IX. *On Fossil Plants, showing Structure, from the Base of the Waverley Shale of Kentucky.*

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[Plates 27–39.]

Introduction.

A large part of the material upon which the present memoir is based was derived from Prof. Charles Eastman, now of the University of Pittsburg but formerly of the staff of the Agassiz Museum of Harvard University. It was presented by him to the junior author. A considerable amount of additional material, some of it of the greatest interest, including, among other things, a Lepidodendrid cone, was purchased by the junior contributor to the present article, from Mr. Moritz Fischer, of Cincinnati, Ohio, who was associated with Prof. Eastman as a collector in his work on the deposits containing the fossil plants here described.

The locality and horizon of the fossil plants under consideration are described as follows by Prof. Eastman in a letter to the junior author: "The collection of fossiliferous nodules, which I turned over to you, was obtained by myself in company with Mr. Moritz Fischer, of Cincinnati, at a locality about one mile west of Junction City in Boyle County, Kentucky, in the spring of 1906. The nodule layer is a well-marked stratum 20 to 24 inches thick, lying at the base of the Waverley (Lower Carboniferous) and immediately above the Genessee Black Shale of Upper Devonian age. The accompanying fish remains are regarded by myself and Dr. Bashford Dean, who have described some of them, as indicating Lower Carboniferous age."

In a subsequent letter the following supplementary statement is made: "Last evening I was speaking to Dr. R. S. Bassler about the nodule-bearing layer near Junction City in Boyle County, Kentucky, and learned that he regards it as occurring at the base of the Waverley, lying unconformably upon the Upper Devonian Black Shale, and corresponding in age, in a general way, to the Burlington limestone of the Mississippi Valley section."

Material.

A few words may be said about the mode of preservation of the fossil plants. They are in the form of weathered fragments, mostly of a grey or greenish-grey colour, which had evidently, in many cases, been exposed for a long time to the air,

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for organisms are growing on their surface. The most conspicuous of these, a small saxicolous Lichen with black apothecia, has been kindly identified for us by Miss A. LORRAIN SMITH, F.L.S., the well-known Lichenologist, as *Verrucaria Dufourii*, D.C.

In several cases two or more separate fragments appear to have originally formed part of the same specimen.

The fossils may in some cases be described as nodules, the actual vegetable fragment being more or less enclosed in a mineral matrix ; in other cases practically the whole mass is formed by the petrified tissue of the plant.

We are indebted to Mr. J. DUDLEY ROBINSON, B.Sc., for an analysis of one of the specimens, a portion of a large *Kalymma*. He has kindly made out the analysis in two forms, A being that in which geological analyses are usually stated, while B gives the chemical compounds approximately as they occur in nature.

PLANT REMAINS FROM KENTUCKY.

A. *Approximate Analysis* :—

	Per cent.
Residue insoluble in hot concentrated HCl	9·89*
CO_2	23·14
P_2O_5	12·20
$Fe_2O_3+Al_2O_3$	34·51
CaO	18·29
MgO	0·23
H_2O	0·59
Undetermined (alkalies, etc.)	1·15
	100·00

B. Assuming the calcium phosphate to be pure, the *approximate composition* would be as follows :—

	Per cent
Calcium phosphate ($Ca_3P_2O_8$)	26·7
Calcium carbonate	6·8
Ferric carbonate	42·5
Iron and aluminium oxides	11·2
Magnesium carbonate	1·1
Water	0·6
Insoluble residue (2 per cent. carbonaceous material)	9·9
	98·8

These figures are, however, only approximately correct, as it is probable that the compounds mentioned are not pure.

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* 2 per cent. carbonaceous material, remainder mainly silica.

The considerable proportion of calcium phosphate is interesting; in the Saalfeld material from which UNGER obtained his plants this compound seems to be the chief constituent.* As regards the state of preservation of the plant remains, it is often good but in some respects disappointing. The transverse sections often make a favourable impression which is not altogether borne out when longitudinal sections of the same objects come under observation. To a great extent the remarks which GRAF ZU SOLMS-LAUBACH makes as to the preservation of the Saalfeld plants hold good for our own material, an interesting point, considering the great similarity of the two floras, to which we shall often have to allude. GRAF SOLMS says of UNGER'S specimens that all the cell-membranes are usually broadened in a peculiar way, as if swollen, with, of course, a corresponding diminution of the lumen; while the pits are lost and are often not to be recognised at all in longitudinal sections.† Even in transverse sections fibres and tracheal elements become, as GRAF SOLMS says, "desperately alike."

All these difficulties are met with in our Kentucky material, though, of course, not always in an equal degree. In some cases the tracheal sculpturing may even be quite easily recognisable, as is the case in *Periastron* and *Stereopteris* (Plate 32, Phots. 40 and 42). A glance through the plates will, in fact, give a better idea of the state of preservation than any amount of description.

The investigation, owing to the peculiarities of the material mentioned above, is more difficult than in the case of ordinary Carboniferous specimens, but with care the limits and characters of the tissues can be sufficiently determined.

The plants described in the present paper are as follows:—

1. *Calamopitys americana*, sp. nov., with a *Kalymma* probably belonging to it, p. 317.
2. *Calamopteris Hippocrepis*, sp. nov., p. 330.
3. *Periastron perforatum*, sp. nov., p. 335.
4. *Stereopteris annularis*, gen. et sp. nov., p. 341.
5. *Archæopitys Eastmanii*, gen. et sp. nov., p. 345.
6. *Lepidostrobus Fischeri*, sp. nov., p. 354.

Most of the sections were cut for the authors by Mr. James Lomax and his son; others were the work of Mr. W. Hemingway. Much has depended on the skill and care of these able collaborators.

1. CALAMOPITYS AND KALYMMA.

The Stem.—The stems of a *Calamopitys*, allied to the Thuringian species, *C. Saturni* and *C. annularis*, described by UNGER,‡ are represented in the Kentucky material by a number of fragments; some of them, however, have proved on

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* SOLMS, '96, p. 7.

† *Loc. cit.*, p. 11.

‡ UNGER, '56; SOLMS-LAUBACH, '96.

investigation to be parts of one and the same specimen.* We propose to name the Kentucky species, *Calamopitys americana.*

It will be seen from the footnote that the dimensions of the pith vary greatly. In the rough measurements given the primary wood is included in the pith, as it is impossible, in many cases, to trace the limits between the two. In fact, as we shall see, there is reason to believe that we have here to do with a "mixed" pith.

A general idea of the transverse section is given in Plate 30, Phot. 23, from a specimen with a small pith, about 4 by 2 mm. in diameter. In such stems the form of the pith is affected by the emission of the successive leaf-traces, its major axis coinciding with the direction of the outgoing trace, as shown in the photograph. The central tissue of the pith is surrounded by a zone of primary xylem, and this again by the broad secondary wood.

Primary Structure.—The primary xylem zone is shown, by the comparison of numerous sections, to be nearly, but not quite continuous, the xylem-strands being separated from one another by narrow bands of parenchyma. One of the best-preserved primary strands is shown in the photograph, Plate 30, Phot. 24, and in the drawing, Plate 35, fig. 1. The structure is evidently mesarch, the protoxylem-group lying nearer the outer than the inner surface of the strand. This structure appears to be constant (*cf.* Plate 35, fig. 4, and Plate 36, fig. 5). Owing to the state of preservation it is almost impossible to observe the characters of the protoxylem in longitudinal section; in one case, however, some narrow elements (about 30 μ in diameter) could be detected in the right position, and they showed, though obscurely, a spiral marking. In one section six primary xylem-strands could be distinguished—probably they were really more numerous, for the preservation is never quite complete.

So far, the primary structure—a pith surrounded by a ring of nearly confluent mesarch xylem-strands—is quite similar to that described in the case of *Calamopitys annularis.*† In the American species, however, there is strong evidence for the somewhat unexpected conclusion that the pith was a "mixed" one, containing tracheides.

In the transverse section shown, from a photograph, in Plate 34, Phots. 49 and 50, a

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* The following list enumerates the various fragments which have come into our hands, under the symbols used to distinguish them; those which are found to belong to the same stem are bracketed together. Except where otherwise stated, the rough dimensions given apply to the wood only, for the cortex is only preserved in exceptional cases.

(C, B 1, B 2.) Same stem. Diameter 20–23 mm. Pith (with primary wood) about 4 × 2 mm.
(F, B 4.) Same stem? Diameter 32 mm. or 40 mm., if cortex is included. Pith about 13 mm.
(G, B 3.) Same stem? Diameter about 30 mm. Pith about 12 mm.
(8, 8 V.) Same stem. Diameter 32 × 25 mm. Pith 15 × 6 mm.
6·5. Diameter 25 mm. Pith 10 mm.
K. Fragment of stem with leaf-base (*Kalymma*) attached.

† SOLMS, '96, p. 74.

great part of the " pith " area is occupied by elements quite like the tracheides of the peripheral xylem-strands, though sometimes larger.

There is a complete resemblance in the thickness of the wall, the distinctness of the middle lamella, and the frequent crenulation of the layer of membrane lining the cavity—probably an expression of the pitting. These tracheide-like elements are in groups, interspersed with tracts of somewhat compressed parenchyma (Phot. 50).

A longitudinal section from the same part of this stem (Phot. 51) cut in the radial direction, so as to pass through the middle of the pith, shows that throughout its whole thickness a number of the elements are of elongated form ; some are of great length, like the tracheides of the peripheral xylem-strands; others, less elongated, have occasional transverse or oblique walls. Interspersed among the elongated elements, patches of ill-preserved short cells, evidently the compressed parenchyma shown in the transverse sections, are seen here and there.

The question to be decided is whether the elongated elements in the pith are tracheides. The observation of pitting is usually a difficult and uncertain matter in these fossils, but at certain places it has been possible to demonstrate the presence of multiseriate pits on the walls, both of the much-elongated tapering elements and of the shorter tubes with square ends (see Phot. 51). The pitting is similar to that which in favourable cases can be detected on the tracheides of the primary xylem strands.

The conclusion seems inevitable that we have to do with genuine medullary tracheides, and that in this species xylem, intermixed with parenchyma, extended throughout the " pith," the structure being thus protostelic.

These conclusions apply immediately to the specimens with a small " pith," about 2–4 mm. in diameter. It has still to be considered whether medullary tracheides also occur in specimens where the pith is relatively large and obviously, to a great extent, parenchymatous. If not, we might be driven to conclude that two different species were present in our material.

In the specimen marked " 6·5," with a pith about 1 cm. in diameter, there is evidently a large amount of medullary parenchyma. The primary xylem at first appears to be limited to a rather narrow peripheral zone, in which the strands seem to be nearly continuous with one another, as in the smaller specimens.

Among the thin-walled tissue of the pith a few scattered elements occur, which in transverse section look like tracheides. The radial section shows that these are long elements, contrasting sharply with the short-celled parenchyma, and exactly resembling the tracheides of the peripheral xylem-strands. The medullary elements in question sometimes occur singly, sometimes in little strands (see Plate 36, fig. 8). Although the preservation here is not such as to show the pits in any part of the xylem, there is no reason to doubt that these elongated medullary elements, like those of the smaller stem, were tracheides. In other specimens the preservation of the pith was not good enough for decisive evidence to be obtained, but the cases described are enough to indicate that medullary tracheides were regularly present, forming an important constituent of the pith where its dimensions were small, but occurring more sparsely in stems where the pith was relatively large. This difference in degree is probably not the mark of a specific distinction.

The structure of the stem of *Calamopitys americana* may thus be described as protostelic, the proportion of tracheides to parenchyma in the "mixed pith" varying inversely with the dimensions of the latter. The bearing of these facts on the affinities of our fossil will be considered when the rest of the structure has been described.

In *Calamopitys*, as in *Heterangium*, it is only the peripheral strands of the primary xylem which are concerned in the emission of leaf-traces.

The Secondary Wood.—The general structure of this tissue, which forms the great bulk of each specimen, is shown in the photographs (Plate 29, Phot. 22; Plate 30, Phots. 23, 25, 27, 29). The tracheides are on the whole smaller than those of the primary strands, the latter commonly ranging from 80 to 120 μ in diameter, while the secondary tracheides vary from 30 to 60 μ. The medullary rays are from two to eight cells in thickness, the thicker rays being more frequent in the larger stems. Tangential sections show that they are of considerable height, commonly from about 2 to 4 mm. The ray cells near the pith are nearly square as seen in radial section, the diameter varying around 120 μ; further out in the wood the muriform character is attained (Plate 30, Phot. 29), the cells here being "procumbent," with the radial and vertical diameters ranging round 280 μ in length and 50–80 μ in height. Tangentially the ray cells are quite narrow, usually about 24 μ wide.

In favourable places the pits, so often obliterated, are found preserved on the radial walls of the tracheides. They are small, and form five or six series on the wall. They are often arranged in transverse or inclined lines and alternate with one another. Their form is sometimes elliptical, sometimes isodiametric.*

There is thus nothing peculiar about the secondary wood—it is of quite the same type as that of the original species of *Calamopitys*, *C. Saturni* and *C. annularis.*

A curious feature of the preservation may be noticed here; in many of the elements the lumen is traversed by simple or branched cylindrical bars connected with the walls. They are well shown in some of the primary tracheides in Phot. 26 (Plate 30). The elements containing them closely resemble the "Tracheæ with transverse bars" (Querbalken-Tracheen) such as occur, for example, in the transfusion-tissue of the leaf of Juniper.† It was at first thought that the bars might be normal features of the structure; they occur, however, in elements of all kinds, primary and secondary tracheides, pith cells and cells of the medullary rays. When the tissue is badly preserved the whole structure may in places be reduced to a framework of such bars. It therefore appears probable that they are in all cases products of disorganisation of

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* Details of primary and secondary tracheides are shown in Plate 36, fig. 7, A—C.

† See DE BARY, '84, p. 164, figs. 62, 63.

the cell-wall, and not normal formations. The same peculiar state of preservation has been noticed in a section of *Calamopitys annularis* (No. 411) kindly lent by GRAF ZU SOLMS-LAUBACH.

It is only rarely that the cambium and phloem are preserved. In some sections of the small specimen (C, B 1, B 2) portions of these tissues are fairly well shown. The tabular cells of the cambium can be seen, while larger and smaller elements can be distinguished in the phloem, though not enough detail to be of any special interest can be made out.

The cortex is quite well preserved in some cases, as, for instance, in specimen F, of which a transverse section is shown in Plate 29, Phot. 22, and a part of the cortex more magnified in Plate 31, Phot. 30. Nearly the whole thickness is preserved, for a portion of the outer "*Sparganum*" zone is shown (Phot. 22). The parenchymatous cortex shows no differentiation; so far as observed it consists entirely of quite short cells, the height being often actually less than the breadth, with moderately thick walls.

Both the parenchymatous cortex and the *Sparganum* hypoderma are shown in tangential section in Plate 28, Phot. 8. This is taken from a leaf-base in connection with the stem. The specimen will be described later, in considering the relation between *Calamopitys* and *Kalymma* (p. 324).

The Leaf-traces.—The course of the leaf-traces in *Calamopitys Saturni* has been described in detail by GRAF ZU SOLMS-LAUBACH,* but chiefly in the outer part of their course, after leaving the wood. In his species the leaf-trace, where it passes out from the wood, is still a single bundle, and only divides into two after entering the cortex.

We shall find evidence that *C. americana* is different in this respect, the trace dividing as it passes out from the pith through the secondary wood, and entering the cortex as two perfectly distinct bundles.

This is shown, for example, in the section represented in the drawing, Plate 35, fig. 2. Two xylem strands are seen leaving the pith and beginning to pass out into the wood. The distance between the centres of the two strands is 1·5 mm., and one strand is slightly in advance of the other. The same condition is shown in other sections; in some cases the precession of one strand before the other is much more marked than in the example figured. One bundle is more perfectly preserved than the other, but in both the characteristic mesarch structure is evident.

Additional evidence is afforded by a tangential section which intersects a pair of bundles farther out in their course through the secondary wood (Plate 35, fig. 3). Here again there can be no question that two distinct outgoing strands are present. They are at different levels, just as the two shown in transverse section (Plate 35, fig. 2) were at different distances from the pith, but here the deviation is greater. The horizontal distance between the bundles (centre to centre) in the tangential

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* '96, pp. 67–71.

section is about 3·5 mm., and the vertical distance about 2 mm. Essentially the same structure is shown in another tangential section from a different part of the specimen. It is therefore evident that two bundles passed out together through the wood, presumably to form the double leaf-trace.

The transverse section from which fig. 2 was taken forms part of a series. With the object of ascertaining how the twin bundles of the trace originated, two such series of transverse sections were prepared at our request by Mr. Lomax; they were cut from the fragments B 1 and B 2, parts of the small stem to which specimen C also belongs. Eleven sections, representing a length of about 4·5 cm., were cut from each piece.

In the lowest section (B 1, I) of the first series a single xylem-strand, apparently with two protoxylem-groups close together, was observed at a prominent angle of the pith. The protoxylems gradually separate, and two sections further up are 300 μ apart, the line joining them making an angle of about 45° with the radius of the stem. After another two sections the protoxylem centres are 500 μ apart, though the xylem strands still appear to be nearly confluent. This is the stage represented in Plate 35, fig. 4, from section B 1, E. One bundle is here much in advance of the other. In the next section the leading strand is entering the secondary wood. In the two succeeding sections the interval between the two strands further increases, and the leading strand begins to divide, as shown by the severance of its protoxylem group into two.

In the last complete section of the series the two original strands are 1·5 mm. apart, while the division of the leading strand has advanced so far that its two protoxylem groups are now separated by an interval of 600 μ.

The uppermost section of the series is incomplete, and the inner of the two strands is missing. The leading bundle, however, is well shown (see Plate 36, fig. 5, from section B 1, *y'*); its division into two strands is here completed; their protoxylem-groups are 750 μ apart. So far as this series is concerned, there is no proof that the strand which lags behind the other passes out at this node; the double trace might be provided entirely by the division of the leading strand. This question is considered below (p. 323).

In the lowest section of the second series (B 2) a very prominent angle of the pith is occupied by two confluent xylem-strands obliquely placed, with their protoxylem centres 480 μ apart. Thus the division is already a good deal farther advanced than at the beginning of the previous series. As we follow the series upwards the protoxylem-groups move further apart, and the xylem-strands themselves separate. Towards the end of the series the strands are widely separated, with a band of secondary wood between them. In the section (B 2, I) shown in Plate 35, fig. 2, already referred to (p. 321) the centres of the two strands are 1·5 mm. apart. In the lower strand the protoxylem-group seems to have divided into two. Both strands having here entered the secondary wood, there can be little doubt that both are passing out to form the double leaf-trace. One is a little in advance of the other, but not so much so as in the former series.

This series shows clearly how a double strand, still confluent where it leaves the pith, has divided into two widely separated strands after entering the wood.

In the series first considered (B 1) a second leaf-trace is present, which is of interest from its showing the bundles farther out in their course than either of those just described.

In the lowest section the strands are beginning to enter the secondary wood, and the distance between their centres is already about 1·6 mm.; they are almost tangentially placed, one being but little in advance of the other. As we follow them farther out, each strand comes to subtend its own arc of secondary wood; about the sixth section from the beginning of the series the two strands have just got clear of the wood of the stele. They are here about 4·5 mm. apart. Though the section is here very imperfect, it can be seen that the secondary wood of each bundle completely surrounded it, extending to its inner or adaxial side. This point is better shown in other sections, especially that represented in Plate 29, Phot. 22, and Plate 30, Phot. 28.

The bundle shown in these photographs is the most complete example we have of a leaf-trace strand at the point where it has just passed out of the wood of the stele. The stem to which it belongs (specimen F) is one with a relatively large pith, about 13 mm. in diameter. The bundle ($l.t.^1$) is one of a pair, but only a portion of its companion is preserved (Phot. 22, $l.t.^2$). Owing to slight decay at the centre of the more complete strand, it could not be determined whether more than one protoxylem-group was present. In a similar bundle, however (shown in a section of specimen C), there are clearly two protoxylem-groups, about 360 μ apart. There is thus a fair amount of evidence for the division of the protoxylem in one or both of the strands of the double leaf-trace.

The interpretation of the case first described remains, however, somewhat doubtful (p. 322). It will be remembered that the leading strand before leaving the wood divided completely into two, which in the uppermost section available were 750 μ apart, centre to centre (see Plate 36, fig. 5). It seems probable that here it was this *second* division which gave rise to the two bundles of the trace, while the previous division (fig. 4) separated the trace as a whole from a reparatory strand which did not immediately pass out.

While some difficulties of interpretation thus remain, we have sufficient evidence to show that to form the leaf-trace a primary xylem-strand divided into two as it left the pith, the daughter strands receding from one another in passing through the wood, and finally entering the cortex as two widely separated bundles. In each strand the protoxylem may divide into two groups.

In the section shown in Phot. 22 the clear interval between the twin bundles is about 3 mm.; the distance from centre to centre would be about 6 mm. This, however, is in a larger stem than that previously described.

The great development of secondary wood around each bundle of the trace is a striking feature (Phot. 28). In the case figured the wood is about 40 cells thick on the abaxial, and about 12 on the adaxial side. A longitudinal section of the same strand, in a plane approximately radial to the strand and obliquely tangential to the stem as a whole, is shown in Plate 36, fig. 6. The primary and secondary wood of the leaf-trace are clearly distinguished, the medullary rays of the latter leaving no room for doubt as to its nature.

The section passes through or near a protoxylem-group; part of a scalariform tracheide from this region is shown in fig. 7, A; a pitted primary tracheide is shown at B, and a similar element from the secondary wood at C.

The strands just described have very much the same structure which we might expect to find in the stele of a branch, and it might be supposed that this was their real nature. We do not think that such a view is tenable. We have direct evidence (see above, p. 323) that such strands with secondary wood of their own are continuous with the paired bundles passing out from the pith. These bundles originate by the division of a single xylem-strand and are clearly of leaf-trace nature; there are in fact no other structures present which could represent the leaf-traces. Further it is highly unlikely that two branches should be given off side by side. It might perhaps be suggested that one strand of the pair was a leaf-trace and the other the stele of a branch, but there is no sign of any essential difference between them.

The only possible interpretation appears to be that the strands in question are the leaf-trace bundles, which retain their secondary wood on first leaving the stele. In the case figured (Phots. 22 and 28) it will be noticed that the leaf-trace lies within the general contour of the wood, though the tissue immediately around it is parenchymatous; in this position it is not surprising that a large amount of secondary xylem should still be retained by the trace-bundles.

Both in *Calamopitys Saturni* and *C. annularis*, GRAF ZU SOLMS-LAUBACH* has found secondary wood accompanying the leaf-trace where it first leaves the stele, but only on its outer side. In a section of *C. annularis*† kindly lent us by GRAF SOLMS, we have noticed that the secondary tissue extends all round the strand, just as in *C. americana*.

The Leaf-base.—The specimens hitherto described only show the leaf-traces up to the point at which they pass out from the wood of the stem. We have another specimen (K) which consists of a leaf-base in connection with a portion of the stem. Transverse sections are shown in Plate 27, Phot. 7, and Plate 28, Phot. 13, and longitudinal in Phots. 8 and 9. Not much of the stele is shown, but there is enough to identify the stem as that of a *Calamopitys*, probably of the species *C. americana* (see Plate 27, Phots. 7 and 6). The structure of the secondary wood, as regards the dimensions of the tracheides, pitting, so far as shown, the width of the medullary rays and the form

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* '96, pp. 68, 71, 74.

† No. 98, Berlin, Coll. Solms, 411.

of the ray-cells, is identical with that of the other stems referred to this species. The main part of the pith is not present, but only a narrow prolongation, such as we find in *C. americana*, where a leaf-trace is about to be given off (*cf.* Plate 35, fig. 4; Plate 34, Phot. 49). In this arm of the pith two mesarch xylem-strands are seen, one at the outer end, next the secondary wood, the other straight behind it, the distance from centre to centre of the two strands being about 1·2 mm. (Plate 27, Phot. 6). Just the same arrangement occurs in *C. Saturni*[*] and *C. annularis*[†]; some approach to it is seen in sections of *C. americana*, see for example Plate 35, fig. 4, where, however, the bundles are placed obliquely and not directly one behind the other.

Unfortunately the serial sections which were cut from specimen K add little or nothing to our knowledge; the wood soon dies out, and in the sections where it is still present there is little change in the position of the strands.

A leaf-base is in connection with the cortex of the stem; the two are separated by an irregular band of fibrous strands, a preparation for the departure of the petiole from the stem.[‡] Vascular bundles are present both in the leaf-base and the cortex. In the former seven are shown. Four of them are ranged on the outer side of the leaf-base in a rank, parallel to the *Sparganum* cortex (Phot. 7). They are all elongated vertically to the surface; in each there are two imbedded protoxylem-groups, nearer one side than the other (Plate 28, Phot. 14). Where two bundles are adjacent their protoxylems face opposite ways. The three other bundles lie towards the inner side of the leaf-base. One of them is long and curved with the concave side inwards and seems to have several protoxylem-groups; it probably represents a fusion of two strands. No doubt the leaf-base is incomplete and would have had more bundles altogether.

The three bundles in the cortex, all, apparently, destined for one leaf, are less elongated in section than those of the leaf-base; the longer axis is placed in the radial direction. *Sparganum* cortex is preserved both on the stem and on the leaf-base. The structure is manifestly of the *Kalymma* type, just as in the specimens described by GRAF ZU SOLMS-LAUBACH. The specimen in fact shows a *Calamopitys* stem in connection with a *Kalymma* leaf-base and thus affords fresh evidence of the connection of these fossils.

It is rather unfortunate that no bundles are seen, in this specimen, immediately outside the wood, so that we cannot tell how long they retained their secondary wood. The best specimens of *Kalymma* in our material are detached from the stem and will be considered separately.

We may now sum up our results as to *Calamopitys americana* and briefly compare it with other species.

1. Primary wood consisting of a ring of closely approximated mesarch xylem-strands,

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[*] Coll. Solms, 422.

[†] Coll. Solms, 413.

[‡] *Cf. C. Saturni*, SOLMS, '96, Taf. 4, fig. 12.

surrounding a mixed pith which contains a varying proportion of tracheides interspersed with parenchyma.

2. Secondary wood with high multiseriate medullary rays. Tracheides with several rows of alternating pits on the radial walls.

3. Cortex of uniform, short-celled parenchyma, with a hypoderma of fibrous strands (*Sparganum* structure).

4. Leaf-traces passing out through the wood in pairs, the pair arising by the division of a single bundle; each leaf-trace bundle surrounded by a ring of secondary xylem where it leaves the wood.

5. Leaf-base containing a number of mesarch vascular bundles, the general structure being that of *Kalymma.*

There are two points in which the organisation of *Calamopitys americana* is peculiar as compared with that described in the case of other species. One point is the mixed pith, containing tracheides in all parts; the other is the presence of paired leaf-trace bundles in the wood. A third, less important point is the considerable development of secondary tissue around the leaf-trace bundles, extending to the inner as well as the outer surface. This last character, however, certainly appears in *C. annularis*, as already mentioned (p. 324).

There is reason to suspect that a mixed pith may have also existed in *C. annularis*, though not hitherto described as such. In a radial section* lent by GRAF SOLMS, the pith contains some long tubes, apparently with a wall of their own, strongly recalling the scattered tracheal elements in the pith of the larger specimens of *C. americana* (Plate 36, fig. 8). In the Saalfeld specimen, however, the preservation is hardly good enough to put the nature of these structures beyond doubt. A re-investigation of the Thuringian species, especially *C. annularis*, from this point of view is desirable.

As regards the double leaf-trace, there can be no doubt that this character is a real point of difference between *C. americana* and *C. Saturni.* The detailed account of the emission of the leaf-trace in the latter species given by GRAF SOLMS† shows clearly that the trace leaves the wood as a single strand, and only begins to divide after reaching the cortex.

Whether this also holds good for *C. annularis* is not stated, and could not be determined from the sections of this species kindly lent by GRAF SOLMS for the purpose of comparison with *C. americana.* It is not impossible that in this respect also *C. annularis* may agree with the Kentucky plant, the leaf-trace becoming double before passing out through the wood. At present, however, the evidence is indecisive, and here also further investigation of *C. annularis* is required.

From the sections examined it seems probable that the species *C. Saturni* and *C. annularis* are really distinct, as GRAF SOLMS was inclined to believe.‡ It is the

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* 97 R, Coll. Solms, 413.

† '96, pp. 67–71, Taf. 4, figs. 1–7.

‡ '96, p. 75

latter which shows the closer agreement with the American species, while *C. Saturni*, at least in the structure of the primary xylem, approaches the British species *C. fascicularis*, one of those separated by Dr. ZALESSKY under his genus *Eristophyton*.

The Petiole (Kalymma).—*Kalymma*, as shown by GRAF SOLMS-LAUBACH in his work on UNGER's Thuringian fossils,* was the petiole of *Calamopitys*. The present investigation has further confirmed this attribution, for, as already described, a leaf-base with the structure of *Kalymma* has been found in connection with a fragment of stem showing the characters of a *Calamopitys*, in all probability referable to the species *C. americana*.

In our Kentucky material there are several detached specimens of *Kalymma*, some of which must have belonged to far larger stems than any of those of *Calamopitys americana* which have come under observation. Whether in all these cases we have to do with the same species must for the present remain an open question. At any rate they are all closely related.†

It has been mentioned in describing the leaf-base attached to the stem that the outer vascular bundles, as seen in transverse section, are elongated vertically to the surface. This seems to be a constant characteristic of our *Kalymma*, subject to some variations where the bundles anastomose. The typical arrangement of the bundles, which are always in a single ring, is well shown in Plate 28, Phot. 11. This section was not from one of our own specimens, but was cut from a *Kalymma* kindly sent us by Prof. F. O. BOWER, F.R.S. His specimen was derived from the Genessee shales of Kentucky, and therefore at a lower horizon than that of our specimens. The species had been identified as *Kalymma grandis*, Unger; it is clearly the same as ours. In the part figured all the bundles but one are of the vertically elongated form. The exceptional case no doubt represents a fusion of two strands; it has a rounded triangular section, with an imbedded protoxylem-group near each corner (see the detailed photograph, Plate 27, Phot. 3). The elongated bundles have two or more protoxylem-groups placed in or near the long axis.

Plate 28, Phot. 10, shows a section of the small specimen (L) from our own material. Here the form of the bundles is more varied, as anastomosis is more frequent; most of them show the elongated form. One of these strands is shown in detail in Plate 27, Phot. 5. There appear to be two protoxylems, asymmetrically placed, one of them near the end, the other in a lateral position, but imbedded, as indeed is always the case. The fusing bundles assume different shapes and there is some approximation to

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* '96, pp. 45 and 66.

† The following specimens of *Kalymma* petioles have been investigated. Fragments which appear to belong to the same specimen are bracketed together.

(D, M.) Probably from the same specimen; portions of a large petiole, 4–4·5 cm. in diameter.

(N, O.) Same specimen. Adjacent portions of a larger petiole, from 5 to over 6 cm. in diameter.

L. Longitudinal half of a portion of a small petiole, not quite 2 cm. in diameter.

the arrangement found in *Calamopteris*, to be described below (p. 330, Text-figs. 1 and 2; Plate 33, Phot. 43).

It will be seen from the photographs (Plate 27, Phots. 1, 2, and 7; Plate 28, Phots. 10 and 11) that the preservation is too good for any considerable displacement of the bundles to have taken place; the position of the elongated bundles, with the long axis approximately vertical to the surface, is clearly the natural one. The same arrangement is shown in one of UNGER'S figures* but not in the others. In the only section of UNGER'S I have seen ("*Kalymma grandis*," Jermyn Street Museum Collection, No. 15867),† the bundles, except where undergoing fusion, are roundish, not elongated, agreeing with the specific character given by UNGER ("vasorum fasciculis . . . subrotundis").‡

In the largest specimen of the Kentucky *Kalymma*, attaining a diameter of over 6 cm., the bundles are more widely spaced and larger than in the smaller petioles, but otherwise there is no real difference in structure; the form and orientation of the bundles is essentially the same (Plate 27, figs. 1 and 2). A bundle is shown in detail in Phot. 4, and in Plate 36, fig. 9, from a drawing. The illustrations are taken from different sections, probably of the same bundle. In Plate 27, Phot. 4, the bundle has four internal protoxylem-groups lying near the median line; one lies towards each end and two near together about the middle. In the other section there are five protoxylems, as shown in the drawing (fig. 9); all the groups are deeply imbedded; three are practically median, while two somewhat approach one side. The structure of the bundle, except for the increased number of protoxylem-groups, is identical with that figured by GRAF SOLMS from the cortex of *Calamopitys Saturni*.§ We have not, any more than GRAF SOLMS, been able to decide whether the bundle was collateral or concentric in structure. As a rule little, if any, phloem is preserved. In one of the smaller bundles of the largest specimen (O) the phloem-zone appears to be complete, though its tissue has collapsed. It is decidedly thicker on that side of the xylem to which the protoxylem-groups are approximated. This agrees with an observation of GRAF SOLMS'S.‖ In a case where the protoxylems approached the outer side of the bundle he found the bast concentrated on that side.

