II. *Petrifactions of the Earliest European Angiosperms.*

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[Plates 6–8.]

Contents.

Object of the Paper.—To record the evidence for the existence of Angiosperms in England in Aptian times, *i.e.*, at a geological period when they were supposed not to exist in Northern Europe; to describe botanically the anatomy of the specimens, which belong to three new genera; and to note the points of structural and phylogenetic interest in them, in particular because they are the oldest Angiosperms of which the anatomy is preserved, and they are contemporaneous with *Bennettites*.

Introductory.

Except the origin of Man himself there are probably no problems in palæontology of greater interest and importance, and of which less is known, than those which centre round the origin of Angiosperms, and the early history of that group.

The much discussed view, that the Mesozoic family of the Bennettitales indicates the Cycadean stock from which modern Angiosperms have sprung, has, notwithstanding its great theoretic interest, added nothing to our actual knowledge of the early history of the true Angiosperms. This is recognised, even by those who have found most interest in the Bennettitales (see Scott, 1911, p. 238). To our ignorance, the Angiosperms appear to have sprung up with surprising rapidity and to have conquered the world with astonishing ease. They appear also to have worn much the same guise as they still present to the world, even in the earliest strata in which they have been found.

Apart from the fact that forms with foliage of modern aspect were widely distributed in Cretaceous times, we have remarkably little knowledge of the

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group. Of the earliest European and American species we have only leaves, generally in the form of casts of the surface impressions. The systematic botanist is fully aware of the unsatisfactory nature of such data, and of the almost insurmountable difficulty of identifying species even of living forms from isolated leaves alone. In modern systematic work, the flowers and fruits are the criteria of a classification, and, as a consequence, leaves have not been studied sufficiently minutely, nor the data about them organised so that they could be used for the determination of species. It is not even certain whether the most exhaustive work would ever yield data of sufficiently constant character for this purpose, except in the case of single genera or species which show marked individual characters. Innumerable fossil Angiosperms have been named and described from leaves and even fragments of leaves alone, but most of these determinations must be looked upon as of the nature of provisional descriptions, awaiting confirmation or otherwise from the revelations of other and more reliable portions of the plants; the discovery and revelation of these have still to be made.

As so many fragments of "petrified wood" are reported from various deposits of Cretaceous and earlier rocks, one might anticipate valuable information from their study. Nevertheless, hitherto but little has been done with them, for two main reasons: (1) Because from the earlier deposits few or none of the specimens are of Angiosperms. The anatomy of the stems of palms and a few dicotyledons of Upper Cretaceous age have been described from various localities, but from the Lower Cretaceous deposits the woods have hitherto proved to be only Gymnosperms, or, if dicotyledon woods have been recognised, they have merely been casually referred to and not described. (2) The modern Angiosperms are too numerous and too little known to be very helpful to the palæobotanist.

Nevertheless, the stem anatomy of Angiosperms will certainly one day prove to be of as much value to science as has that of the Gymnosperms; while the need for knowledge of the earliest Angiosperms is most urgent. Hence, I feel it of value to publish now the following account of the earliest known petrified stems of Angiosperms, even though no final systematic conclusions can immediately be drawn from them.

The discovery of petrified stems of Gymnosperms and Pteridophytes undoubtedly stimulated the study of the anatomy of modern forms of the groups and led to the wide-reaching results of systematic, morphological and geological importance which such study has yielded. In regard to the anatomy of Angiosperms, living and fossil, we are to-day in much the same position as botanists and palæobotanists were for the earlier groups, when BRONGNIART'S notable contributions appeared in 1828. This is, however, a spur to one to take up the study and at the same time an excuse for the necessary incompleteness of present attempts.

The earliest Dicotyledonous stem of which the anatomy has hitherto been described is one from Madagascar, described by FLICHE (1905), from rocks of Albian age. This

specimen was but poorly preserved, and only the secondary wood was known. It is consequently very incomplete evidence of the nature of the plant to which it belonged. The wood, however, is of quite modern aspect, and like that of a typical woody Dicotyledon.

The Albian of Madagascar corresponds approximately to our Gault, and is consequently at the base of the Upper Cretaceous series. The three stems to be described in the present paper belong to the older formation, the Aptian, which is of Lower Greensand age, and is the Upper of the *Lower Cretaceous* series of beds.

Material.

Specimens which scarcely would be worth description from the Tertiary or Uppermost Cretaceous rocks, where Angiosperms are exceedingly abundant, are of great interest and value from an earlier horizon in which no Angiosperms were hitherto known to occur.

The three specimens which form the subject of the present paper are all in the collections of the British Museum of Natural History. When I undertook to catalogue the Cretaceous plants in these collections, I found them with a large number of other pieces of petrified woods and semi-petrified fragments roughly classified as Gymnospermic wood. Most of these barely promised to repay the labour of studying them; but, with the sanction of Dr. Smith Woodward, all the specimens that seemed to me to be promising were cut. The three Angiosperms were among the earliest I selected for cutting, because even their external texture suggested to me that they were not Gymnosperms, but Angiosperms. The thin sections immediately proved this, and a note was sent to 'Nature' (Stopes, 1910) some months later announcing the discovery of British Angiosperms from the Lower Greensand.

I have to thank the Keeper of the Geological Department for permission to publish a full account of the specimens. Their interesting nature seemed to demand further description than would be suitable for the pages of the 'Catalogue' for which I undertook their study in the first instance. The specimens are V 5654, V 5452, and V 11,517 in the Collections of the Geological Department, British Museum.

While I have not the same absolute guarantee that these specimens are from the deposits whence they are described which I should have had I found them myself, yet there is nothing to cause one to doubt the correctness of their registration. There are, moreover, a number of points of internal evidence in the specimens themselves (see p. 78), which confirm their allocation, and appear to be entirely convincing when taken in conjunction with the Museum labels.

V 5654 was a small twig of isolated, petrified wood about 4 cm. long and 2·5 × 2 cm. in diameter. The exterior was very clean and showed the wood fibre structure and a "knot," while the end was broken at an angle and showed the

irregular surface of the rings. There was no external sign of the branching which the first microscopic section shows was just about to take place at the upper end of the specimen. In the cut surface the vessels, medullary rays, and pith are quite apparent to the naked eye.

The specimen is from the Lower Greensand of Woburn Sands in Bedfordshire.

V 5452 is more fragmentary and does not include the centre of the stem. It is simply a wedge-shaped piece about 3 × 2 × 1 cm. The rays are obvious to the naked eye, and the vessels are extremely large and noticeable. There is no sign of an annual ring; suggesting that they were not present, or that they were so wide that the fragment is a portion within one of them.

The specimen is also from the Lower Greensand of Woburn Sands in Bedfordshire.

The third and much the best specimen is V 11,517. It consisted of a short segment, about 3 cm. in length, of a stem about 3·5 cm. in diameter, and nearly circular. This is partly enclosed in matrix, of a very dark, almost black colour, and of a coarse, sandy texture, which in section shows a large admixture of green glauconite grains. The part of the stem enclosed in the matrix has its bark and phloem preserved in most places, while the rest, where exposed, has been worn down to the wood. This is in places water-worn and shows the ridges of the medullary ray and wood structure. The specimen is registered as coming from the Lower Greensand, but the locality is not certainly known. On the specimen, in addition to the register number, was a small blue label in old handwriting, giving the horizon as the Lower Greensand.

The granular matrix is extremely like that of several other specimens of petrified woods of Gymnosperms recorded from Luccomb Chine, and now in the British Museum. Its granular nature, with a mixture of angular quartz grains and green glauconite grains, is fully characteristic of these Lower Greensand rocks. The specimen is registered as the next entry to a Luccomb Chine specimen, and I think there is little doubt that the Angiosperm also came from the same locality. A further small point in support of this view is the reaction of HCl on the surface of the petrified woods and their matrices. This is identical in the case of the Angiosperm under discussion, and of the stem known to be from Luccomb Chine. The acid acts very slowly on the petrifaction, as it is principally silicified, but it attacks the small quantity of carbonate which is present after a moment or two of apparent inaction. It is also worth noting that the colour and type of preservation of the two petrifactions are also identical. It is well known to palæobotanists that the colour, etc., of a petrifaction is so characteristic that a specialist can generally recognise the locality of a given slide of "coal balls."

Consequently, for all the above reasons, the evidence in favour of the view that the specimen originated from Luccomb Chine seems very strong.

There appears to be no need to question the registration and label regarding its *age*, which is, of course, the main point—and the mere question of which of one or

two English counties it came from is of minor importance. Consequently one can treat the specimen as of Lower Greensand age, probably from Luccomb Chine.

The stem split, and had been put together again some time ago, so that the pith and centre are unfortunately not so perfect as would have been desirable, though one of the sections shows some primary wood and pith fairly well preserved. Annual rings are scarcely visible to the naked eye in the block, but are apparent in the sections. The phloem and cortex form a solid zone 1·5 mm. in width. The preservation of the detail, even of the pit canals in the transverse sections of the wood elements, is extraordinarily beautiful in this specimen.

Geological Data.

In the preceding paragraph it is noted that all three specimens under present consideration are of Lower Greensand age.

The geological position of the English Lower Greensand has been discussed a good deal in geological literature, and perhaps the clearest classification is that recommended by Jukes-Brown and Topley (1888). It is fully sufficient for our present purpose, and is also in general agreement with the system still adopted by most geologists. In it the Cretaceous system is divided as follows:—

		English.	*Continental.*
Cretaceous System	Upper Series	——	Danian.
		Upper Chalk	Senonian.
		Middle Chalk	Turonian.
		Lower Chalk, Upper Greensand	Cenomanian.
		Gault	Albian.
	Lower Series	Lower Greensand (including Carstone, Woburn Sands, etc.)	Aptian.
		Weald, Hastings Sand	Neocomian.

The flora of the British Lower Greensand has been practically ignored except for a few isolated specimens which have been botanically described from time to time. Of these the principal are *Cupressinoxylon* from the Isle of Wight, described by Barber, 1898; the supposed "Dragon tree" (see Mackie, 1862; Seward, 1896; and Stopes, 1911); and the notable specimens of *Bennettites* (see Carruthers, 1870), which have been constantly referred to by later writers. Several Lower Greensand plants, chiefly Gymnosperms, were described in the Report of the British Association Committee for the study of the Tertiary and Secondary Floras of Britain (see Gardner and others, 1886), and a number of others were described from time to time by Carruthers.

In his 'Catalogue of the Wealden Flora,' Seward (1894–5) includes several plants from Potton and Leighton Buzzard, but these are truly Wealden in all probability, for though they occur in the Lower Greensand deposits they have every

indication of being derived fossils. SEWARD, 1895, p. 166, says: "The exact age of fossils from these beds must be a matter of some uncertainty, owing to the fact of many of them being clearly derived forms; it may be noted, however, that some of the plant fossils from Potton appear to be specifically identical with Wealden types." In his 'Catalogue' also SEWARD includes some other Lower Greensand plants from different localities which probably are not derived but are really of Lower Greensand age. This was probably largely a matter of convenience, as at that time the extent and interest of the true Lower Greensand flora was unsuspected. Stratigraphical geologists distinguish between the Wealden and the Lower Greensand, and from data in my possession but still unpublished I should incline also to distinguish sharply between the floras of the two periods. The discovery of the present Angiosperms is in itself sufficient basis for this, for, as is well known, the Wealden flora is characteristically of the older facies, and devoid of Angiosperms. SEWARD, 1895, p. 240, says: " . . . we search in vain among the abundant samples of the Wealden vegetation for any fragments of monocotyledonous or dicotyledonous plants . . . The true Wealden vegetation would seem to have been without any examples of the highest class of plants, and may be looked upon as the last of the Mesozoic floras in which the gymnosperms represented the limit of plant development."

The separation of the Lower Greensand flora from that of the Weald will help to bring palæobotanical work more into line with stratigraphical geology; as well as, at last, focussing attention on the flora of a period of special interest to palæobotanists because in it both the Angiosperms and the now extinct Bennettitales were flourishing side by side.

We will now turn to a consideration of the beds in which the present specimens were found. The Lower Greensands of Woburn district, from which two of the specimens come, have long been known as a source of fossil wood, although, so far as I can discover, none of this wood has ever been scientifically described or figured. It has been assumed to be Gymnospermic, and most of what has passed through my hands undoubtedly is so. One of the interesting specimens in the British Museum is a fine branch of silicified wood from Woburn Sands, in the original Sloane Collection, a collection which formed a nucleus of the British Museum itself in its early days.

CONYBEARE and PHILIPS (1822, p. 138) quote *in extenso* a paper published by Mr. HOLLOWAY in the 'Philosophical Transactions' for 1723 on the beds of fuller's earth in Bedfordshire. This describes the pits by Woburn, which have been worked intermittently ever since, and it is from these pits that the present specimens appear to have originated.

WOODWARD (1887, p. 378) gives references to the earlier notes on the Woburn beds, and remarks on the fossils of Leighton Buzzard, Woburn, and Potton Lower Greensand, many of which are derived from older horizons.

The actual age of the beds, however, is determined by the fact that they are clearly overlain by the Gault, and also by the presence of indigenous fossils such as *Waldheimia woodwardi*, *Terebratula depressa*, *Opis neocomiensis*, *Trigonia alæformis*, and others *in situ*.

