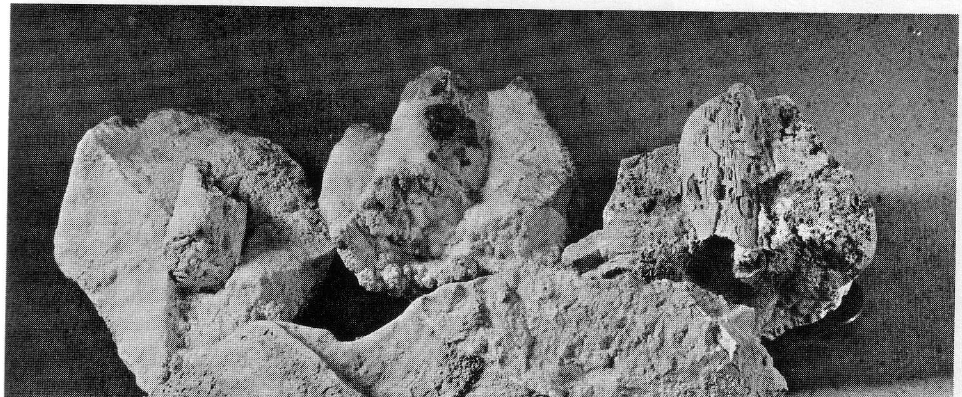
Several examples of stems with spiny structures are found among Wyoming fossil palms. The spines have been broken off close to the stem due to mechanical forces which occurred before or after the process of petrification had taken place. Only scars of the bases of the spines or short stumps remain. The spines are scattered diffusely throughout the internodes between the trunk rings (Fig. 6) without a definite distribution pattern, except in one specimen where the spines were lined up in a more or less parallel fashion. No fossil palms were found where the spines were lined up along the leaf scar rings.