As we have seen (p. 324), the bundles of the leaf-trace, where they first leave the wood of the stem, have secondary xylem all round them, an indication of concentric structure at that level. This, however, is no proof that the structure remained concentric farther out in their course, for in *Medullosa anglica* and other species the leaf-trace starts as a concentric strand, and becomes collateral as it breaks up into the

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* UNGER, '56, Taf. 1, fig. 5.

† On the glass of the slide is the number 95. The section is said to be figured by UNGER, Taf. 1, fig. 4, but in that figure the bundles are very obscure. The Saalfeld sections from the Jermyn Street Museum were kindly lent by the Director of the Geological Survey for purposes of comparison.

‡ p. 157.

§ SOLMS, '96, Taf. 4, fig. 11.

‖ '96, p. 45.

petiolar bundles.* We shall have occasion to refer to the question again in describing the petiole named *Calamopteris Hippocrepis*, an ally of *Kalymma* (see p. 332).

The preservation of the *Kalymma* material is such that the longitudinal sections are usually very unfavourable for observing the pitting of the tracheides. In one case, however (Specimen D, Section 21), several spiral elements, some of them with a loosely coiled band, were clearly seen, about the middle of the xylem. In other parts of the strand they passed over into scalariform tracheides; evidently this section happened to pass through a protoxylem-group. Scalariform pitting is recorded by GRAF SOLMS in the Saalfeld specimens.† It is not surprising that scalariform tracheides should predominate in the petiole while those in the stem mostly have multiseriate pits; the same difference exists in *Medullosa anglica*‡ and other cases.

Little need be said about the other tissues of the *Kalymma* petioles. The parenchyma (Plate 28, Phot. 12) is of the uniform, short-celled form, already described in the case of the cortex of the stem (see above, p. 321). A line corresponding in position to the middle lamella is extremely conspicuous in the walls of the cells. Sometimes the cells immediately surrounding a vascular bundle are rather smaller and thicker-walled than the rest; no well-marked sheath has been observed. The only differentiation in the ground tissue of the petiole or rather leaf-base is the presence of irregular bands of sclerenchyma, marking, as it appears, the junction with the cortex of the stem (Plate 27, figs. 1 and 2, *sc.*). The structure of these internal bands is the same as that of the *Sparganum* hypoderma. In these cases it seems that a portion of the cortex had been torn off with the leaf-base.§

In the larger petioles the *Sparganum* zone consists of bands of sclerenchyma much elongated radially, resembling that of the *Myeloxylon radiatum* of RENAULT. The bands are separated by broad tracts of parenchyma. In the smaller specimens the bands are shorter radially, more crowded, and sometimes confluent.

Tangential sections show that the fibrous bands have an accurately parallel course (*cf.* Plate 28, Phot. 8); anastomosis by means of a narrow, oblique, connecting strand has been observed. Parenchymatous cells occasionally occur among the fibres, which have a much-thickened wall, but preserve a different lumen.

The facts concerning our *Kalymma* may be summarised as follows:—

1. Vascular bundles in a single ring, crowded in the smaller, scattered in the larger, petioles.
2. Bundles commonly elongated, as seen in transverse section, at right angles to the surface. In the smaller specimens fusion of the bundles frequent.

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* SCOTT, '99, p. 94.

† '96, p. 45.

‡ SCOTT, '99, p. 95.

§ *Cf.* SOLMS, '96, p. 44.

3. Concentric or collateral structure uncertain, xylem mesarch, with 2–5 protoxylem-groups.
4. Parenchyma uniform, short-celled.
5. Fibrous bands of the *Sparganum* hypoderma radially elongated and remote in the larger petioles, shorter and more crowded in the smaller.

It is probable, as GRAF SOLMS has pointed out,* that several species are included under *Kalymma grandis.* UNGER himself distinguished a species, *K. striata,* a slender form, "vasorum fasciculis internis sectione transversali semiorbiculatis hinc illinc coacervatis."† From the figure‡ this seems to have somewhat resembled our smallest petiole (Plate 28, Phot. 10), and in the occasional fusion of the bundles shows, like the latter, an approach to *Calamopteris* (see below). Among our own specimens, we do not feel sure that there is any specific distinction; the differences in structure may merely be correlated with difference of size, and the whole may belong to the stem which we have named *Calamopitys americana.*

The form next to be described, however, appears to be quite distinct.

2. CALAMOPTERIS HIPPOCREPIS.

Among our material there were three specimens of a very characteristic petiole, no doubt allied to *Kalymma,* which we have decided to place provisionally in UNGER'S genus *Calamopteris,* as a new species.§

The general structure will be evident from Plate 33, Phot. 43, and the diagram, text-fig. 1.

The vascular system, as seen in transverse section, may be described as forming a split horse-shoe, *i.e.*, the bundles are ranged in an interrupted ring, with a wide opening on one side and a narrower opening on the other. One may conjecture that the wider gap was on the side turned towards the stem, but this cannot be proved. The slight changes in arrangement met with in the different sections do not affect the general scheme. Taking the sections figured, we find that bordering the wider opening there are two separate elongated strands turned a little inwards (B). On each side of them there are one or two more or less isolated strands, beyond which we come on either side to a long band of almost or quite continuous vascular tissue or fused bundles. At the narrower gap the ring is much invaginated. There are here

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* '96, p. 46.

† RICHTER and UNGER, '56, p. 158.

‡ *Loc. cit.*, Taf. 1, fig. 7.

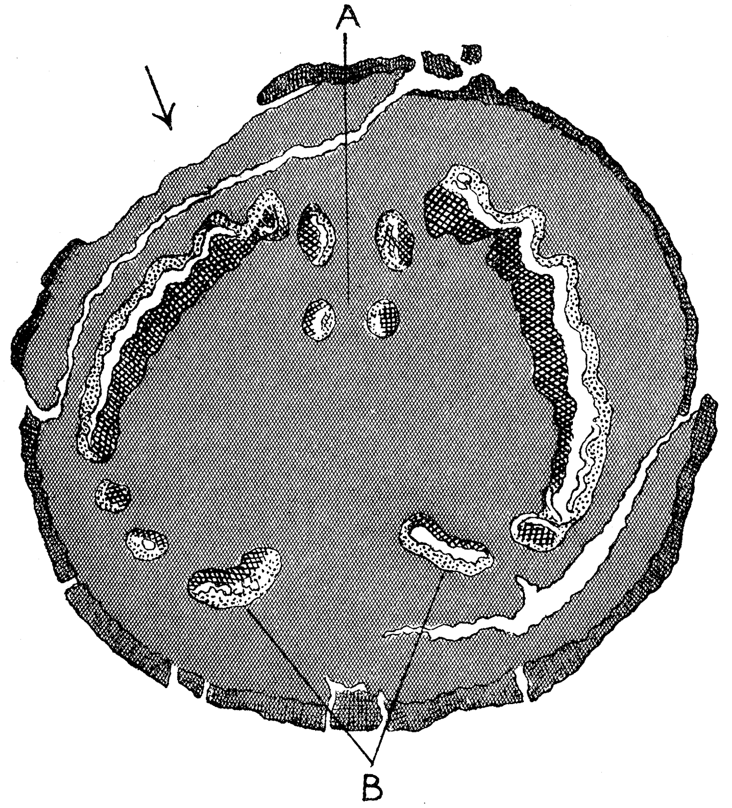
§ The specimens referred to are:—

A. Portion of petiole, about 16 mm. in diameter, widening in the course of about 13 mm. to a diameter of about 20 mm. Total length of fragment about 27 mm.

(H, J.) Fragments about 15 mm. and 14 mm. in diameter respectively. H and J are almost certainly parts of the same specimen; possibly this is true of all three fragments.

four bundles (at A), the inner pair of which is deeply imbedded in the central ground tissue.

In the more continuous lateral bands there are outward prominences, which may be taken as marking the position of constituent bundles. Such prominent portions are in some places almost detached, at least as regards the xylem, as shown on the left-hand side of the narrower gap (*a*) in the photograph (Plate 33, fig. 43) and on the right-hand side of text-fig. 1. The grouping of the bundles is, on the whole, very definite, and gives the section quite a different character from that of a typical *Kalymma*, so much so as to appear to justify generic separation. The two transverse sections figured in text-fig. 1 and Phot. 43, cut at a distance of about 14 mm. from each other, show no appreciable difference in the arrangement of the vascular tissue. The section from the larger end of the same fragment, where the diameter has increased to 20 mm., presents some slight differences. The lateral bands are even more extensively continuous than before; the inner pair of invaginated bundles at the narrower gap almost reaches the centre of the petiole; one bundle of the other pair appears to be dividing; the opposite gap is very wide, but flanked by the same two elongated bundles as before.



TEXT-FIG. 1 (G. T. G.), *Calamopteris Hippocrepis.* Transverse section of petiole, showing the arrangement and form of the partly confluent bundles, and the position of xylem (cross-hatched) and phloem (dotted). At A are the four bundles of the invagination, at B the two bundles flanking the wide gap. The arrow points to the part of the vascular zone drawn in Plate 37, fig. 10. × 6. Section A, 2.

The two smaller fragments (H and J) are alike in structure. Here the narrower gap is closed, the four isolated bundles being replaced by a marked invagination of the ring, with only partial separation of the strands, or, in other words, they are represented by a **U**-shaped group, with its concavity outwards. At the opposite side the gap is wide with the usual elongated flanking bundles. On each side of these there are two isolated bundles before we come to the more or less continuous lateral bands.

These are all trifling changes—the general conformation of the vascular system of the petiole remains the same throughout.

The vascular bundles show a definite orientation. The xylem, indicated in transverse section by its generally well-preserved, moderately thickened cell-walls (see Plate 33, Phot. 43), is directed inwards; the phloem, imperfectly preserved, with small irregular elements, faces outwards. At the smaller gap the four bundles have their xylem on the sides remote from the gap, as follows from their forming an invaginated portion of the ring (text-fig. 1, A).

We are inclined to believe that the structure of the bundles was really collateral; the masses of ill-preserved, somewhat collapsed tissue, which we interpret as phloem, are always found on the outer side; on the inner side, adjacent to the "pith," the xylem often abuts almost immediately on the ground tissue, with at most only a layer or two of intervening collapsed cells, which may well be regarded as pericycle (Plate 37, fig. 10).* At any rate there can be no doubt that the great mass of the phloem was on the morphologically external side. This is confirmed by the longitudinal sections, in which the xylem can sometimes be seen to abut directly on the ground tissue on the inner side of the bundle, while the less definite, long elements presumably representing the phloem are limited to the opposite (outer) side.

As regards the position of the protoxylem, there seems to be no doubt that the xylem was mesarch (Plate 37, fig. 10). Both in the separate bundles and in the prominent angles of the continuous vascular bands, a group of small, rather disorganised elements can often be detected embedded in the xylem not far within its external surface. In one case, in longitudinal section, a narrow densely spiral or scalariform element could be recognised a little to the inside of the disorganised part. The evidence is not as good as one could wish, but, from the frequency of the structure described in transverse section, we feel convinced that the bundles were mesarch, with the protoxylem-groups near the external surface of the xylem. The tracheides, so far as the imperfect preservation allows us to judge, were scalariform throughout.

The ground tissue of the petiole is of the short-celled kind, exactly as we found in *Kalymma* (Plate 33, Phot. 44; *cf.* Plate 28, Phot. 12). The *Sparganum* hypoderma, like that of the smaller Kalymmas, is very strongly constructed, the sclerenchyma exceeding the intervening parenchymatous bands in sectional area.

We have now to consider the affinities of this well-characterised fossil. That it is

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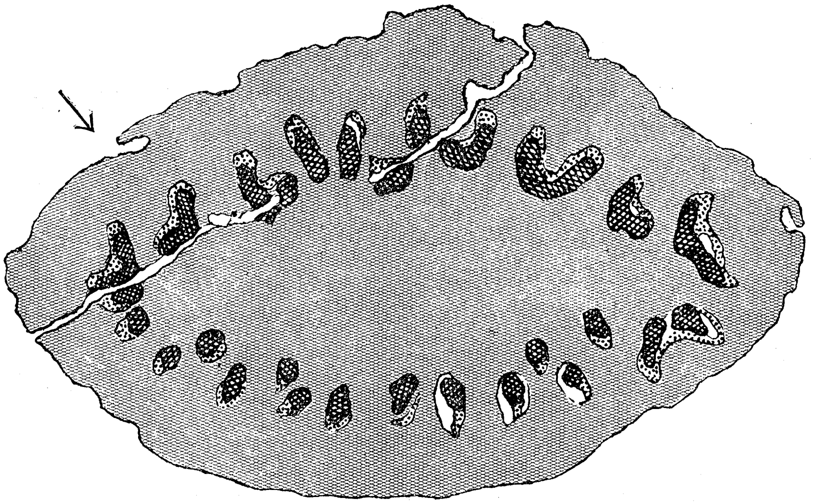
* In the part figured there is a gap on both sides of the xylem, but the phloem is only present on the outer side.

allied to *Kalymma* seems clear, from the structure of the hypoderma and ground tissue, and from the mesarch character of the bundles. The evidence for collateral structure is stronger here than in *Kalymma* but it may be true of both (see above, p. 328).

A glance at UNGER'S figures* at once shows a resemblance between his *Calamopteris debilis* and the Kentucky petiole. His fig. 2, especially, from a specimen in which the bundles are much fused, is strikingly like our sections. The hypoderma, shown in detail in UNGER'S fig. 3, is the same as in our plant; the vascular bundles† quite sufficiently similar.‡ A section of *Calamopteris debilis* which GRAF SOLMS kindly sent for the purpose of comparison (No. 435 in his collection) is represented diagrammatically in text-fig. 2. It shows the form of *Calamopteris debilis* in which the bundles are separate and thus differs considerably from our fossil, approaching the small *Kalymma* shown in Plate 28, Phot. 10. The diagram, text-fig. 2, shows the arrangement in GRAF SOLMS'S specimen. There are about 25 strands, most of which are of simple form, while several, especially those on one side, are of U-shape with the concavity outwards. The latter form may be regarded as due to the fusion of two or more of the simple strands. U-shaped groups have also been observed in the Kentucky form, though not characteristic of it.



TEXT-FIG. 2 (G. T. G.), *Calamopteris debilis*, Unger. Transverse section of petiole, showing the arrangement and form of the bundles and the apparent position of xylem and phloem. The arrow indicates the bundle drawn in Plate 37, fig. 11. *Cf.* text-fig. 1, p. 331. × 6. Solms Collection, 435.

As regards the structure of the individual bundle in *C. debilis*, we may refer to Plate 37, fig. 11, representing a somewhat U-shaped strand. The xylem shows two groups of small elements, both directed outwards, and placed near the ends of the arms of the U. The rest consists of fairly uniform, large tracheides. No doubt the

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* RICHTER and UNGER, '56, Taf. 2.

† *Loc. cit.*, figs. 4 and 7.

‡ See also UNGER'S Taf. 8, figs. 11 and 12 (*Stephanida gracilis* and *duplicata*); GRAF SOLMS has shown that *Stephanida* is merely a *Calamopteris* which had lost its *Sparganum* hypoderma.

protoxylem lay in the small-celled groups, as Graf Solms observed.* Whether the structure was truly exarch or mesarch, with the protoxylem near the outer surface, cannot be decided, but there is no reason to suppose that there was any essential difference from *Kalymma* or the Kentucky *Calamopteris* in this respect. In all these forms the exact position of the protoxylem was subject to variation, though the structure, when clearly determinable, has proved to have been more or less mesarch.

The band of small-celled tissue on the external side of the xylem-mass is no doubt the phloem. In this case no such tissue is seen on the inner side, but this is not conclusive, as there is a gap. So far, however, as can be seen in this section the structure of the bundles is either collateral or irregularly concentric, the bast being at any rate concentrated on the outer side (text-fig. 2).†

On the whole there seems to be no doubt that an affinity exists between our fossil and the *Calamopteris debilis* of Unger (under which his *Stephanida gracilis* and *duplicata* may be included). The resemblance is closest to those forms‡ in which the bundles are largely confluent, so as to form long continuous bands. Whether, among Unger's specimens, this character possessed specific value (as indicated by the name *Stephanida duplicata*) cannot be determined. In the Kentucky fossil the arrangement of the bundles is so definite, and in the main so constant in the various fragments, that a specific name is certainly called for. We propose to call the species *Calamopteris Hippocrepis*. Its characters may be summed up as follows :—

1. Vascular system of the petiole forming a horse-shoe, with a marked invagination at the bend.
2. Lateral bundles confluent, forming continuous bands.
3. Structure of the bundles collateral.
4. Xylem mesarch, with the protoxylem-groups near the morphologically outer surface.
5. Parenchyma uniform, short-celled.
6. Fibrous bands of the hypoderma crowded, with relatively little intervening parenchyma.

The question of nomenclature presents some difficulties ; it may be doubted whether Unger's genus *Calamopteris* ought to be kept up. We might have called our plant *Kalymma Hippocrepis*, but it seems to us to differ very definitely from the typical *Kalymma* and we have taken advantage of the existence of the genus *Calamopteris* to emphasize the distinction.

Graf Solms proposed to include all the fossils of this group in the provisional genus *Rachiopteris*, under the names *R. Kalymma*, *R. debilis* and so on.§ Since 1896, however, our knowledge of the petioles of palæozoic ferns and fern-like plants has

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* '96, p. 32.—*Stephanida.*

† *Cf.* Solms, '96, pp. 36, 42.

‡ Richter and Unger, Taf. 2, fig. 2 ; Taf. 8, fig. 12.

§ Solms, '96, p. 97.

grown rapidly, and the vague name *Rachiopteris* is generally abandoned, or at most only used in the most obscure cases as a confession of ignorance. There is no obscurity about *Kalymma*, which is known to have been the petiole of *Calamopitys; Calamopteris* belongs, at any rate, to the same group as *Kalymma.*

It may be asked, why keep up separate names for the petioles at all? Why not drop the name *Kalymma*, and call the fossil what it is, the petiole of *Calamopitys?* This is a question which constantly recurs in Fossil Botany; as a rule, it has been found convenient to maintain names for separate organs, because we are seldom able to refer them to a particular species of stem, though we may know the genus. In the case of *Calamopteris* (especially the new species, *C. Hippocrepis*) we cannot even be certain that it belonged to a *Calamopitys*, though no doubt if its stem were known it would prove to be of the same family.

For these reasons we have used the name *Calamopteris Hippocrepis* for the Kentucky petiole, while fully recognising that the genus *Calamopteris*, and indeed the whole group, requires revision.

3. PERIASTRON PERFORATUM.

This interesting and very distinct fossil appears, from its bilateral symmetry, to have been a petiole, but we have no clue whatever to the nature of the stem to which it belonged. The two specimens* differ somewhat in size, but agree in structure, apart from some small variations no doubt correlated with their dimensions.

Two conspicuous features at once strike the eye, on observing a transverse section:—

1. The vascular bundles are confined to a median band in which they are ranged in a nearly straight row, coinciding with the major axis of the elliptical transverse section (see diagram, text-fig. 3 and photograph, Plate 32, Phot. 37).
2. The cortical tissue on either side of the median band, extending from the latter to the hypoderma, is perforated by numerous lacunæ, of varying size, between which the persistent parenchyma forms walls only a few cells thick (Plate 32, Phots. 37, 39).

These two characters, the median row of bundles and the lacunar cortex, at once distinguish *Periastron* from all other fossils with which we are acquainted.

The arrangement of the bundles is best shown in the diagram, text-fig. 3, from the most complete transverse section. It appears that the full number is preserved. There are ten bundles,† which are, on the whole, separate from one another; the four bundles next the centre, however, form two definite pairs; the two bundles of each pair are to some extent connected (see Plate 32, Phot. 38; Plate 37, fig. 12). The degree of

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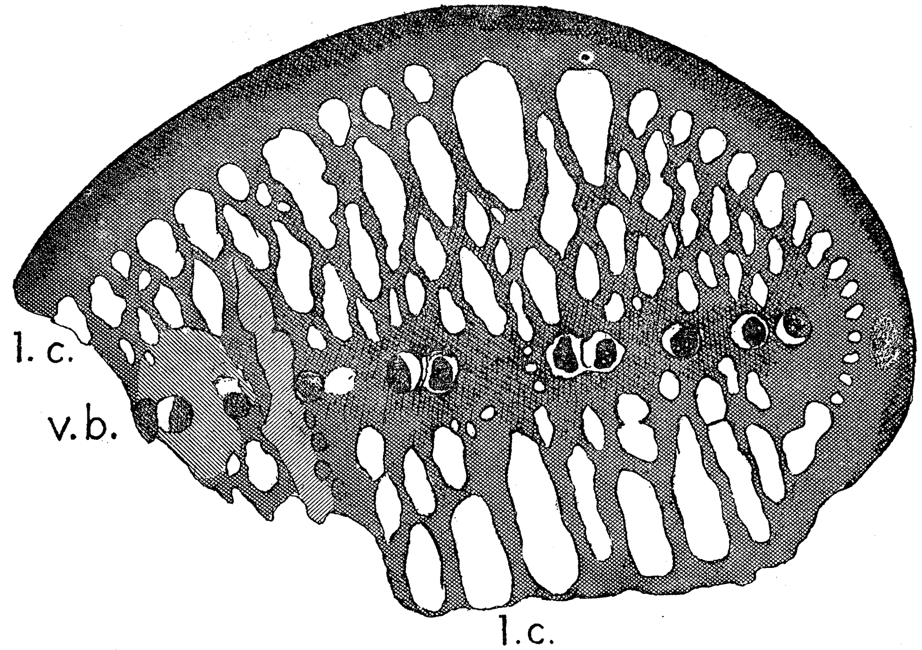
* They are:—

E. The more complete specimen. A portion of a petiole 16 × 13 mm. in diameter, partly embedded in a rounded, pebble-like nodule.

P. Fragment of a larger petiole, of which only about half the thickness is preserved. The diameter when complete would apparently have been about 24 × 16 mm.

† Or eleven if we regard the terminal strand on the left as double.

connection between the bundles of a pair varies a little in different sections ; otherwise the arrangement of the bundles remains practically constant in the smaller specimen (E).



TEXT-FIG. 3 (G. T. G.), *Periastron perforatum.* Diagram of the most complete transverse section, showing the position and form of the vascular bundles and lacunæ. *v. b.*, the median band containing the bundles ; *l. c.*, the lacunar zone of cortex. × 7. Section E, *b.*

The larger specimen (P) is more fragmentary and only about half the transverse section is present. Five bundles are shown, the two nearest the middle of the petiole forming a pair, so presumably the arrangement was the same as in the first specimen. In the smaller specimen (E) the maximum diameter of a bundle is 0·86 mm. ; in the larger specimen (P) the bundles are larger in proportion, attaining 1·3 mm. in diameter.

In some cases the bundles are very fairly preserved, but the lumina of the tracheides are commonly occluded by some disorganisation-product similar in colour and density to the cell-walls, so that careful illumination is necessary to bring out the latter clearly (Plate 32, Phot. 38 ; Plate 37, fig. 12). The xylem forms a solid mass, composed for the most part of rather large tracheides, about 80–90 μ in diameter.

Towards the exterior there is some diminution in the size of the elements (more marked in the larger specimen) but it has not been possible to localise the protoxylem ; neither do the longitudinal sections show any spiral elements.

The tracheides appear to be scalariform throughout, as is very well seen in the photograph, Plate 32, Phot. 40, from a bundle in the larger specimen.

It is not always easy to fix the limit between xylem and phloem, but in many places a zone with clear lumina is preserved (see Plate 32, Phot. 38, and especially the drawing, Plate 37, fig. 12). The elements of this zone, as seen in transverse section, are angular and irregular; the longitudinal section shows that they are long tubes and that their walls are without any tracheal markings; they cannot therefore belong to the xylem. One may assume that this zone represents the phloem. A part of it is seen (to the left) in the longitudinal section, Plate 32, fig. 40, though here the lumina of the cells are obliterated.

In the transverse sections, though the phloem zone is never quite complete, the position of the best-preserved portions proves that it extended all round the xylem, and that the bundles were therefore concentric (Plate 37, fig. 12). In certain sections the phloem of the two bundles of a pair is confluent, forming a considerable mass, as much as eight cells thick, where the bundles join.

Surrounding each bundle are some layers of narrow cells, appearing thick-walled, and constituting a bundle-sheath (Phot. 38; fig. 12). Towards the exterior these cells become larger and pass over into the parenchyma of the median band between the bundles. This is confirmed by longitudinal sections, in which the cells next the bundle are seen to be narrow and elongated, while farther out they show more frequent transverse walls and become parenchymatous. The tissue of the median band has, on the whole, smaller cells than the cortical tissue farther out, between the lacunæ; its cells are also somewhat longer vertically, and appear thicker-walled, but thickness of wall is an untrustworthy character in this material, in which there has clearly been much *post-mortem* alteration. The differentiation of the median band is more marked in the smaller than in the larger specimen. In the former the small-celled tissue widens at the end of the median band and joins the hypoderma (Plate 32, Phot. 37; text-fig. 3); in the latter the band stops short after the last bundle, and the narrow end of the elliptical section is occupied by ordinary cortical tissue.

We have now to consider the wide lacunar zone of cortex which forms so striking a feature of the fossil (Plate 32, Phots. 37 and 39; text-fig. 3). The lacunæ start from the median band and extend to within a short distance of the hypoderma, from which they are separated by a band of continuous parenchyma; they are in several ranks and vary extremely in size, diminishing towards the narrow ends of the ellipse. Otherwise there is no constancy in their arrangement, the same lacuna evidently varying in size in different transverse sections. Most of the lacunæ are elongated in the radial direction. The walls of tissue between them are, on the whole, well preserved, and are from one to five cells in thickness; the cells composing them are elongated radially, *i.e.*, parallel to the major axis of the lacunæ (see Plate 32, fig. 39). In the smaller specimen (E) a single series of very small lacunæ extends across the end of the median band (text-fig. 3); in the larger specimen (P) the lacunæ in this position are more numerous and not specially small.

The question arises whether the lacunæ were really empty spaces during life, like those in an aquatic plant, or whether they were originally filled with some delicate tissue which has perished. No decisive evidence is available on this point. Very often the lacunæ are empty, *i.e.*, only occupied by the mineral matrix with occasional fragments of organic débris. In other cases they are traversed by irregular rods or trabeculæ, such as, in this material, sometimes indicate the presence of a disorganised tissue. In the larger specimen (P) many of the lacunæ are coated by a thick membrane, internal to the cellular wall, and clearly due to some *post-mortem* deposit (Plate 32, Phot. 41). On the whole, there is nowhere any clear proof that tissue existed within the lacunæ, except perhaps at one place in a longitudinal section, where a lacuna is crossed by an apparently cellular diaphragm. The transverse section (Plate 32, Phot. 37) shows well how some of the lacunæ are perfectly empty, and others filled by structureless but probably organic material. We are inclined to think that the lacunæ were real intercellular spaces, but do not regard this opinion as by any means established.

The tissue of the median band bordering on the inner edge of the lacunæ consists of more or less isodiametric cells. They appear to be ranged in rows somewhat inclined to the horizontal, a point which would hardly be worth mentioning did it not recur, in a more striking form, in the cortex of the fossil next to be described (*Stereopteris annularis*). As the tissue is followed outwards into the walls of the lacunæ, its cells, as already mentioned, become radially elongated (Plate 32, Phot. 39). The continuous band of cortex between the outer edge of the lacunæ and the hypoderma again has roughly isodiametric cells, which become vertically elongated where they border on the hypoderma. The latter consists of long, narrow, prosenchymatous fibres. We have found no trace of *Sparganum* structure; the fibrous zone appears to be quite continuous (Plate 32, fig. 37).

We have now to consider the affinities of the plant. A fossil from Saalfeld, described by UNGER under the name *Periastron reticulatum*,[*] has so much in common with our specimens that we regard his plant and ours as belonging to the same genus. UNGER'S generic character gives one point strongly suggestive of the Kentucky fossil. "Rhachis herbacea compressa parenchymatosa, fasciculi vasorum medii majores, teretes vel subcurvati, *in lineam rectam juxtapositi*, peripherici multi minores superficie paralleli" (the italics are ours).

The arrangement of the median bundles in a straight line is, as we have seen, one of the main characters of our plant. The "peripheral bundles" of UNGER, as GRAF SOLMS-LAUBACH has shown, are not vascular bundles at all, but were probably of the nature of gum or oil canals.[†]

The elongated form of the transverse section is regarded both by UNGER and SOLMS as natural; in our specimens the form is elliptical. In UNGER'S fossil the total number of the bundles was nine, the central one being twice as large as the others and somewhat hippocrepiform (see his fig. 13). UNGER'S numerous "smaller peripheral bundles," ranged parallel to the surface, are the gum-canals.

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[*] RICHTER and UNGER, '56, p. 170, Taf. 8, figs. 13–15.

[†] SOLMS, '96, p. 34.

He describes the whole space between the "middle and peripheral bundles" as occupied by a large-meshed cellular tissue. He found that the median bundles consisted of only one kind of elements, which he regarded as bast-fibres and not vessels; they are widest at the middle of the bundle, becoming narrower and thicker-walled towards the edge. His fig. 14, showing part of a bundle and adjacent tissue, agrees well enough with the structure in the Kentucky fossil (see our Plate 37, fig. 12).

Graf Solms* confirms Unger's account as regards the arrangement of the bundles, but finds more differentiation in their detailed structure; there is a compact strand of polygonal tracheæ in the middle, with no pits visible, then a ring of thin-walled phloem (better preserved than the tracheides), much thicker on one side than the other,† with a maximum thickness of five cells. The phloem is surrounded by a well-marked sheath of flattened elements.

Among the sections of the Saalfeld fossils kindly lent by Graf Solms, there is one which is certainly of *Periastron reticulatum*, and another probably of the same. The former is labelled "*Periastron reticulatum*, Culm Saalfeld: Coll. Solms n. 443." It is a transverse section, apparently including a little more than half the petiole. The smaller diameter is 11 mm., the larger (incomplete) 17 mm. The general appearance of the section is much like Unger's fig. 13, Taf. 8, and it may probably have been cut from the same specimen. The line of bundles, following the major axis of the section, is evident; some are very obscure, others, including the large, somewhat dumb-bell-shaped strand which was presumably in the middle, are fairly preserved. The state of preservation is much like that of the bundles in the Kentucky plant, but in some respects worse, so many of the tracheides being filled up with a substance which makes the mass almost homogeneous.

The structure of the bundles appears to be the same as in our fossil. The central mass of tracheides, the "clear zone" (no doubt phloem) and the small-celled bundle-sheath, all agree. The tissue in which the bundles are imbedded is like that in our larger specimen (P).

The most interesting point we have detected is that Graf Solms's section of *P. reticulatum* shows large lacunæ in the cortex like those of the Kentucky plant. They appear to have been overlooked by previous observers, no doubt because they were taken for damaged places in the tissue. They are less conspicuous than in ours, because they are mostly filled with the same substance which chokes up so many of the cell-cavities. In some cases the lacunæ have no organised contents; in others they contain trabeculæ (possible but doubtful remains of tissue) just as in our specimens. The cells between the lacunæ are often radially elongated as in our plant.

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* '96, p. 32.

† Graf Solms finds that the phloem towards one surface of the petiole is much thicker than towards the other; we have not been able to detect any such differentiation in *Periastron perforatum*.

The question now arises, is not the Kentucky plant the same species as UNGER's *P. reticulatum?* There is one definite distinction, and one only, so far as we have observed. The gum-canals of *P. reticulatum* are absent in our fossil.

These structures are beautifully shown in GRAF SOLMS's section; fig. 15 in UNGER's Taf. 8 is an excellent representation of the structure where it is best preserved. The diameter of the canal is about 320–400 μ; a single or double row of thin-walled cells surrounds a central cavity. The canals are ranged in a ring, immediately inside the sclerotic hypoderma, and within a millimetre of the surface. They are perfectly definite structures, quite distinct from the large lacunæ of the inner cortex.

Nothing of the kind is present in the corresponding region of our plant. The hypoderma and adjacent cortex are quite well preserved, and the gum-canals could not be overlooked if they were present. The smallest lacunæ may be of about the same size as the gum-canals of *P. reticulatum*, but they are irregular in their arrangement and obviously of the same nature as the larger lacunæ with which they are associated. The conclusion at which we arrive is that the Kentucky petiole is a species of UNGER's genus *Periastron*, differing from the type-species *P. reticulatum* in the absence of the gum-canals.*

The characters of *Periastron perforatum* may be summed up as follows:—

1. Petiole elliptical in transverse section.
2. Vascular system forming a straight median row (corresponding to the major axis) of about 10 distinct bundles, the more central bundles paired.
3. Each bundle round in section, concentric in structure, and provided with a bundle-sheath.
4. Tracheides scalariform.
5. Cortex perforated by numerous lacunæ of different sizes.
6. Sclerotic hypoderma continuous (not of *Sparganum* type).
7. Gum-canals absent.

While the close affinity between our fossil and UNGER's *Periastron reticulatum* is evident, we have no light on the wider question of the systematic position of *Periastron*. UNGER called his species a "Farnspindel," and the presumption is that these fossils belonged to one of the two main groups Ferns or Pteridosperms. The concentric bundles and scalariform tracheides suggest a fern, but we are not acquainted with any palæozoic fern in which the petiole contained numerous distinct bundles.† The arrangement in a straight median row is equally peculiar in either class of plants, and we know of no analogous case. The structure persists unaltered in all parts of our two specimens, and is the same in the sections of UNGER's

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* The second section from GRAF SOLMS (Coll. Solms, n. 442) is certainly of a *Periastron*, as shown by the arrangement and structure of the bundles. Gum-canals appear to be present, but there are no cortical lacunæ. This may be due either to specific difference or to the level at which the section was cut.