LAMPLUGH and WALKER (1903), in an important paper on the neighbourhood, established the fact that, in undoubted Lower Greensand which was overlain by Gault, was a fossiliferous band containing a fauna with distinctly Upper Cretaceous affinities. From the present point of view, it is of interest to note this in connection with the flora, which also suggests a more modern aspect than that of the preceding beds. It is also germain to the subject to note LAMPLUGH'S and WALKER'S remark, p. 264, in their summary, where they say: "The lithological characters of the bed indicate a sea-bottom of moderate depth, swept by powerful currents; and the conditions were thus similar to those which persisted in the neighbourhood throughout Lower-Greensand times. The overlying Gault shows a change to more tranquil waters, probably of greater depth."

At present we have no palæobotanical knowledge of the continent or islands which caused those currents and supplied the *débris* that has been petrified in the sands.

The beds which yield the petrified wood are *below*, and not above the fuller's earth band, and are consequently a little older than the beds in which LAMPLUGH and WALKER obtained their fauna, but the fossils now to be described also "present facies different from that of any previously-known fossiliferous horizon of the Lower Greensand."

From Potton and Leighton Buzzard, both geographically near to Woburn, several well-known plants have been found, such as *Cycadeoidea Yatesii* of CARRUTHERS (1867) and SEWARD (1895). But these are generally recognised as being derived from the underlying strata, and are consequently of Wealden age, if not older.

This raises the point—whether the present fossils are truly from the Lower Greensand, or are also derived. If they should be derived, it would merely add to their interest and make these Angiosperms of Wealden or Jurassic age instead of Aptian. But there is no ground for pushing the age of these plants back beyond the legitimate geological age of the beds in which they are found. LAMPLUGH and WALKER note in their fossiliferous band (p. 243), that despite their delicacy the shells show no abrasion, and "it is clear that the Molluscs have flourished at the site where their shells now occur." This strengthens the likelihood that, in the neighbouring, plant-containing beds, the plant fossils are also indigenous. The dark, often pyritised stems of the Leighton Buzzard *Cycadeoidea* differ considerably from the colour and texture of the beds in which they lie, and even externally suggest that they are derived fossils, but the pieces of wood of the Woburn beds are unlike them, and are mostly simple, iron-stained silicified fragments of the colouring and texture one would expect from the beds in which they lie. Taking into account the Gymnospermic wood, of which there are numerous specimens from these beds, one

can say that they are scarcely water-worn, drift fragments, which look as if they had not drifted far before they were enclosed in the swiftly accumulating sand and petrified, and had not moved since.

Beds at Woburn Sands have long been worked for the fuller's earth, and, in the course of this working, the plants have come to light from time to time. They have always been found only a few at a time, and the findings have been scattered over long periods. Consequently, though petrified wood is distinctly rare in the beds, considerable numbers of pieces of it have accumulated by now.

When my attention was directed to the district by the discovery of Angiosperms among the specimens coming from it, the Rev. Dr. HORT, of Woburn Sands, proved kindly helpful and instrumental in getting further specimens, and also in inducing the present manager of the fuller's earth works to allow me to examine the beds *in situ*.

In the hill above the village of Woburn Sands are several excavations exposing a reddish iron-stained sand, which lies above the fuller's earth, and which is almost devoid of fossils. To reach the fuller's earth beds a shaft is cut in the hill through the sand for about 100 feet in depth. The fuller's earth itself is a rather irregular band of 3–8 feet in thickness. In it practically no fossils are found. In the sand immediately below this most of the recorded pieces of wood were obtained, according to the workmen. They state that the place to look for fossil wood is immediately below the earth, though one large piece of Gymnospermic wood was found immediately above it.

The Lower Greensand at Luccomb Chine is principally noteworthy from the discovery of some splendidly petrified *Bennettites* trunks in it. *B. gibsonianus* of CARRUTHERS (1870) is from these beds. In the British Museum of Natural History there are also several undescribed petrified woods from the same locality, of which mention has been made already (p. 80).

For botanists, it is a suggestive and attractive thought that we have Angiospermic petrifactions, not only from the same horizon as *Bennettites*, but that probably one of them grew on the very spot beside this ancient type.

Distribution of Lower Greensand Angiosperms.

In Europe hitherto, Portugal has yielded the earliest representatives of the Angiospermic families. These are, however, only leaf impressions. SAPORTA (1894) described a number of species from several beds, in considerable quantities. Their locality, on the coast of southern Europe, has hitherto seemed to fit in with the theory that the modern type of Angiosperms arose in the Atlantic basin of the American continent, and in Lower Cretaceous times had already spread and multiplied considerably on the trans-Atlantic lands. They are supposed to have reached no further than the opposite shore in Europe by Lower Cretaceous times. CHAMBERLIN and SALISBURY (1906) in their advanced text-book, p. 131, say: "The

evidence as it now stands points to the borders of the North Atlantic as the place of origin [of the Angiosperms] and the late Jurassic or earliest Comanchean, as perhaps the time, though the evidence is less strong on this point."* In Portugal the Angiosperms appear in the Aptian stage and are abundant in the Albian. They are not yet present in the true Neocomian. CHAMBERLIN and SALISBURY continue, p. 133: "The view that seems best justified at the present stage of evidence is that the Angiosperms developed on the old lands of the eastern part of North America, and that until the close of the Lower Cretaceous they had only spread westward as far as Kansas and the Black Hills, northward as far as Greenland, and eastward to the coast of Portugal, but not to Europe generally, nor to the western part of North America."

Though these general conclusions continue to stand in most particulars, the present paper, by describing three species of Angiosperms in England at a date when they were hitherto supposed not to have spread further than Portugal, suggests that the early Angiosperms were probably more widely spread than is supposed.†

Against this important conclusion, it might conceivably be argued that, as I myself have been at some trouble to make clear, the plants from the Woburn beds at least, if not also that from the Luccomb, are drift wood, and that consequently it might have drifted up from Portugal, or even across from the Atlantic coast of America, and consequently does not represent a local flora. Such travelled trunks are to-day found in quantity on the shores of Spitzbergen.

This seems most unlikely, however, for three principal reasons:—

(1) The present fossils are not at all teredo-bored, as is nearly all wood which has travelled any distance or floated about in the sea for any length of time. (2) In two of the specimens the wood is remarkably little decayed prior to petrifaction and is not patchy and locally decayed as is typical of drifted plants when petrified. In

* It should be noted that actual reliable finds do not antedate the lowest Cretaceous; but as the Angiosperms are so numerous in the Cretaceous and so widely spread, it is reasonable to suppose that they must have originated earlier.—M. C. S.

† Since the present paper was completed, Dr. BERRY'S important work on the Lower Cretaceous flora (BERRY, 1911) has reached me. His general account of the Lower Cretaceous plant impressions, and the elucidation he gives of the many difficulties of correlation of the different deposits, are invaluable, but he describes no petrified specimens, so his species do not bear very directly on the subject of this paper. The large majority of the Angiosperms he describes are of Albian (Patapso) age. *Rogersia*, *Ficophyllum*, and *Proteæphyllum* of Neocomian (Potomac) age are regarded by him with suspicion. Dr. BERRY (p. 148) says: "The writer is convinced that these forms are not Angiosperms. . . . The evidence of the angiospermic nature of any of these remains is scarcely worthy of confidence. Nothing remotely suggestive of this class is known from the Wealden floras of England, Belgium, or Germany, the Neocomian flora of Japan, the Kootanie flora of Montana and British Columbia, or even from the Barremian of Russia, France, and England. The so-called Urgonian of Greenland contains undoubted dicotyledons, but their exact age is not altogether beyond question, and they may be considerably younger. There is fairly satisfactory evidence of Angiosperms in beds which are classed as Aptian, and by the close of the Albian dicotyledons become a considerable element in the floras."

this connection one might contrast the beautiful preservation of V 11,517 with that of a typical piece of wood from the "roof-nodule" of the carboniferous. (3) That one of the specimens has not lost its comparatively well-preserved phloem and bark layer, which it certainly would have done had it travelled any distance.

One may take it therefore as most unlikely that these stems are representatives of a far distant flora; and they may fairly be held to indicate the existence of Angiosperms in England in Aptian times. It is a strengthening of this conclusion, that the Lower Greensand from two such widely separated localities as Woburn and the Isle of Wight have yielded the fossil stems.

Owing to the physical character of the sandstones, etc., which represent the Lower Cretaceous epoch in England (apart from the Wealden), it is not surprising that plant remains are so poorly preserved in them in the form of impressions, and that consequently the assumption has been made that Angiosperms were not growing in the locality at these times. Petrified specimens of wood, etc., have been little noticed by collectors in most places, but it is from the study of such unobtrusive remains that Palæobotany is likely to advance most in its knowledge of the Angiosperm problem.

The botanical interest of the present specimens is not affected by the question of the *locality* in which they grew. From whatever place they originated they appear certainly to be not later than Lower Greensand age, and are consequently the earliest petrified Angiosperm stems to be described. Points of morphological and systematic interest will be noted after their detailed structure has been described.

Botanical Description of the Specimens.

Specimen V 11,517, Nat. Hist. Mus. Coll. (See p. 77.)

[*Aptiana radiata, gen. et spec. nov.*]

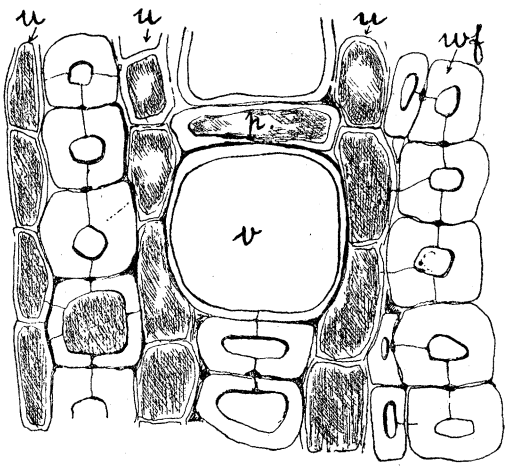
This fossil consists of the petrified wood and bark of a small branch, which is exquisitely preserved. The wood is 3·5 cm. in diameter, and the phloem and bark form a zone outside this about 1·5 mm. in thickness. Plate 6, Photo 1, shows the general appearance of a transverse section. The broad and numerous rays are very apparent, and the phloem and cortex is seen on the side which has been protected by the granular matrix. Photo 3 is an enlargement of a portion of the same section, and illustrates the details more clearly. Noticeable features of the stem are the funnel-like expansion of the rays in the phloem and cortex, and the irregular sclerised patches in the phloem. In this photograph the narrow medullary rays, principally uniseriate, which run between almost every two radial rows of tracheids and vessels are apparent. These can be better seen in Photo 4. In Photo 4 also the relative sizes of the vessels and fibre tracheids is apparent, and it will be noticed at once how small the vessels are and how little they disturb the radial series of fibre elements, which is one of the most salient characters of this wood.

The Pith.—Although the stem was broken by longitudinal fractures before its nature was noted, and the sections cut, it still shows fragments of the pith. The cells seem to have been unspecialised, without noteworthy characteristics. In diameter they are about 0·03–0·04 mm., and they fit together closely in approximately hexagonally compressed circles. The walls are somewhat thickened, and most of the cells are packed with roundish, slightly irregular bodies which suggest storage starch grains. The small cells of the primary vascular tissue abut directly on these cells without any definite sheath.

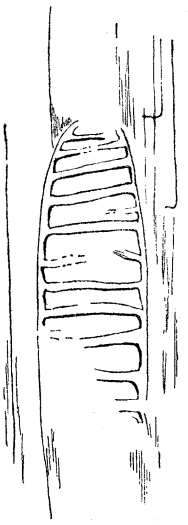
The Primary Wood.—There are no prominent primary bundles, but a nearly continuous ring of primary woody tissue round the pith, which is of interest in connection with the various views held by botanists as to the real significance of primary bundles in modern Dicotyledons. Among the cells of this inner zone of tissue there are no large vessels, and the small cells composing it average about 0·017 mm. in diameter for the first 12–15 cell rows. Their walls are thickened, but considerably less so than those of the fibres that come outside them. Longitudinal sections actually cutting the protoxylems have not been obtained.

The Secondary Wood.—The secondary wood is compact and uniform in structure, the annual rings are structurally recognisable but are not clearly marked by any noticeable change in the character of the wood or size of the vessels. There appear to be about 28–30 years' growth, but it is a little difficult to determine the limit of some of the rings.

The Vessels, with a few exceptions, are isolated and stand separated from each other in the radial rows of fibre tracheids (see Photos 4, 6, and 10, and text-fig. 1).



TEXT-FIG. 1.



TEXT-FIG. 2.

TEXT-FIG. 1.—Transverse section of wood of *Aptiana*, showing *u*, uniseriate rays; *wf*, wood fibre-tracheids, some with bordered pits; *p*, parenchyma (?) cell spanning between two uniseriate rays immediately behind vessel, *v*.

TEXT-FIG. 2.—Scalariform pitting of a vessel of *Aptiana*.

In one or two cases two vessels stand adjacent in the tangential direction, but such pairs are few. The vessels are roughly circular in outline, and average 0·028–0·04 mm. in diameter, about 0·033 being the commonest size. The walls are thickened, but not remarkably so, and the lignified wall is much thinner than that of the adjacent cells. In longitudinal section not many of the vessels show the character of their walls, but those that do have broad, simple scalariform pitting (see text-fig. 2), or else irregularly placed simple round or slightly oval pits of smaller size.