Damage from Insects and Fungi

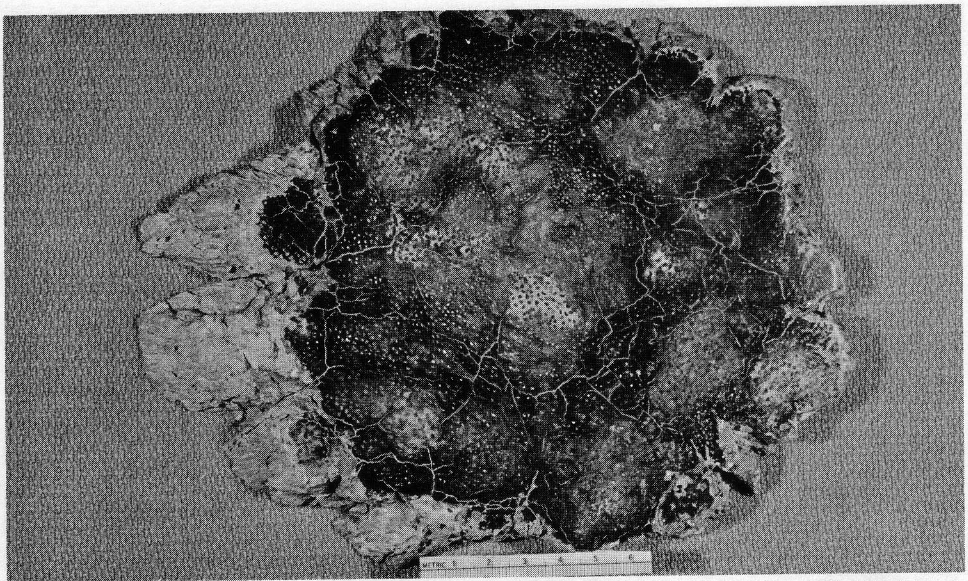
A distorted specimen of fossil palm



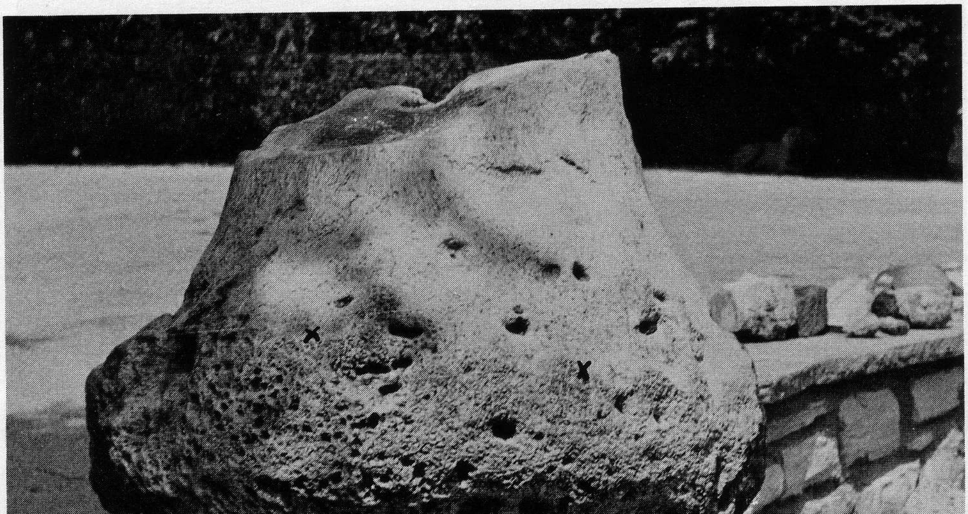
9. Wyoming fossil palms with cane-like stems. The spaces between the trunk rings vary from 2-10 cm. in length. The surface layers have partially disappeared in most of the specimens probably due to weathering.



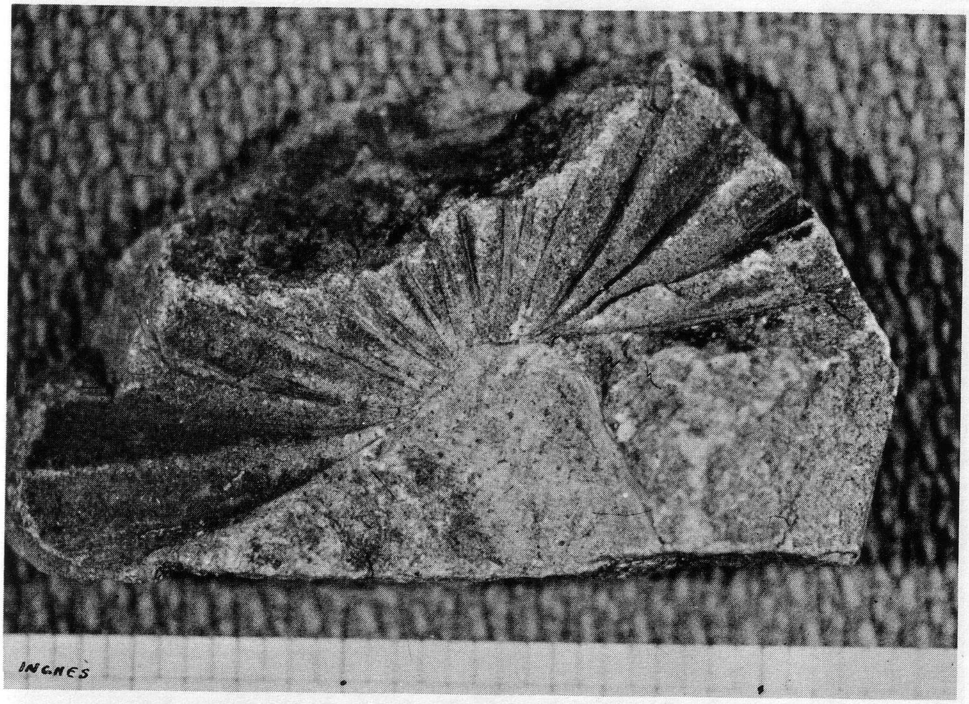
10. Segments of cane-like Wyoming palms. Photograph reduced 60%. The upper specimens represent cane-like stems embedded in a lime-stone matrix. The lower specimen without the stem shows an external mold with trunk ring markings.



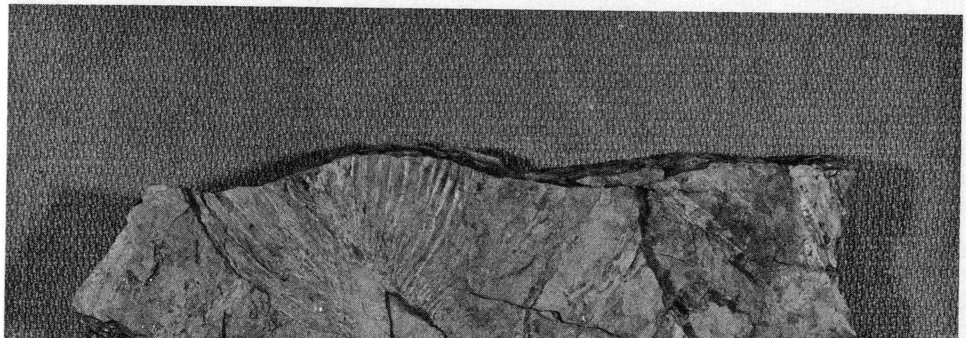
11. Distorted fossil palm (diameter of stem 18 cm.), Mule Canyon, Yermo, Calif. Polished cross-section showing a diffusely mottled gray surface with a few areas having recognizable vascular bundles. In the area to the left are several tiny holes suggestive of beetle borings before petrification. Peel preparations and thin sections show evidence of fungus involvement.