† Unless it be *Tietea singularis*, a new representative of the Psaroniaceæ, with which any comparison is clearly out of the question (SOLMS, '13).

P. reticulatum; it cannot therefore be supposed that the straight-line arrangement was peculiar to the base of the lamina or to any other special region. We cannot, from the evidence of the petiole alone, go beyond the conclusion that *Periastron* was the petiole either of a fern or of one of the fern-like Seed-plants.

4. Stereopteris annularis.

Of this fossil, presumably the petiole of a fern, we have only a single specimen.* The diameter is 16 by 14 mm. One end of the fragment is much better preserved than the other, especially as regards the wood, which is remarkably perfect in the sections figured (Plate 33, Phots. 45–47). Towards the opposite end the greater part of the wood has perished, though the other tissues are well preserved throughout.

The following zones of tissue can be distinguished (see the general transverse section, Plate 33, Phot. 45 and Phot. 46):—

1. In the centre the solid band of xylem (*x*). This has a characteristic sectional form—enlarged in the middle and to a less degree at the two ends. The bundle, as a whole, is somewhat concave on one side and convex on the other, thus having only one plane of symmetry. The xylem is 1·4 mm. broad in the middle, 0·5–0·6 mm. at the constricted necks, and 0·8–0·9 mm. at the enlarged ends, the whole length being about 5·5 mm.

2. A narrow band of tissue, perhaps phloem, immediately surrounding the xylem, but too ill-defined to measure.

3. A broad zone of prosenchymatous tissue (*sc*) enclosing the bundle; its thickness ranges from 0·4 to 0·8 mm., the thickness being greatest on the concave side, and least on the convex side and at the ends.

Beyond the prosenchymatous zone there comes a gap, which is not reckoned as representing a distinct zone, as its formation seems to have been chiefly or wholly due to shrinkage of adjacent tissues.

4. The very wide zone of radiating tissue (*r.c.*), suggesting at first sight a secondary structure, but really a part of the cortical parenchyma; it varies from 3 to 4 mm. in thickness.

5. The parenchymatous outer cortex (*p.c.*), about 0·8 mm. thick.

6. The sclerenchymatous hypoderma (*hy*), about 1·2 mm. thick, the inner part consisting of wider fibres than the outer. In transverse section the inner part of this zone can scarcely be distinguished from the parenchymatous cortex immediately within.

The epidermis does not appear to be preserved.

Zones 1 and 2 undoubtedly belong to the vascular bundle; the nature of the prosenchymatous zone, 3, will have to be discussed later.

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* Specimen B, a small nodule in which the fragment of the petiole was partly imbedded. There is very little matrix present.

1. *The Xylem.*—If we leave the comparatively obscure indications of protoxylem out of account for the moment, the xylem forms a perfectly solid mass of scalariform tracheides (see Plate 33, Phots. 46, 48 ; Plate 32, Phot. 42 ; Plate 37, fig. 13). The more central tracheides are large, 90–100 μ in diameter and sometimes as much as 120 μ near the middle of the band ; they diminish in size towards the edges of the xylem, the diminution being most marked at the ends. The scalariform markings are well seen in longitudinal section, and are very uniform (Phot. 42). The preservation is remarkably good and the middle lamellæ of the tracheides stand out with striking clearness (Plate 37, fig. 13). The general form of the bundle suggests a petiole of one of the Zygopterideæ ; there is, however, no sign of peripheral loops or sinuses, and nothing therefore to indicate where the protoxylem is to be sought, except that, if localised at all, it must have been external.

At the ends of the xylem-band, as already mentioned, the tracheides diminish much in size—down to a diameter of about 25 μ, as shown by the longitudinal section ; in the transverse sections it is very difficult to determine where the xylem ends. All these elements, however, so far as they form part of the main mass of wood, appear to be scalariform like their larger neighbours. But farther out, beyond the limits of the xylem, and imbedded in parenchyma, we occasionally find small elements, isolated or in little groups, which have a peculiar thickening of their walls, suggestive of a spiral or annular band (Plate 37, fig. 14). Such elements are chiefly found opposite the enlarged ends of the xylem-plate. The appearance, whether in transverse or longitudinal section, is not conclusive, for the preservation, though relatively good, is not favourable for detecting histological differentiation. The evidence, as far as it goes, indicates that the first-formed tracheides were external, chiefly or wholly localised around the ends of the xylem-plate, and separated from the metaxylem mass by a few cells of conjunctive parenchyma. The approximate position of a probable protoxylem group is indicated at *px* in the general drawing of part of the bundle (Plate 37, fig. 13), but the scale is too small to show the distinctive characters, for which the detailed drawing, fig. 14, must be consulted.

2. *The Phloem.*—The phloem (Plate 33, fig. 46; Plate 32, fig. 42; Plate 11, fig. 13, *ph*) is presumably the narrow zone surrounding the wood and passing outside the supposed protoxylem-groups at the ends of the plate ; the tissue lying between protoxylem and metaxylem must be regarded as conjunctive or xylem parenchyma. Apart from position, however, it is impossible to distinguish between the two tissues ; the elements have little to characterise them, beyond the fact that they are long and narrow ; where measurable the cells are about 20–35 μ in diameter ; the lumina are usually obliterated.

The supposed phloem-zone is narrow throughout ; its apparent increase in thickness at the ends of the bundle is probably due to the great development of the conjunctive tissue in that region. On the flat side of the xylem, towards the middle of its length, the phloem appears to be about four cells thick, and this may have been about its real thickness throughout, apparent differences being due to compression or faulty preservation.

3. *The Prosenchymatous Zone.*—This extensive region begins with elements not very different from those of the supposed phloem; they increase in size towards the middle of the zone, becoming smaller again further to the outside (Plate 33, Phot. 46). The larger cells are about 50–70 μ in diameter, their major axis being usually tangential. The apparent thickness of the cell-walls is very variable, the lumen being sometimes obliterated, sometimes quite clear; the walls, however, are always fairly thick; about 8–12 μ is probably the normal thickness, apart from *post-mortem* deposits. The tissue is a very regular prosenchyma, as shown in Plate 38, fig. 15, from a tangential section. On the whole the characters of this zone are not very different from those of the hypodermal sclerenchyma (Plate 38, fig. 16; *cf.* fig. 15).

The nature of the prosenchymatous zone is somewhat doubtful. It seems decidedly too extensive to be regarded as phloem. A rough calculation of the dimensions gives the sectional area of the xylem as about 5 sq. mm., that of the prosenchymatous zone as about 9 sq. mm. Phloem with an area nearly double that of the xylem is extremely rare, and its occurrence improbable in a plant of the Fern-type. Probably the narrow intermediate zone is rightly interpreted as phloem, and the broad prosenchymatous zone is best regarded as part of the mechanical system. As it is closely associated with the bundle, we may, perhaps, characterise it as a sclerenchymatous pericycle.

In the gap surrounding the prosenchyma no definite traces of structure have been found. Such disorganised material as occurs in the gap may well be derived from torn shreds of adjacent tissues or from chance rubbish. It is probable that the gap was chiefly, if not wholly, formed by contraction of the outer tissues rather than by the disappearance of a special tissue. The contraction no doubt took place principally in the radiating zone, the cells of which have often collapsed.

4. *The Radiating Zone.*—This is much the widest of all (3–4 mm.), and presumably was wider still before it contracted. The appearance, under a low power, suggests, as has already been mentioned, a secondary tissue (Plate 33, Phots. 45, 47); there is, however, no further evidence to support this, and though there is a general arrangement of the elements in approximately radial rows, the regularity is hardly sufficient to justify the idea of a cambial origin.

The structure is difficult to understand clearly, and had no doubt been a good deal altered by maceration or decay before petrifaction took place. The cell-walls are often swollen and thrown into irregular folds (Plate 38, fig. 16). The apparent cell-cavities vary greatly in size; the form of the cells is either roughly isodiametric or radially elongated. Some of the longest radial spaces, however, appear to be intercellular, and due to a splitting apart of the cell-walls, probably after death. On the other hand, some of the smallest lumina may be the expression of foldings of the cell-wall, and not real cell-cavities. But making every allowance for such deceptive appearances, there seems to have been a considerable real variation in the size of the cells.

Radial sections (see Plate 33, Phot. 47; Plate 38, fig. 16) show that all through the radiating zone the cell-rows keep nearly horizontal. At its outer edge, however, they turn up or down (we cannot tell which) in a curve and become an ordinary parenchymatous tissue, no longer showing the irregularities of the radiating region. They then gradually pass over into the vertically elongated cells which form the transition to the hypodermal sclerenchyma (fig. 16). There is thus no sharp break between the various regions of the cortex, and no possibility of a cambium having existed on the *outer* side of the radiating zone.

5. *The Parenchymatous Cortex.*—This, as we have just seen, is really nothing but the outer part of the radiating zone, where the cell-series become inclined and the cells more regular in form. The radial arrangement, however, is lost, so it is best to regard this zone as distinct. As already noted, there is no boundary in transverse section between this parenchyma and the inner hypodermal prosenchyma, the cells of which have about the same transverse dimensions. The transition is somewhat gradual, but the prosenchymatous form is soon attained (fig. 16).

6. *The Hypoderma.*—The diameter of the inner prosenchymatous elements of the hypoderma is about 85–95 μ, that of the outer fibres about 50 μ. The cell-walls appear to become thicker towards the outside, but in this material such appearances may be deceptive. The hypodermal fibres form a perfectly continuous zone, uninterrupted by parenchyma; there is thus no trace of a *Sparganum* structure.

It will be seen that the structure of *Stereopteris annularis* is decidedly complex, as is shown by the following summary of its characters :—

1. Petiole somewhat elliptical in transverse section, traversed by a single vascular bundle.
2. Xylem-plate enlarged in the middle and at the two ends, slightly curved, consisting of a solid mass of scalariform tracheides.
3. Protoxylem probably external, localised at the ends of the xylem-plate.
4. Phloem probably forming a narrow zone round the xylem.
5. Bundle surrounded by a broad zone of prosenchyma, possibly pericyclic.
6. Inner cortex forming a very broad zone of radiating tissue, passing over into the—
7. Middle cortex, consisting of vertically elongated parenchyma.
8. Outer cortex (hypoderma) composed entirely of sclerenchymatous fibres.

The number of zones is indicated by the specific name *annularis*. The generic name *Stereopteris*, originally suggested by the solid xylem, is also appropriate to the strong mechanical construction.

The sharply differentiated, apparently pericyclic zone of prosenchyma, and the highly developed radiating zone of the cortex, are characteristic of this fossil. We have found no analogy for these layers among the Primofilices. It is true that in various species of *Anachoropteris* the space enclosed by the curve of the involute bundle is occupied by sclerenchyma, but this does not surround the bundle externally.

Traces of radial arrangement are common in the cortex of various early ferns (*e.g.*, *Diplolabis Römeri*, *Stauropteris oldhamia*, *Clepsydropsis antiqua*), but in the form of the cells there is no resemblance to the radiating zone of *Stereopteris*. There is a case of radial elongation of cortical cells in the aëriferous or palisade tissue of *Stauropteris oldhamia*.* These cells, however, belong to the outer cortex, were probably assimilatory in function, and obviously cannot be compared to the dense, internal radiating zone of *Stereopteris*.

From the form of the single vascular bundle one is led to suspect an affinity with the Zygopterideæ, but in the absence of any indication of the mode of branching of the frond, it is impossible to arrive at a definite conclusion. The general outline of the bundle is somewhat suggestive of *Clepsydropsis* or *Asterochlæna*, especially the latter,† but the perfectly solid xylem, with no peripheral loops, and with the protoxylem external, precludes any nearer comparison. *Stereopteris* cannot belong to this special line of descent.

Etapteris is of some interest in this connection, owing to the external position of the protoxylem, and the "apolar" (median band) sometimes swollen in the middle.‡ One might imagine *Stereopteris* to be an undifferentiated *Etapteris*, with the antennæ and "pièces réceptrices" very little developed, and the protoxylem imperfectly localised. This is, perhaps, as good a comparison as any, but it is at best a remote one. The new genus, however, finds its place among the Primofilices of ARBER (Cœnopterideæ of SEWARD), and on the imperfect evidence available appears to stand nearest to the Zygopterideæ.

5. ARCHÆOPITYS EASTMANII.

This is one of the most interesting specimens in our material, and represents a new type of stem.§ The fossil includes the wood and pith of the stem (Plate 31, Phot. 33); no cortex is present, and the wood is incomplete. The diameter of the pith is about 5·5 mm.; the maximum radius of the wood (as preserved) about 14 mm. The wood has a dense appearance, though, as we shall see, the medullary rays are often multiseriate; it is secondary wood of an ordinary Cordaitean type.

The pith is the characteristic part of the structure, for it contains, scattered throughout its substance, a number of small mesarch xylem-strands (Plate 31, Phots. 33 and 32; text-figs. 4 and 5); similar strands occur in contact with the

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* SCOTT, '05, p. 115, fig. 2; P. BERTRAND, '09, pp. 61–63, Plate 6, fig. 41; Plate 7, figs. 45 and 47.

† P. BERTRAND, '11, Plate 3, fig. 16; Plate 6, fig. 46.

‡ P. BERTRAND, '09, Plate 16, fig. 112; '12, text-fig. 3.

§ The single specimen (9·3) when it came into our hands was in two longitudinal halves, about 5 cm. long. Consequently the pith is not complete in any section. The whole specimen tapered towards one end, and appeared as if water-worn. There was very little matrix attached to the fossil. Maximum diameter, 2·7 cm.

inner edge of the secondary wood, or partly embedded in it. The resemblance of these xylem-strands to those of *Pitys*[*] suggested the name *Archæopitys*, given to the new genus. In *Pitys* the strands are limited to the outer medullary zone, near the secondary wood, while in *Archæopitys*, as already stated, they are present in all parts of the pith. There is no section in which the pith is complete, but, judging from sections in which half or more than half the area is shown, the total number actually embedded in the pith could not have been less than 16, not counting those which are in more or less close contact with the wood. Of the latter, 7 were counted in half the circumference—presumably about 14 altogether—so it would appear that the xylem-strands commonly number about 30 in all, of which nearly half are in contact with the inner edge of the wood, the rest being free in the pith.

The number, however, varies somewhat at different levels, for strands pass outwards from the pith to join those at the edge of the wood, while new strands appear, to take their place (see p. 350).

Structure of the Xylem-strands and Pith.—The structure of the medullary and circum-medullary strands will first be described, after which their course will be traced, so far as the limits of the specimen allow.

The strands imbedded in the pith have a typically mesarch structure, the smallest elements lying at or near the centre of the strand as seen in transverse section. The structure is shown in the photograph, Plate 31, Phot. 32, and in the drawings, Plate 38, figs. 17 and 18. The appearance of a strand in longitudinal section is shown in Phot. 31, where the sharp contrast between the tracheides of the xylem and the short cells of the pith is manifest.

The central elements—unquestionably protoxylem—are very minute—about 12 μ in diameter. The dimensions increase rapidly outwards, the more external tracheides reaching a diameter of about 80 μ. There is often some slight disorganisation in the neighbourhood of the protoxylem. The outer elements are often somewhat elongated radially to the strand (Phot. 32; fig. 17). There seems to be no xylem-parenchyma in the interior of the strand; at its outer border pith-cells may, of course, intrude between the tracheides. The latter, as shown in longitudinal section, are of the usual elongated form, with oblique walls (Phot. 31); some of the outermost seem to have been comparatively short. The sculpturing on the smaller elements, belonging to or near the protoxylem, can be made out fairly well, and is densely spiral or scalariform. The pitting of the larger metaxylem-elements is very obscure, but there are indications of small multiseriate pits.

The diameter of the typical medullary strands ranges from about 240 to 400 μ. Smaller strands also occur, and will be considered when we deal with the course of the bundles; it appears that they represent the lower ends of the larger strands.

The circum-medullary xylem-strands, *i.e.*, those which are in contact with the inner edge of the wood, vary a little in structure according to their position. Those

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[*] See SCOTT, '02, p. 347, Plate 2, Phot. 8; Plate 5, fig. 14.

which are only in slight contact with the wood have precisely the same mesarch structure as the strands imbedded in the pith ; those, however, which are partly imbedded in the wood, may appear to be exarch, because the obvious primary xylem is only present on the side towards the pith, while on the outer side the protoxylem appears to abut directly on the radial series of the secondary wood (Plate 38, fig. 17, outer bundle). Intermediate states also occur, and sometimes the primary nature of the elements immediately outside the protoxylem is only indicated by their shutting off the inner end of a medullary ray. The fact that the outer part of the mesarch xylem-strand assumes in these cases the radial arrangement proper to the secondary wood is of some general interest. It shows once more how, when cambial growth is once established, primary centrifugal wood tends to become merged in the secondary, so that it is here impossible to draw any sharp distinction between the two. We may say with equal justice, either that the centrifugal primary xylem of the strand is in this part replaced by secondary, or simply that it assumes a radial arrangement of the elements.

The pith, in which the xylem-strands are imbedded, consists of rather large cells, from 80 to 160 μ in transverse diameter. They are usually quite short, shorter than they are broad (Plate 31, Phot. 31). Occasionally longer cells may be found near the xylem-strands, but this is not regularly the case. The walls of the pith-cells are perceptibly thinner than those of the tracheides ; little triangular spaces are present where three cells meet.

Here and there large sacs or cavities occur in the pith ; one of them, of a roundish form, is shown in Phot. 31 near the bundle ; others are of a more elongated shape. They commonly show traces of broken-down cell-walls at the edges. It is very doubtful whether these cavities existed as such during life.

It will thus be seen that the pith was a perfectly typical one, remarkable only for the fact that it was traversed by strands of primary xylem.

Course of the Xylem-strands.—A series of 24 transverse sections was cut for us by Mr. W. Hemingway, the length of the piece cut having been 25 mm. (one inch). This series has been of great value in tracing the course of the xylem-strands, as all the sections except one show more or less of the pith. At the beginning of the series more than half is shown, the area diminishing somewhat towards the other end. One of Mr. Lomax's sections immediately precedes the first of this series, and serves to extend it.

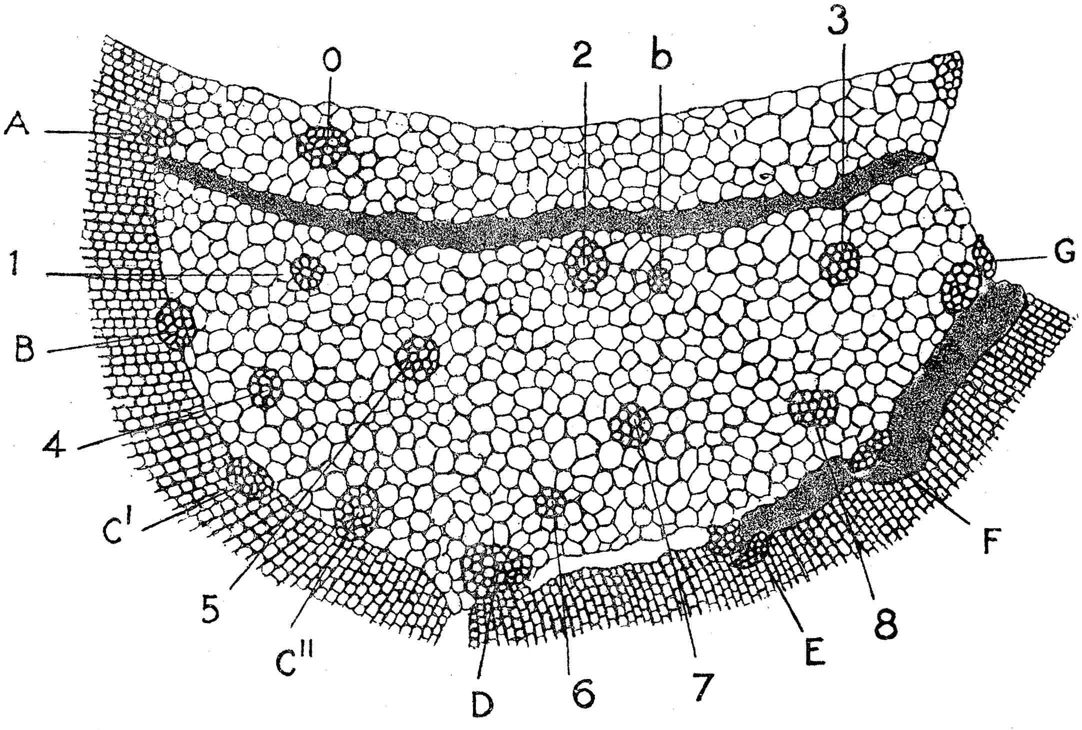
Unfortunately nothing is shown of the exit of leaf-trace bundles. At two places local interruptions in the continuity of the secondary wood have been observed, but there is no proof that they are connected with outgoing strands.

The very curious structure shown, in tangential section, in Plate 31, Phot. 35, might be connected with the outward passage of bundles. Several roundish groups of elements are seen, around each of which the tracheides are strangely convoluted. There is no evidence of any tracheides passing out, and the groups of elements shown may well be merely dilated medullary rays, such as we find in so pronounced a form in parts of the wood of *Pitys primæva*.* The number and irregular arrangement of the groups are certainly points against their representing leaf-trace bundles, though it is possible that the disturbance of the normal structure may be correlated, as in *Pitys primæva*, with the neighbourhood of some appendage. None of the xylem-strands which we have been able to follow pass out through the wood within the limits of the transverse series available, so we can only conclude that a node is not met with.

Very definite changes, however, take place in the arrangement of the strands. These changes are of four kinds :—

1. Fusion of medullary strands with one another.
2. Fusion of medullary with circum-medullary strands.
3. Fusion of circum-medullary strands with one another.
4. Appearance of new medullary strands.

Only one clear case of the fusion of medullary strands with one another has been observed in the limited material available. The two strands shown in Plate 31, fig. 32, have fused into one in the next section (see text-fig. 4, strand 5), and remain united throughout the series.



TEXT-FIG. 4 (G. T. G.) *Archæopitys Eastmanii*. Diagrammatic transverse section, taken at the bottom of the series of 24 sections, showing the position and approximate dimensions of the medullary and circum-medullary xylem-strands. The medullary strands are numbered 0–8, the circum-medullary are lettered A–G. *b*, a small transitory medullary strand. For details see text. × about 20. Section 9·3, 1, Hemingway.

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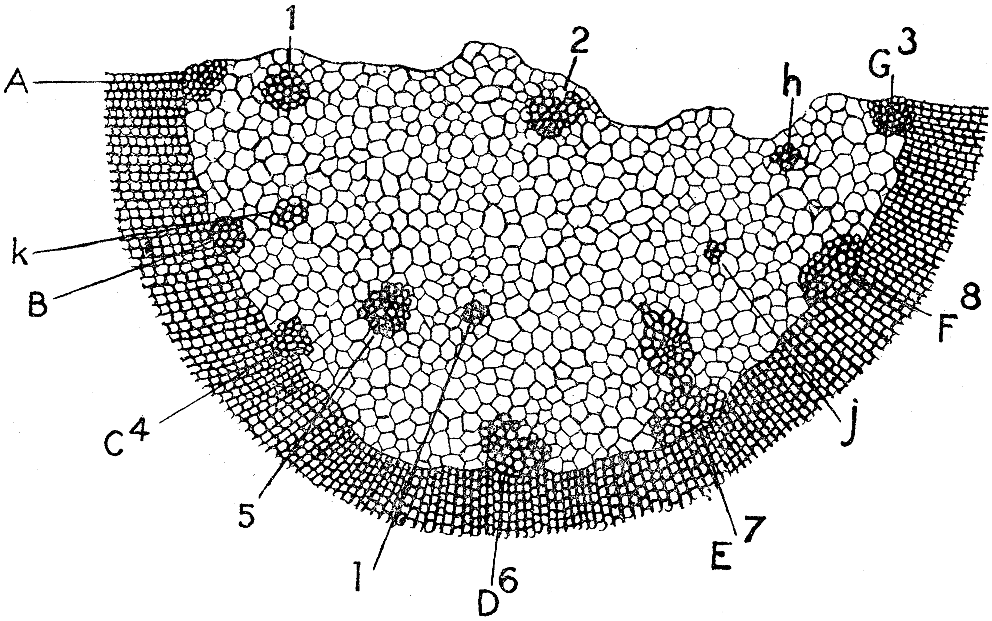
* Cf. *Lyginodendron anomalum* of WILLIAMSON (see SCOTT, '02, p. 355, Plate 6, fig. 23).

The fusion of medullary strands with those at the inner border of the wood (circum-medullary strands) is very frequent; probably this fate overtakes each of the medullary bundles in turn. Of the eight well-marked strands shown in the half-pith at the beginning of the Hemingway series* (text-fig. 4), no less than five have passed outwards and joined circum-medullary strands before the end of the series is reached (text-fig. 5). The comparison of the two diagrams just cited will give a good idea of the changes which take place in the arrangement of the strands in this part of their course. Text-fig. 4 was drawn from a section at the beginning of the series, and text-fig. 5 from one near the end, the distance between the two being about 20 mm. The absence of any leaf-traces passing out through the wood prevents us from determining with absolute certainty the upward or downward direction of the series. The fact, however, that all the movements of the medullary strands, so far as they go, are outwards leaves little doubt that the series (1-24) runs from below upwards, and in what follows it will be assumed that this is the case.



TEXT-FIG. 5 (G. T. G.). Corresponding diagram to text-fig. 4, taken from a section near the upper end of the series. This, compared with text-fig. 4, shows the changes in the position of the strands in a length of stem of about 20 mm. Numbering and lettering as before. Where a medullary has fused with a circum-medullary strand, the product is indicated by the corresponding letter and number, *e.g.*, C4, D6. *h*, *j*, *k*, *l*, small medullary strands, some of which represent new bundles. For details see text. × about 20. Section 9·3, 21, Hemingway.

In the lower section figured (section 1; text-fig. 4), nine main bundles, marked 0-8, are imbedded in the part of the pith shown. The fate of No. 0, as it lies so near the edge of the section, is doubtful, but it is probable that it fuses with the neighbouring medullary strand, No. 1. Of the other eight medullary strands, one of which (No. 5) has arisen, as we have seen, by the fusion of two such strands (see Plate 31, Phot. 32),

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* One of them (No. 5) is the product of the inter-medullary fusion already mentioned.

only three remain in the pith at the upper end of the series (text-fig. 5). The three survivors are Nos. 1, 2 and 5. Two of these (Nos. 1 and 5) have moved outwards, while the third (No. 2) approximately maintains its nearly central position. The remaining five medullary strands (Nos. 3, 4, 6, 7 and 8) have all fused or are fusing with strands at the inner edge of the wood (lettered A–G in the diagrams).

The first fusion is between the medullary strand No. 8 and the circum-medullary one, F; this begins in section 12.

The small strand No. 6 enlarges rapidly and comes in contact with the wood as early as section 5, but does not fuse with a circum-medullary strand till about section 14. It appears to unite with the strand D, but owing to local damage this is not quite certain.

The behaviour of the medullary strand No. 4 is interesting. The two circum-medullary strands C′ and C″ (text-fig. 4) approach each other and fuse early in the series (about section 4); it is only after this fusion has been completed that the medullary strand No. 4 approaches and fuses with the united pair C (about section 16; see text-fig. 5). Here, then, we have an instance of the fusion of two circum-medullary strands preparatory to their union with a strand from the interior of the pith.

The medullary strand No. 3 fuses with G (circum-medullary) about the 18th section, while No. 7 begins to unite with E in the 21st. This last case is illustrated in detail in Plate 38, figs. 17 and 18. The former figure (from section 13) shows the two strands while they are still far apart, with a considerable expanse of pith between them; in fig. 18 (from section 21) the strands are beginning to fuse, their xylem being already continuous. At both levels the inner (medullary) strand has the typical mesarch structure, while the circum-medullary strand shows the peculiarity, already noticed, that the centrifugal portion of its xylem is radially seriated like the secondary wood.

It is evident that the number of the original medullary bundles must steadily diminish, owing to their successive fusions with circum-medullary strands. We have seen that out of eight medullary strands, only three remain in the pith at the end of the series. Unless we are dealing with a branch of limited growth, we must suppose that this diminution was compensated for by the appearance of new strands in the pith. The latter assumption appears to be correct.

As we follow the series upwards a number of new strands make their appearance. Some of them, it is true, are short-lived; thus the strand *b*, shown in text-fig. 4, is only transitory; it disappears about the 6th section, having perhaps fused with the neighbouring medullary strand No. 2. Other strands, or groups simulating strands, appear and disappear, but some persist.

In the upper section figured (text-fig. 5), four little strands are shown in the pith (*h*, *j*, *k* and *l*). Of these, *h*, which first appeared 10 sections lower down, is fairly well marked, and may be a persistent strand; *j* is obscure and probably only transitory; *k* is a fairly important strand, apparently with about 10 xylem-elements; it first appeared, as a much smaller strand, three sections lower down. *l* is another well defined strand in which seven elements are clear; it appeared about the same level as *k*. There seems to be no doubt that these two strands, and perhaps *h* as well, are really new medullary bundles, destined to persist and replace some of those which have passed outwards. This probability is heightened by the analogy of the medullary strand No. 6, which, where it is first seen at the beginning of the series (text-fig. 4) is quite small, comparable in size to the new bundles appearing higher up; it soon, however, grows larger, acquires the typical structure of a medullary strand, and behaves in all respects like its fellows. There is thus every reason to believe that additional strands appear *de novo* in the pith, replacing those which pass out to join the circum-medullary system. They do not, however, appear, so far as observed, in sufficient numbers to keep up the full supply of medullary strands; from this we may perhaps infer that the growth of the branch was limited; there seems to be also a slight diminution in the size of the pith from below upwards, but owing to the incompleteness of the sections this is difficult to estimate.

We have found evidence that the medullary strands, if we trace the series in what we believe to be the upward direction, arise *de novo*; in other words, if followed downwards, they end blindly in the pith. This suggests that they are merely medullary branches of the regular leaf-traces (circum-medullary strands) which remain at the inner edge of the wood. This blind-ending of the medullary strands is rather surprising and suggests that these bundles may be already becoming vestigial; any further discussion of the homologies of the bundle-system may, however, be postponed to the final summary.

The Secondary Wood.—The secondary wood has a dense appearance, though many of the medullary rays are multiseriate (Plate 31, Phot. 36; Plate 38, fig. 19). The tracheides are generally small, the diameter being commonly from 36 to 54 μ, and in some parts much less, down to about 24 μ. The pitting is badly preserved; in some parts of the radial sections it could be made out that the pits were in two or three rows.

The medullary rays vary much in size, but are never of any great height. Fig. 19 shows a good example of one of the larger rays, nearly a millimetre in total height, and five to six cells thick in the middle. A certain differentiation of the ray-cells is noticeable in rays such as this. Most of the cells are small (12–24 μ in diameter), but along one side there runs a row of larger cells about 50–60 μ high and 30–36 μ wide. Uniseriate as well as multiseriate rays are common, and some consist of only a single cell as seen in tangential section (fig. 19). The uniseriate rays often have larger cells than most of those in the multiseriate rays.

Seen in radial section the rays present the usual muriform appearance. Their cells are of considerable length radially, the longer ones ranging from 80 to 120 μ in this dimension.

In transverse section it has been observed that at several places the cells of a ray where it approaches the pith are much dilated tangentially, as in *Pitys antiqua.* This may be the case in uniseriate as well as multiseriate rays. An example is shown in fig. 18, but the dilatation is often much greater than this.

The irregularities in the structure of the wood at certain places, where the tracheides form marked convolutions around altered rays (Plate 31, fig. 35), have already been noticed.

Although the preservation is not such as to permit of so detailed a study of the secondary wood as could be wished, it is evident that it was of the type so well known in the Cordaiteæ.

Summary.

The characters of *Archæopitys Eastmanii* may be summed up as follows :—

1. Pith continuous, not discoid; traversed in all parts by mesarch strands of primary xylem.
2. Circum-medullary xylem-strands, also mesarch, present at the inner edge of the wood; almost equalling the medullary strands in number.
3. Medullary strands passing outwards one by one and each fusing with a circum-medullary strand; new strands appearing in the pith to replace those which have passed outwards.
4. Medullary and circum-medullary strands respectively, also occasionally fusing among themselves.
5. Secondary wood of a Cordaitean character, consisting of small tracheides with two or three rows of pits and of medullary rays, both multiseriate and uniseriate, but of no great height.

The specific name is given in honour of Prof. C. R. EASTMAN, of Pittsburg University, to whom the discovery of the fossils described in this paper is due.

We have now to consider the affinities of our fossil.

The presence in the pith of a number of small, well defined, mesarch strands of primary xylem at once suggests a comparison with *Pitys*, especially *P. antiqua*, the species in which the primary structure has been most fully investigated.[*] It was this comparison which suggested the name, *Archæopitys*, given to the Kentucky plant. ZALESSKY'S fossil, *Callixylon Trifilievi*, of Devonian age, also demands consideration.[†] No other genera appear to be sufficiently near to admit at present of profitable comparison.