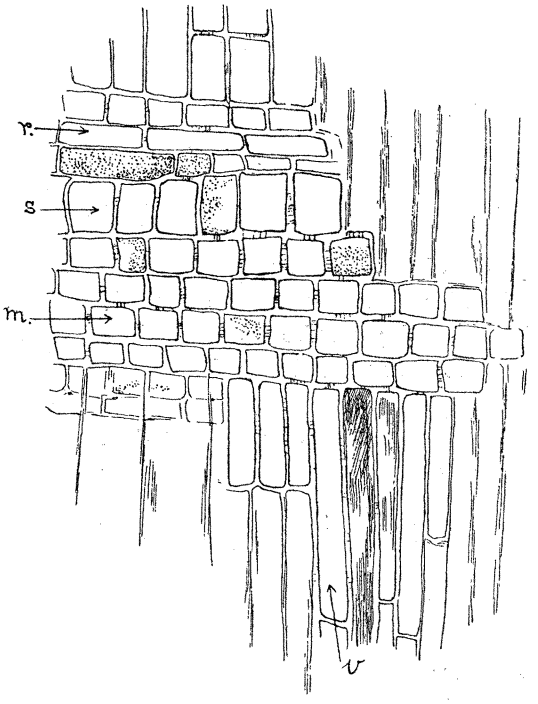
The Fibre Tracheids.—Apart from the vessels the wood appears to be entirely composed of thick-walled, fibre tracheids. They average 0·015–0·005 mm. in diameter, and are arranged with considerable regularity in radial rows which are remarkably little disturbed by the vessels. In most cases the wall is thickened so that the lumen of the cell is one-third or less that of its whole diameter (see Photo 10, Plate 8, and text-fig. 1). In the thickened walls, in transverse section the pit canals show with quite remarkable clearness. In innumerable cases, numbers of cells in the same microscopic field will all show the pit canals and the bordered pit in the walls (see Photo 10, Plate 8, and text-fig. 1). All the elements appear to have these bordered pits, and must therefore be looked on as tracheids, though many of them have unusually thick walls, and were the pits not so unmistakably preserved, would be taken for fibres. Where necessary to fit in a given space the cells are hexagonal or slightly irregular, but where they are undisturbed the cells tend to be square or oblong, with the tangential walls slightly the longer. In longitudinal section the fibres show one, and in a few cases two, slightly irregular rows of pits in each wall. The pits are round and clearly bordered. They are not very closely arranged in vertical position, each being spaced at a distance from its neighbour roughly equal to its own diameter.

Wood Parenchyma.—In only one or two cases have I been able to detect cells which bear examination and still leave one with the feeling that they are parenchyma cells. These, also, have thickened walls, but in them only simple pits (if any) are visible, and they have more blackened contents than the others. Several such lie just behind vessels, spanning the distance between the rays, as in *p*, text-fig. 1. Scarcity, and possibly even lack, of wood parenchyma must then be considered characteristic of this wood. The rays are so numerous and run in such a way that nearly every fibre and vessel is in direct contact with them, so that there seems no physiological necessity for wood parenchyma in addition.

The Wood Rays.—The structure of the "medullary" rays is of great interest and importance in all woods. In this particular specimen there are several features that call for special notice.

The low-power view of the wood, Photo 1, Plate 6, shows that the rays are numerous and broad, though none are as broad as the large compound rays of the Cupuliferæ. The broad rays are principally 4 cells wide (a few are 3 or 2) and a dozen cells in height. Between these are innumerable uniseriate rays, 4–10 cells in height. A

noticeable feature of the transverse view of the wood is the way many of the broader rays die out altogether, or dwindle down to one cell thick in transverse section. None of the "primary" rays ever reach the cortex to form the spreading ended rays there. Such a case is seen in Photos 3 and 4 at *dm*, and many of them can be seen with a lens in Photo 1. This arrangement is represented diagrammatically in text-fig. 4. This shows that on a transverse section, broad rays, starting in the wood, do not reach the cortex at all, or only reach it as uniseriate rays. While it is very possible that, as both Prof. OLIVER and Dr. SCOTT have suggested to me, this is due to the rays therein lying somewhat oblique, in a radial sense, so that any transverse section passes through them, yet it remains an unusual feature in the truly transverse

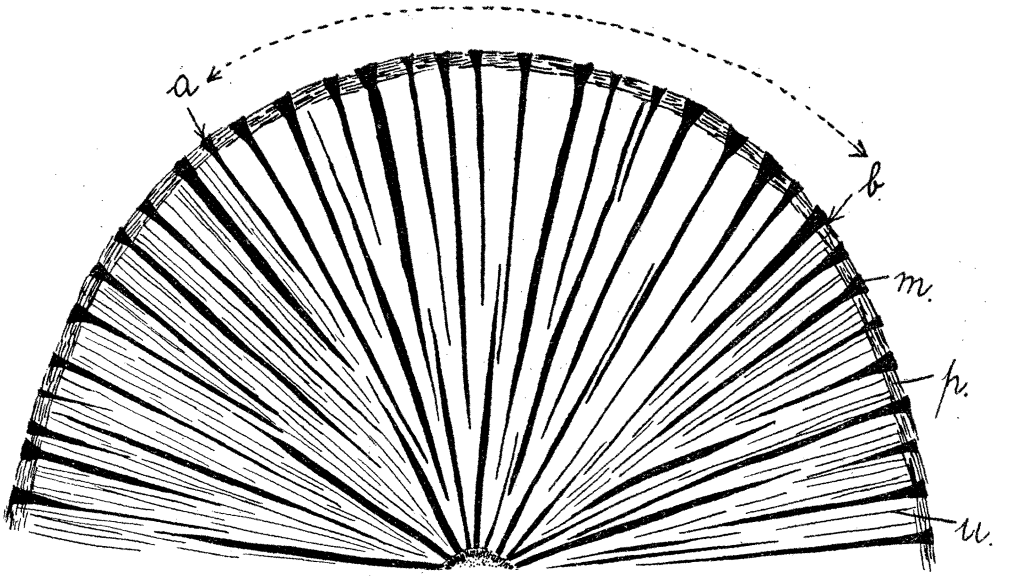


TEXT-FIG. 3.—Radial longitudinal section of wood of *Aptiana*, showing different types of cells composing the rays. *m*, small rectangular cells forming the majority of the ray cells; *s*, larger square cells of similar type; *r*, radially elongated cells; *v*, vertically elongated cells at top and bottom of ray.

section of the wood, and gives it the character shown in text-fig. 4, which separates it from any wood with which I am acquainted.

Such an arrangement in transverse section is correlated with a compound system in tangential section, as is seen in text-fig. 5. The remarkable height of a number of the individual cells is particularly noticeable in the smaller rays. The individual cells composing the rays are of three principal types. The almost square or rectangular cells, which form a brick-like band in the main thickness of the ray, *m*, text-fig. 3; slightly larger cells of the same type, *s*, text-fig. 3, and other rectangular ones which are elongated considerably in radial direction, *r*, text-fig. 3. There are also several sizes of cells of greater or less vertical elongation, *v*, text-fig. 3,

which can also be clearly seen at the ends of the rays in tangential section in fig. 5, Plate 6, *v*.



TEXT-FIG. 4.—Somewhat simplified diagram to show the structure of the ray system in the transverse stem. *p*, phloem cortex in which the broad rays expand in a funnel-shaped manner; *m*, broad rays (3–4 cells in width in the wood); *u*, uniseriate rays. These latter have been entirely left out in the part of the stem *a–b* so as to show more clearly the distribution of the broad rays.

TEXT-FIG. 5.—Tangential view of the "medullary" rays in the same stem.

The "medullary" ray cells all appear to have thickened and pitted walls (see Photo 10, Plate 8, *m*). The rays are multiseriate and uniseriate, and it should be noted that there are none of the broad compound rays which are common in some woods, and which have been found in Upper Cretaceous woods (see STOPES and FUJII, 1910), and from whose presence in the Cretaceous THOMPSON (1911) drew support for his theories of the origin of rays. If, as THOMPSON (1911, p. 1013) says: "The multiseriate ray represents the most recent development in ray structure among the Dicotyledons," it was well developed in the plant at present under description at the early date when *Bennettites* was alive, and the same plant is without any sign of the supposedly more ancestral compound rays in its structure.

The Phloem.—The general character of the phloem is well seen in Photo 3, Plate 6. It is composed of rather irregular alternating groups of soft tissue (presumably sieve tubes, but in the fossil they are somewhat crushed) and sclerised fibres. Each of the nests of fibres consists of from two or three cells to a dozen. Through the larger nests the uniseriate rays are continued in the form of thinner-walled cells with blackened contents. Most of the multiseriate rays that run through the outer zone of the wood are continued into the cortex, and there expand into the broad funnel-shaped ends seen at *r*, Photo 3, Plate 6. In these ends the cells are small and are tangentially arranged, but there are few tangentially elongated elements. These funnel-shaped ends of the rays immediately suggest a comparison with those of *Tilia*, but the rest of the structures are so unlike the wood of that genus that I think there is no real basis for any comparison of the two plants.

The Cambium is preserved in places and is quite a normal one.

The Cortex.—Beyond the phloem zone the cortical tissues are crushed and blackened too much for description of any actual elements. There is some suggestion of a cork layer. There do not appear to be any special cells with crystals, resin canals, or any characteristic features.

This plant, now described in some detail from its anatomy, must be named and diagnosed. I will here forestall my account of its possible affinities by saying that it does not resemble any living genus sufficiently to be placed with certainty in any known family. Consequently, in the interests of science I shall give it an entirely non-suggestive name, for nothing is more detrimental to palæobotanical work than the giving of names which suggest supposed likeness without foundation for such connection.

The plant is from rocks of Aptian age, and this is its main point of interest apart from its anatomical structure. Consequently the name I give it is the generic name of *Aptiana*, and the specific name of *radiata*, which is descriptive of the appearance of the transverse section with its numerous rays.

Aptiana radiata, gen. et spec. nov.

As the single specimen alone is known, and also as modern botanists are not yet in a position to determine which features in stem anatomy are of generic and which of specific importance, I will define the species and genus together.

Diagnosis.—Primary wood without marked "bundles." Secondary wood consisting entirely of fibre tracheids with well-marked bordered pits, and of small singly placed vessels which are so arranged as barely to disturb the radial rows of the fibre tracheids. Wood rays uniseriate and very numerous, generally between each pair of radial rows of wood elements. Multiseriate rays principally 3–4 cells wide, also numerous. None of these run all through the stem in transverse section but they dwindle to uniseriate rays, or die out entirely. The multiseriate rays reaching the phloem expand to funnel-shaped ends. The phloem composed of sclerised elements and of soft cells in irregular alternating patches. Annual rings developed, but not very noticeably differentiated as regards number and size of vessels.

Age.—Lower Greensand (Aptian): locality, probably Luccomb Chine.

Type.—Brit. Mus. Nat. Hist., No. V 11,517, block and series of sections.

Discussion of Affinities.—Before a palæobotanist can discuss the affinities of a fossil, he must either himself have considerable knowledge of allied modern groups, or must have such knowledge on the part of another, available for his use. Now, it is essential to point out here that there is perhaps no branch of modern botany in a more chaotic condition than that dealing with the anatomy of Angiosperms. The Gymnosperms are few in number, and the facts have been sufficiently marshalled to be of use. Angiosperms are enormously numerous, and the facts, incompletely collected, are not marshalled at all. It is, therefore, entirely premature to attempt any such discussion of the possible affinities of this fossil, as one could give, let us say, to a new *Poroxylon* or *Araucaria*. In evidence of this I may mention that for more than a year I have been showing this fossil wood to many of the leading botanists of this country, Europe, and America, and that among the numerous opinions kindly offered, I have been told it resembled closely nearly every family ranging from the Gnetales on one hand to the Malvales on the other. This is not to be interpreted to mean that the woods of all these families are alike, and that consequently classification of them is impossible, but it is due to the comparatively few samples that any one individual studies and to the great range of variations between the woods of so-called species of so-called genera. By far the best account of wood structures with which I am acquainted, viz. Moll and Janssonius (1906), gives, for example, a very different account of the Magnoliaceæ from the one that would have been written had the woods from temperate regions and not those from Java been the main object of their study.

Further difficulties arise from the fact that as the new fossil wood is of such an early age, it is most unlikely that it belongs to any living genus. At the same time

we know almost nothing of the plants of intermediate age, the details of whose structure, were they fully known, would indicate the lines of descent connecting the earlier Angiosperms with those now extant.

Several points, however, may be noticed. There is not a single feature of "Cycadean"-like character in the wood, and if Angiosperms arose from that group, they must have done so even further back than has been supposed. Nor are there, so far as I can detect them, any features suggestive of descent from the woody Gymnosperms. The plant indeed is in every detail like one or other of the modern, highly specialised types of Angiosperms. Its bordered-pitted wood fibres resemble many of the higher types, for such bordered pits are common to half at least of the principal families. The entire, or nearly entire absence of wood parenchyma, however, is much less common. Indeed, I have not succeeded in finding a living family in which this is a characteristic feature.

To save a rather profitless recapitulation of comparisons I may state that, after having looked through all the available wood sections at a number of Universities here and abroad, after examining all the published figures available, and using with considerable profit the set of more than two thousand micro-photographs of woods by JAMES WEALE, the conclusion is apparent that there is none of them which coincides with the fossil entirely. The genera which I was able to examine which showed most points of likeness to the fossil were some species of Lonicera, of Viburnum, of Magnolia, and of Liriodendron.