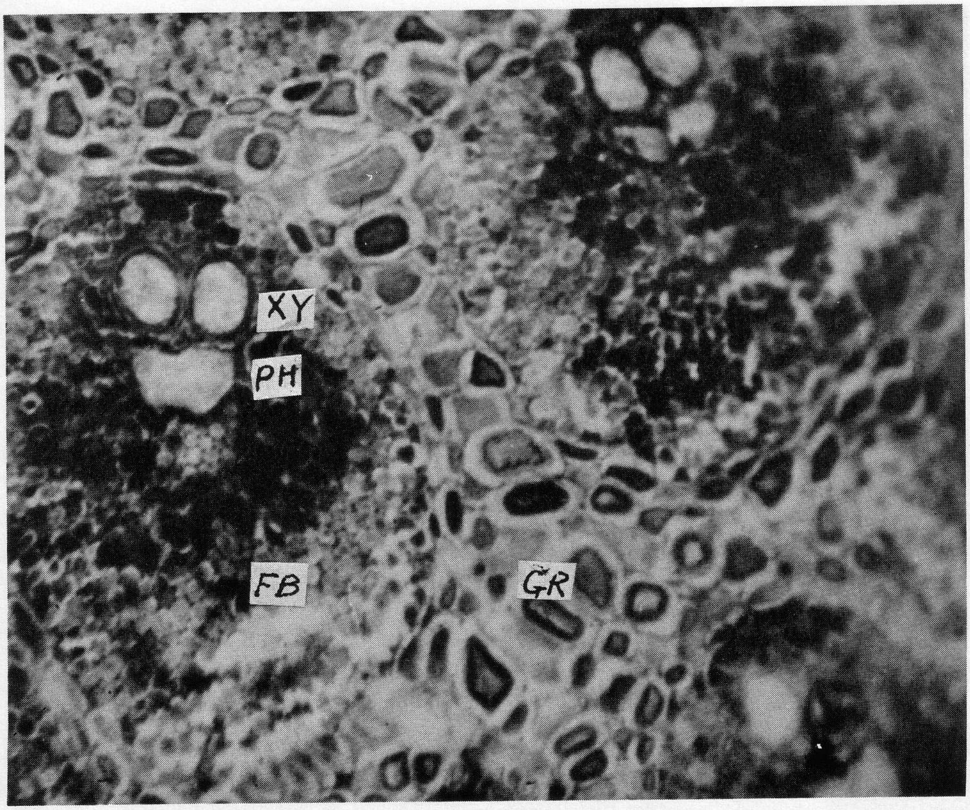
12. Fossil palm stump from LaGrange, Texas. Junction of lower end of trunk (X) and root mass, measuring 22 × 18 × 17 inches and weighing 230 lbs.



13. Fossil palm leaf imprint. Horse Canyon, Kern Co., Calif. Enlarged 2×.



14. Fossil palm leaf imprint, Horse Canyon, Kern Co., Calif. There is a continuation of the petiole as a rib extending into the blade (costapalmate). In the petiole with its rib extension, there is an area which is unfortunately missing.