Taking *Pitys antiqua* first, the general agreement in the character of the primary xylem-strands will be evident on comparing our figures (Plate 31, Phot. 32; Plate 38, figs. 17 and 18) with those of *Pitys antiqua.*[‡] The dimensions are not very different,

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[*] SCOTT, '02, p. 346.

[†] ZALESSKY, '09 and '11, p. 28.

[‡] SCOTT, '02, Plate 2, Phot. 8; Plate 5, figs. 14 and 15.

and the structure the same, except that there is a little xylem-parenchyma in *Pitys* which seems to be absent in *Archæopitys.*

The obvious difference in the distribution of the strands in the pith of the two genera has already been noticed, namely their limitation to the outer zone in *Pitys* and their presence in all parts of the pith in *Archæopitys.* But besides this there is another important distinction: the extensive system of circum-medullary strands in the Kentucky stem, contrasted with their almost complete absence in the other genus. In *Archæopitys,* as we have seen, they are almost equal in number to the medullary strands, and may perhaps constitute by themselves the leaf-trace system of the stem.

In *Pitys* it is not certain that any circum-medullary system of strands exists. All the primary xylem-strands are imbedded in the pith (medullary) except where occasionally one is seen passing out into the wood. In *Archæopitys* there is no reason to suppose that the medullary strands, as such, ever pass out; they merely undergo fusion with members of the circum-medullary system. In other words, while in *Pitys* the evidence appeared to show that the medullary strands are themselves the leaf-traces, in *Archæopitys* they seem to be merely medullary branches of true leaf-traces which remain at the inner border of the wood.

It is impossible to suppose that the few strands found in contact with the wood in *Pitys antiqua** represent the circum-medullary system of *Archæopitys.* It is almost certain that the former are really medullary leaf traces, which have just reached the wood on their outward course. The other leaf-traces, which had not begun to pass out, must be represented by some, at least, of the medullary strands, perhaps by all except the most deeply seated. No regular fusions, comparable to those between the medullary and circum-medullary strands of *Archæopitys,* have been observed in *Pitys.* We cannot in fact, trace anything like a complete homology between the primary xylem-strands of the two genera, for in *Archæopitys* there appears to be a sharp distinction between circum-medullary leaf-traces and accessory strands imbedded in the pith, while in *Pitys* no differentiation is evident. The difficulty is probably due to the imperfection of our knowledge in each case; the presence and similar structure of the primary strands in the pith of the two genera is sufficient, as it seems, to establish a relationship between them.

The secondary wood does not afford much material for close comparison. In both genera it is of the *Araucarioxylon* type, but the rays form a more important constituent of the whole in *Pitys* than in *Archæopitys,* in which the wood is altogether of a denser structure. The dilatation of the inner ends of the rays may be mentioned as a point common to both.

It is interesting to extend the comparison to Prof. ZALESSKY's stem *Callixylon Trifilievi.*† This form, which is of Upper Devonian age, resembles *Pitys antiqua* in many characters, and notably in the presence of numerous small, mesarch strands of

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* Three out of 46 in the case figured (SCOTT, '02, diagram 5, p. 347).

† ZALESSKY, '09 and '11, p. 28.

primary xylem round the pith. These strands resemble those of *Pitys* in every particular, except in their position. While in *Pitys* the strands are usually imbedded in the pith and separated from the wood, in *Callixylon* they are usually in contact with the wood, though sometimes separated from it by a few small cells. Further, the secondary wood in Dr. ZALESSKY'S plant is arranged in wedges corresponding to the primary strands, which is not the case in *Pitys*. *Callixylon* is clearly much nearer to *Pitys* than to any other known genus, though the narrower rays and other differences may justify generic separation.

Callixylon approaches *Archæopitys* in the fact that most of the primary xylem-strands, like the circum-medullary strands of the Kentucky plant, are in contact with the wood. The wedge-like arrangement of the wood noticed in *Callixylon* also appears to a certain extent in *Archæopitys*. On the other hand, there are no strictly medullary strands in *Callixylon*, all the bundles lying close to the edge of the wood.

The three genera, *Pitys*, *Callixylon*, and *Archæopitys*, certainly form a group of allied plants, but we are not yet in a position to determine the exact relation between them. All may be provisionally included in the family Pityeæ, which, in the present state of our knowledge, appears to form a part of the alliance Cordaitales.*

We have not thought it necessary to extend the comparison to fossils such as *Parapitys* (*Dadoxylon*) *Spenceri* or *Mesoxylon* spp., in which there are no strands imbedded in the pith, or to those, like *Calamopitys americana* and *Heterangium* spp., in which the structure is protostelic. The latter is a primitive type of organisation, essentially different from the case of *Archæopitys*, where the pith is traversed by definite and distinct xylem-strands, each with its own protoxylem.

In the species of *Calamopitys* (*C. fascicularis* and *Beinertiana*) separated by Dr. ZALESSKY under the name *Eristophyton*, and also in *C. Saturni*, Unger, the xylem-strands, especially in the lower part of their course, are sometimes a little separated by pith-cells from the inner edge of the secondary wood.† Whether this character may be accepted as justifying an approximation of the Calamopityeæ to the Pityeæ, through *Callixylon*, is an open question ; at any rate, it is inadequate to suggest any direct relation to *Archæopitys*, which lies at the opposite extremity of the Pityeæ.

6. LEPIDOSTROBUS FISCHERI.

This cone is represented by a single specimen, shown, natural size, in Plate 39, fig. 20. The drawing was made before any sections were cut.

The specimen, in its original form, as drawn, tapered towards one end, and showed an obliquely transverse fracture at the larger end. The portion preserved was roughly about one-quarter of the whole cone, as regards transverse dimensions, for the two approximately radial fractures were about at right angles to each other

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* SCOTT, '09, p. 514.

† SCOTT, '02, p. 338.

(rather less towards the smaller, and rather more towards the larger end). The axis, however, is more complete than the cone as a whole, for more than half its thickness (including the whole of the stele) is preserved towards the smaller end of the specimen (see Plate 29, Phot. 15).

The cone was a large one; the radius, as shown on the radial fracture, is quite 2 cm. (4 cm. diameter), and this estimate is no doubt too low, for the laminæ of the sporophylls are not preserved. The radius of the axis is about 3·75 mm. (7·5 cm. in diameter).

The length of the original specimen along the angle coinciding with the axis was about 6 cm.; the extreme length of the whole about 8·5 cm.

Sections were cut both from the large and small ends of the specimen, leaving a middle piece still untouched.*

As will be seen from the drawing (fig. 20), the naked-eye features of the cone are well shown, the axis being conspicuous at the angle, while the sporophylls stand out boldly on the radial surfaces. The appearance of the uncut specimen is, however, in one respect deceptive, for the direction of the sporophylls at first suggests that the larger end is the upper and the smaller the lower; on this assumption the sporophylls would have an upward slope. The examination of the sections shows, however, that the reverse is the truth. The sporophylls, perhaps from some accidental cause, have a slightly *downward* direction, and the small end of the specimen is really towards the top† (see Plate 29, Phot. 18; Plate 39, fig. 21; also p. 358). The appearance of our uncut specimen was much like that of LAURENT'S cone of *L. Brownii*, figured by Prof. ZEILLER.‡

The preservation is in some respects very good, especially as regards the axis, all the tissues of which are very fairly shown (see Plate 29, Phots. 15–19). The sporophylls, as far as their bases and pedicels are concerned, are also not badly preserved (Plate 29, Phot. 20; Plate 39, fig. 21), but in some parts the sporangia have completely disappeared. Fortunately, however, a radial section from the larger end of the specimen passes through a part where the sporangia are preserved, and four of them, filled with microspores, are well shown (fig. 21). This section, together with the tangential sections through the sporophylls (Phot. 20) and those showing the structure of the axis (Phots. 15–19), leaves no doubt that the specimen represents a typical *Lepidostrobus*.

The Axis.—The tissues of the axis, as shown in the general transverse section (Plate 29, Phot. 15), are, apart from details, remarkably perfect. The stele, measured to the outer limit of the xylem, is 1·65 mm. in diameter. Outside this is the

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* The remaining fragment, which is enough to give an idea of the macroscopic characters of the specimen, measures about 2 cm. along the axis and about 3 cm. in extreme length.

† Sections 1–3 were cut from the larger (lower) and sections 4–7 from the smaller (upper) end of the specimen.

‡ *Cf.* ZEILLER, '11, Plate 1, fig. 5.

ill-defined zone of phloem and pericycle, enclosed by an undulating sheath of prosenchymatous cells. The whole of this zone is 0·4–0·5 mm. thick; it is crowded with leaf-trace bundles, seen in nearly transverse section (Plate 29, Phot. 17). Beyond the sheath comes a quite narrow band of large-celled inner cortex only about 0·25 mm. in thickness. The rest of the axis is formed by the wide external cortex, about 2·25 mm. thick, consisting of narrow prosenchymatous elements. This wide zone shows no clear distinction into middle and outer cortex. We will now go on to describe the various tissue-systems more in detail, beginning with the stele.

In transverse section the stele shows little differentiation within the corona (Plate 29, Phot. 16); the longitudinal sections, however, show that the xylem forms a peripheral zone eight or nine elements (not quite 0·2 mm.) in thickness. The central tissue within this zone does not differ from the xylem, except in the absence of scalariform markings; the elements are long and tapering like the tracheides, and of nearly the same size, 40–60 μ in diameter (Plate 29, Phots. 17 and 19). The walls appear quite as thick in the central tissue as in the xylem, and the preservation of both is equally good. Thickness of wall, however, is an untrustworthy character in this material. The central tissue makes the impression of undifferentiated xylem, or of the "fibres primitives" of French authors, rather than of an actual medulla.

The xylem has a kind of "corona," the angles of which simply represent the abutment of the leaf-traces on the stele; they therefore vary in prominence according to the position of the trace (Plate 29, Phots. 16 and 17). The recognisable projecting angles are numerous, about 25 altogether, so far as could be estimated, but this number does not represent that of the vertical series of leaf-traces, which is considerably higher, about 35 or 36.

The smallest tracheides (about 12 μ in diameter) are found at the exterior of the less marked projections; in the longitudinal sections closely wound spiral elements have been observed in a corresponding position, otherwise all the tracheides are scalariform.

As the leaf-trace becomes free from the wood of the stele this exarch structure changes. In the outgoing bundle the smallest elements sometimes occur about the middle of the strand (mesarch structure) (Plate 29, Phot. 17, *l.t′.*), but often no indication of protoxylem can be detected.

The leaf-traces, as seen in transverse section, are very numerous in the zone of the pericycle and inner cortex; here their course is steep and they are cut nearly transversely; further to the exterior they bend rapidly outwards, and are less often met with in the transverse section (Plate 29, Phots. 15 and 17).

Each leaf-trace, as it gets clear of the stele, acquires a very definite sheath several cells thick. The elements of the sheath are elongated, usually with oblique or pointed ends; their walls, when well preserved, appear black, and they form a conspicuous feature in the sections (Phots. 17 and 19). The sheaths of the adjacent traces become confluent, and form collectively the undulating sheath already mentioned as surrounding the stele.

The tissue between the sheath and the wood is the worst preserved part of the structure, and it is impossible to distinguish between phloem and pericycle. The phloem of the individual leaf-traces is equally obscure.

Immediately outside the undulating sheath we come to the narrow band of inner cortex, rendered somewhat irregular by the disturbance due to the passage of the leaf-trace bundles. This layer, best shown in radial sections (see Plate 29, Phot. 19), appears to consist chiefly of rather large, short cells, about 80–120 μ in diameter. They are sometimes enclosed in loops of narrower cells which appear to wind round them. A similar interwoven texture has often been observed in the cortex of Lepidodendreæ.* In our fossil the tissue has a peculiar appearance, suggesting that possibly the structure may have altered, some of the cells having, perhaps, broken down and given rise to the larger cavities, which in that case would not be true cells. Many of the cavities contain some brown product of disorganisation.

All the rest of the cortical tissue, about 2·25–2·5 mm. in thickness, is best considered together as outer cortex. Any apparent differentiation is mainly due to accidents of preservation. The whole zone consists of long, prosenchymatous elements, more or less hexagonal in transverse section, with a diameter of about 36–50 μ. The whole tissue shows a tendency to radial arrangement, such as is shown in the outer primary cortex of *Bothrodendron mundum.* This radial seriation is more marked in the external part of the zone, in which also the cells are often somewhat flattened tangentially.

The epidermis is not preserved.

The Sporophylls.—We have sections of the sporophylls in all three planes: transverse (Plate 29, Phot. 15), radial (Plate 29, Phot. 18, and Plate 39, fig. 21), and tangential (Plate 29, Phots. 20 and 21) to the cone. Only the pedicel, however, *i.e.*, the part which bore the sporangium, is preserved. The greater part of the organ is formed of prosenchymatous cells, much like those of the outer cortex, with which they are continuous (Plate 29, Phot. 18).

In transverse section (tangential to the cone) the pedicel has a bluntly triangular form. The somewhat curved base of the triangle shows a marked depression, or groove, and in the middle of this groove there is a median ridge (Plate 29, Phots. 20 and 21). The side on which the groove and ridge are placed is clearly the upper. The pedicel figured in Phot. 21 measures 2 mm. in width by 1·3 mm. in maximum depth (from the lower angle to the top of the grooved surface). Some are a little smaller than this.† The largest observed (ignoring obviously oblique sections)

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* See, *e.g.*, BOWER, '93, Plate 17, fig. 13.

† A sporophyll shown free in the transverse section, and evidently cut near the axis, is only 1·5 mm. wide. A sporophyll seen attached to the axis is scarcely narrower, so this was about the minimum width.

measured 2·8 mm. in width by 2 mm. in extreme depth. The latter dimension is probably exaggerated by obliquity of the section.

The tissue of the pedicel is, on the whole, very uniform, the cells being fairly thick-walled and about 30–60 μ in diameter. The cell-walls appear to be thickest in the outer part, especially towards the lower side, but we cannot be sure how far this appearance is natural.

The median ridge, rising up into the groove, is composed of smaller cells, about 20–25 μ in diameter, prosenchymatous like the others, but with not very thick walls.

The chief difficulty was to determine the position of the vascular bundle. Not a sign of any such structure can be found anywhere within the transverse section of the pedicel. The clue was given by Prof. ZEILLER'S description and figures of the pedicel of *Lepidostrobus Brownii.*[*] In that species also the dense tissue of the pedicel has a median ridge towards the upper surface; at the top and sides this ridge is embraced by an arc of soft tissue[†] continuous above with the base of the sporangium. The vascular bundle lies in this soft tissue, exactly above the ridge, on a level with, or even slightly above, the upper surface of the lateral parts of the pedicel.[‡] Imagine the soft tissue, and the vascular bundle with it, to have perished, and we have exactly the structure of the pedicel as usually preserved in the Kentucky fossil.[§] We infer, then, that in our cone the vascular bundle was placed immediately above the median ridge in the groove of the pedicel. After a careful search for traces of vascular tissue in this position, a group of ill-preserved scalariform elements was found, in a somewhat oblique section of a sporophyll; the group lay just on the top of the median ridge, nearly on a level with the upper edges of the groove. The vascular strand is about as wide as the ridge, and is imbedded in a soft tissue, with brown cell-contents. Though badly preserved, this section appears to remove all doubts as to the position of the bundle, which thus lay high up in the pedicel, above the median ridge, imbedded in a delicate tissue, which has usually perished, together with the bundle it contained.[||]

The sporangia are completely absent from all the sections except the radial one already mentioned (Plate 39, fig. 21). This section was cut from the lower part of the specimen. A fragment of the axis is shown, bearing the bases of two sporophylls; the pedicels, more or less complete, of three detached sporophylls are also shown, as well as four sporangia and a fragment of a fifth.

The section is of importance for determining the direction of apex and base in

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[*] ZEILLER, '11, p. 30; Plate 7, figs. 5–7.

[†] *Loc. cit.*, fig. 7.

[‡] *Loc. cit.*, figs. 5 and 6.

[§] *Cf.* ZEILLER'S Plate 7, fig. 7, with our own Plate 3, Phot. 21.

[||] The sporophyll in question is contained in slide "Lepidostrobus 3," a tangential section, but in this instance oblique to the pedicel.

the specimen (see above, p. 355). The pedicel attached to the axis (Plate 39, fig. 21) is cut very obliquely, and shows a definite groove on one surface; this, according to all analogy, must be the *upper* surface. In the detached pedicel next below, cut more nearly lengthways, there is also an indication of the groove on the corresponding surface. The uppermost sporangium has clearly been torn from the underlying pedicel, as shown by the interruption of the palisade-layer, on part of the lower surface of the sporangium.* These points, together with the direction of the leaf-traces in radial section of the axis (Plate 29, Phot. 18), are sufficient to prove that, as stated above, the slope of the pedicels was *downward*, with reference to the apex of the cone, and thus that the position given to the specimen in fig. 20 is the natural one.

The Sporangia.—As our knowledge of these organs is entirely derived from one radial section (Plate 39, fig. 21), our data are necessarily incomplete. The most perfect sporangium is about 17 mm. long and about 2 mm. in maximum depth. The former dimension is probably about correct, the latter too small, as it is unlikely that the plane of section corresponds exactly with the median line of the sporangium. The sporangium, except where attached to its sporophyll, is surrounded by a wall of palisade or columnar cells, such as is constantly found in *Lepidostrobus.* The thickness of the wall appears to range from 120 to 180 μ, but probably the former is more correct, the apparent thickness being of course exaggerated where the section is at all oblique. The palisade cells as a rule, if not always, are in a single layer (Plate 39, figs. 22 and 23); their width, where most clearly shown, is about 30–40 μ.

At the distal end of the uppermost sporangium shown in fig. 21, and at the upper corner, there is a slight prominence where the wall is a little thicker than elsewhere. This appears to correspond to the "crest" described by Prof. ZEILLER in the sporangia of *L. Brownii,*† regarded previously by SCHIMPER as marking a line of dehiscence, but which Prof. ZEILLER prefers to compare, though with much doubt, to the annulus of a fern-sporangium.‡

No inner layer of the sporangial wall is preserved, except in a very imperfect manner at the base of the sporangium which shows the place of attachment to the pedicel (fig. 21). The shreds of tissue which are here shown at the base of the sporangium no doubt belonged to the "sub-archesporial pad." The spores are often found in contact with the palisade layer, except for a thin band of disorganised material (Plate 39, figs. 22 and 23).

All the sporangia shown are full of microspores (fig. 21) which are everywhere in tetrads. It is doubtful whether any of the spores had become naturally isolated.

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* There is also an interruption on the upper surface, but this is obviously due to accidental damage to the section.

† ZEILLER, '11, p. 35; Plate 10, figs. 3 and 8.

‡ *Loc. cit.*, p. 38.

The spores of the tetrad are, as usual, tetrahedrally arranged, only three showing in one plane (Plate 39, figs. 22 and 23). The diameter of the whole tetrad is about 96 μ, while the individual spores measure about $60 \times 48 \mu$. The walls of the spores are of moderate thickness and smooth (fig. 23). No trace of megaspores has been found in any part of the specimen.

Summary.

1. Cone large (4 cm. in diameter to the outer end of the sporangia. Length unknown, but exceeding 8·5 cm.).
2. Sporophylls in about 35 vertical series.
3. Axis about 7·5 mm. in diameter.
4. Stele (about 1·65 mm. in diameter) with a large "pith" of prosenchymatous cells, surrounded by a somewhat narrow ring of xylem, with prominent angles corresponding to the leaf-traces.
5. Leaf-traces with a definite sheath, their sheaths confluent around the stele.
6. Inner cortex narrow (about 0·25 mm.) with an interwoven structure, but no gaps.
7. Outer cortex very wide (up to 2·5 mm.), prosenchymatous.
8. Pedicels of sporophylls triangular in section. Upper surface with a groove and median ridge; vascular bundle (rarely preserved) lying in soft tissue above the median ridge.
9. Sporangia reaching 17 mm. in length, with a palisade-wall and distal crest. Microspores in tetrads, arranged tetrahedrally. Tetrads about 96 μ, individual spores about $60 \times 48 \mu$ in diameter, with smooth walls.

The species is named after Mr. MORITZ FISCHER, the collector from whom the specimen was acquired by one of the authors (see above, p. 315).

Lepidostrobus Fischeri presents no very striking peculiarities as compared with other members of the genus; at the same time it appears to be a perfectly distinct species.

The only described species with structure preserved to which our cone bears any close resemblance is the well-known *L. Brownii*, which, as Prof. ZEILLER has recently proved, was of Lower Carboniferous age (Dinantian).* The preservation of the Kentucky fossil is not equal to that of the best specimens of *L. Brownii*, so fully described in Prof. ZEILLER's memoir, so that a complete comparison is impracticable, but the following points may be noticed :—

In dimensions the Kentucky cone agrees very well with the specimens of *L. Brownii*, if we bear in mind that in the former the laminæ of the sporophylls are entirely missing. Our specimen, as we have seen, has a diameter of fully 4 cm. measured up to the distal end of the sporangia. This is very nearly the same as in

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* ZEILLER, '11.

LAURENT'S cone of *L. Brownii*[*] already referred to (p. 355). The diameter of the latter to the outer limit of the sporangia is slightly less than in ours, but the sporophylls are more oblique, which would nearly account for the difference. In the large cone from Caillavet[†], with a total diameter of about 7·5 cm., the diameter to the outer limit of the sporangia is nearly 5 cm. Thus the dimensions of our cone would appear roughly to correspond to those of an average specimen of *L. Brownii.*

The axis in that species appears to vary much in size, ranging from 5–7 mm. (Abbé THÉRON'S specimen) to 11–12 mm. (large cone from Caillavet).[‡] In our fossil it is relatively rather small, about 7·5 mm. in diameter.

On the other hand, the sporangia in *L. Fischeri* appear to be among the largest, or at least the longest, described in the genus, reaching 17 mm. in length. This is long compared with most specimens of *L. Brownii*, but is practically equalled in the specimen originally named *L. Rouvillei* by SAPORTA and RENAULT, where the length is given as 16–17 mm.[§]

On the whole, so far as dimensions are concerned, our cone may be said to agree with *Lepidostrobus Brownii.*

Coming now to structural characters, the stele has, in essentials, the same structure in both, a ring of primary xylem surrounding a central tissue composed of elements resembling the tracheides except for the absence of scalariform or other sculpturing. Prof. ZEILLER describes this central tissue in almost the same terms which we have used in the case of our fossil.[||] The xylem-ring seems to be somewhat thicker in *L. Brownii*, but that is all. The angles of the xylem corresponding to the leaf-traces are also quite similar in both.

It is interesting to note that in *L. Schimperi*, Zeiller, a species otherwise closely similar to *L. Brownii* and formerly united with it, the xylem is solid, the tracheides extending to the centre and leaving no medulla.[¶] The existence of this difference between forms so nearly related confirms the view that the central tissue in *L. Brownii* and in our species is to be regarded as undifferentiated xylem rather than as a typical pith.

The phloem in our specimen is not well enough preserved for comparison with *L. Brownii;* when we come to the cortex, differences between the two species begin to show themselves.

The inner cortex of M. ZEILLER'S description may perhaps be compared to our undulating sheath; the former is, however, considerably more developed, perhaps twice as thick on the average, and apparently with shorter cells.[**]

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[*] ZEILLER, '11, Plate 1, fig. 5.

[†] ZEILLER, '11, Plate 1, fig. 3.

[‡] ZEILLER, '11, pp. 19 and 51.

[§] ZEILLER, '11, p. 47.

[||] ZEILLER, '11, p. 19.

[¶] ZEILLER, '11, pp. 11 and 43.

[**] ZEILLER, '11, pp. 19, 22; Plate 2, fig. 7; Plate 3, fig. 13.

The next layer, called by M. ZEILLER "l'écorce moyenne," differs greatly from anything in our plant. It is described as forming an annular space, 0·3–0·4 mm. wide, containing remains of very delicate tubular cells, running transversely.* There is no such space in our specimen; the whole cortex appears continuous (Plate 29, Phots. 15 and 18). The zone corresponding to the middle cortex of *L. Brownii* is probably the narrow layer which we have called inner cortex. This, though it shows a partially trabecular structure, contains no obvious intercellular spaces; there may, as suggested above (p. 357), have been some local breaking down of cell-walls, but the tissue as a whole is solid and well preserved (Plate 29, Phot. 19). This zone in our fossil much more resembles the continuous, interwoven, middle cortex of such stems as *Lepidodendron fuliginosum* than the lacunar zone of *L. Brownii* and other *Lepidostrobi.*

The thick outer cortex, of uniform prosenchymatous tissue, has much the same character in *L. Brownii* as in our plant.† The absence of the lacunar zone, however, appears to cause a difference in the neighbourhood of the leaf-traces, which in *L. Fischeri* are not, so far as can be seen, accompanied by any definite lacunæ on their course through the outer cortex. The continuity of the outer cortex with the tissue of the sporophyll-pedicels is as noticeable in our cone as in *L. Brownii.*‡

The structure of the pedicel has been fully discussed above (p. 357); though less well preserved in our specimen, it appears to have been identical with that of *L. Brownii*, apart from a slight difference in the form of the transverse section.§

As regards the sporangia, any full comparison is impracticable, as we only have a radial section; an obvious difference is the absence, in our specimen, of any inner layers of the sporangial wall; only the palisade layer is preserved. The sporangia are so full of microspores that there does not seem to be room for any considerable extra thickness of the sporangial wall; hence it is probable that the inner layers had disappeared naturally at this stage.

The microspore-tetrads themselves are much like those of *L. Brownii*, but slightly larger.

Taking the whole of the available characters into consideration, it is evident that *L. Fischeri* is a species nearly allied to *L. Brownii*, but differing from it in some definite characters, and notably in the structure of the inner or middle cortex.

A detailed comparison with the new species *L. Delagei*, Zeiller, is unnecessary, as the distal portion of the sporophylls, on which the distinction between *L. Delagei* and *L. Brownii* chiefly depends, is not preserved in our specimen.

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* ZEILLER, '11, pp. 19, 23; Plate 4, fig. 1–7; Plate 5, figs. 7–9. See also BOWER, '93, pp. 334, 341; Plate 16, fig. 2; Plate 17, fig. 8A.

† ZEILLER, '11, p. 23; Plate 4, figs. 10–12.

‡ *Cf.* ZEILLER, '11, Plate 4, fig. 12, with our Plate 3, Phot. 18.

§ *Cf.* ZEILLER, '11, Plate 7, fig. 7, with our Plate 3, Phot. 21.

In any case, it seems that the Kentucky cone belongs to the same group as the Lower Carboniferous forms, *L. Brownii* and *L. Delagei.*

A word may be said about the relation of our fossil to two other cones which approximately agree with it in dimensions. One of these is of interest as being, as it appears, the only American *Lepidostrobus* hitherto recorded with structure preserved.[*] The specimen was collected "in a coal pocket in Warren County, Iowa," and was presumably of Upper Carboniferous age. The axis was not preserved, so that no detailed comparison with our cone is possible. In dimensions there is near agreement, the Iowa specimen being quite 5 cm. in diameter, while the sporangia attain a length of 17 mm., the same as in ours.[†] The form and structure of the sporophyll-pedicel, however, appear to preclude any close comparison with *L. Fischeri.*[‡]

The other cone in question is *L. Bertrandi,* Zalessky, so fully described and illustrated by the discoverer.[§] This cone is of Upper Carboniferous age (Middle Westphalian of the Donetz Basin), and is of the type of the well-known British species *L. oldhamius.* It thus differs widely from the Kentucky species, notably in the great width of the lacunar middle cortex and the comparatively thin zone of external cortex.[||]

The dimensions of the specimen are of the same order as those of our fossil, the cone reaching 5 cm. in diameter, but the axis is thicker (12·5 mm.). One point of interest may be noted. Dr. ZALESSKY describes the "inner cortex" of his specimen in terms which suggest an analogy with the "undulating sheath" of *L. Fischeri.* He says[¶]: "L'écorce interne ne s'est conservée que partiellement autour des traces foliaires, en formant une espèce de gaîne, là où ces dernières sont déplacées et rapprochées, les gaines produisent au contact l'impression d'un tissu continu (fig. 1, Plate 2)."

We might have called our undulating sheath the "inner cortex" and the thin interwoven layer outside it the "middle cortex," but preferred to emphasise the relation of the former to the bundle-sheaths.

So far as we are aware, *L. Fischeri* is alone among known Lepidostrobi in possessing a solid, continuous cortex with no lacunar zone.

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[*] COULTER and LAND, '11.

[†] *Loc. cit.*, pp. 449 and 451.

[‡] *Loc. cit.*, Plate 28, fig. 4; Plate 29, figs. 9–13.

[§] ZALESSKY, '08.

[||] ZALESSKY, '08, Plate 1, fig. 1.

[¶] *Loc. cit.*, p. 26.

CONCLUSION.

We have now completed our survey of the available specimens of the Kentucky petrifactions, leaving out of consideration one or two fragments of a doubtful nature, as to which it seems wisest to await further information.

The species described fall into three categories—

1. Fossils of the same type as certain of UNGER's Saalfeld plants. Under this head fall *Calamopitys americana* with the *Kalymma*, *Calamopteris Hippocrepis*, and *Periastron perforatum*.
2. Fossils of altogether new genera, namely, *Stereopteris annularis* and *Archæopitys Eastmanii*.
3. A fossil of a familiar Lower Carboniferous type, *Lepidostrobus Fischeri*.

The positive evidence afforded by the fossils named under the first head is ot considerable value. *Calamopitys americana*, as we have seen, is in many respects nearly allied to *C. annularis* (Unger), and it is not unlikely that a renewed investigation of the latter plant would bring further points of resemblance to light. The agreement with *C. Saturni*, Unger, seems to be less close, while the species *C. fascicularis*, Scott, and *C. Beinertiana* (Goepp.), separated by ZALESSKY under his new genus *Eristophyton*, are decidedly more remote. The *Kalymma*, the petiole of *Calamopitys*, but not necessarily in all cases of the species *C. americana*, agrees generally with the fossils described by UNGER under this name, though probably not specifically identical with any of them. It is interesting to note that our *Kalymma* appears to be identical with that described by DAWSON and PENHALLOW (1890–91) from the Genessee Black Shales (of Devonian age) of Moreland, Kentucky. If the horizon is rightly given by those authors, it has an important bearing on the age of our plants.

The petioles named *Calamopteris* by UNGER do not appear to have been found hitherto, except at Saalfeld. Our Kentucky species, *C. Hippocrepis*, is evidently nearly allied to UNGER's (*C. debilis*), though distinct.

The same remarks apply to *Periastron*, another Saalfeld plant represented in Kentucky by a distinct but closely similar species.

These cases are sufficient to establish a close-relation between our little Kentucky flora and that of the Thuringian bed. Unfortunately the age of the latter is still open to doubt. RICHTER, UNGER's colleague, included the plant-bearing deposit in the "Cypridinenschiefer," thus making it Devonian. His successors on the Prussian Geological Survey, LIEBE and ZIMMERMANN, excluded the locality in question from the Devonian and put it in the Culm, a view which was accepted by GRAF SOLMS-LAUBACH when he wrote his memoir on UNGER's plants. He is now, however, inclined to regard the horizon as after all Devonian,* partly on purely geological

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* SOLMS, '06, p. 354.

grounds, which cannot be discussed here, and partly on account of the strange and antique elements in the flora, unlike what is found in Lower Carboniferous deposits elsewhere.* This peculiar *facies* certainly also characterises the Kentucky fossils or most of them, but according to Prof. EASTMAN'S present opinion they belong to the base of the Lower Carboniferous.

The two new genera, *Stereopteris* and *Archæopitys*, enhance the peculiar character of the Kentucky group of fossils. *Stereopteris* is decidedly unlike any known member of the Zygopterideæ, though it seems, assuming it to be a petiole, to approach this family more nearly than any other. It has been suggested to one of the authors that the form of the bundle in *Stereopteris* resembles that of the primary wood in the stem of *Protopitys Buchiana.*† This is the case, but the resemblance is a purely superficial one, for the central tissue in *Protopitys* is chiefly pith, with only a comparatively narrow mantle of xylem, while in *Stereopteris* the xylem forms an absolutely solid mass. In order to compare the two plants we should have to imagine a protostelic *Protopitys* with a solid xylem! Even then the curvature of the bundle in *Stereopteris* would be unexplained. On the whole of the evidence there seems no reason to suppose *Stereopteris* to be anything but a petiole; it is certainly a peculiar one, finding its only analogy among the Zygopterideæ, but not readily falling into line with any of the known types of that much-investigated family.

Archæopitys Eastmanii is a more satisfactory fossil, for, being a stem, it gives us a better insight into the essential characters of the plant. It quite clearly belongs to the family Pityeæ, and, at the same time, is perfectly distinct from any previously described member of that group. It is much more peculiar in structure than the Devonian *Callixylon* of ZALESSKY, but whether it is more primitive is another question. The presence, throughout the whole of the pith, of separate xylem-strands, each with its own protoxylem, is not a condition which can be readily derived from a protostele, and may indicate considerable antecedent modification. At any rate, *Archæopitys* seems to be a much more advanced type of stem than the contemporary *Calamopitys.*

Lastly, the one fructification which our material has yielded, *Lepidostrobus Fischeri*, is, as we have seen, of the same general type as the well known *L. Brownii*, and is thus quite the kind of fossil which one would expect from a Lower Carboniferous horizon.