On this, however, I lay no stress, and consider that for the present more definite statements regarding possible affinities would be purely theoretical and unprofitable. There is every reason to hope that in the future the structure of this and other early Angiosperms will be associated with the fructifications and other parts.

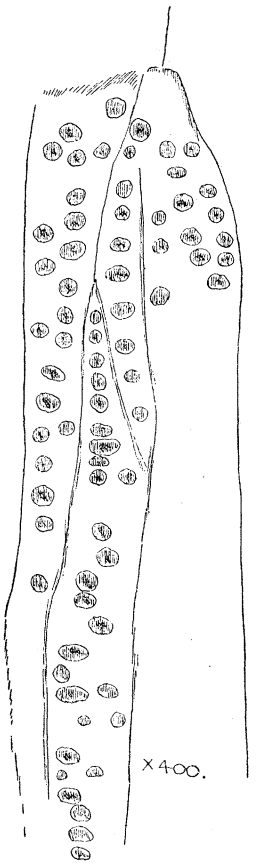
Specimen V 5452, Nat. Hist. Coll. (See p. 77.)

[*Woburnia porosa, gen. et spec. nov.*]

In striking contrast to the small-vesselled, compact wood of Aptiana, the wood of V 5452 is very irregularly built, with extremely large vessels. The differences between the two woods are immediately apparent on comparing Photos 6 and 7, Plate 7, which are micro-photographs of the same scale of magnification.

Of this specimen, all that is retained is the *secondary wood.* In this, though the surface of the transverse section of the wood is a wedge-shaped portion measuring as much as 2·5 × 1·7 to 2·5 × 1 cm., there is no sign of any annual ring. Consequently, it might be supposed that there were no annual rings. This conclusion seems less certain when one considers several of the tropical woods in which they are either very broad, or very apt to fade almost to extinction sometimes, even though they are generally developed.

The porous character of the wood shows well in Photo 8, Plate 8, which renders further general description superfluous.



TEXT-FIG. 6.—Longitudinal view of pitting of wood elements of *Woburnia*.

The vessels are very large, averaging 0·28–0·37 mm. in diameter. They are exceedingly numerous, and arranged close together in more or less even distribution. The great majority of them stand singly, but a few are in radial pairs. The lignification of the wall appears to have been slight, and the pitting, so far as is preserved, to have consisted entirely of small roundish or oval simple pits.

The tissues between the vessels are poorly petrified, but, as can be seen in Photo 7, Plate 7, at *f*, sufficient of the cells are preserved to show something of their character. A large proportion of them are comparatively thin-walled, hexagonal cells, with no remains of contents. Among these, which are probably the wood parenchyma, are isolated rounded fibres with considerably thickened walls. These occur singly or in radial rows alternating with the thin-walled cells as at *t*, *s*, Photo 7, Plate 7.

In longitudinal section the fibres have pointed ends and roundish, probably bordered pits (see text-fig. 6).

"Medullary" *rays* (M, Photo 7, Plate 7) from about 5 to 8 cells broad, lie between every two or three radial series of vessels. Between these are a few narrow rays which seem to end blindly at the vessels in several cases. In tangential section the broad rays are about 40–60 cells high.

In regard to naming and diagnosis, the same remarks hold as in the case of *Aptiana* (see p. 90).

The above-described specimen I name *Woburnia*, as it was found at Woburn Sands. The species name of *porosa* is suggested by the very open and porous character of the wood.

Woburnia porosa, gen. et spec. nov.

Diagnosis.—Wood with very numerous and large vessels. Vessels round, placed singly, about 0·35 mm. in diameter. Rays broad, about 40 cells high. Narrow rays numerous. Much wood parenchyma around vessels. Wood fibres few, isolated, with roundish bordered pits. Annual rings either very wide or not marked.

Horizon.—Lower Greensand (Aptian).

Locality.—Woburn Sands, Bedfordshire, England.

Type.—Block and sections V 5452, Brit. Mus. Nat. Hist.

Discussion of Affinities.—The general remarks on p. 89 *et seq.* apply equally to the determination of this fossil. So far as the fossil goes, however, I have found it to

be in complete agreement with some of the Dipterocarpaceæ. The genus *Shorea* in this family is said by GAMBLE (1902) not to show the annual rings except in the fresh wood. *Hopea odorata* and other Hopeas also resemble the fossil very closely indeed.

The fossil is incompletely preserved, and consequently several important data cannot be determined, but so far as it goes everything points to a Dipterocarpacean affinity. This is of considerable interest in connection with some of the American Cretaceous impressions.

Specimen V 5654, Nat. Hist. Mus. Coll. (See p. 77.)

[*Sabulia Scottii, gen. et spec. nov.*]

This fossil consists of the wood and pith of a decorticated stem. Without its bark the stem is now about 2·5 by 2 cm., and was probably larger when alive, as the woody zones are not quite complete. As is shown in Photo 6, Plate 6, the outline is still roughly that of an unabraded twig, but as its surface is irregularly destroyed there is no means of ascertaining its true size. The section shown in Photo 2 has two pith centres, which suggests that the stem had just branched. The next section below this, however, is lower down and shows the branching finished, with the pith merely slightly extended at one side. This same section, at K shows a "knot" which was presumably the base of another branch; and also a wound at *w* which had completely healed over some years previous to the time of petrifaction.

Wounded stems of fossils have been of some interest (see SEWARD, 1898; JEFFREY, 1906; STOPES, 1907; BAILEY, 1910), but, so far, no wounded Angiosperms among petrifactions have been noted. In the present instance, the wound has no positive interest, because it seems to be without traumatically produced canals, rays, and other structures which lend wounded tissues their supposed phylogenetic importance.

Describing the normal tissues of the stem:—

The *pith* is irregular, roughly pentagonal in outline, and composed of large cells with walls that appear to have been much thickened. The whole character of the twig is that of a highly lignified and thickened xerophyte.

The *primary wood* is rather poorly preserved. It consists of small, very much thickened cells, not arranged in any well-marked primary bundles but in a ring. In the *secondary wood* the annual rings are not at all well marked. Though a number of dark, concentric streaks in the matrix are at first suggestive of rings, most of them are due to petrifaction.

The *vessels* average from 0·025 to 0·06 mm. in diameter. They tend to lie in radial pairs or triplets, though nearly half of them are isolated (see Photo 9, Plate 8). The vessels are more or less uniformly scattered and not noticeably placed in relation to the annual rings. They have thick walls, and in longitudinal sections they are not well enough preserved to show their true character. Most of them have

appearances similar to strong transverse walls, but this is very possibly due to petrifact.*

The wood fibres are small and roughly hexagonal. They appear to have been thick walled, and to have formed a uniform, compact tissue, with little or no admixture of wood parenchyma.

The *rays* are all narrow and very inconspicuous. The majority are uniseriate, some with two or three rows of cells. The cells composing them are rectangular, but little elongated radially. Thus, very few of them have their radial walls exceeding one and a-half times the length of their tangential walls. All the walls are more or less thickened, and the pits show well in radial section.

As regards naming and diagnosis, see the general remarks on p. 89.

I name this new fossil *Sabulia* (Latin, *Sabulo*, coarse sand), as Bedfordshire, the place in which it was found, has been appropriated by a living genus of Angiosperms. The species name of *Scottii* I give in honour of Dr. SCOTT, our greatest palæobotanist. His important book concludes with *Bennettites*, but as *Sabulia* is one of the links connecting the new cohorts of plants with the archaic types, I trust he will accept the tribute and allow his name to be associated with the neophytic flora.

Specimen V 5654.

Sabulia Scottii, gen. et spec. nov.

A branching woody stem with primary wood in a ring without well-marked primary bundles. The wood uniform and compact in structure, with vessels uniformly scattered, singly, or in radial pairs. Vessels about 0·3–0·06 mm. in diameter, with thick walls. Medullary rays inconspicuous, all either uniseriate, or only two or three cells in width. Cells of rays rectangular, without radial extension, thickened and pitted.

Horizon.—Lower Greensand (Aptian).

Locality.—Woburn Sands, Bedfordshire.

Type.—Block and sections V 5654, Brit. Mus. Nat. Hist.

Discussion of Affinities.—In the parts preserved so far, this plant is without any salient features which would help to place it in any special family. I am not in a position to draw any useful comparisons between it and any living plant. Its wood, with the well-marked vessels in radial pairs, is characteristic of the higher Dicotyledons, and shows no similarity to any primitive family.

GENERAL CONCLUSIONS.

While I deliberately refrain from entering into an elaborate and theoretical discussion on all the points raised by these new fossils, and on the origin of the Angiosperms, for

* I am not aware if the word "petrifact" has been coined by any previous writer. If it has not, I would suggest it as a useful term, corresponding to "artifact" in modern fixed material.

which they might very easily be taken as a text, there are, nevertheless, a few points which may be noted in conclusion.

The Character of the Wood.—The view that the Angiosperms arose from the Gymnosperms is now more or less generally accepted, one school looking direct to the Bennettitales, another to some of the woody Gymnosperms, as their ancestors. It is therefore of interest to see if anything in the structure of the wood of these three early Angiosperms shows any points which lend support to either of these views. The answer, in its simplest terms, is—nothing. The woods do not appear in any degree like any group of Gymnosperms, but, on the contrary, like quite highly-placed Angiosperms in all their details. This may either mean that the Angiosperms originated even earlier than we thought, or that the current views of Gymnospermic origin require modification. Personally, I incline to both views.

Primary Wood.—The structure of the primary wood, being without definite bundles, will probably be of interest to, and be noted by, Prof. JEFFREY and his school, in support of his views on the reduced, rather than primitive, nature of the herbaceous type. The point is worth noting, but until we know the structure of a great many more fossil Angiosperms it seems an insecure platform for the erection of theories.

Ray Structure.—The question of the rays in Angiosperms has assumed a new interest, since the valuable and stimulating work of Prof. JEFFREY and his pupils has made the need of more detailed work on the subject, and the useful results likely to be obtained from it, apparent. The rays in *Aptiana*, however, do not fit in with the current conclusions of the researchers in the subject, for the multiseriate ray is in much evidence in *Aptiana*. This makes one hesitate to accept it as the most modern type of ray developed in the Angiosperms, as has been suggested.

Indications of Climate.—A point which may be asked in connection with the new fossils is—What indication do they give of the local climate? Judging by the rather feebly marked annual rings, it looks as if there was a fairly uniform, possibly a sub-tropical, climate, or, at least, one without very marked winter cold. The great likeness of the fossil *Woburnia* to the tropical *Shorea* certainly strengthens this view, but it must be remembered that in evergreen plants the rings are less marked than in others, and there appears in botanical literature to be a general impression that the early Angiosperms were evergreen—though I am not aware of any reliable evidence for this view.

Other Cretaceous Angiosperms.—Mention has already been made of the Albian (Upper Cretaceous) Angiosperm described by FLICHE (1905). There is, however, apparently no similarity of structure between that genus and any of those just described. The same applies to the Cenomanian *Hamamelidoxylon* so admirably described in such detail by LIGNIER (1907). Further Upper Cretaceous Angiospermic woods are described by STOPES and FUJII (1910), as well as some other isolated specimens, mention of which is scattered in the literature.

None of these seem to be the same as those now described, and all are of a much more recent geological age, so that the three new genera must remain for the present in a very isolated position. The chief importance they possess is that they are so old, and that they prove the existence of undoubted higher woody Angiosperms in Northern Europe at this time.

In conclusion, I must thank the many botanists who have looked at and expressed opinions on these fossils. If, as I mentioned on p. 91, I found these views so conflicting that they tended to neutralise each other, it leaves me no less grateful to all who expressed them. I must specially mention Mr. L. A. Boodle, F.L.S., Prof. Percy Groom, F.L.S., and Prof. F. W. O. Oliver, F.R.S., to whom I have been indebted for various kindnesses, and Dr. D. H. Scott, F.R.S., who communicates the paper. My thanks to Dr. Smith Woodward are recorded on p. 77. To the Rev. F. F. Hort I am indebted for help and kindness at Woburn Sands. I must also acknowledge with thanks the fact that some of the expenses of the work were defrayed out of the Royal Society Government Grant, which had been given me for the general study of Cretaceous plants.

LITERATURE QUOTED.

Bailey, J. W., 1910. "Reversionary Characters of Traumatic Oak Woods," 'Botanical Gazette,' vol. 50, p. 374.

Idem, 1911. "The Relation of the Leaf-trace to the Formation of Compound Rays in Lower Dicotyledons," 'Annals Botany,' vol. 25, pp. 225–241, Plates 15–17, January, 1911.

Barber, C. A., 1898. "*Cupressinoxylon vectense;* a Fossil Conifer from the Lower Greensand of Shanklin, in the Isle of Wight," 'Annals Botany,' vol. 12, pp. 329–361, Plates 23 and 24, Oxford, 1898.

Berry, E. W., 1911. "The Lower Cretaceous Floras of the World" and "Systematic Palæontology" in the 'Maryland Geologic Survey, Lower Cretaceous,' pp. 99–151 and 214–508, Plates 22–97.

Boulger, G. S., 1902. "Wood, a Manual of the Natural History and Industrial Applications of the Timbers of Commerce," 8vo, pp. 369, 82 illustrations, London, 1902.

Carruthers, W., 1867. "On *Cycadoidea Yatesii*, a Fossil Cycadean Stem from the Potton Sands, Bedfordshire," 'Geol. Mag.,' vol. 4, pp. 199–201, Plate 9.