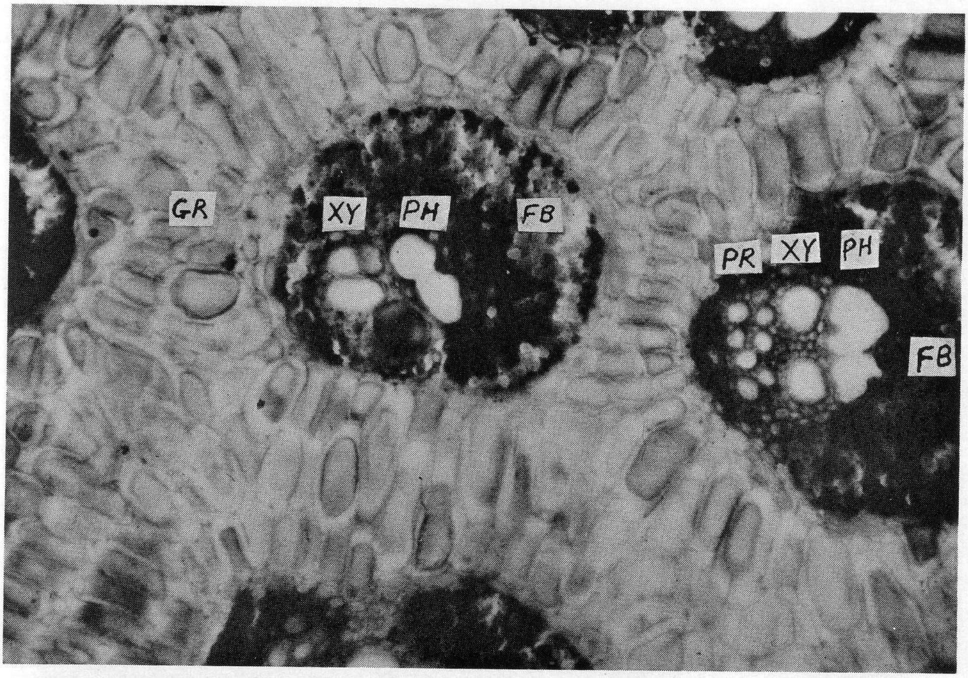
15. Black Wyoming fossil palm (diameter of stem 2.5 cm.). Photomicrograph of peel preparation, magnification 30×, enlarged 2.5×.

(Fig. 11) from Mule Canyon north of Yermo, California is of interest in that cellulose - acetate peel preparations showed filament-like structures suggestive of fungal involvement. Also on the surface of one end of the same specimen are several small superficial borings possibly due to insect damage. These might conceivably have served as the point of entry for fungi, but there is no way to prove such a relationship.

Several thin sections (30 microns thick) were made from the mottled gray areas of the specimen shown in Fig. 11. Most of these thin sections show filament-like structures. Areas are also seen containing several concentric lamellar bodies which with ordinary light show filament-like structures occupying segments of the circumference of some of the lamellae. They are not visible with polarized light. Also scattered throughout some of the micro-crystalline material are single or clumped filament-like structures. Fine fracture lines are observed in the micro-crystalline material. A thin section from this specimen was sent to Dr. E. S. Barghoorn of Harvard University who agreed that the filamentous structures were of fungal origin. Stevens (31) has reported finding fungal hyphae in the central cylinder and roots of a fossil palm coming from the upper Cretaceous, Monmouth formation, Sea Bright, New Jersey.

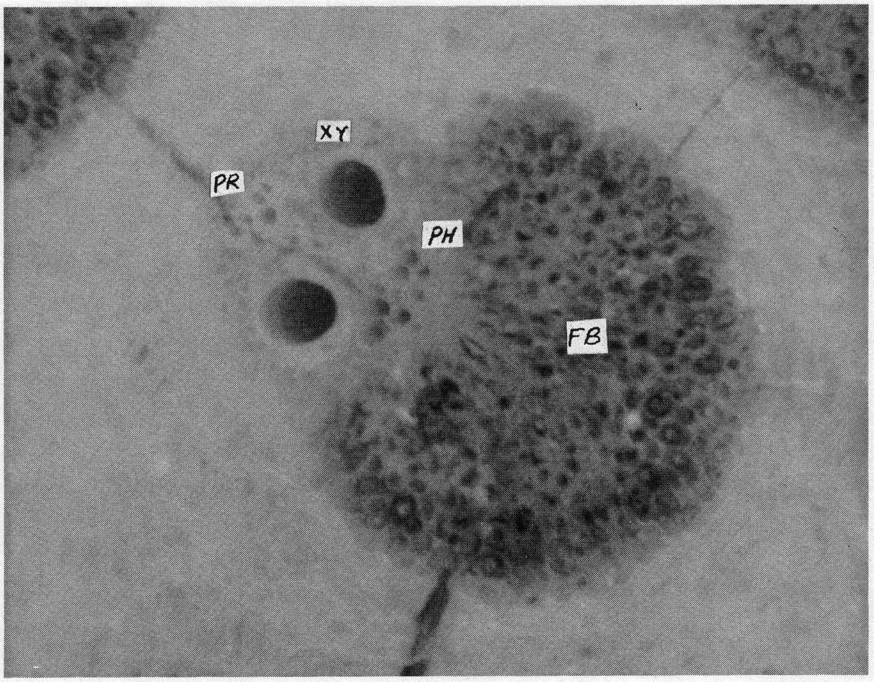
Acknowledgements

This project could not have been



16. Photomicrograph of thin section from same palm as 15, magnification 30×, enlarged 2.5×. PH-phloem. XY-xylem vessels. FB-fibrous bundle sheath or "cap". PR-protoxylem. GR-lacunae in ground tissue.