The evidence of the Kentucky plants, collectively, appears to be in harmony with a position at the base of the Lower Carboniferous, but, taken by itself, it would not, so far as we are able to judge, be inconsistent with a greater antiquity, going back to the Upper Devonian.

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* We are indebted to GRAF SOLMS for much information on this question in a recent letter.

† SOLMS, '93, p. 202; Plate 7, figs. 1–5.

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EXPLANATION OF THE PLATES.

(The photographs often require the use of a lens.)

PLATE 27.

Kalymma and Calamopitys.

Phot. 1.—General transverse section of a portion of a large leaf-base; *v.b.*, vascular bundles; *sc*, interrupted band of sclerenchyma, probably separating leaf-base from cortex. × 3⅓. Section N, 10.

Phot. 2.—Another portion of the same specimen. Lettering as above; only two of the vascular bundles are lettered. × 3⅓. Section O, 11.

Phot. 3.—A single vascular bundle from Plate 28, Phot. 11, on the extreme left. × 50. Prof. BOWER's specimen.

Phot. 4.—A single vascular bundle from Phot. 1, showing four median protoxylem groups. × 16. Section N, 10.

Phot. 5.—A single vascular bundle from a small *Kalymma* (Plate 28, Phot. 10, on the left). × 50. Section L, 6.

Phot. 6.—*Calamopitys*, probably *C. americana.* Portion of stem in transverse section, seen in Phot. 7 in connection with a *Kalymma*. *x*, primary xylem. × about 15. Section K, 3.

Phot. 7.—*Calamopitys* in connection with the *Kalymma*—general section. *sc*, sclerenchyma separating cortex from leaf-base; *v.b.*, *v.b.*[1] vascular bundles in cortex and leaf-base; *st*, stele of stem; *sp*, Sparganum cortex of the *Kalymma*. × about 5. Section K, 3.

PLATE 28.

Kalymma and Calamopitys.

Phot. 8.—Tangential section of the *Kalymma* in connection with *Calamopitys*, passing on the right through the Sparganum cortex. × about 5. Section K, 5.

Phot. 9.—Approximately radial section of the same specimen, showing the wood of the *Calamopitys* stem towards the right. × about 5. Section K, 4.

Phot. 10.—Transverse section of a small *Kalymma*, about half of which is preserved. *sp*, part of the Sparganum cortex. The left-hand bundle is shown in detail in Plate 27, Phot. 5. × about 5. Section L, 6.

Phot. 11.—Transverse section of part of a *Kalymma* from Prof. F. O. Bower's specimen (Genessee Shales). The left-hand bundle is shown in detail in Plate 27, Phot. 3. This section is chosen for the bundles; it does not show the Sparganum cortex which is present in other sections. × about 5.

Phot. 12.—Longitudinal section, passing through a vascular bundle, *v.b.*, of the small *Kalymma* shown in Phot. 10. × about 5. Section L, 11.

Phot. 13.—*Kalymma* in connection with *Calamopitys*. Another transverse section from the same specimen as in Plate 27, fig. 7. *st*, small portion of the stele of the stem; *Sp*, Sparganum cortex. × about 5. Section K, C.

Phot. 14.—Vascular bundle from right of Phot. 13. × about 50. Section K, C.

Plate 29.

Phots. 15–21, *Lepidostrobus Fischeri*.

Phot. 15.—Transverse section of the axis of the cone, showing the bases of two sporophylls. *st*, stele. The continuous, non-lacunar cortex is the most striking feature. × 10. Section 4.

Phot. 16.—The stele, with leaf-traces being given off. Though so well preserved, the limit between xylem and "pith" is almost unrecognisable. On the left the somewhat lighter zone approximately corresponds to the xylem, while on the right it is indicated by the numerous clear lumina. × 30. Section 4.

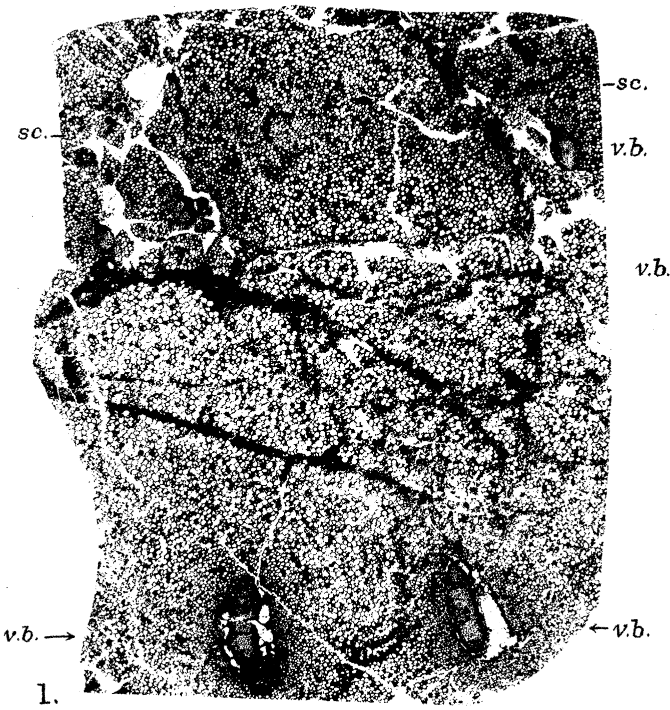
Phot. 17.—Portion of stele, with leaf-traces. *x*, xylem-zone. *l.t.*^{1}, leaf-trace showing mesarch xylem clearly; *l.t.*^{2}, leaf-trace with well-preserved sheath. × 56. Section 4.

Phot. 18.—Radial section of axis, showing the bases of three sporophylls. *st*, stele; *i.c.*, narrow inner cortex; *o.c.*, wide outer cortex. × 10. Section 5.

Phot. 19.—Part of the same section (reversed) more highly magnified. *x*, xylem-zone; *l.t.*, leaf-trace with its sheath on either side; *i.c.*, inner cortex. × about 56. Section 5.

Phot. 20.—Tangential section, passing through the pedicels of several sporophylls, cut transversely. × 7. Section 6.

Phot. 21.—The right-hand bottom pedicel from the last photograph, more highly magnified. *v.b.*, position of vascular bundle (which has perished) above median ridge. × 37. Section 6.



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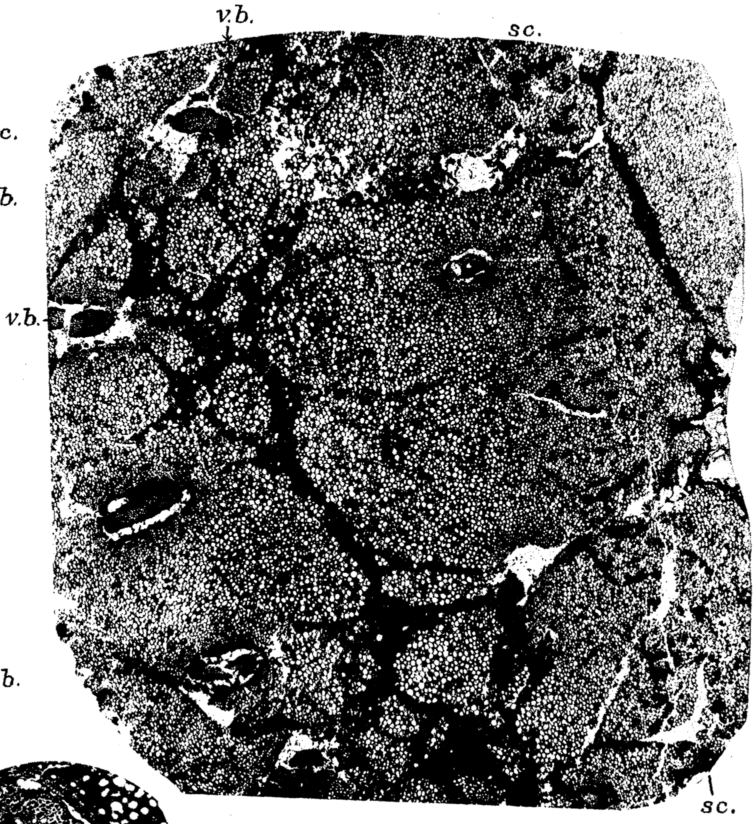

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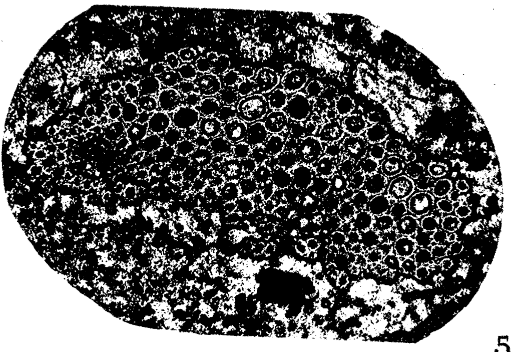

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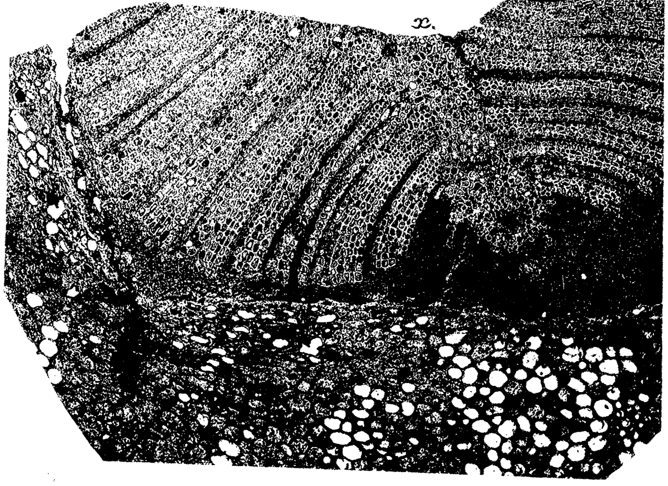

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KALYMMA AND CALAMOPITYS.

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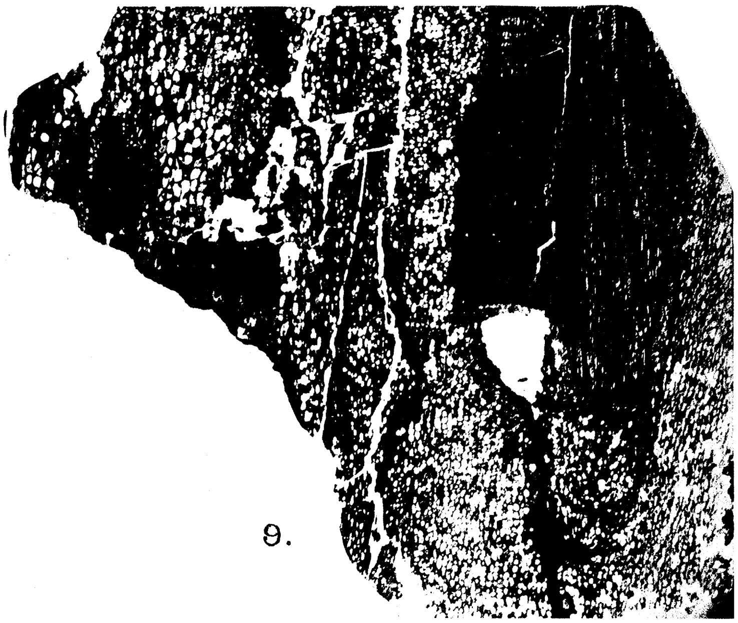

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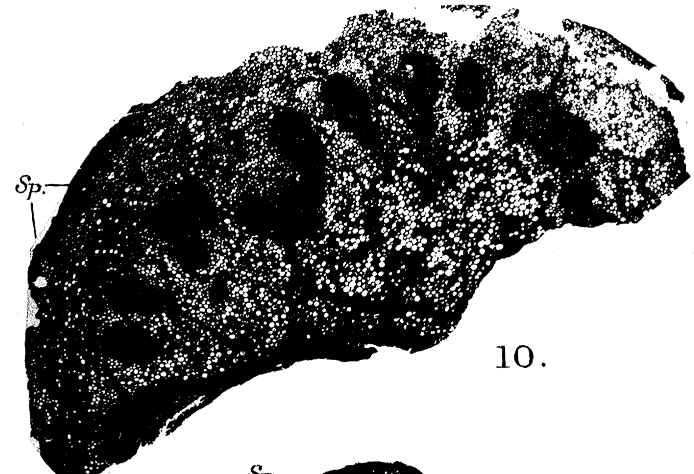

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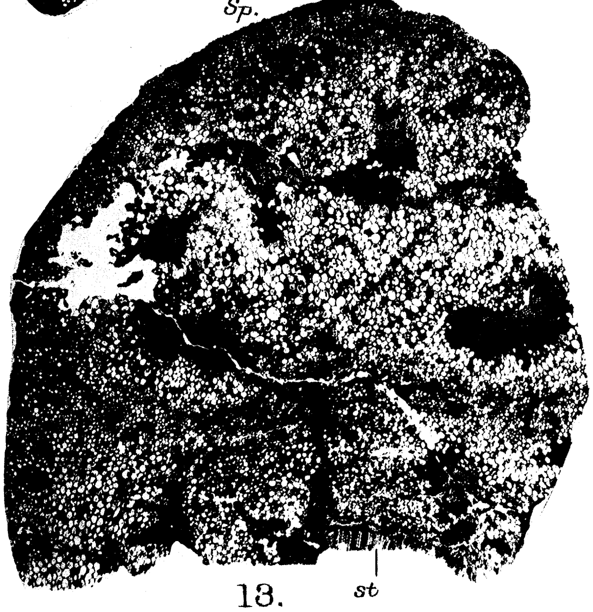

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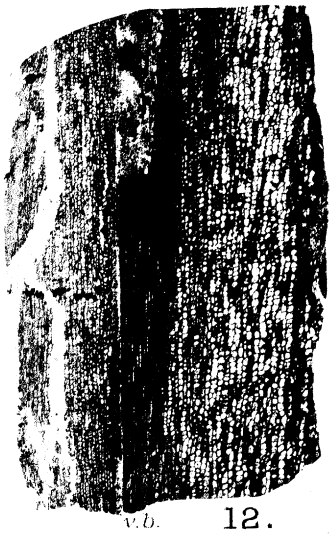

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KALYMMA AND CALAMOPITYS.

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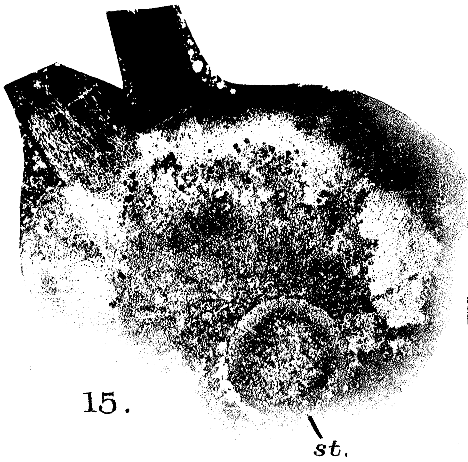

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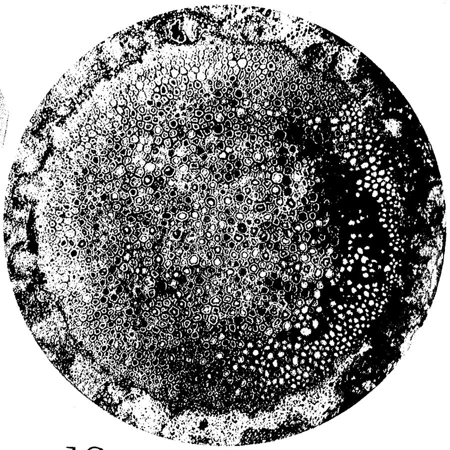

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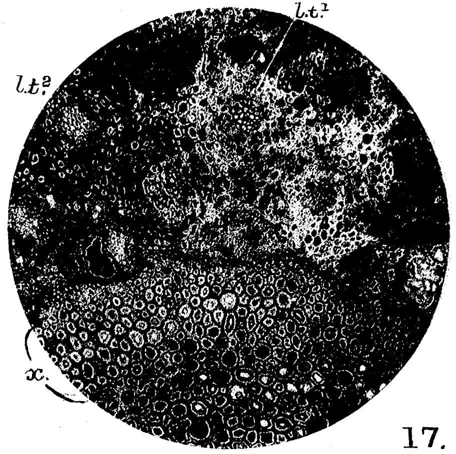

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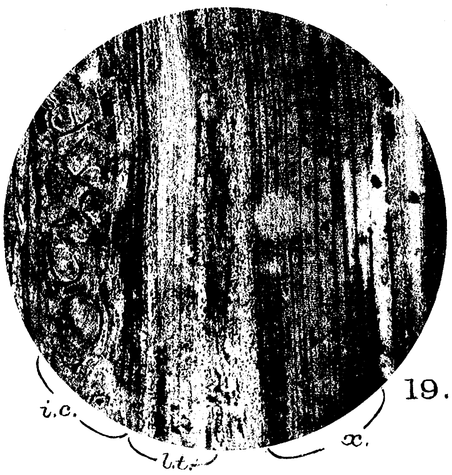

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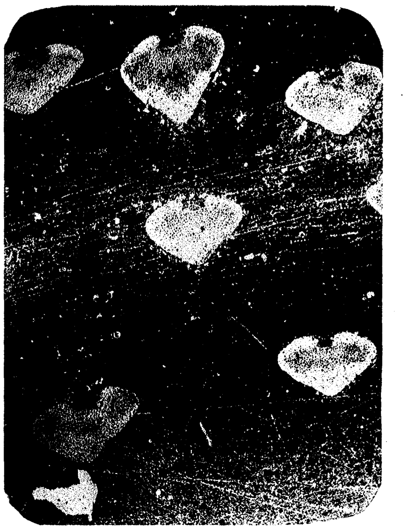

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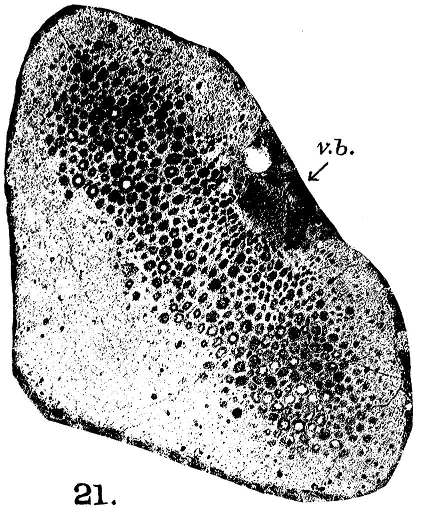

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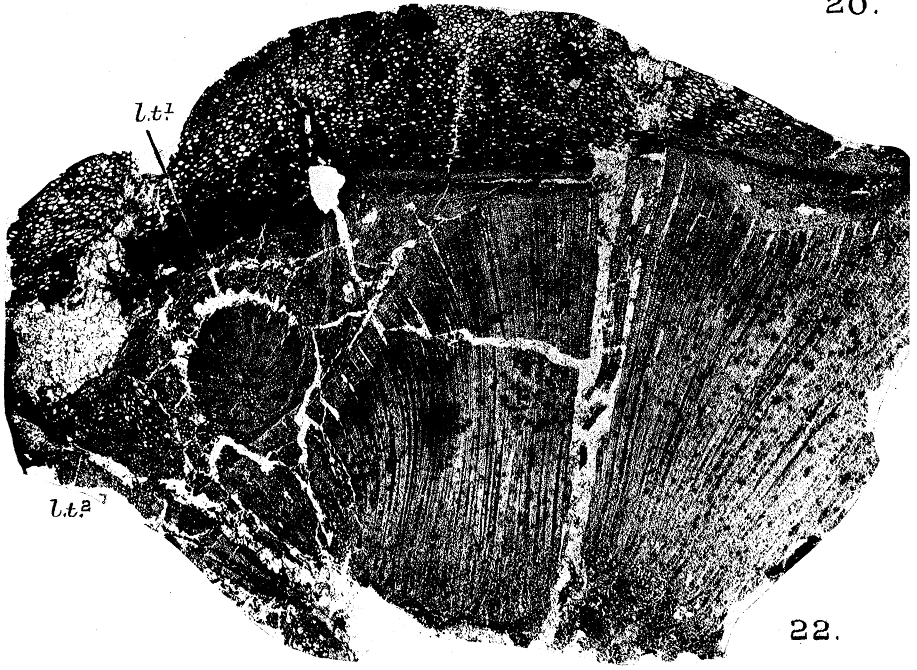

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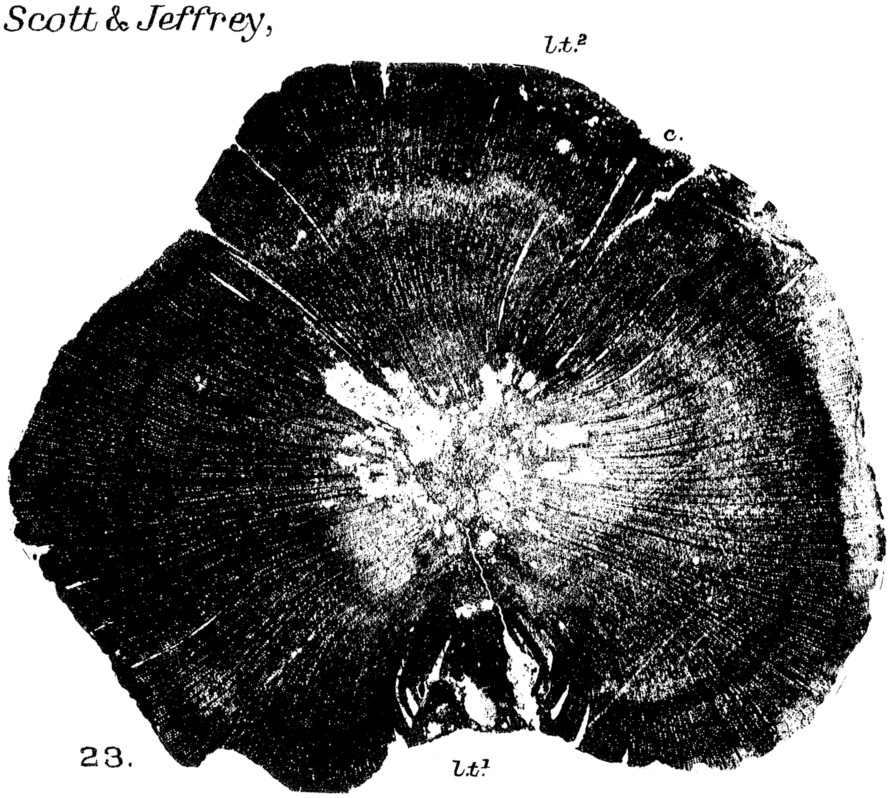
15-21, LEPIDOSTROBUS FISCHERI.
22, CALAMOPITYS AMERICANA.



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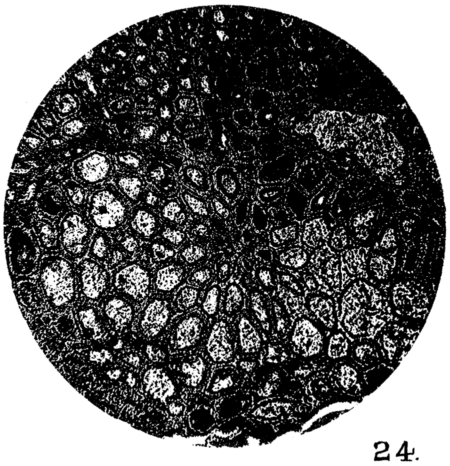

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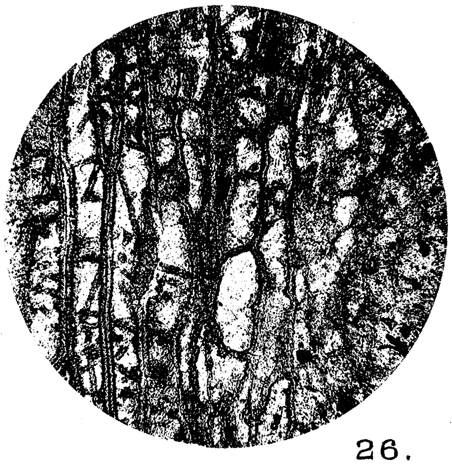

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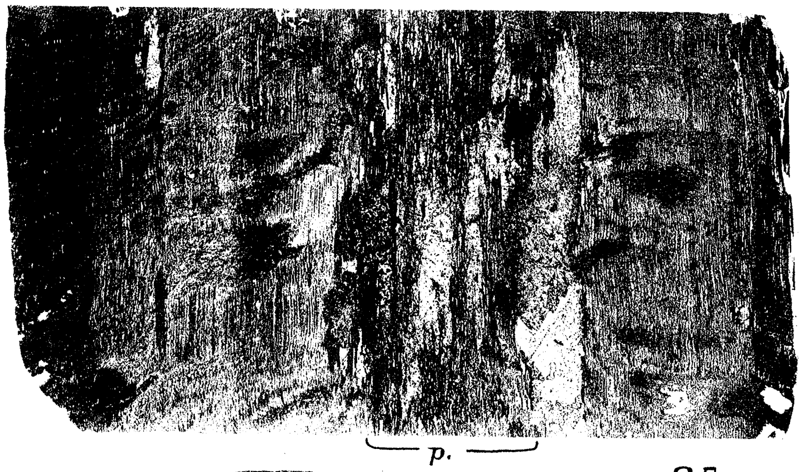

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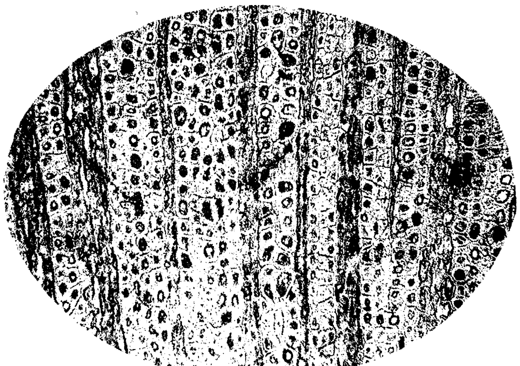

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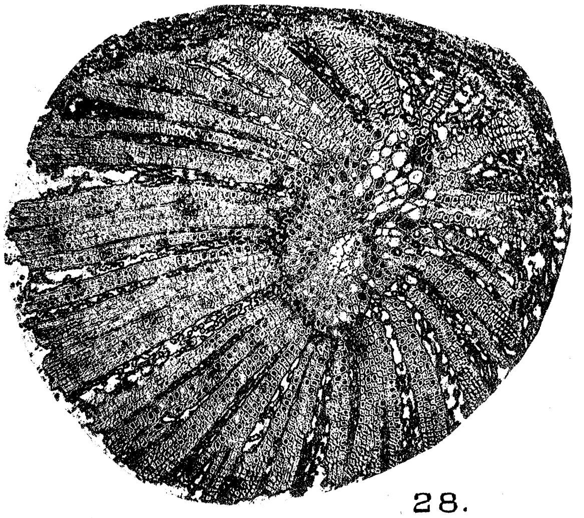

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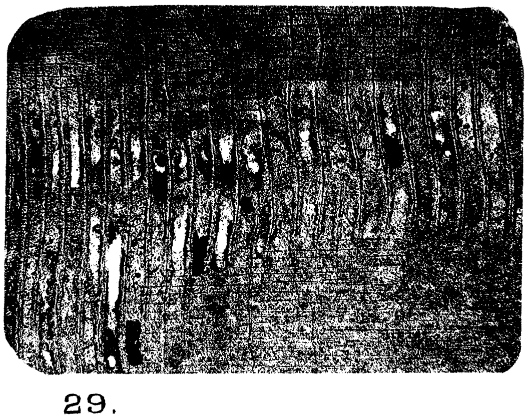

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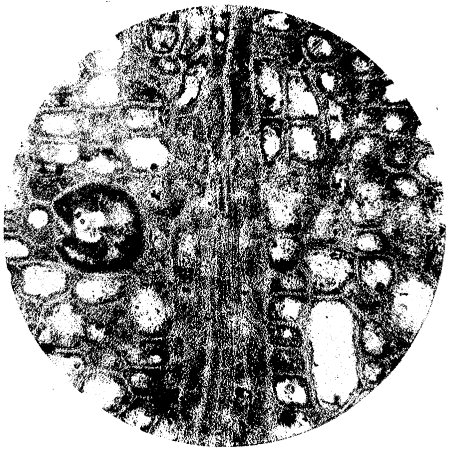
CALAMOPITYS AMERICANA.



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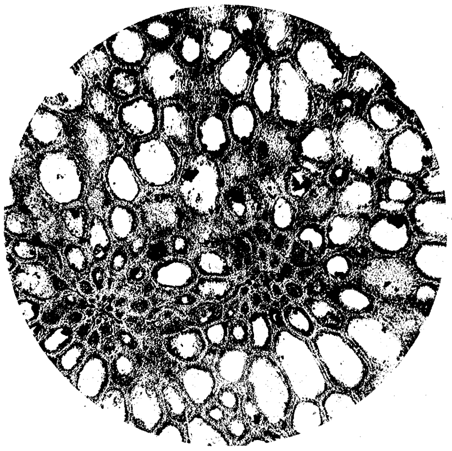

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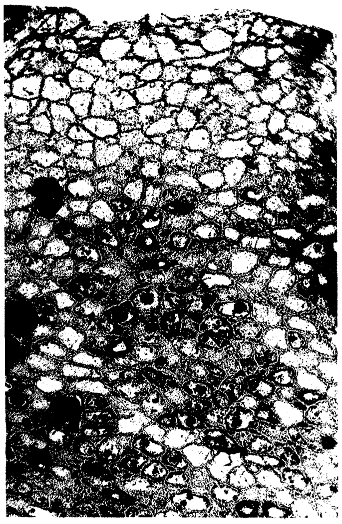

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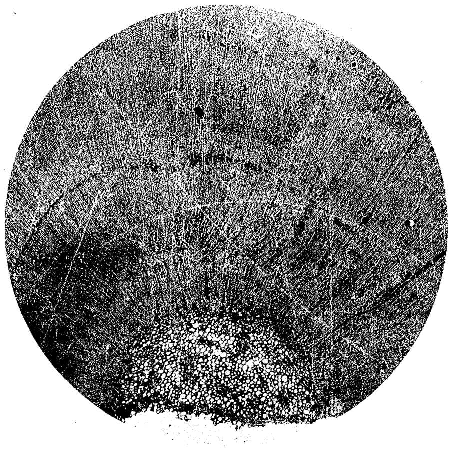

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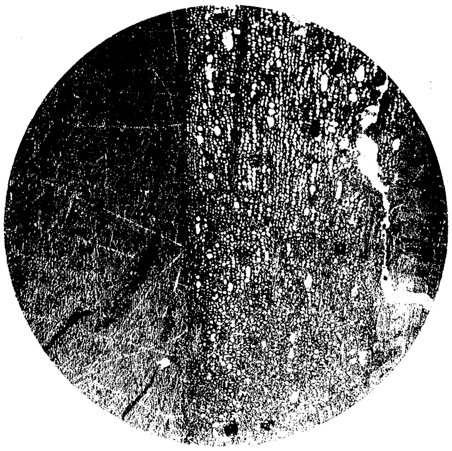

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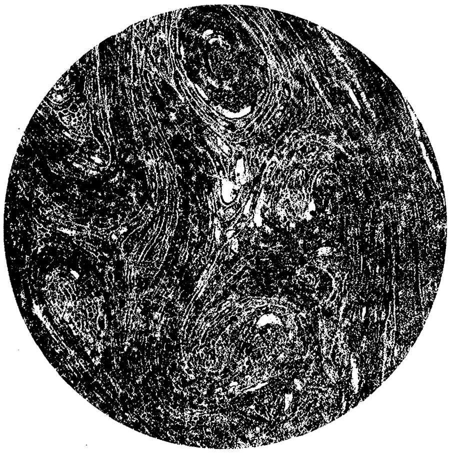

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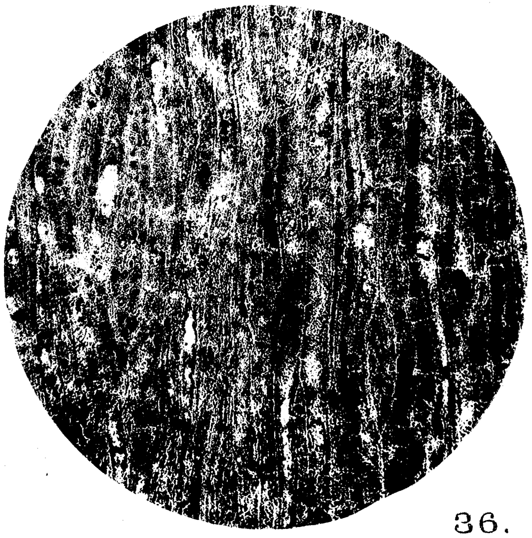


36.

Jeffrey phot. Huth coll.

30, CALAMOPITYS AMERICANA.
31–36, ARCHAEOPITYS EASTMANII.