Idem, 1870. "On Fossil Cycadean Stems from the Secondary Rocks of Britain," 'Trans. Linn. Soc.,' vol. 26, pp. 675–708, Plates 54–63, London, 1870.

Chamberlin, T. C., and Salisbury, R. D., 1906. 'Geology,' vol. 3, pp. 624, 8vo, Chicago, U.S.A.

CONYBEARE and PHILLIPS, 1822. 'Outlines of the Geology of England and Wales,' etc., 8vo, pp. 470, 2 plates, 1 map.

EAMES, A. J., 1910. "On the Origin of the Broad Ray in Quercus," 'Botanical Gazette,' vol. 49, March, 1910, pp. 161–167.

Idem, 1911. "The Origin of the Herbaceous Type in Angiosperms," 'Annals Botany,' vol. 25, pp. 215–224, Plate 14, January, 1911.

FLICHE, P., 1900. "Note sur un bois fossile de Madagascar," 'Bull. Soc. Géol. France,' Series 3, vol. 28, pp. 470–472, text-fig. 1.

Idem, 1905. "Note sur des bois fossiles de Madagascar," 'Bull. Soc. Géol. France,' ser. 4, vol. 5, pp. 346–358, Plate 10.

GARDNER, J. S., BLANFORD, W. T., JUDD, J. W., CARRUTHERS, W., WOODWARD, H., 1886. "Second Report of the Committee appointed for the purpose of reporting on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom," 'Rep. Brit. Assoc. Sci., Birmingham,' 1886, pp. 241–250, plate 7.

GOTHAM, W., 1908. "Die Frage der Klimadifferenzierung im Jura und in der Kreideformation im Lichte palæobotanischer Tatsachen," 'Jahrb. K. Preuss. Geol. Landesanst.,' vol. 22, pp. 220–242, Plates 16–19.

GAMBLE, J. S., 1902. "A Manual of Indian Timbers," revised edition, 1902.

GROOM, P., 1911. "The Evolution of the Annual Ring and Medullary Rays of Quercus," 'Annals Botany,' vol. 25, pp. 983–1003, plates 74–76, Oct., 1911.

JEFFREY, E. C., 1906. "The Wound Reactions of Brachyphyllum," 'Annals Botany,' vol. 20, pp. 383–394, plates 27 and 28.

JUKES-BROWNE, A. J., and TOPLEY, W., 1888. 'Congrès géologique international, Compte Rendu de la 4me Session, 1888,' "Report No. 11, Cretaceous," London, 1891.

LAMPLUGH, G. W., and WALKER, J. F., 1903. "On a Fossiliferous Band at the Top of the Lower Greensand near Leighton Buzzard (Bedfordshire)," 'Quart. Journ. Geol. Soc.,' vol. 59, pp. 234–265, Plates 16–18.

LIGNIER, O., 1907. "Végétaux fossiles de Normandie IV.—Bois Divers," 'Mém. Soc. Linn. Normandie,' vol. 22, pp. 239–332, Plates 17 and 18.

MACKIE, S. J., 1862. "The 'Dragon-Tree' of the Kentish Rag," 'Geologist,' vol. 5, pp. 401–404, Plate 22.

MOLL, J. W., and JANSSONIUS, H. H., 1906. "Mikrographie des Holzes der auf Java vorkommenden Baumarten," vols. 1 and 2, 1906–8, Leiden.

NORDLINGER, H., 1852–1888. "Querschnitte von hundert Holzarten," text and actual sections, Stuttgart.

SANIO, C., 1863. "Vergleichende Untersuchungen über die Elementarorgane des Holzkörpers" and "Über die Zusammensetzung des Holzkörpers," pp. 85, 93, 101, 113, 121, 357, 369, 377, 389, 401, 'Bot. Zeit.,' vol. 21.

SAPORTA, G. DE, 1891. "Sur les plus anciennes Dicotylées Europeennes observées dans le Gisement de Cercal, en Portugal," 'Comptes Rendus Acad. Paris,' vol. 113, pp. 249–253.

Idem, 1894. "Flore fossile du Portugal, nouvelles contributions à la Flore Mésozoïque," 'Trav. Géol. Portugal,' p. 288, Plate 39.

SCHENK, A., 1883. "Fossile Hœlzer," 'Palæontographica,' vol. 30, Part II, pp. 1–17, Plates 1–5.

SCOTT, D. H., 1907. "The Flowering Plants of the Mesozoic Age, in the Light of Recent Discoveries," 'Journ. R. Microsc. Soc.,' vol. for year 1907, pp. 129–141, Plates 6–9.

Idem, 1911. "Evolution of Plants," 8vo, London, 1911.

SEWARD, A. C., 1894. 'Catalogue of the Mesozoic Plants in the Department of Geology, British Museum,' "The Wealden Flora, Part I.—Thallophyta-Pteridophyta," pp. 1–179, 11 Plates.

Idem, 1895. "The Wealden Flora, Part II.—Gymnospermæ," pp. 259, 20 Plates.

Idem, 1896. "Notes on the Geological History of Monocotyledons," 'Annals Botany,' vol. 10, pp. 205–220, Plate 14.

Idem, 1898. "Fossil Plants," vol. 1, 8vo, pp. 452, Cambridge.

SOLEREDER, H., 1908. "Systematic Anatomy of the Dicotyledons," vols. 1 and 2, English translation, Oxford, 1908.

SOLMS-LAUBACH, H. GRAF ZU, 1890. "Ueber die Fructification von *Bennettites Gibsonianus*, Carr.," 'Bot. Zeit.,' vol. 48, pp. 789–798, 805–816, 821–833, 843–847, Plates 9 and 10 (translated 'Annals Botany,' vol. 5, pp. 419–452, Plates 25, 26).

STONE, H., 1904. "The Timbers of Commerce and their Identification," 8vo, pp. 311, 186 photos, London, 1904.

STOPES, M. C., 1907. "A Note on Wounded Calamites," 'Annals Botany,' vol. 21, pp. 277–280, Plate 23.

Idem, 1910. Letter in 'Nature,' vol. 85, p. 139.

Idem, 1911. "The 'Dragon-Tree' of the Kentish Rag," 'Geol. Mag.,' vol. 8, pp. 55–59, text-fig.

Idem and FUJII, K., 1910. "Studies on the Structure and Affinities of Cretaceous Plants," 'Phil. Trans.,' vol. 201 B, pp. 1–90, Plates 1–9.

THOMPSON, W. P., 1911. "On the Origin of the Multiseriate Ray of the Dicotyledons," 'Annals Botany,' vol. 25, pp. 1005–1014, Plates 77 and 78, October, 1911.

WEALE, J. 'Microphotographs of Wood.'

WOODWARD, H. B., 1887. "The Geology of England and Wales," edit. 2, pp. 670 and map, London, 1887.

DESCRIPTION OF PLATES.

The photographing of the sections has been admirably done by the following photographers:—Photos 1, 2, and 8, by Mr. H. G. Hering; Photos 3, 4, 5, 6, 7, 9, and 11, by Messrs. Flatters and Garnett; and Photo 10 by Mr. F. Pittock. In the last case I am much indebted to Prof. HILL, of University College, for the loan of his splendid photographic apparatus.

PLATE 6.

Photo 1.—*Aptiana.* Transverse section of the stem. × $1\frac{3}{4}$. Showing wood rays, etc. The black zone at *p* is the phloem; *m*, granular, glauconitic matrix.

Photo 2.—*Sabulia.* Transverse section of the stem. × $2\frac{4}{5}$. Showing two piths, owing to branching. *w*, wound, healed over; *k*, "knot," due to another branch. Note the uniformly scattered arrangement of the vessels.

Photo 3.—*Aptiana.* Portion of transverse section enlarged, showing phloem zone with enlarged rays *r* and some of the outer zones of wood. Note in this *dm*, one of the rays dying out in transverse section, *cf.* text-fig. 4; *m*, quartz and glauconite grains of matrix.

Photo 4.—*Aptiana.* Further enlarged portion of transverse section of a part of the wood. *dm*, broad ray becoming uniseriate in older zones of the wood. Note the numerous uniseriate rays between the radial rows of fibres and small vessels.

Photo 5.—*Aptiana.* Tangential view of rays. Note the very much elongated cells at the top and bottom of some rays, *v*.

PLATE 7.

Photos 6 and 7 are on the same scale of magnification, to illustrate the marked difference in the characters of the two woods.

Photo 6.—*Aptiana.* Transverse section of portion of the wood showing several multiseriate rays. At *dm* one of these is seen, which becomes uniseriate. This photograph illustrates the general character of the wood, notably its small vessels and regular fibre-tracheids.

Photo 7.—*Woburnia.* Transverse section of portion of the wood. At *m* a broad multiseriate ray is seen; at *t* a thin walled, and *s* a sclerised cell alternating on the same radius; *f*, thin walled tissue preserved near the vessel.

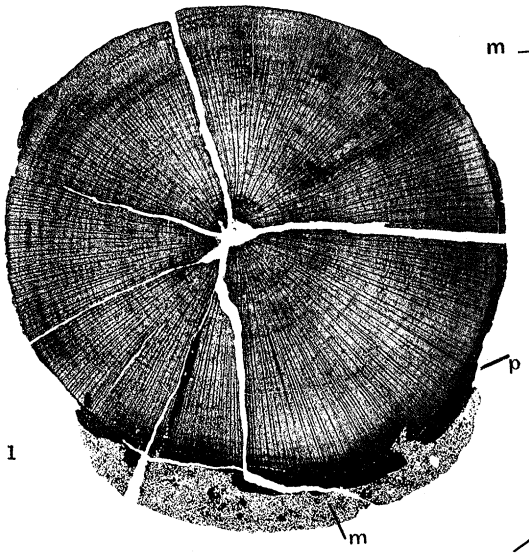
PLATE 8.

Photo 8.—*Woburnia.* Transverse section of portion of wood to show the numerous large vessels, and broad wavy rays.

Photo 9.—*Sabulia.* Transverse section of part of the wood, showing the scattered vessels, some of which are in radial pairs.

Photo 10.—*Aptiana.* Transverse section of a small part of the wood, showing details of vessels, fibre-tracheids, and rays in excellent preservation; *m*, multiseriate ray, note the pittings in the thickened walls; *b*, note numbers of clearly marked bordered pits in the fibre-tracheids.

Photo 11.—*Aptiana.* Radial, longitudinal view of wood and rays.



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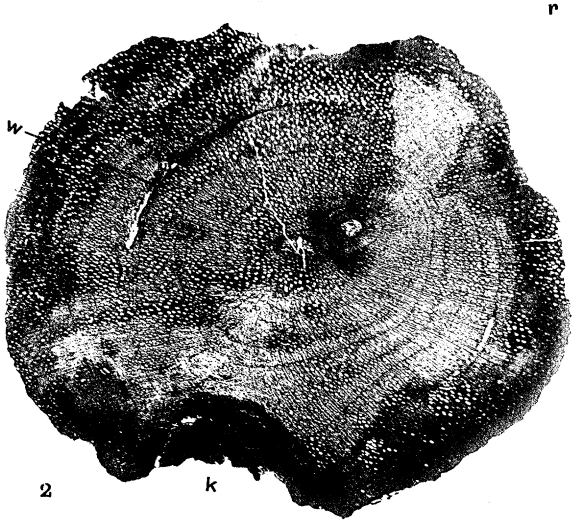

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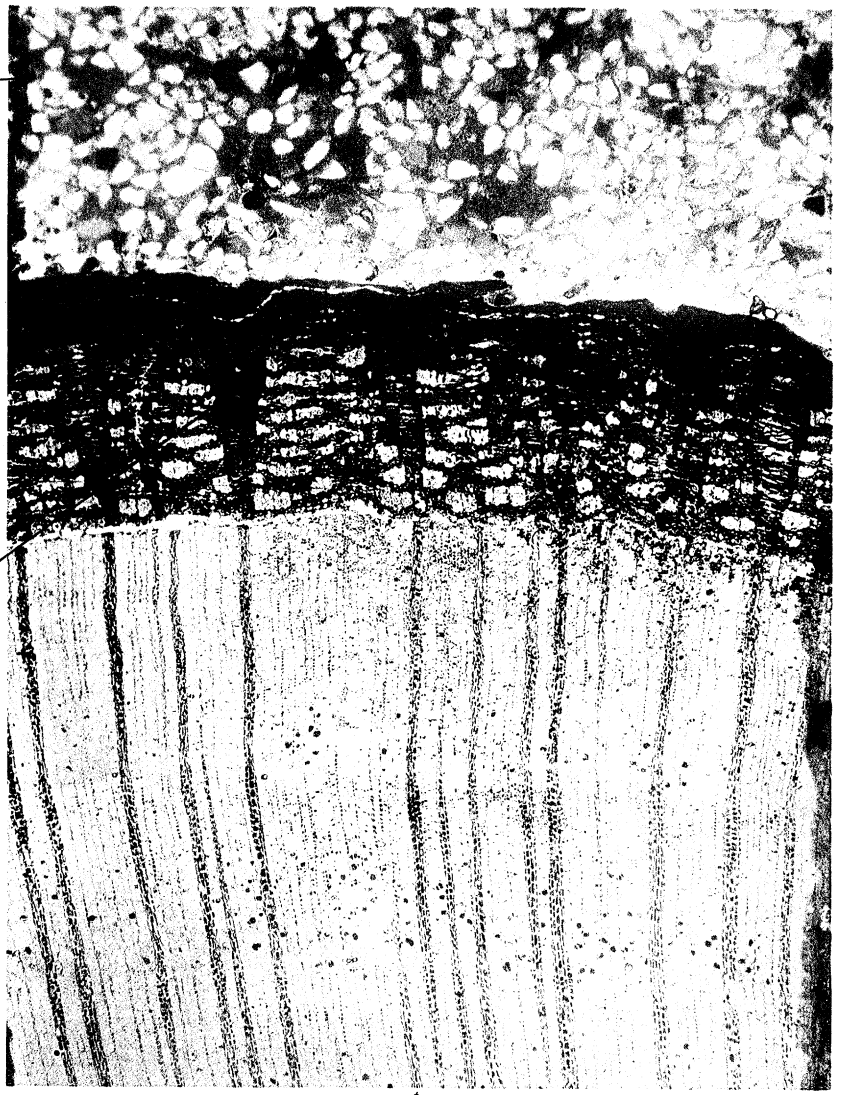