carried out without the help of interested friends who gave of their time and experience and valuable specimen material. I am indebted to Dr. Chester A. Arnold, Professor of Paleobotany at the University of Michigan for his generous help in identifying many fossil plants from the western states. Dr. E. S. Barghoorn kindly examined one of the fossil palm specimens for fungal involvement. Mr. and Mrs. Samuel E. Kirkby of Riverside, California have been generous in making their private collection of plant fossils available for study, and also for giving expert advice on fossil material. Dr. H. H. Dibbern, Dr. M. Itano and Dr. J. W. Reynolds, associates in the Dept. and Pathology, Memorial Hospital of Long Beach, Calif. and Dr. Ruth Russell of the Long Beach State College have helped with much of the photographic work. Miss Francis Ishii and Mrs. Jackie Young, hospital librarians, obtained references through the inter-library loan arrangement. Mr. and Mrs. Leo D. Berner of Glendora, Calif. and Mr. and Mrs. J. D. Rittenhouse of Azusa, Calif. have beautiful and valuable collections of petrified material which I have had the opportunity to study. Mr. and Mrs. Harry F. Ohlsen of Wilmington, Calif. have furnished several of the Wyoming specimens, which they collected over a period of 25 years. Their exceptional interest in unusual petrified material has been particularly helpful. Mr. James Frank Britsch of Long Beach, Calif. A. Greene, Mr. Archie Greene and Mr. have been of great assistance in cutting and polishing many of the specimens. Mr. and Mrs. Lowell Gordon, Long Beach Gem and Mineral Dealers, have furnished me with several Mule Canyon, Yermo, Calif. specimens. Dr. Grant Beckstrand of Palos Verdes Estates,



17 & 18. Wyoming black fossil palm, diameter of stem 5 cm. Microphotographs using polaroid film, Leitz-Wetzlar metallograph using polarized light.

17. Magnification ×100 taken from peripheral portion of central cylinder showing a single vascular bundle. FB-fibrous bundle "cap". PH-phloem structures. XY-two xylem vessels. PR-protoxylem.

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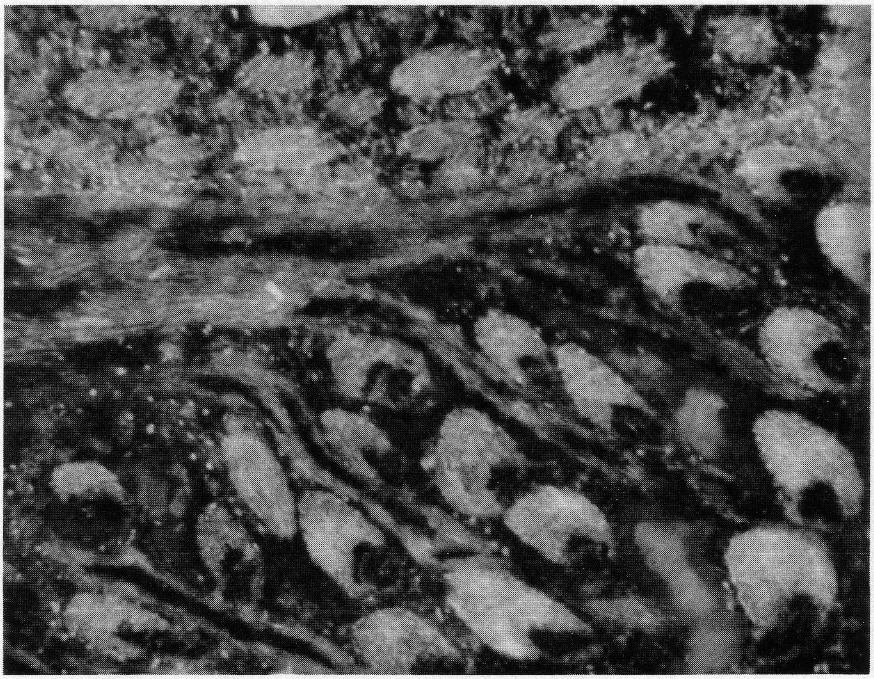

18. Magnification ×50. Upper zone: cortex. Lower: peripheral zone of central cylinder with intricate ramifications of leaf base complexes.

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1. *Allagoptera arenaria* cultivated at Fairchild Tropical Garden with an apparently dichotomous crown. Photo M. V. Parthasarathy.

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2. Close-up of plant shown in Fig. 1. Developing leaf primordia belonging to two buds are indicated by arrows. The leaf immediately below the crown is held by the hand. Photo M. V. Parthasarathy.