Phot. 22.—*Calamopitys americana.* Transverse section of a large stem, showing wood and cortex. *l.t.*^{1}, large leaf-trace bundle with secondary wood; *l.t.*^{2}, fragment of the wood of a second bundle. × about 5. Section F, 28.

PLATE 30.

Calamopitys americana.

Phot. 23.—Transverse section of a small stem, showing mixed pith, wood, and some slight remains of cortex, *c.* *l.t.*^{1}, leaf-trace passing through wood. *l.t.*^{2}, leaf-trace bundle outside wood. × about 5. Section C, 13.

Phot. 24.—Mesarch xylem-strand at the edge of the pith in the same section. The secondary wood is above, the pith below. *Cf.* Plate 35, fig. 1. × 56. Section C, 13.

Phot. 25.—General radial section of the same stem, showing mixed pith (*p*) and wood with medullary rays. × about 5. Section C, 16.

Phot. 26.—Part of the pith in longitudinal section, showing trabeculæ in the tracheides and cells. × 56. Section C, 16.

Phot. 27.—Transverse section of part of the secondary wood of the stem shown in Plate 29, Phot. 22. × 37. Section F, 28.

Phot. 28.—Leaf-trace bundle (*l.t.*^{1}) from the same section, showing primary and secondary wood. × about 20. Section F, 28.

Phot. 29.—Part of secondary wood in radial section (same stem as Phot. 25) showing medullary rays. × 37. Section C, 16.

PLATE 31.

Phot. 30.—*Calamopitys americana.* Part of cortex, transverse, from the stem shown in Plate 29, Phot. 22. × 20. Section F, 28.

Phots. 31-36, *Archæopitys Eastmanii.*

Phot. 31.—Longitudinal section of part of pith, passing through a primary xylem-strand, *x*. A large sac or cavity is seen on the left. × 56. Section 9·3, 2. Radial.

Phot. 32.—Transverse section of part of pith, showing two medullary mesarch xylem-strands, which fuse in the succeeding sections. × 56. Section 9·3, 1. Lomax.

Phot. 33.—General transverse section showing the pith with the primary xylem-strands, and part of the secondary wood. × about 5. Section 9·3, 1. Lomax.

Phot. 34.—General radial section, showing the pith with some primary xylem-strands, and part of the secondary wood. × about 5. Section 9·3, 2. Radial.

Phot. 35.—Tangential section of part of the secondary wood, showing "knots," possibly connected with the neighbourhood of an appendage. × 22. Section 9·3, 3. Tangential.

Phot. 36.—Tangential section of the normal secondary wood, showing some medullary rays. × 66. Section 9·3, 3. Tangential.

PLATE 32.

Phots. 37–41, *Periastron perforatum*.

Phot. 37.—General transverse section of petiole; *v.b.*, the median row of bundles; the two middle pairs and three bundles to the right are clearly shown; also one to the left, damaged. On either side is the wide lacunar zone, and at the top the outer cortex. × 7½. Section E, 23.

Phot. 38.—Transverse section of one of the middle pairs of bundles with the surrounding tissue. *Cf.* Plate 37, fig. 12. × 37. Section E, 23.

Phot. 39.—Transverse section of part of the lacunar zone. × 37. Section E, 23.

Phot. 40.—Vascular bundle in longitudinal section, showing the scalariform tracheides, with phloem (*ph*) on the left. × 37. Section P, 14.

Phot. 41.—Tangential section through the outer part of the lacunar zone. × 37. Section P, 13.

Phot. 42.—*Stereopteris annularis.* Radial section through the xylem, showing scalariform tracheides. × about 56. Section B, 10.

PLATE 33.

Phots. 43, 44, *Calamopteris Hippocrepis*.

Phot. 43.—General transverse section of the petiole, showing the horseshoe arrangement of the partially confluent bundles, *cf.* the diagram, text-fig. 1. The letters A and B give the orientation. × 6½. Section A, 1.

Phot. 44.—General radial section, passing through the zone of bundles (*v.b.*) and showing the short-celled ground-tissue. × 7. Section A, 4.

Phots. 45–48, *Stereopteris annularis*.

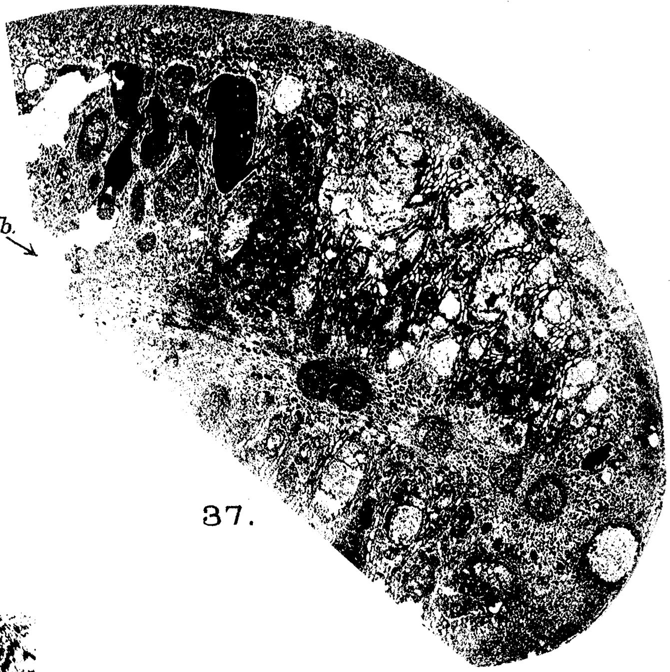
Phot. 45.—General transverse section of the petiole, showing the vascular bundle and the whole of the cortex. *r.c.*, radiating zone of cortex; *p.c.*, parenchymatous cortex; *hy*, hypoderma. × about 5. Section B, 6.

Phot. 46.—Vascular bundle and surrounding tissue, more highly magnified. *x*, xylem; *sc*, sclerenchymatous zone; *r.c.*, radiating zone of cortex × 11. Section B, 6.

Phot. 47.—General radial section, in the plane of the long axis of the bundle. The various cortical layers are well shown, specially on the left. Lettering as above. × about 5. Section B, 10.

Phot. 48.—Part of the xylem in transverse section. × 56. Section B, 6.

41.



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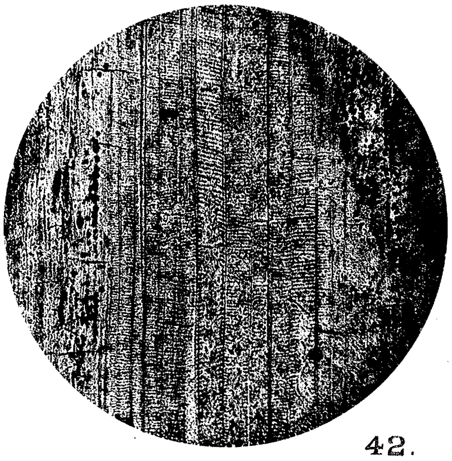

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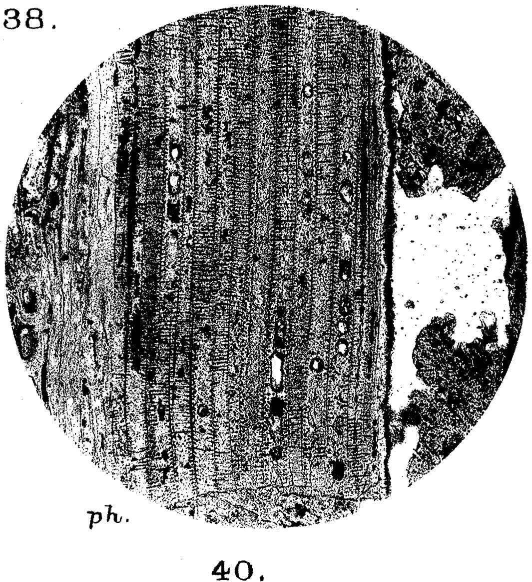

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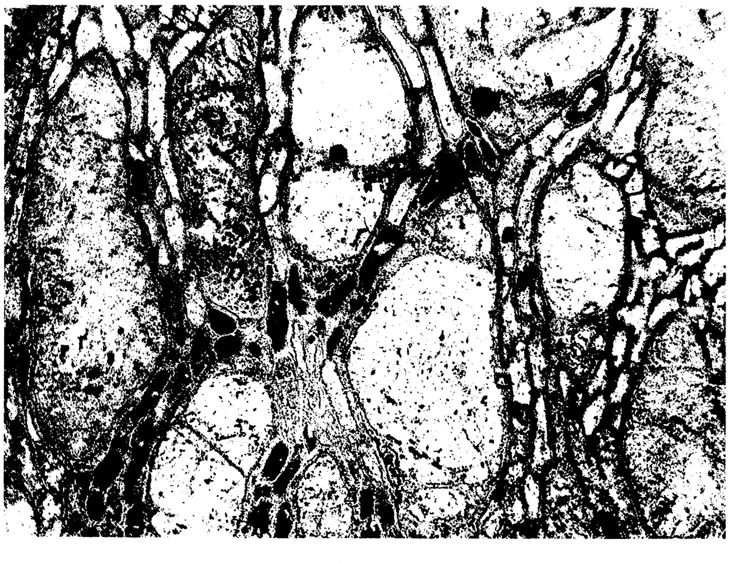


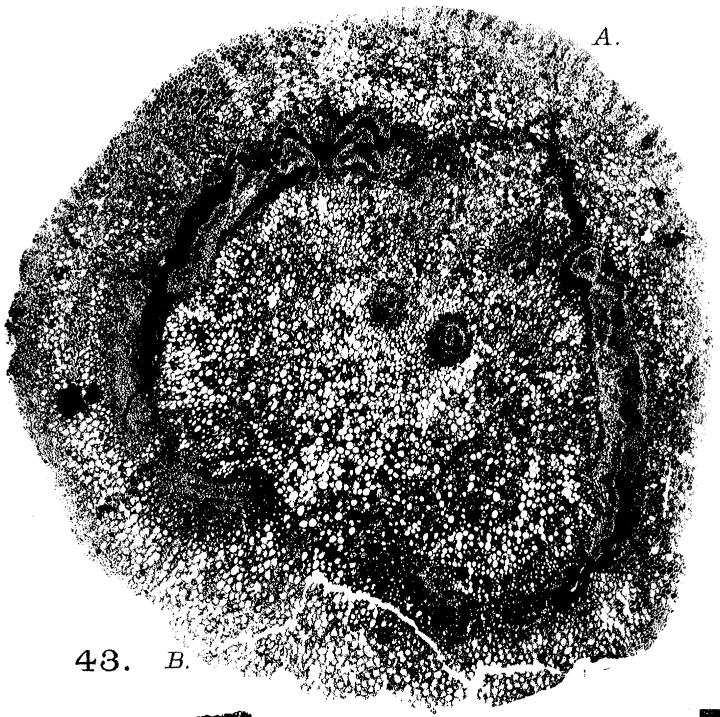
39.

Jeffrey phot.

Huth coll.

37–41, PERIASTRON PERFORATUM.
42, STEREOPTERIS ANNULARIS.

Scott & Jeffrey, Phil.Trans.B.vol.205,Pl.33.



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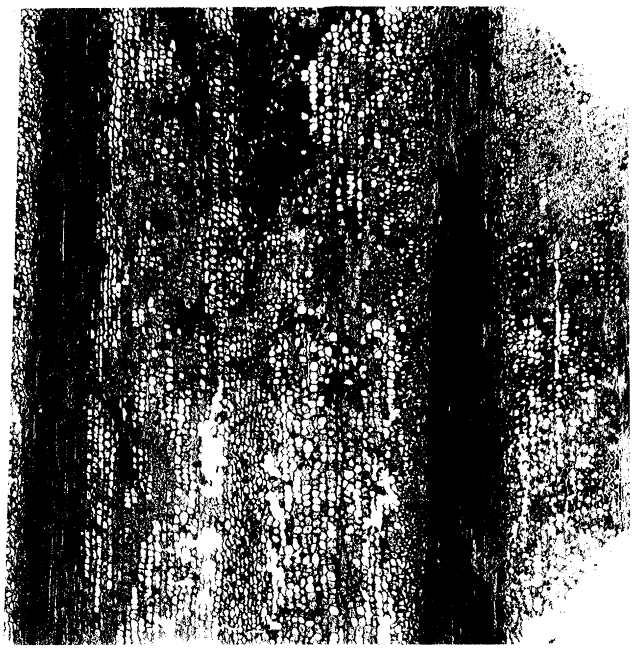

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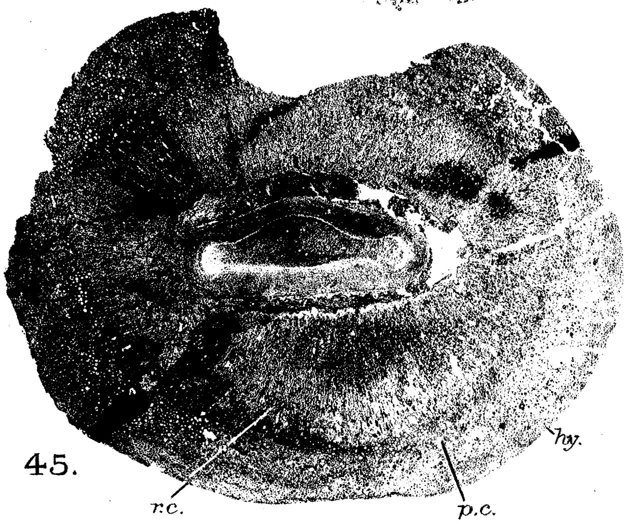

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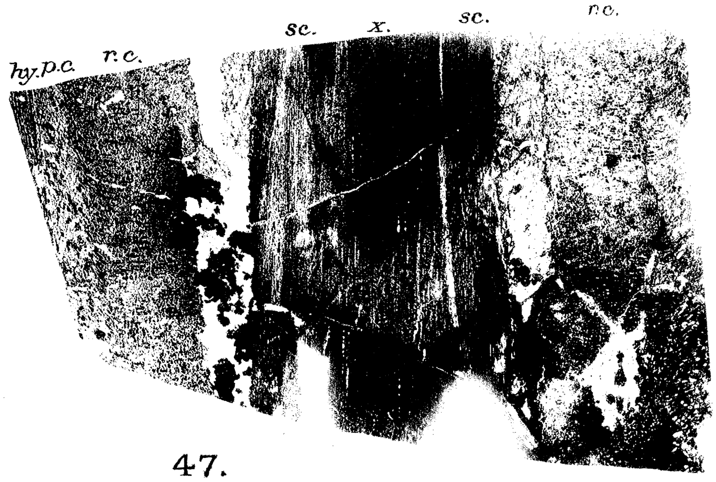

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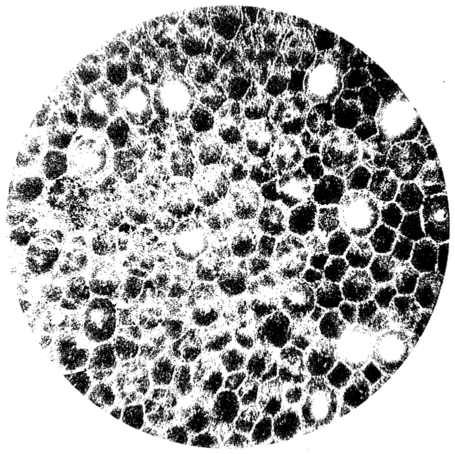

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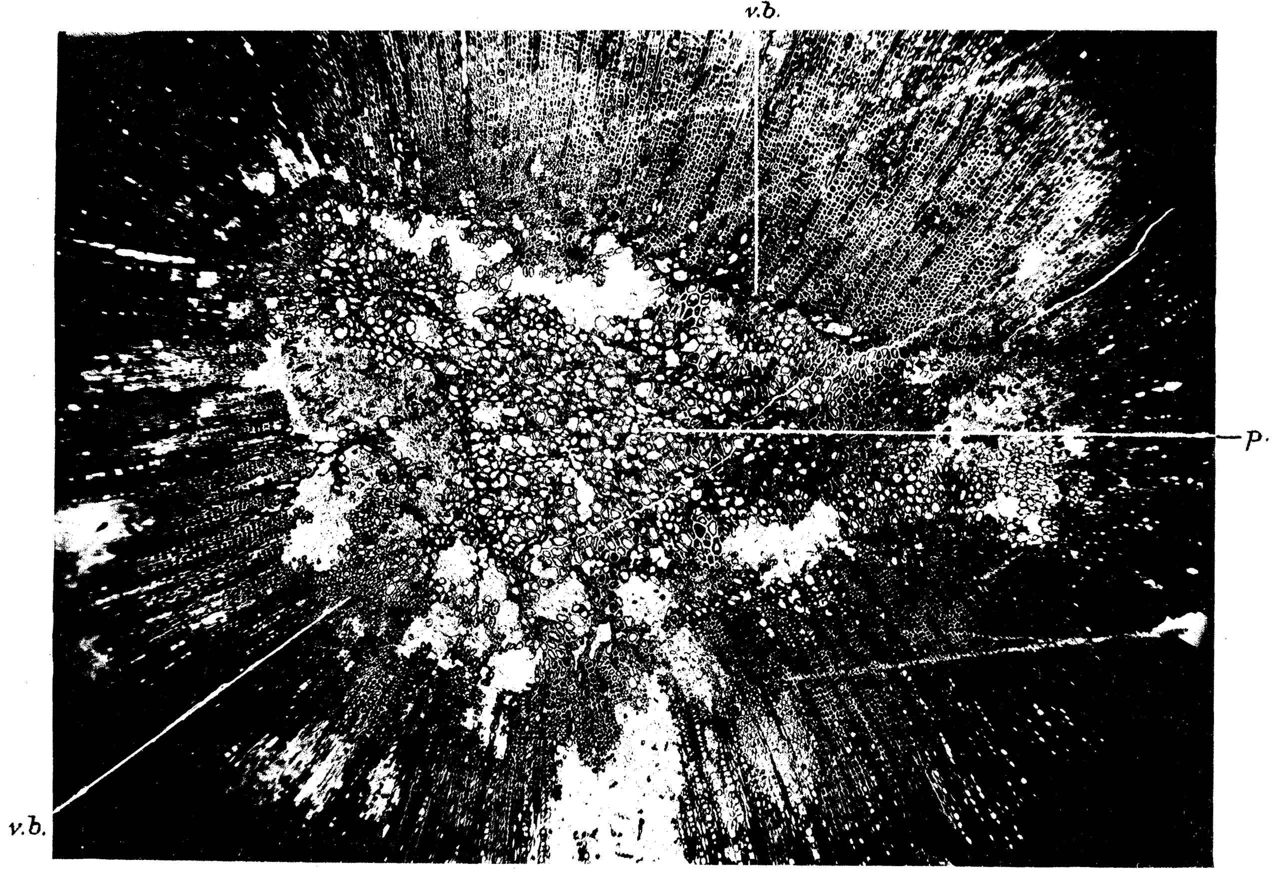
Huth, coll.

43, 44, CALAMOPTERIS HIPPOCREPIS.
45–48, STEREOPTERIS ANNULARIS.



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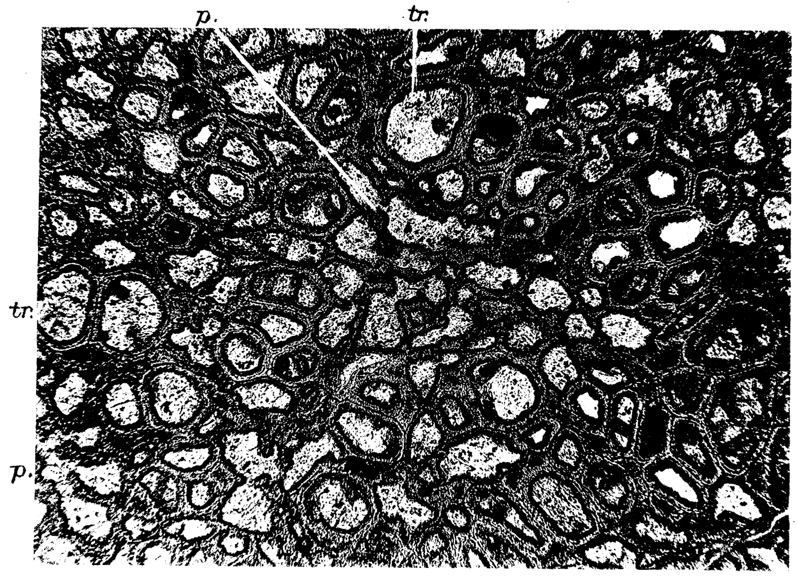

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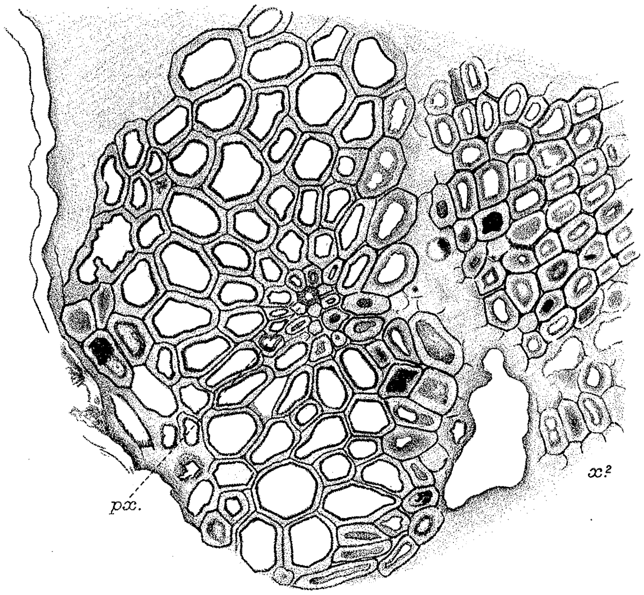
Tams phot.

Huth coll.

CALAMOPITYS AMERICANA.



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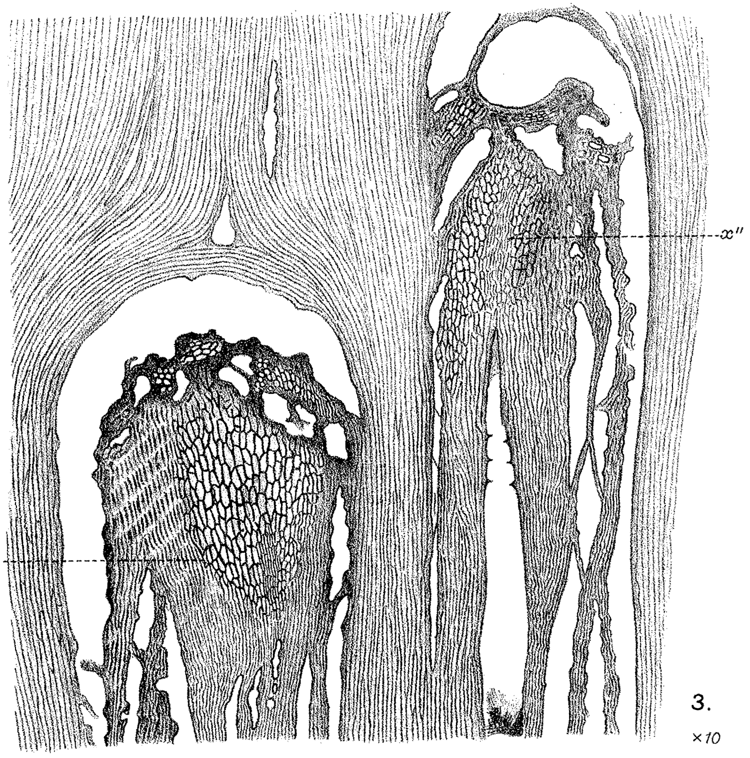

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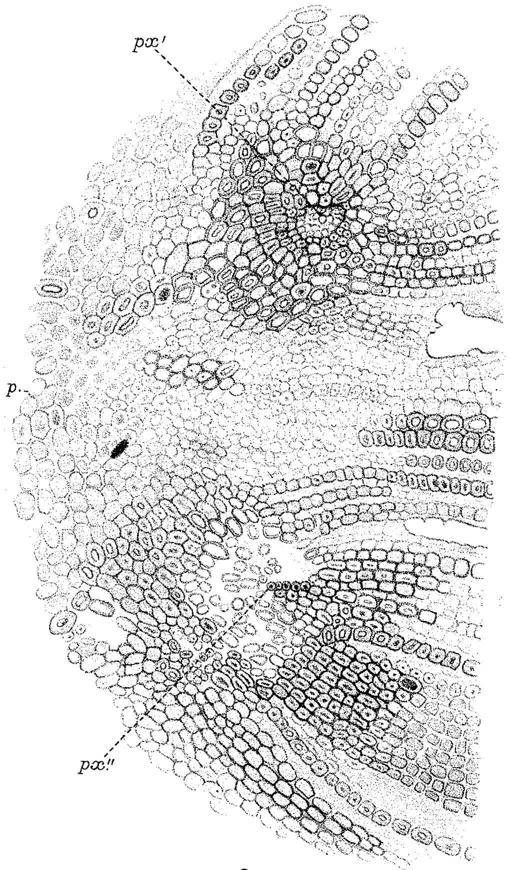

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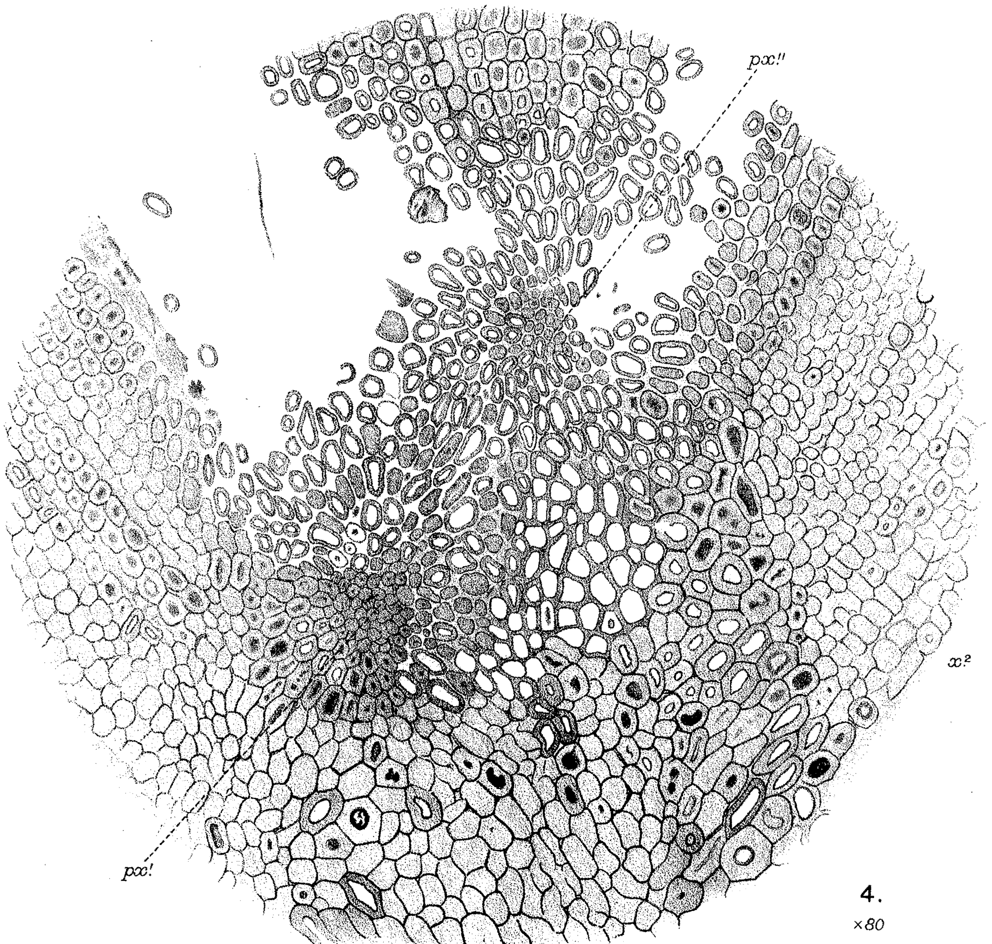

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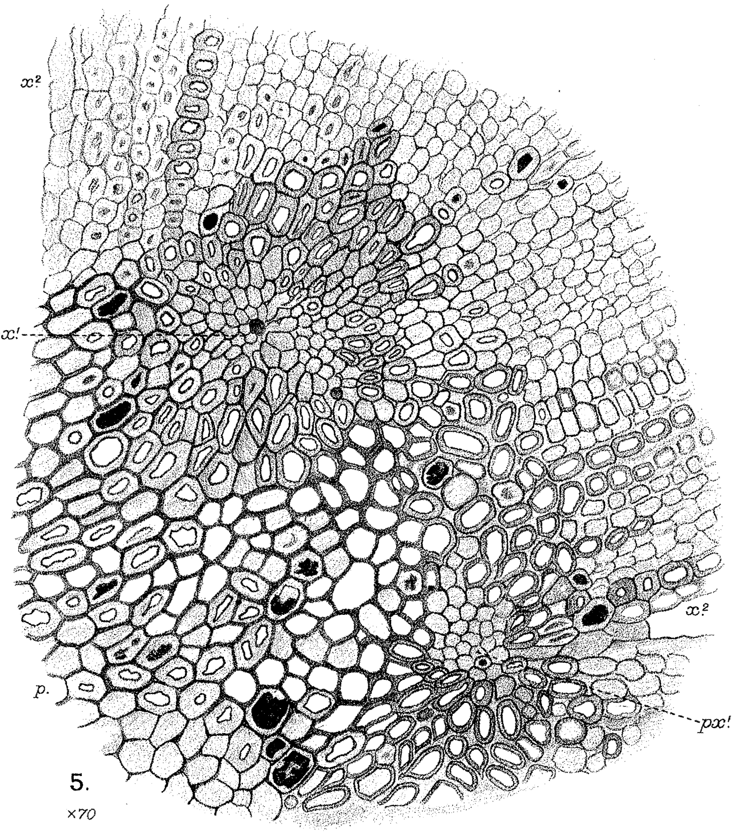
Gwilliam, del.

CALAMOPITYS.

Cambridge University Press.



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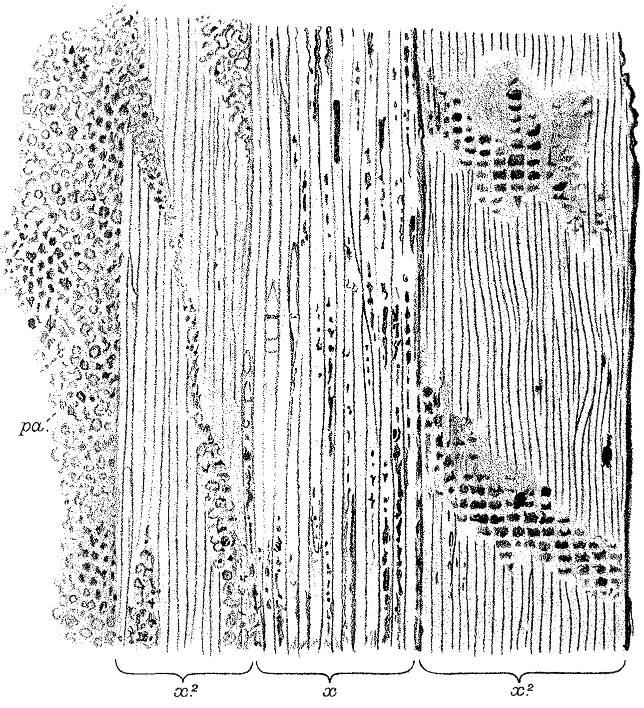

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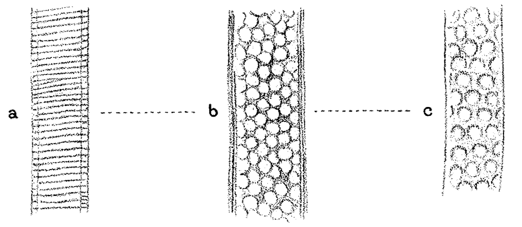

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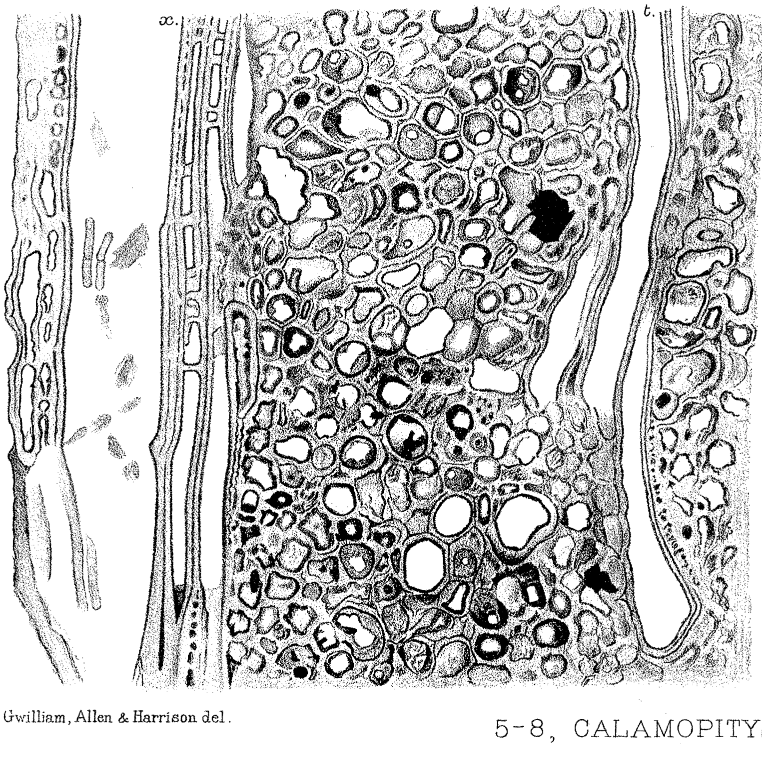

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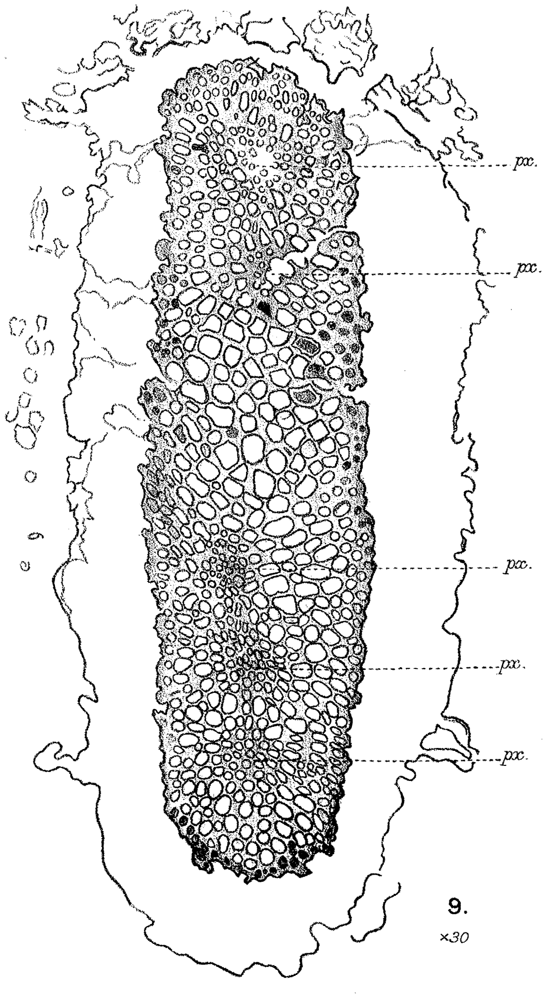

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Gwilliam, Allen & Harrison del.