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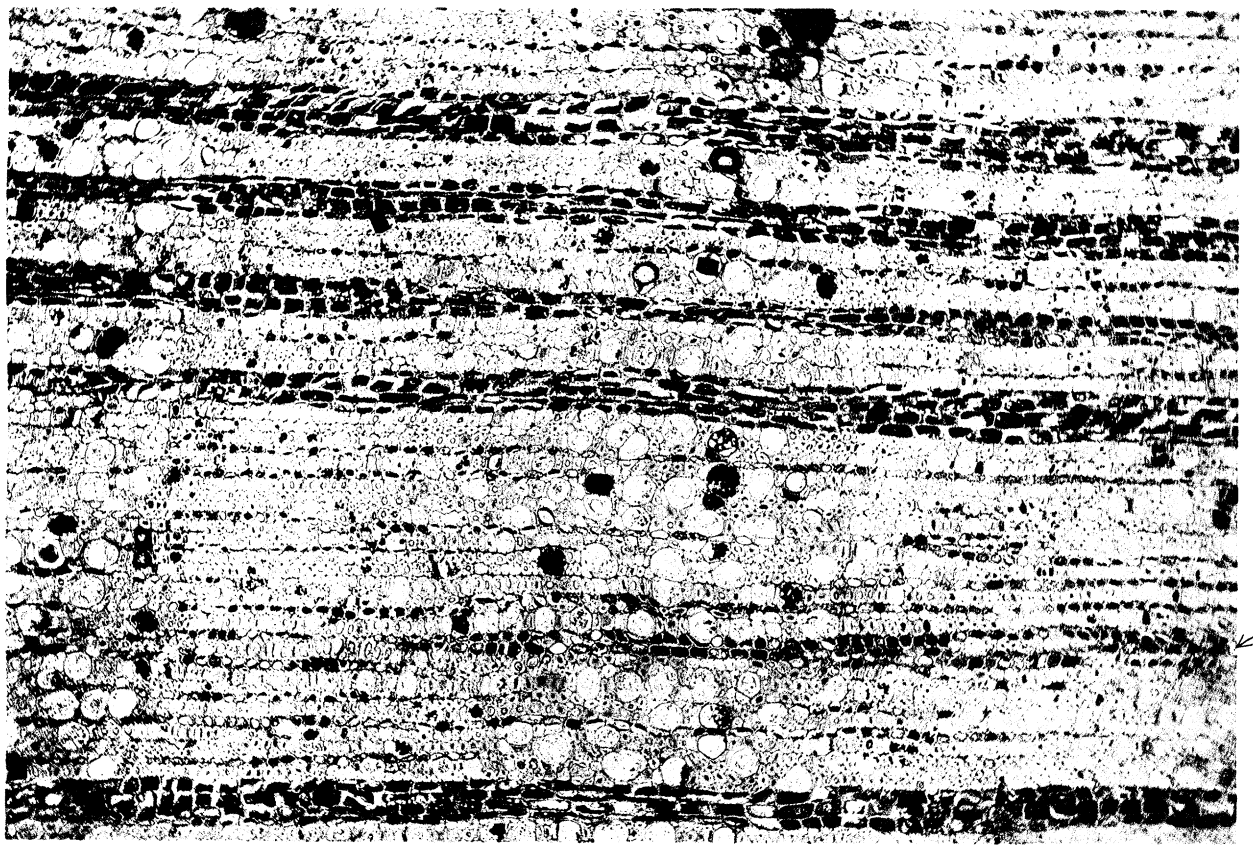

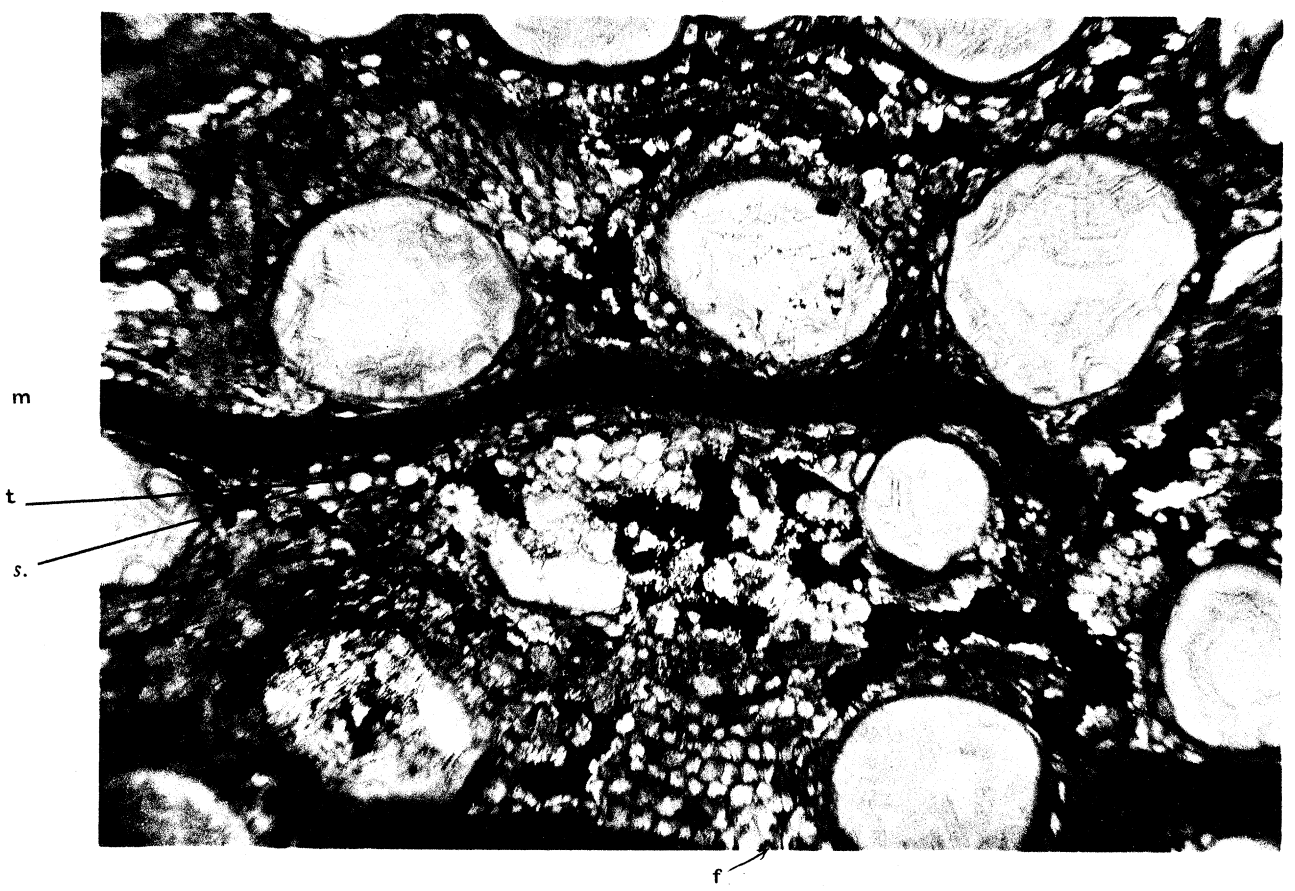

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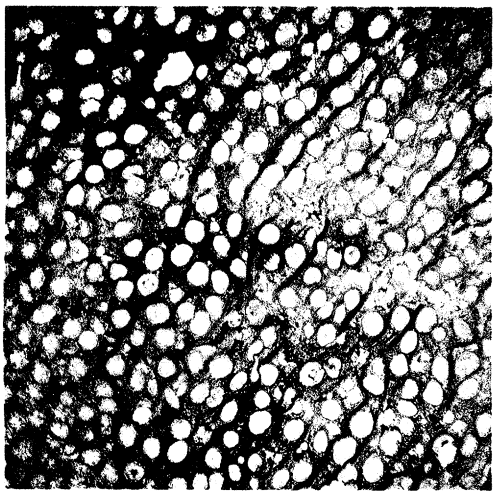

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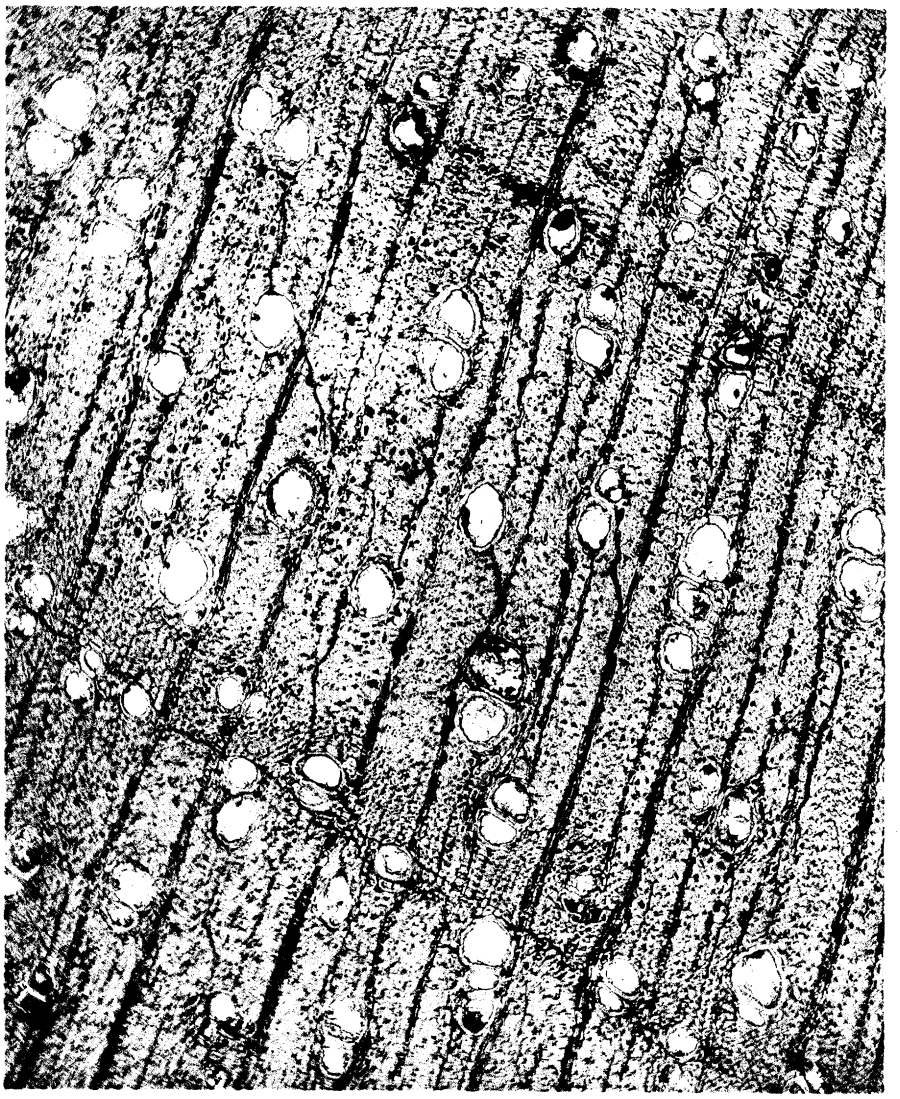

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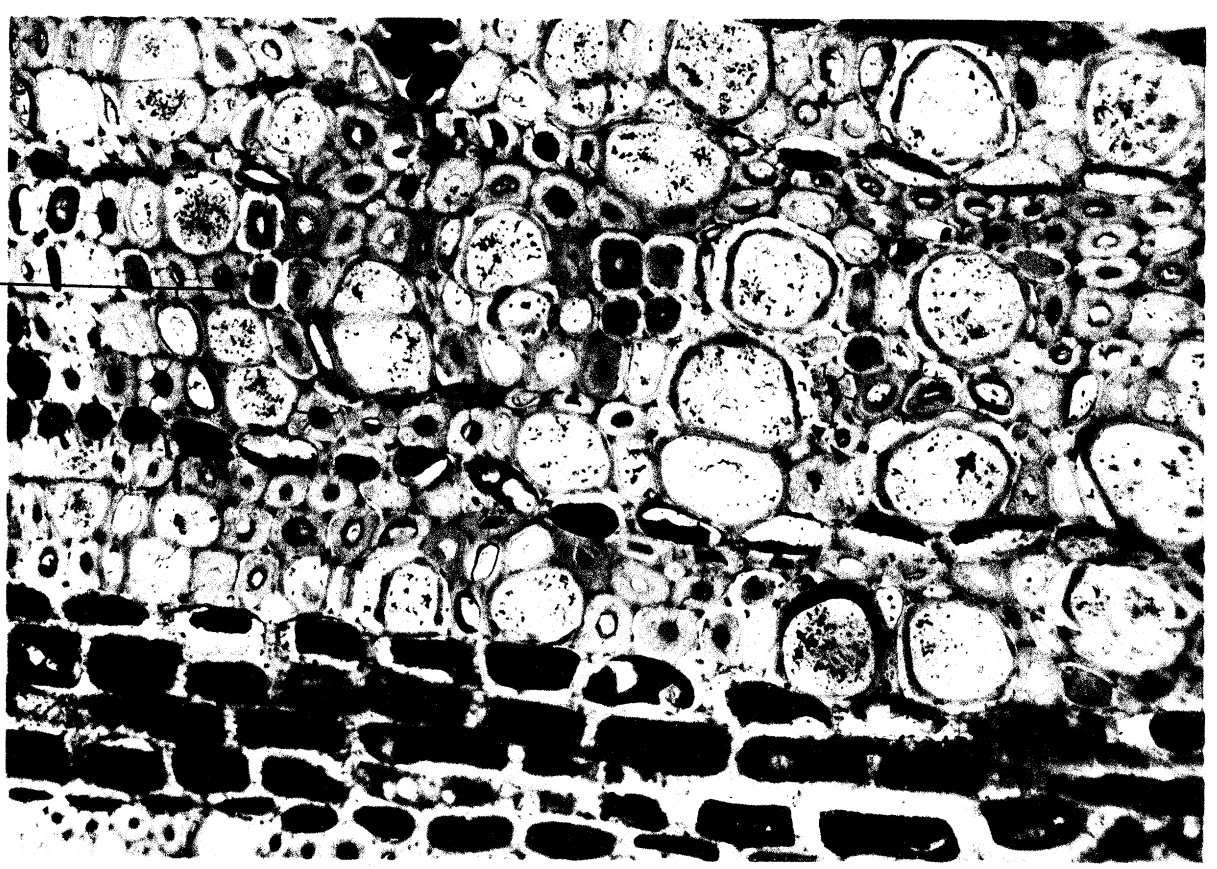

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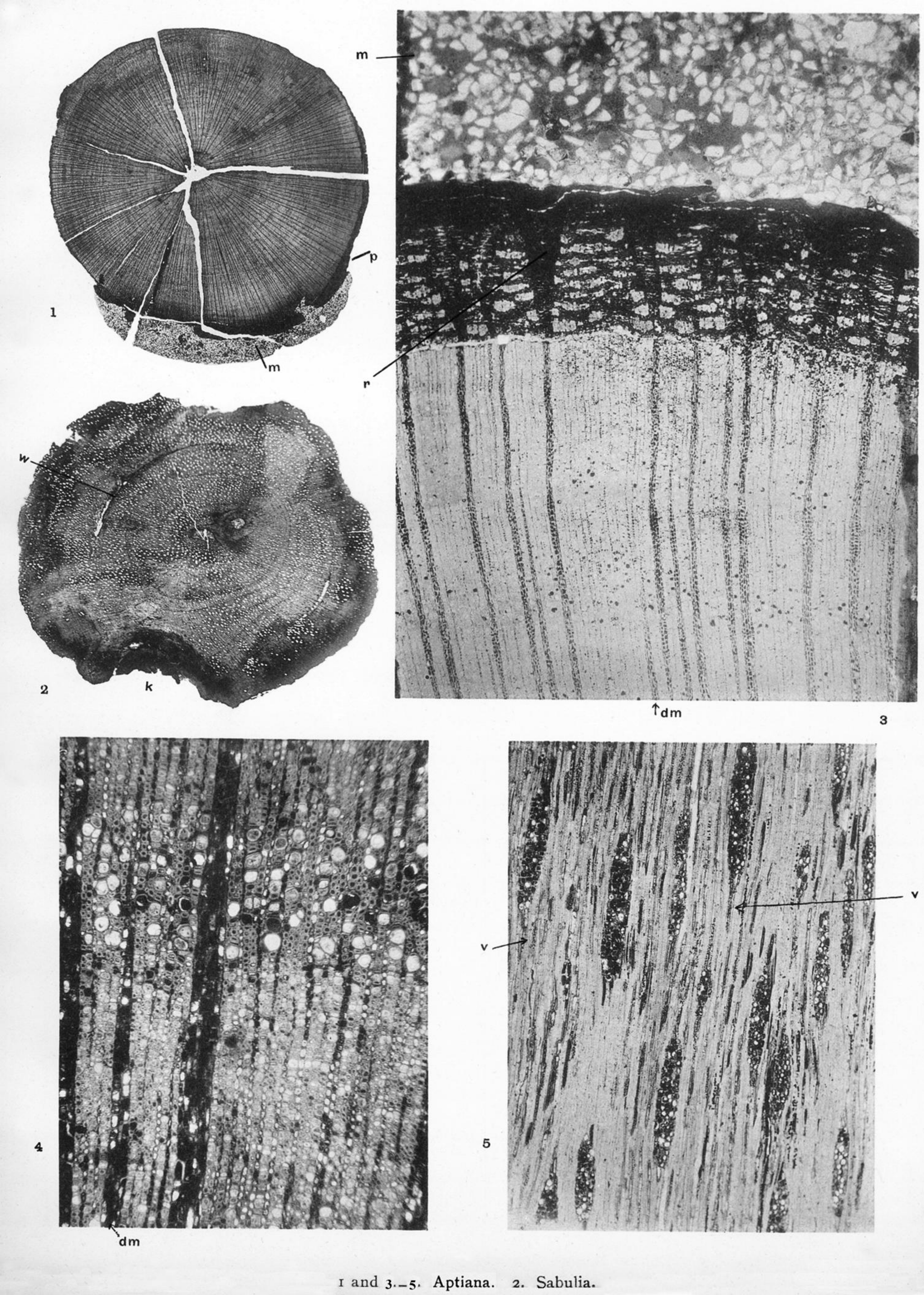

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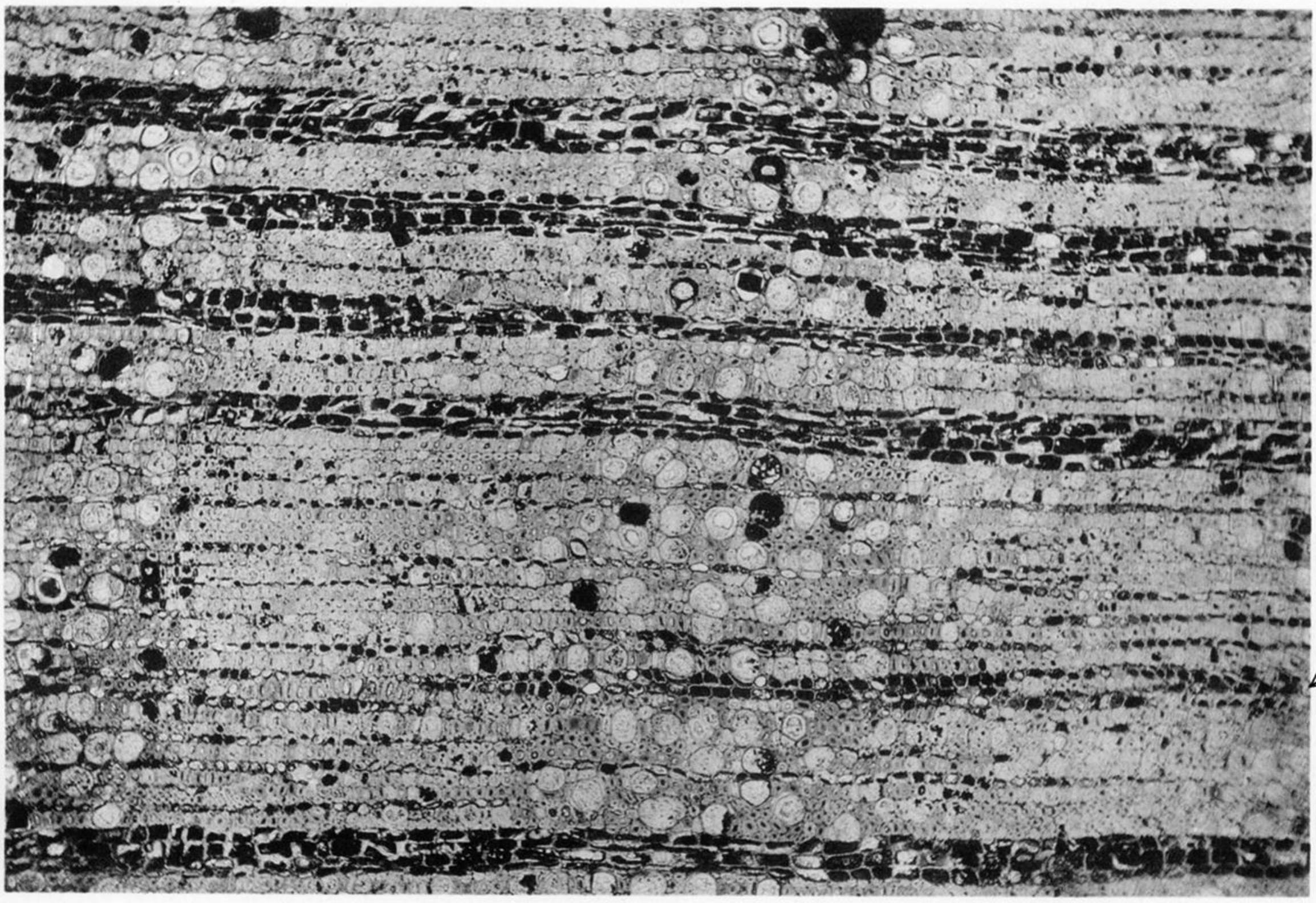