5-8, CALAMOPITYS. 9, KALYMMA.

Cambridge University Press.

PLATE 34.

Calamopitys americana.

Phot. 49.—Transverse section of small stem showing the mixed pith and part of the secondary wood. *v.b.*, two of the primary xylem-strands; *p.*, middle point of part of mixed pith enlarged in Phot. 50. × 17. Section B 1, A.

Phot. 50.—Part of the mixed pith from the same section, more highly magnified to show the medullary tracheides, *tr.* *p*, parenchyma. × 80. Section B 1, A.

Phot. 51.—Medullary tracheides in longitudinal section, from the same stem, to show the multiseriate pits. *tr*, a medullary tracheide; *p*, parenchyma. × about 100. Section B1, y, C.

PLATE 35.

Calamopitys americana.

Fig. 1 (G. T. G.).—Primary, mesarch xylem-strand in transverse section. See also Plate 30, Phot. 24. *px*, protoxylem; x^2, secondary wood. × 73. Section C, 13.

Fig. 2 (G. T. G.).—Transverse section showing a double leaf-trace passing out. *px′*, *px″*, protoxylem groups of the two strands; *p*, pith. × 32. Section B 2, I.

Fig. 3 (G. T. G.).—Tangential section of the wood, showing a double leaf-trace passing out. *x′*, *x″*, primary xylem of the two strands. × about 10. Section C, 14.

Fig. 4 (G. T. G.).—Transverse section, showing a double bundle. *px′*, *px″*, protoxylem-groups of the two strands; x^2, secondary wood; *p*, pith. × about 80. Section B 1, E.

PLATE 36.

Figs. 5–8, *Calamopitys americana.*

Fig. 5 (G. T. G.).—Transverse section of the outer strand of the double bundle shown in fig. 4, farther out in its course, where it has itself divided into two. Lettering as in fig. 4. × about 70. Section B 1, *y′*.

Fig. 6 (J. A.).—Longitudinal section of a leaf-trace bundle with secondary wood, after it has left the stele. The same bundle is shown in transverse section in Plate 29, Phot. 22, and Plate 30, Phot. 28. *x*, primary xylem, x^2, secondary xylem of strand; x^2 shows the medullary rays; *pa*, surrounding parenchyma. × 20. Section F, 31.

Fig. 7 (J. A.).—Details of tracheides from last section. A, scalariform primary tracheide; B, pitted ditto; C, pitted secondary tracheide. × about 150. Section F, 31.

Fig. 8 (G. T. G.).—Longitudinal section showing tracheides embedded in the pith, and part of a xylem-strand. *t*, medullary tracheides; *x*, part of a xylem-strand. × about 35. Section 6·5. Radial.

Fig. 9 (G. C. H.).—*Kalymma.* Transverse section from a large petiole, showing a single bundle with five protoxylem-groups, *px*. × 30. Section O, 11.

Plate 37.

Fig. 10 (G. T. G.).—*Calamopteris Hippocrepis.* Transverse section of part of the bundle-zone, indicated by an arrow in text-fig. 1. *px*, protoxylem; *ph*, remains of phloem. × about 100. Section A, 2.

Fig. 11 (G. T. G.).—*Calamopteris debilis*, Unger. Transverse section of a vascular bundle (indicated by an arrow in text-fig. 2). *px*, *px*, approximate positions of the protoxylem; *ph*, phloem; all the part above this is xylem. × 80. Section 435, Solms collection.

Fig. 12 (G. T. G.).—*Periastron perforatum.* Transverse section of a middle pair of bundles. See also Plate 32, Phot. 38. *x*, *x*, xylem; *ph*, *ph*, phloem of the two bundles; *sh*, sheath. × 73. Section E, 23.

Fig. 13 (J. A.).—*Stereopteris annularis.* One end of the vascular bundle, transverse. *x*, xylem; *px*, approximate position of protoxylem; *ph*, probable phloem; *sc*, sclerenchyma of pericycle (?). × 90. Section B, 6.

Fig. 14 (R. S.).—Transverse section of part of the same, showing probable protoxylem. *px*, protoxylem; *x*, elements of the xylem mass. × about 330. Section B, 6.

Plate 38.

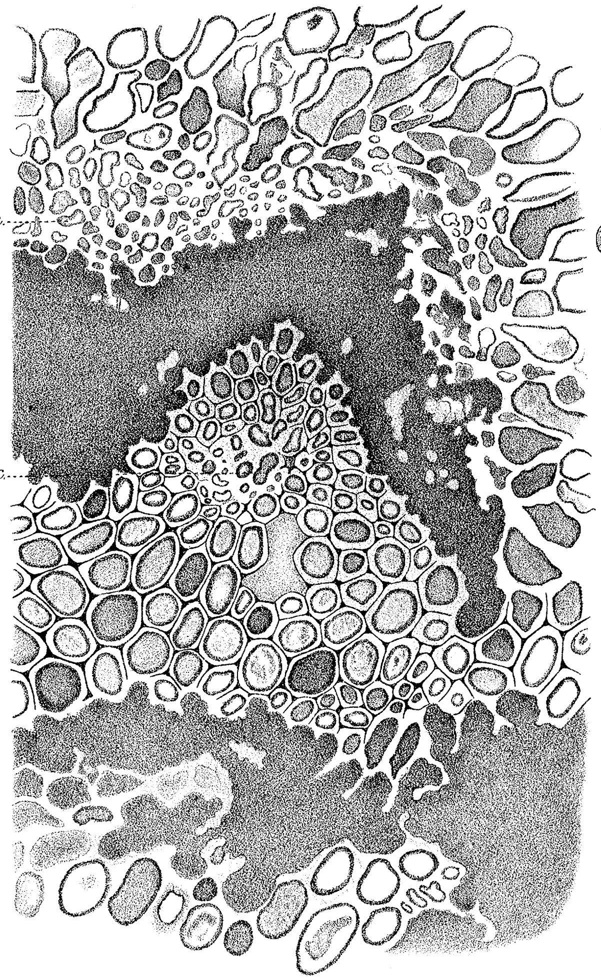
Figs. 15 and 16, *Stereopteris annularis.*

Fig. 15 (G. T. G.).—Tangential section through the sclerenchymatous zone (pericycle?) surrounding the bundle. × about 35. Section B, *a*.

Fig. 16 (G. T. G.).—Approximately radial section through the outer part of the cortex. *r.c.*, part of radiating zone; *p.c.*, parenchymatous cortex; *hy*, hypoderma. × about 40. Section B, *a*.

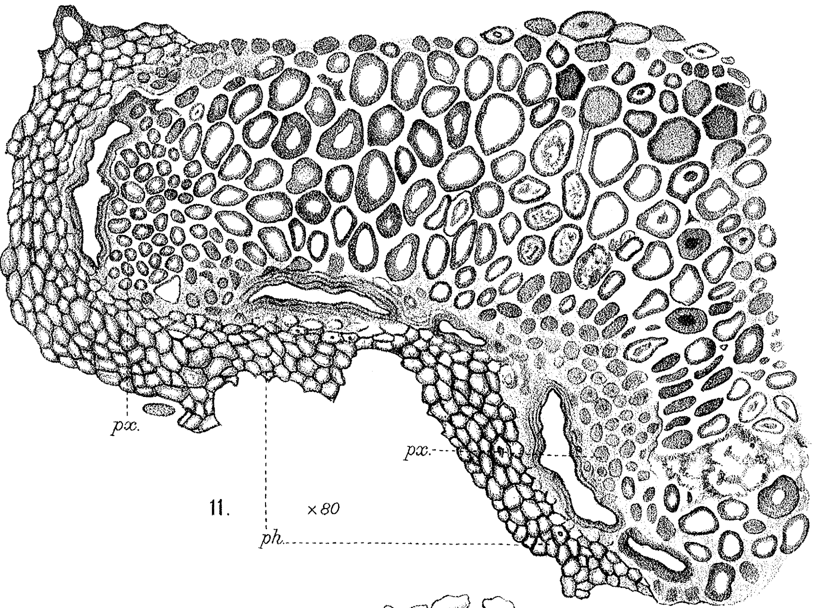
Figs. 17–19, *Archæopitys Eastmanii.*

Fig. 17 (G. T G.).—Transverse, showing two xylem-strands (marked 7 and E in text-fig. 4), one in the pith, the other in contact with the wood. px', px'', protoxylem of the two strands; x^2, secondary wood; *p*, pith. × about 90. Section 9·3, 13. Hemingway.

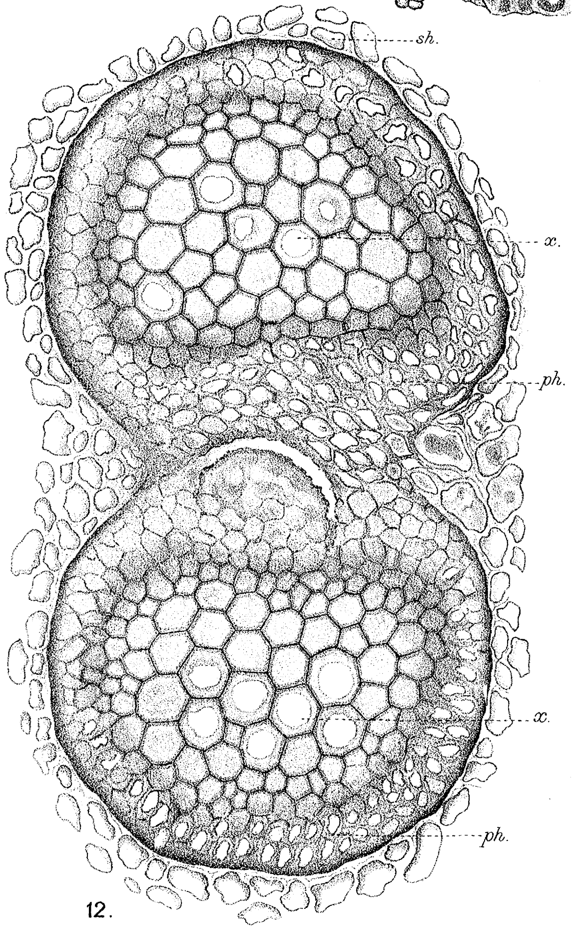


10.

× abt. 100



11. × 80



12.

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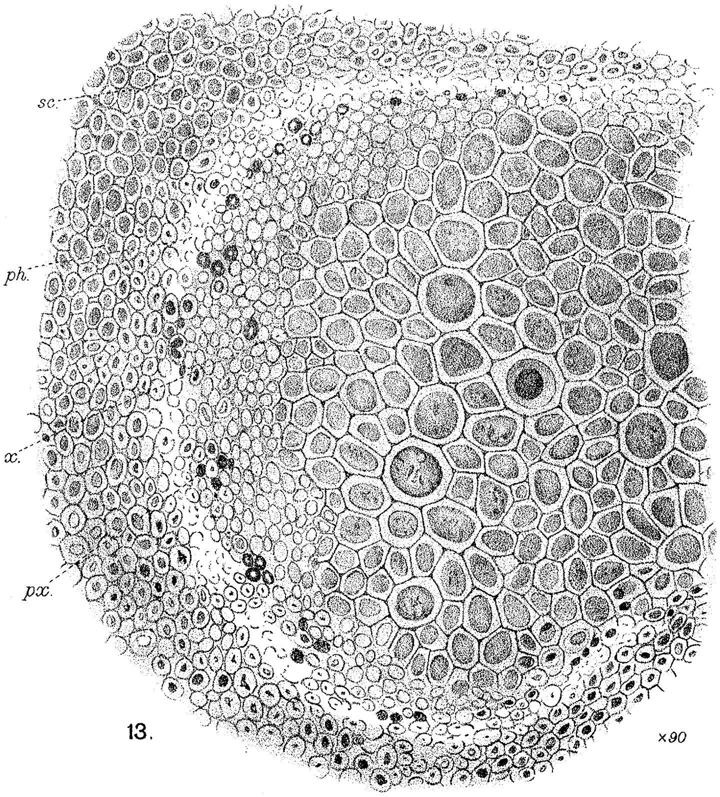
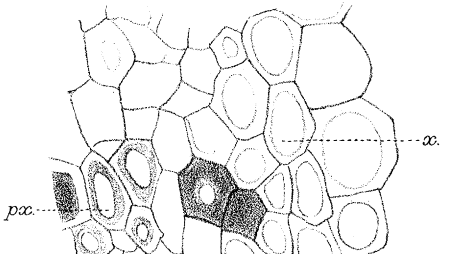


13. × 90



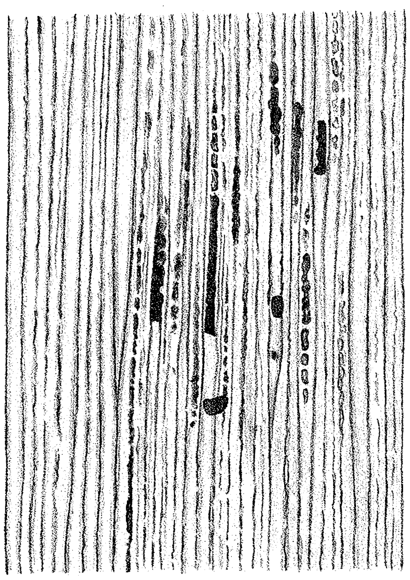
× abt. 330

14.

Gwilliam; Allen & R. Scott del.

10, CALAMOPTERIS HIPPOCREPIS. 11, C. DEBILIS.
12, PERIASTRON 13, 14, STEREOPTERIS.

Cambridge University Press.



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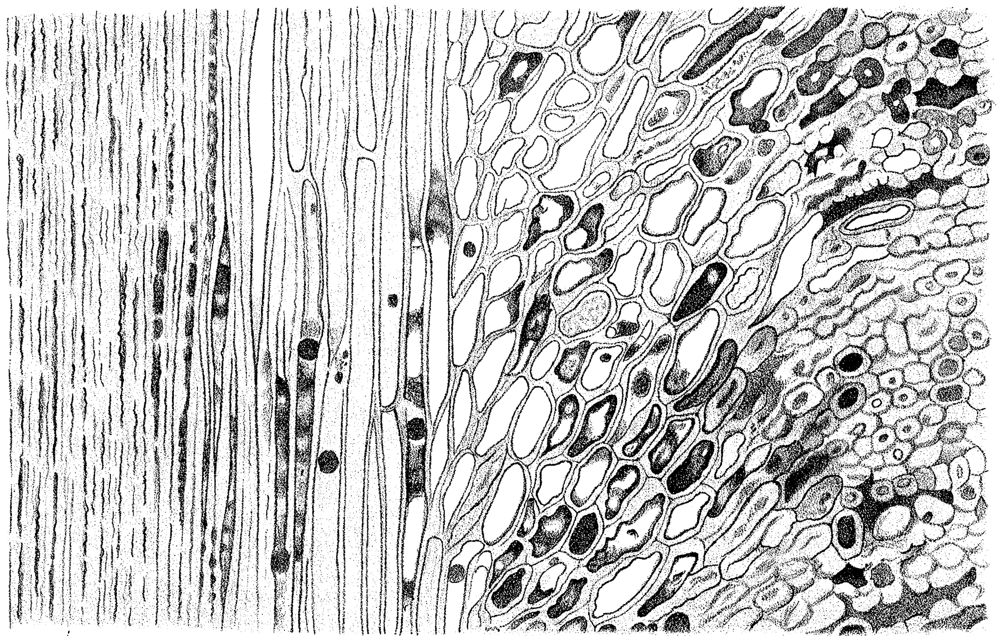
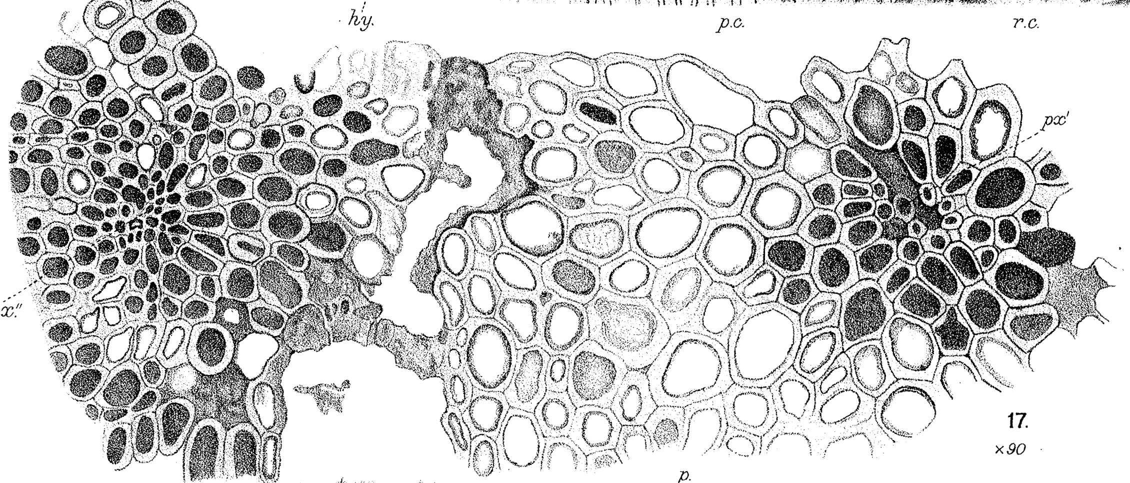
×35



16.

×40



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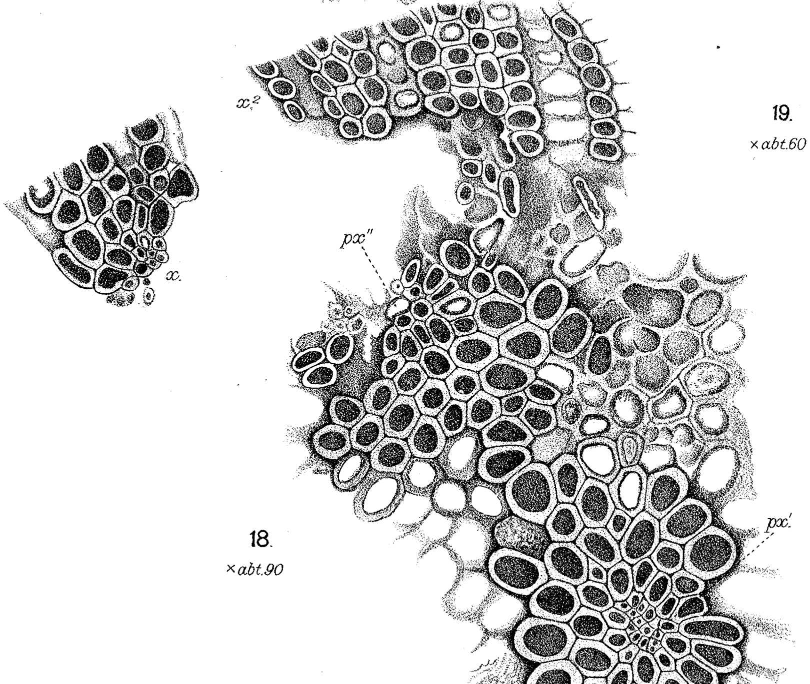

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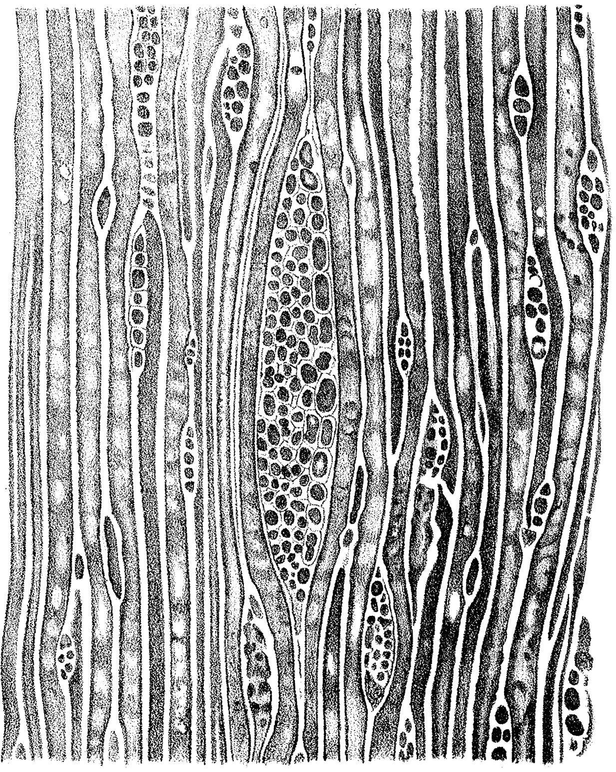

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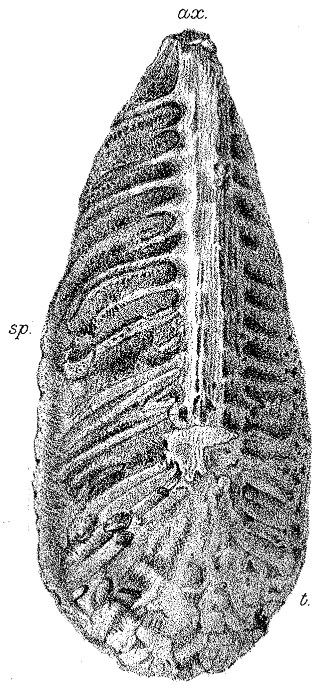
Gwilliam del.

15, 16, STEREOPTERIS. 17–19, ARCHÆOPITYS.

Cambridge University Press.



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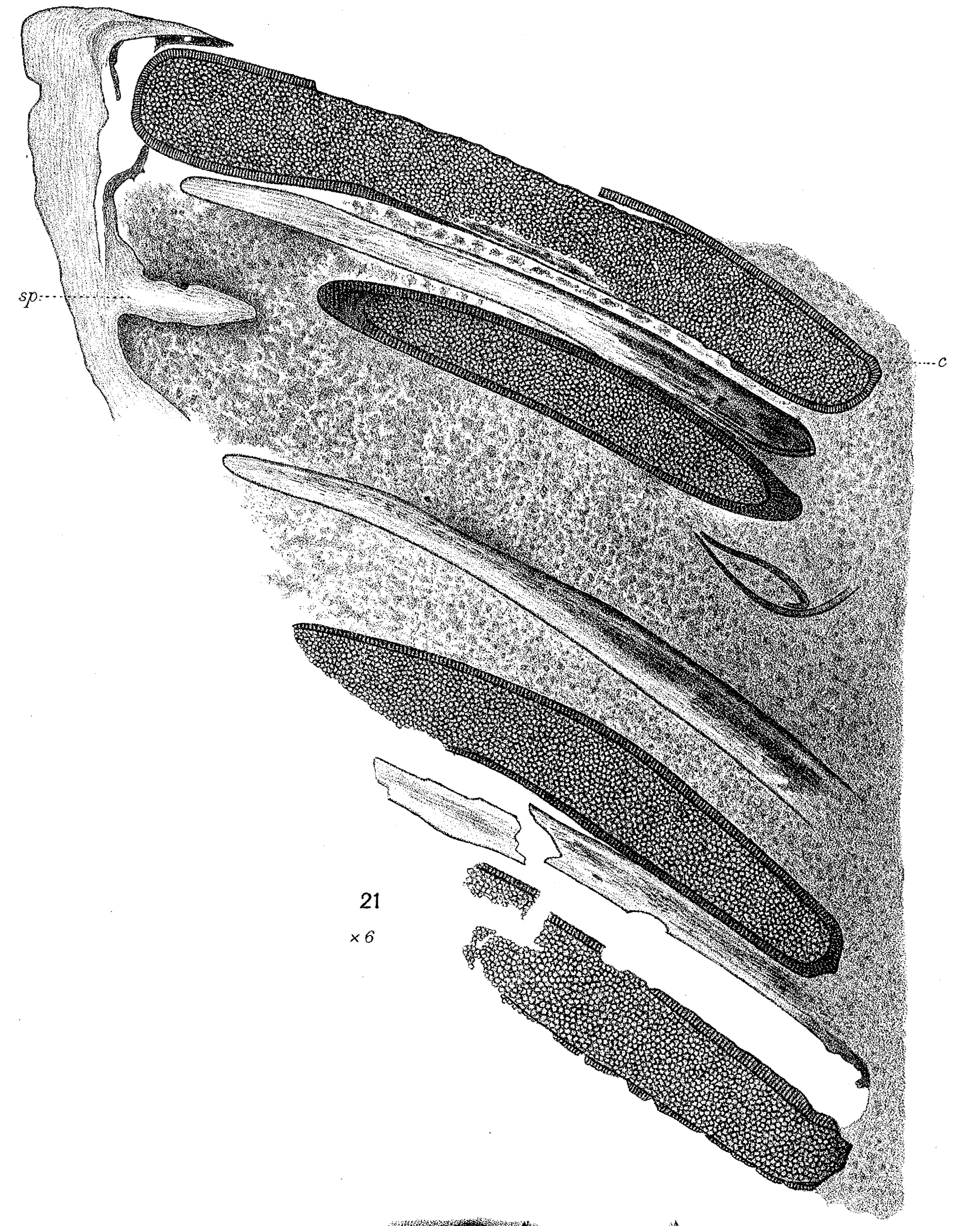

21

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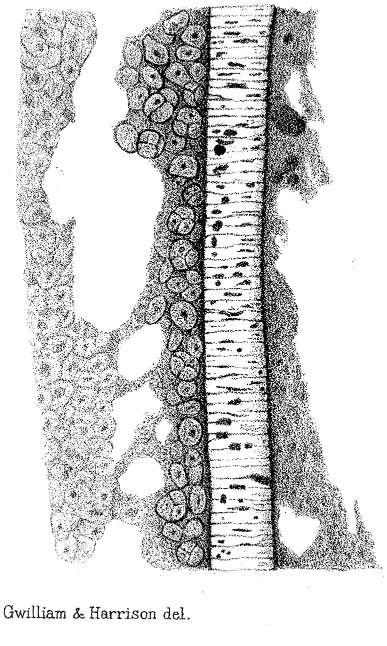
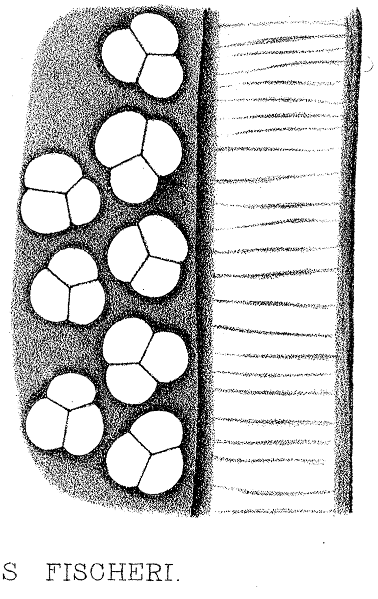


22

× 50



23

× 115

Gwilliam & Harrison del.

LEPIDOSTROBUS FISCHERI.

Cambridge University Press.

Fig. 18 (G. T. G.).—The same two strands beginning to fuse (see text-fig. 5, E 7). *px'*, *px''*, protoxylem of the two strands; *x*, detached fragment of primary xylem of outer strand; x^2, secondary wood; *p*, pith. × about 90. Section 9·3, 21. Hemingway.

Fig. 19 (G. T. G.).—Tangential section through secondary wood, showing the medullary rays. × about 80. Section 9·3, D. Lomax.

PLATE 39.

Lepidostrobus Fischeri.

Fig. 20 (G. C. H.).—General view of the specimen before any sections were cut. The radial fractures and the oblique terminal fracture (*t*) are shown. *ax*, axis; *sp*, sporophylls. Natural size.

Fig. 21 (G. T. G.).—Radial section, showing a fragment of the axis, sporophyll-pedicels and four sporangia. *sp*, sporophyll base, showing groove on upper surface; *c*, distal crest of the uppermost sporangium. × 6. Section 1.

Fig. 22 (G. T. G.).—Part of a sporangial wall and numerous spore-tetrads. × 50. Section 1.

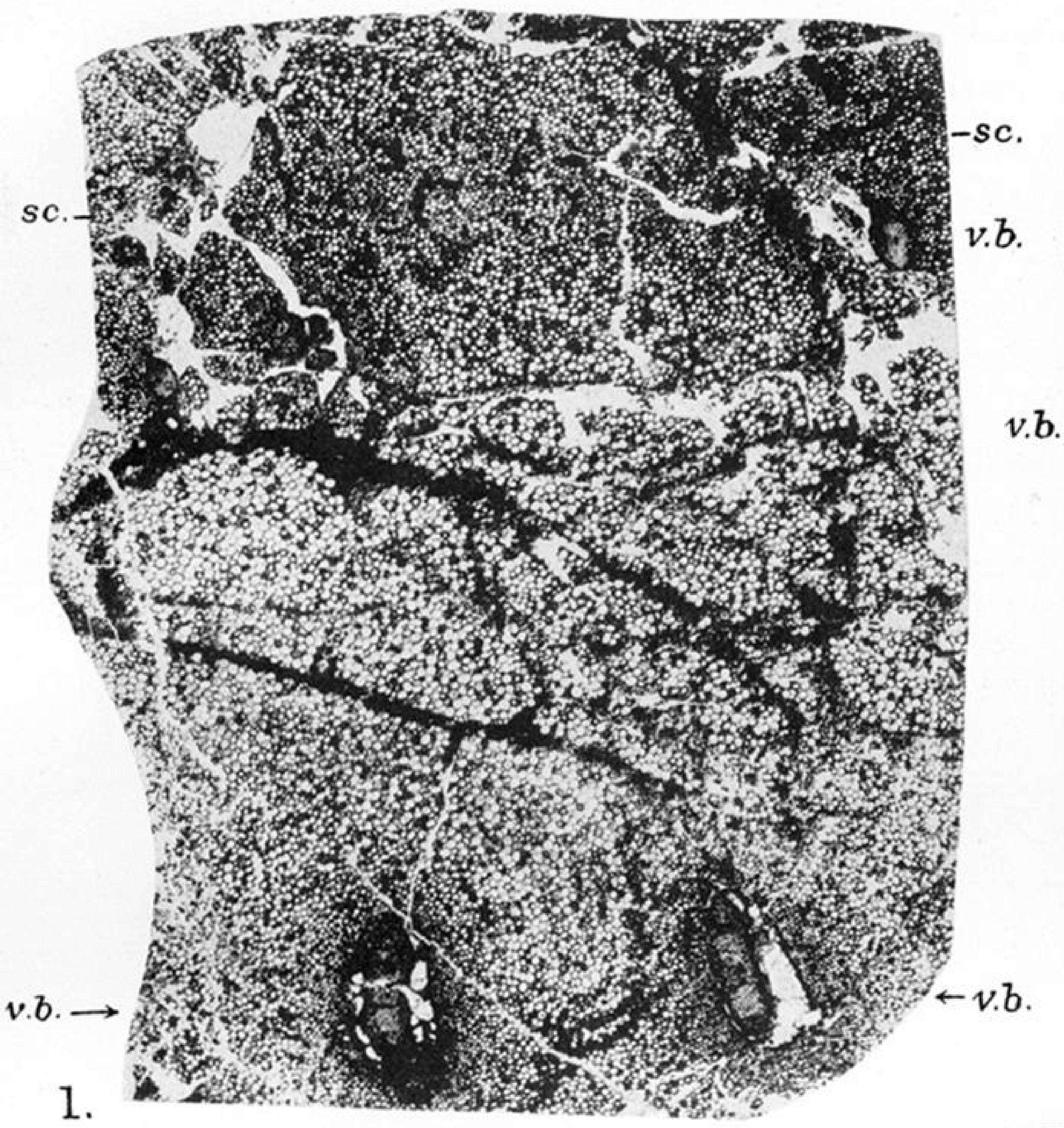
Fig. 23 (G. T. G.).—Part of another sporangial wall, with a few tetrads; more highly magnified. × about 150. Section 1.