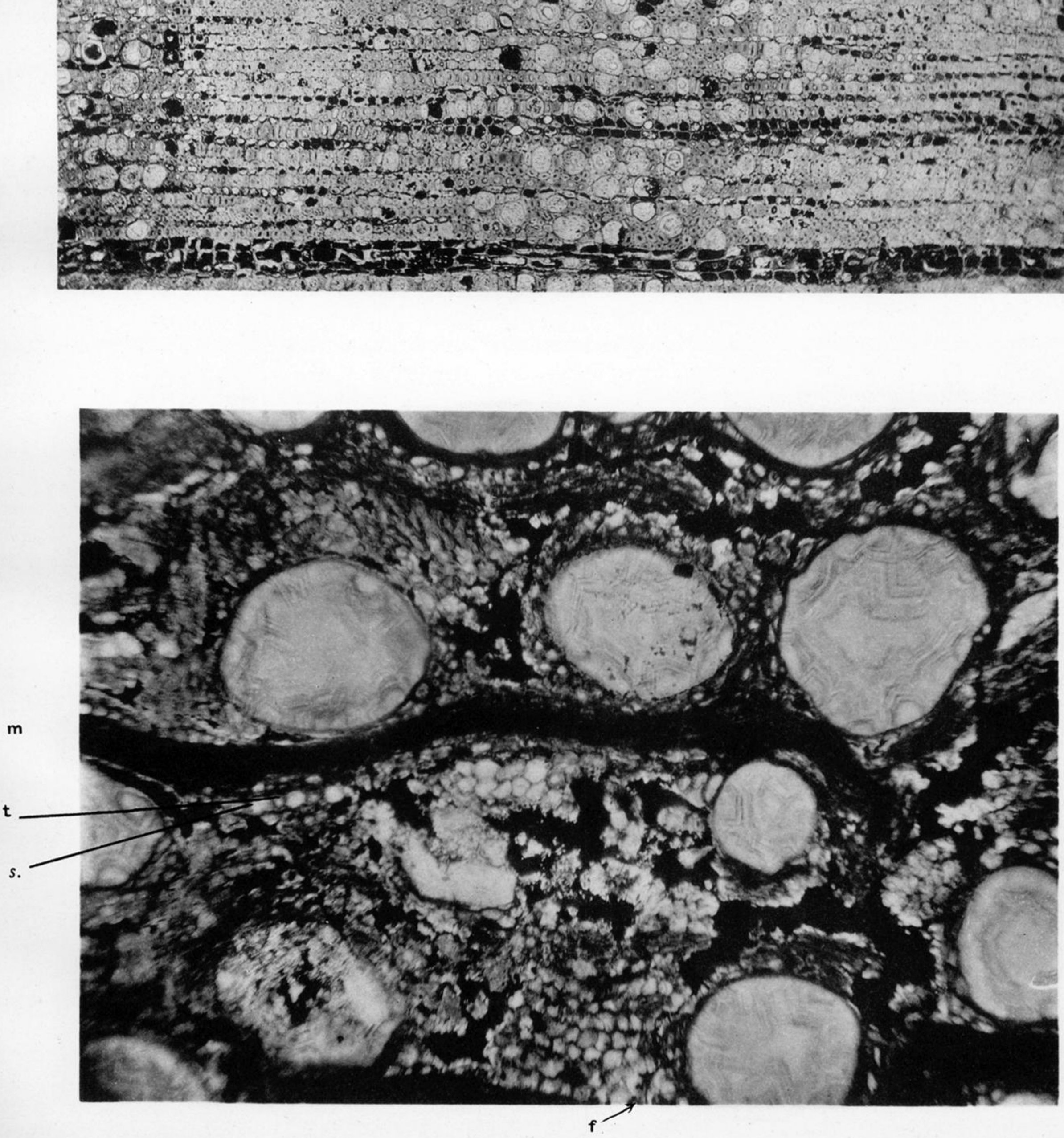

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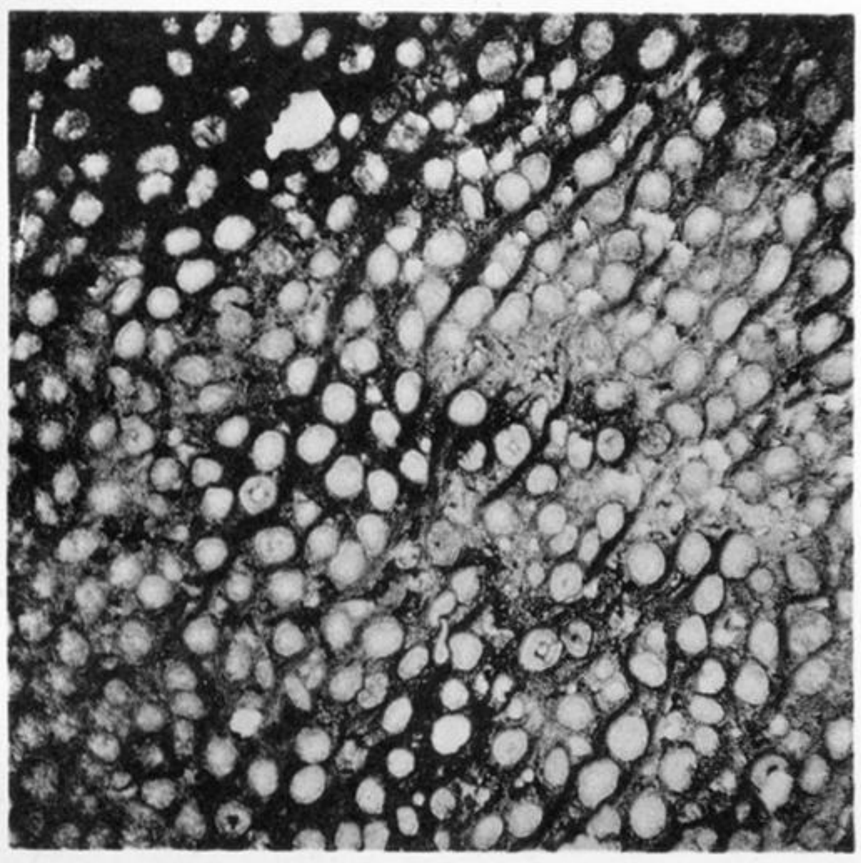

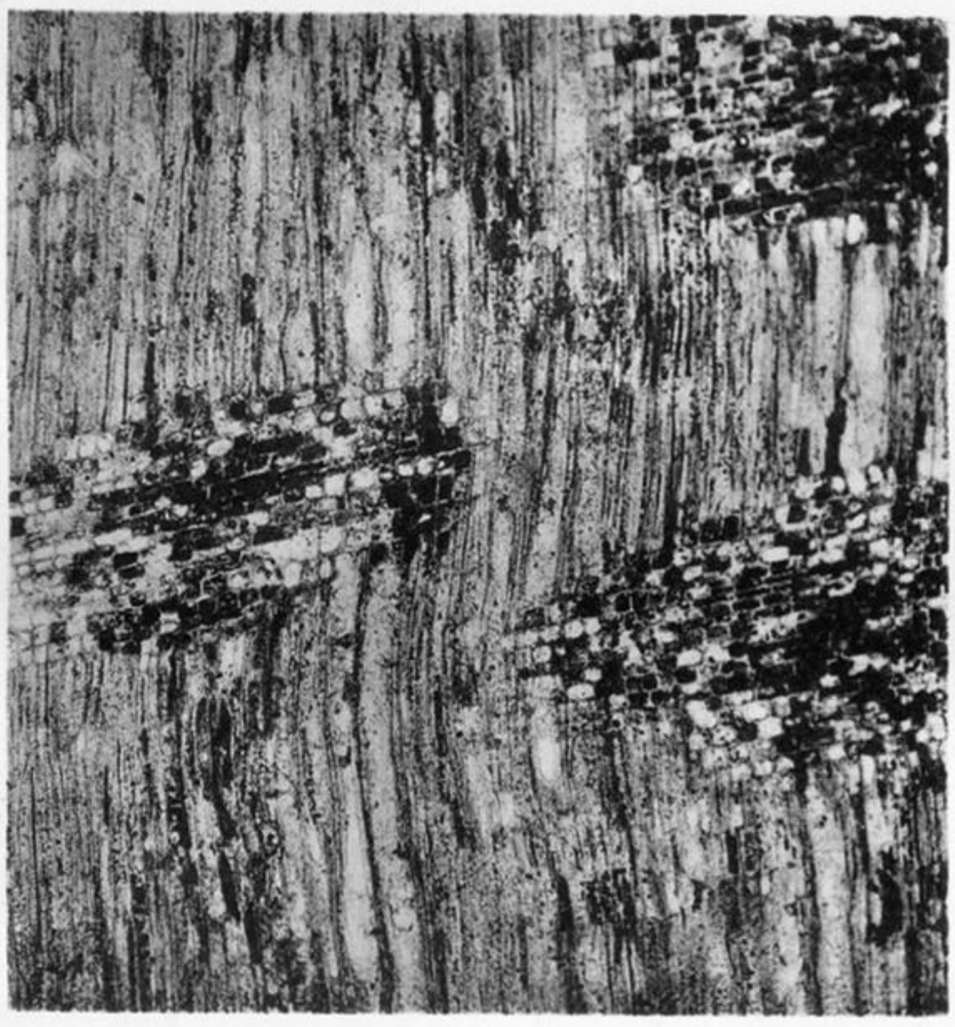

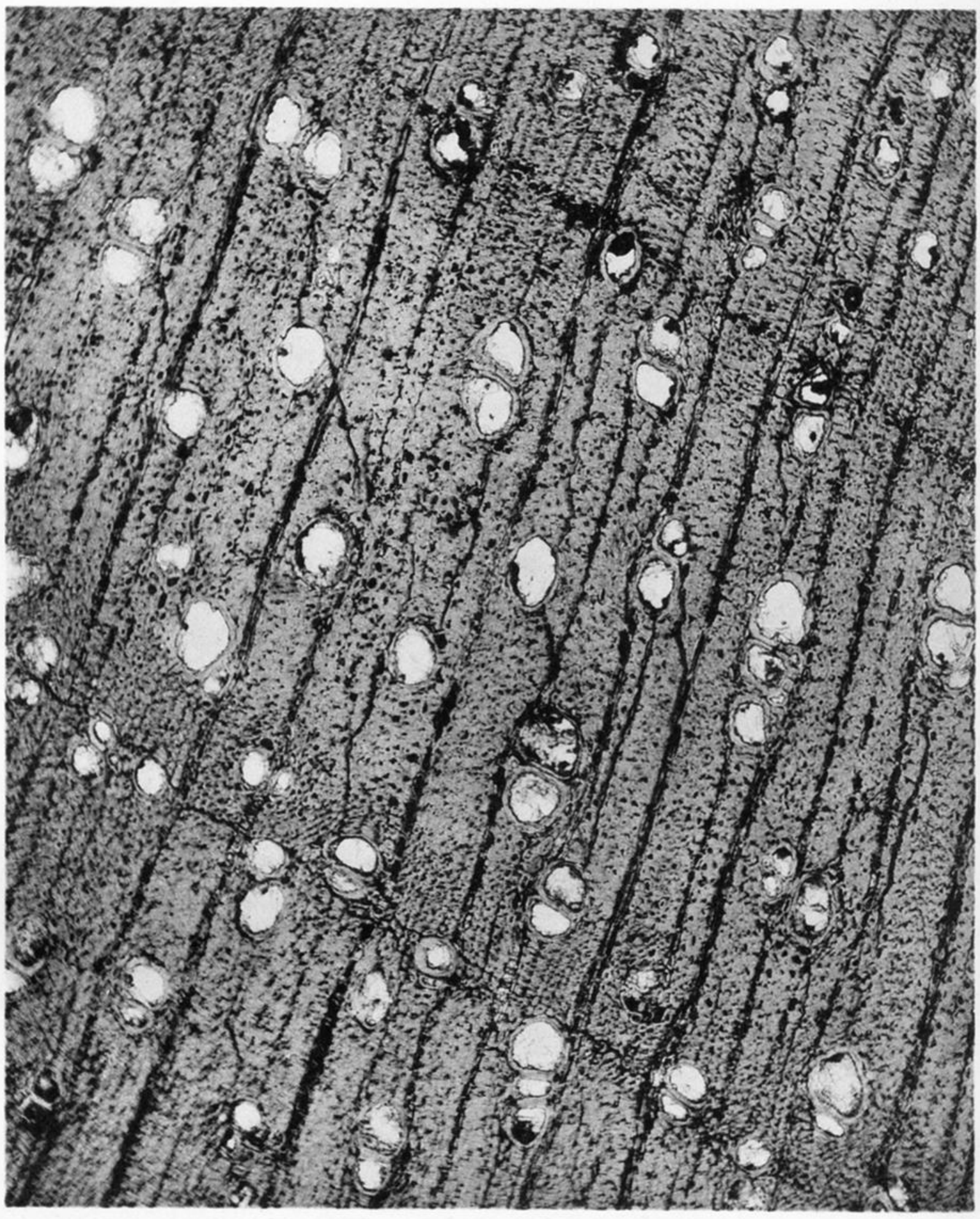

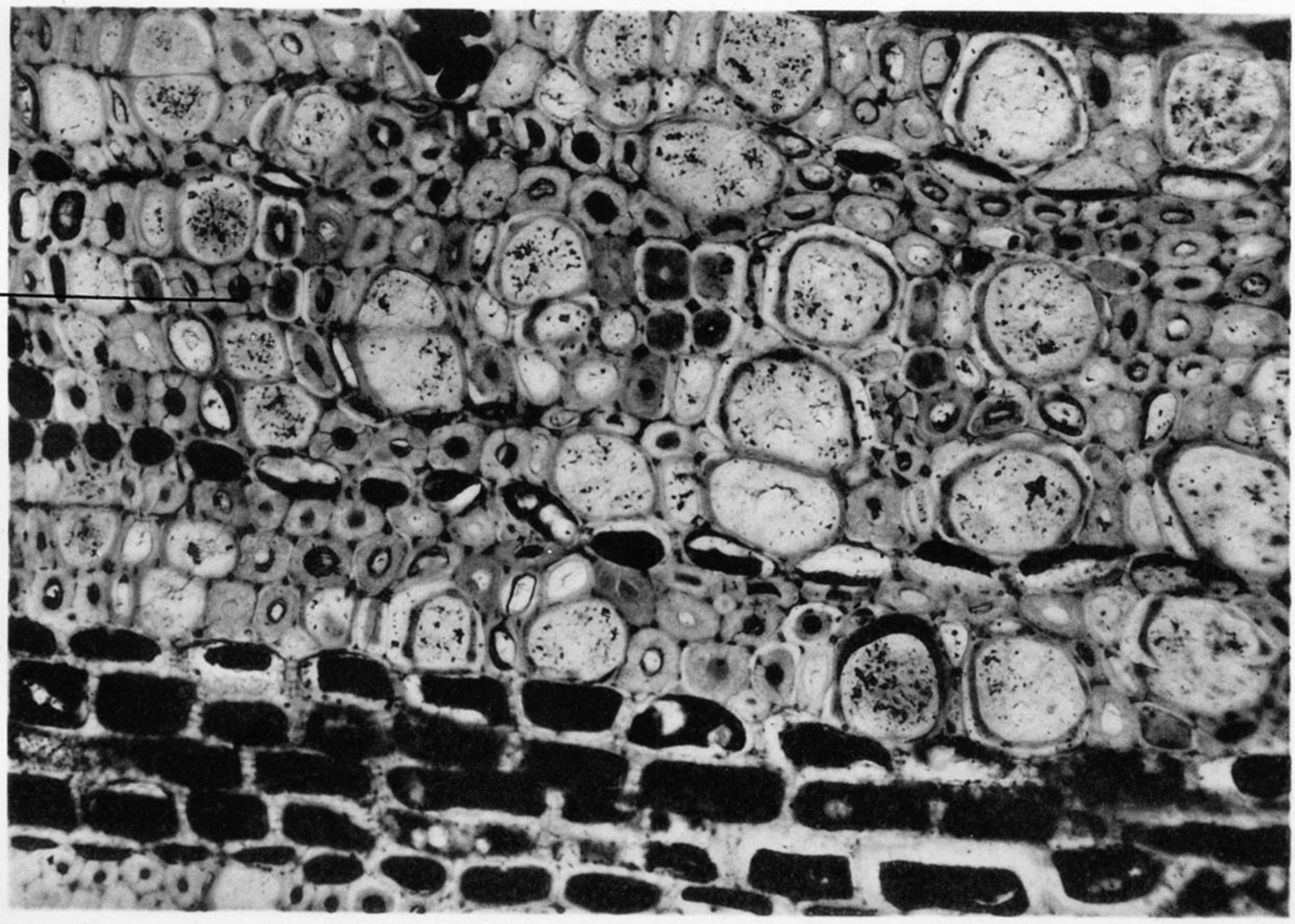

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