PLATES 27–33.—Photographs taken by Prof. JEFFREY.

PLATE 34.—Photographs by Mr. W. TAMS.

PLATES 35–39.—From drawings by Mr. G. T. GWILLIAM (G. T. G.), Mr. JAMES ALLEN (J. A.), Miss HARRISON (G. C. H.), and Mrs. D. H. SCOTT (R. S.).

All the figured sections of the Kentucky plants, and some others, are in the possession of Dr. D. H. SCOTT, East Oakley House, Basingstoke, England. A duplicate set is in the hands of Prof. E. C. JEFFREY, Harvard University, Cambridge, Mass., U.S.A.—*Note added August* 18, 1914.



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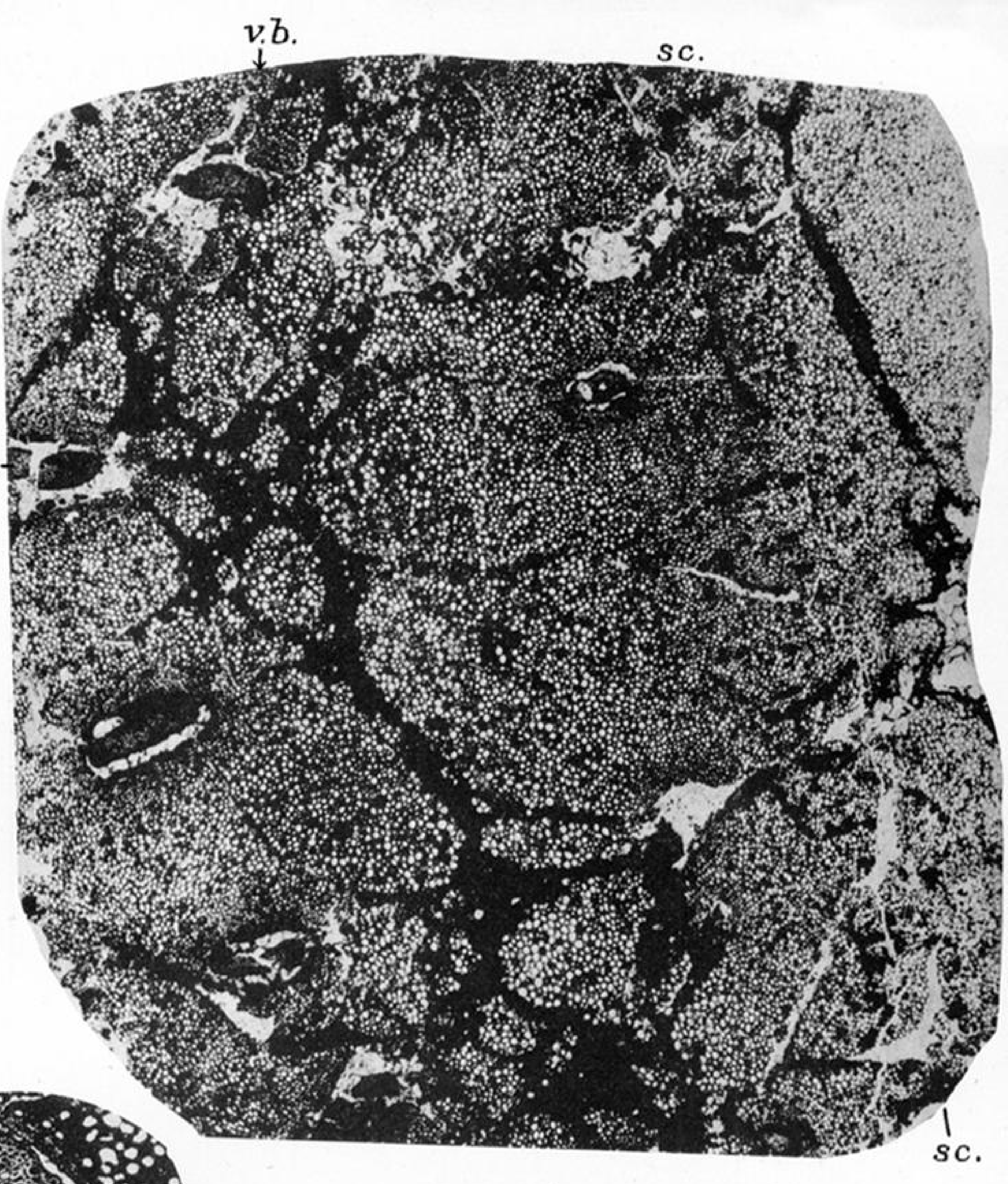

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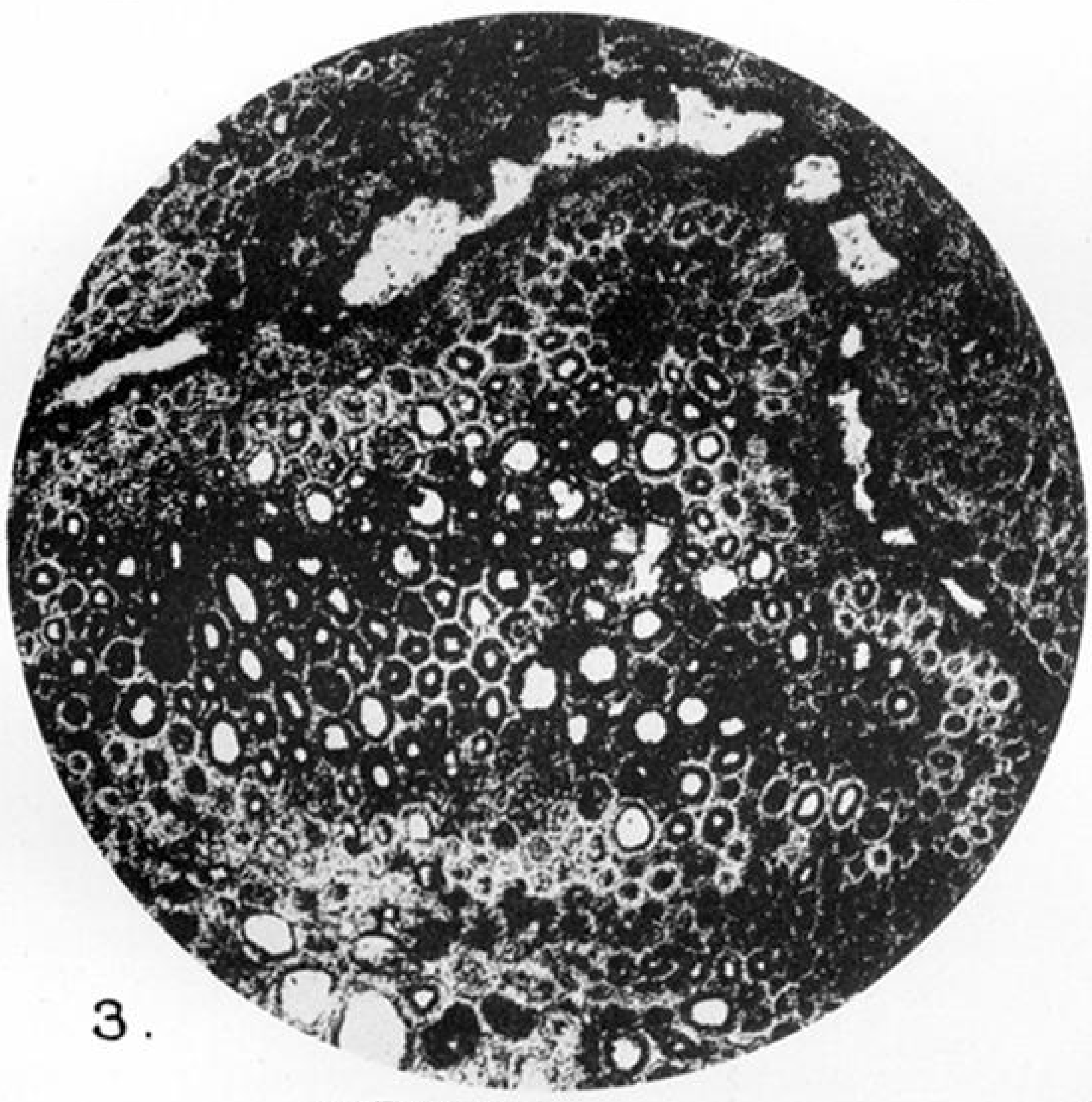

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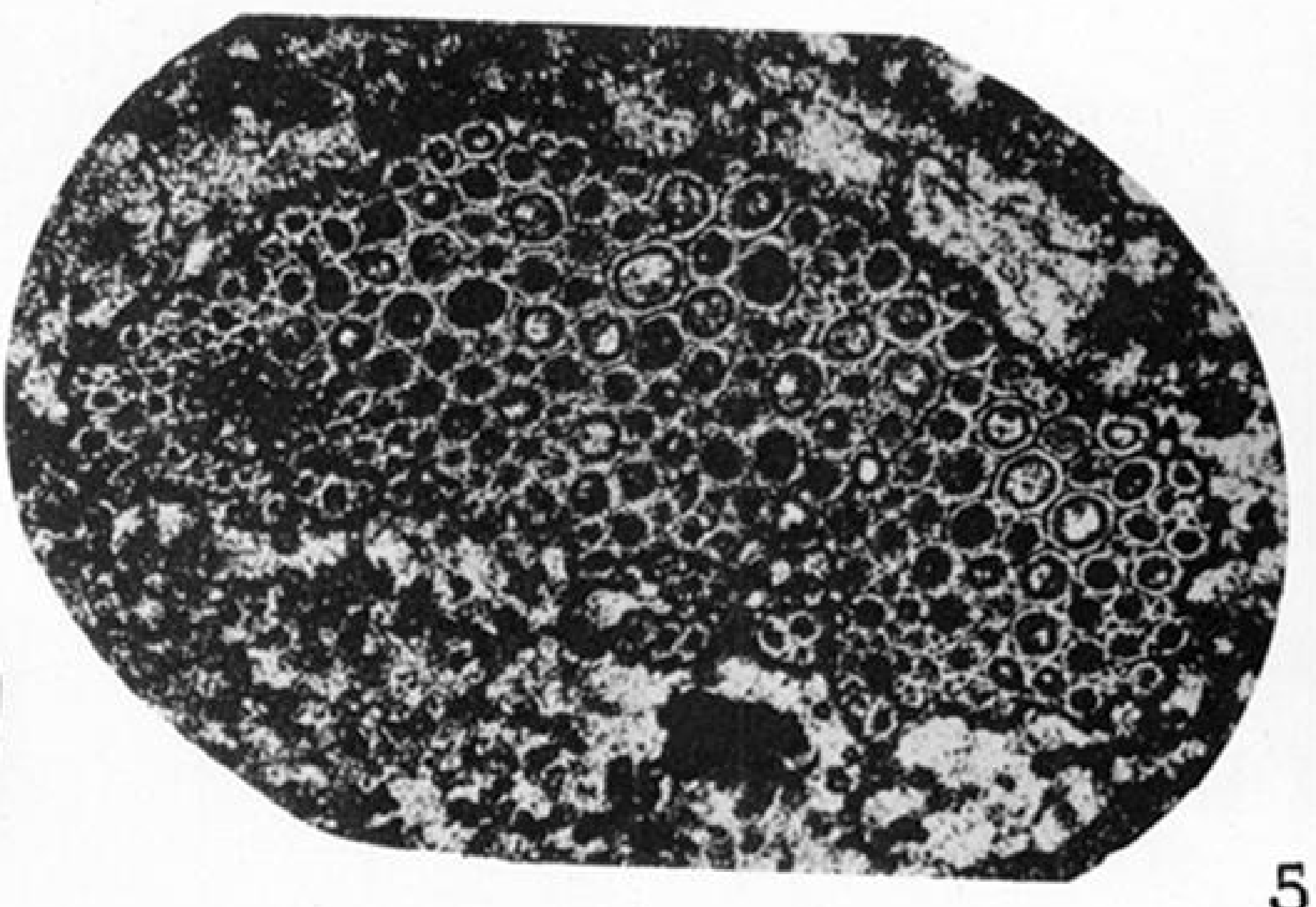

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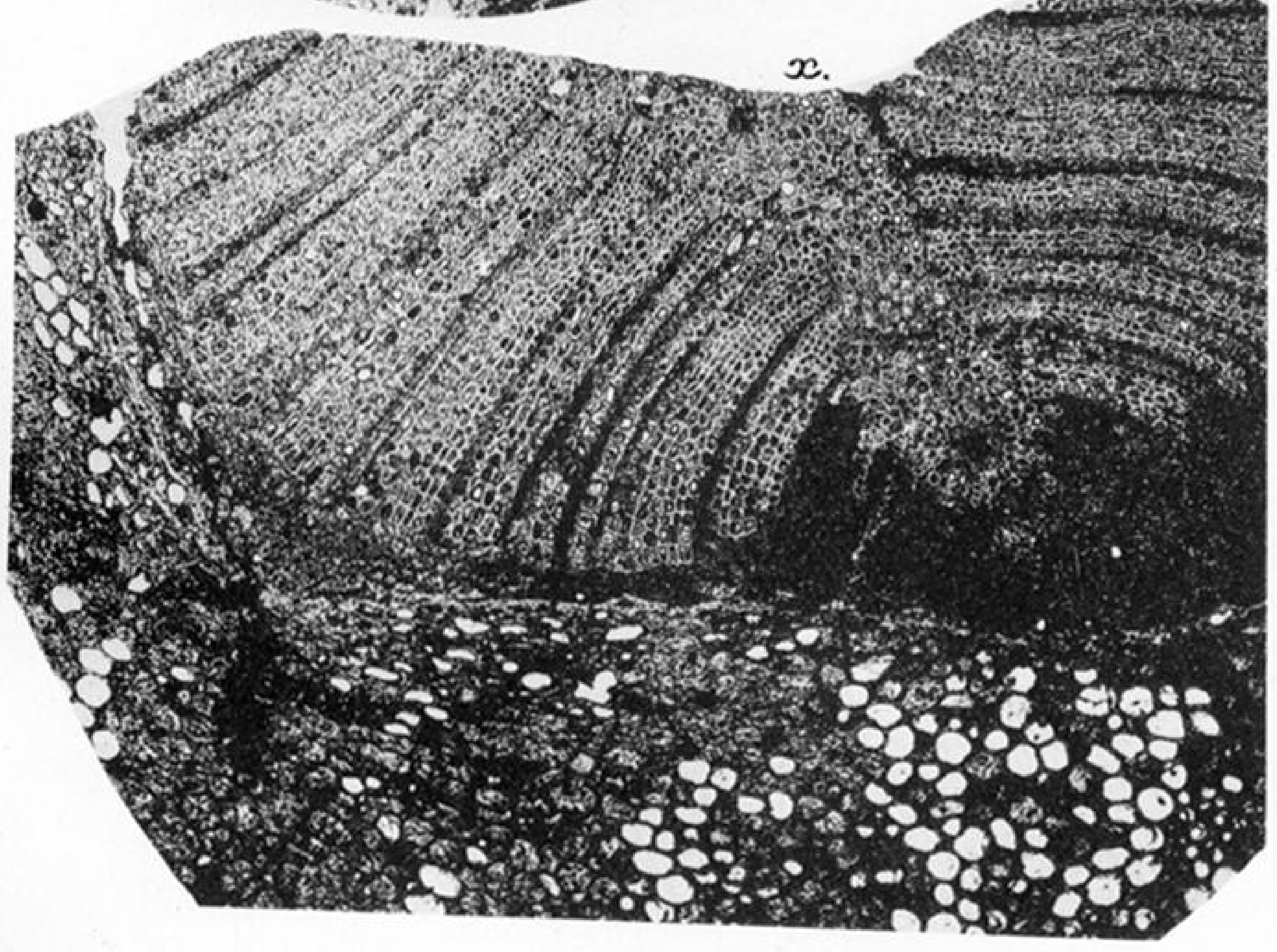

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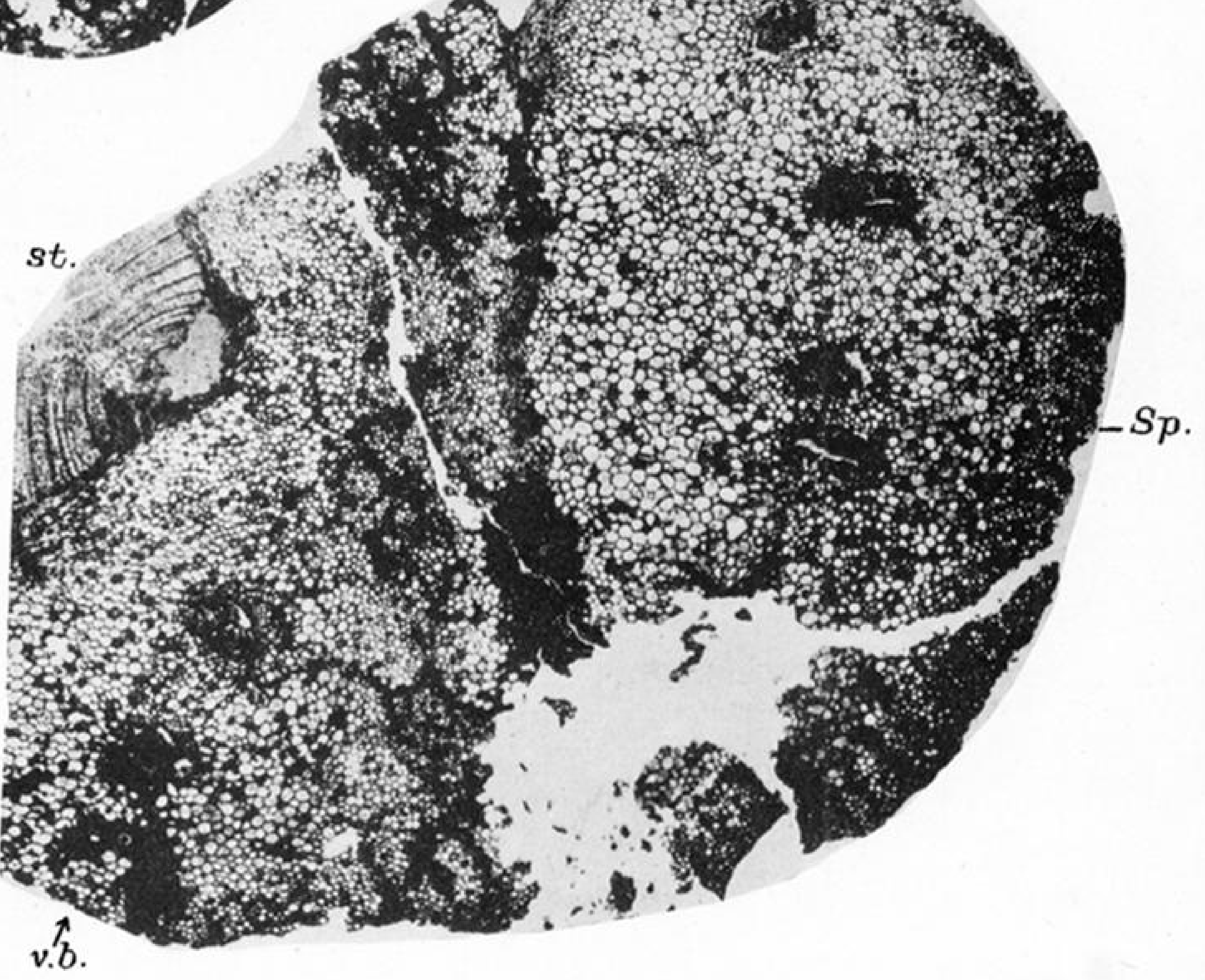


7.

PLATE 27.

Kalymma and Calamopitys.

Phot. 1.—General transverse section of a portion of a large leaf-base; *v.b.*, vascular bundles; *sc*, interrupted band of sclerenchyma, probably separating leaf-base from cortex. × $3\frac{1}{3}$. Section N, 10.

Phot. 2.—Another portion of the same specimen. Lettering as above; only two of the vascular bundles are lettered. × $3\frac{1}{3}$. Section O, 11.

Phot. 3.—A single vascular bundle from Plate 28, Phot. 11, on the extreme left. × 50. Prof. BOWER'S specimen.

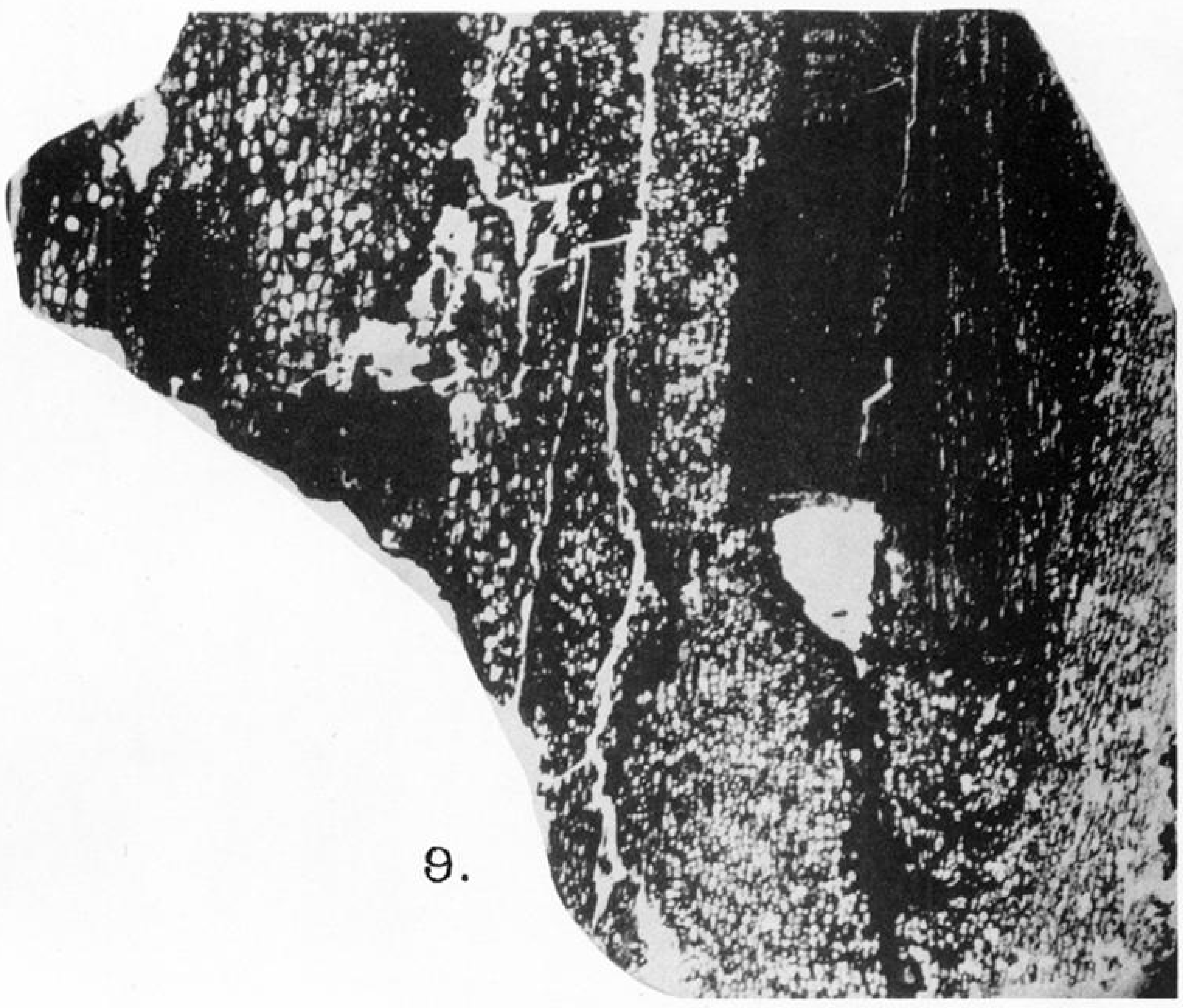
Phot. 4.—A single vascular bundle from Phot. 1, showing four median protoxylem groups. × 16. Section N, 10.

Phot. 5.—A single vascular bundle from a small *Kalymma* (Plate 28, Phot. 10, on the left). × 50. Section L, 6.

Phot. 6.—*Calamopitys*, probably *C. americana.* Portion of stem in transverse section, seen in Phot. 7 in connection with a *Kalymma*. *x*, primary xylem. × about 15. Section K, 3.

Phot. 7.—*Calamopitys* in connection with the *Kalymma*—general section. *sc*, sclerenchyma separating cortex from leaf-base; *v.b.*, *v.b.*[1] vascular bundles in cortex and leaf-base; *st*, stele of stem; *sp*, Sparganum cortex of the *Kalymma*. × about 5. Section K, 3.

8.



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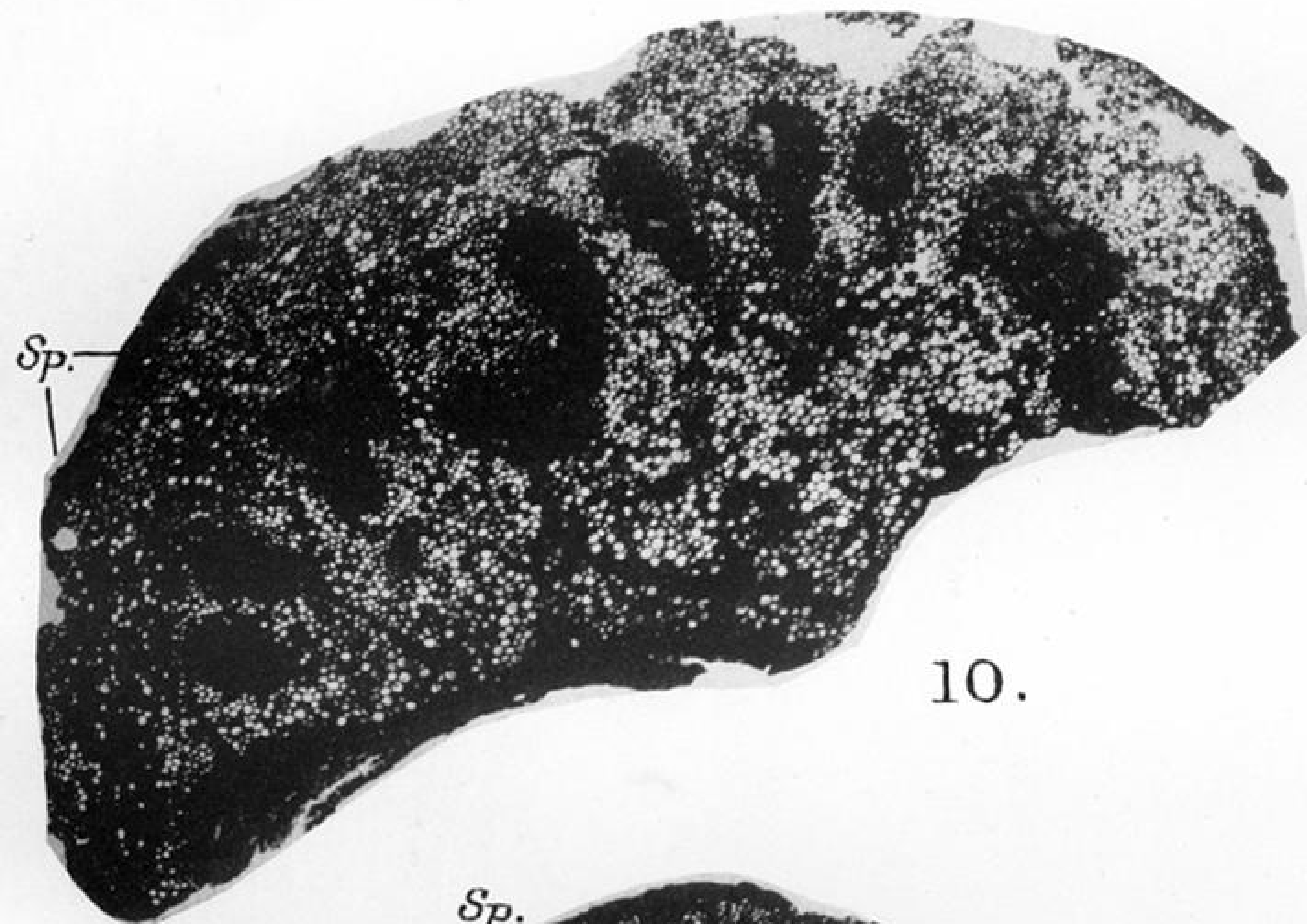

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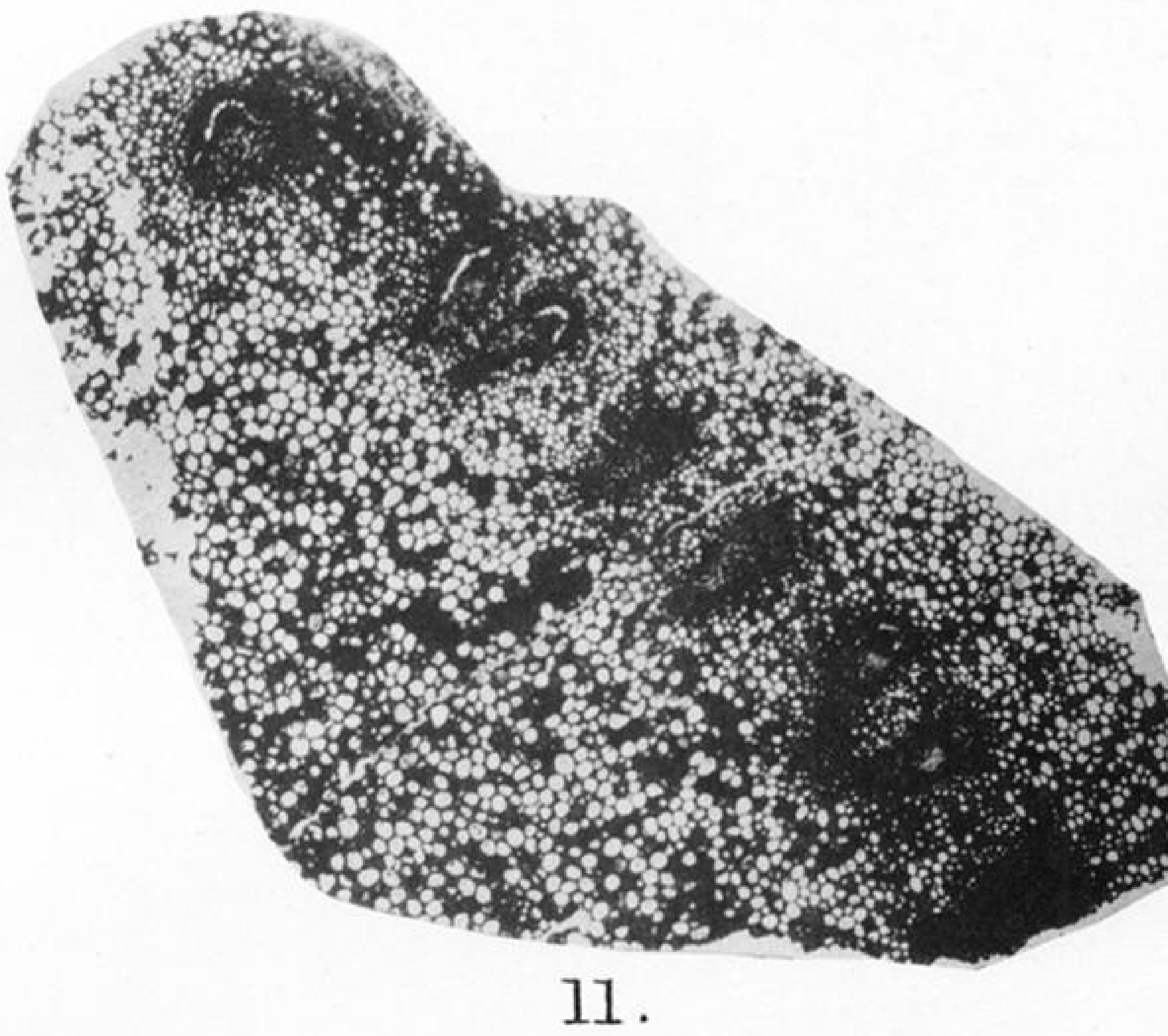

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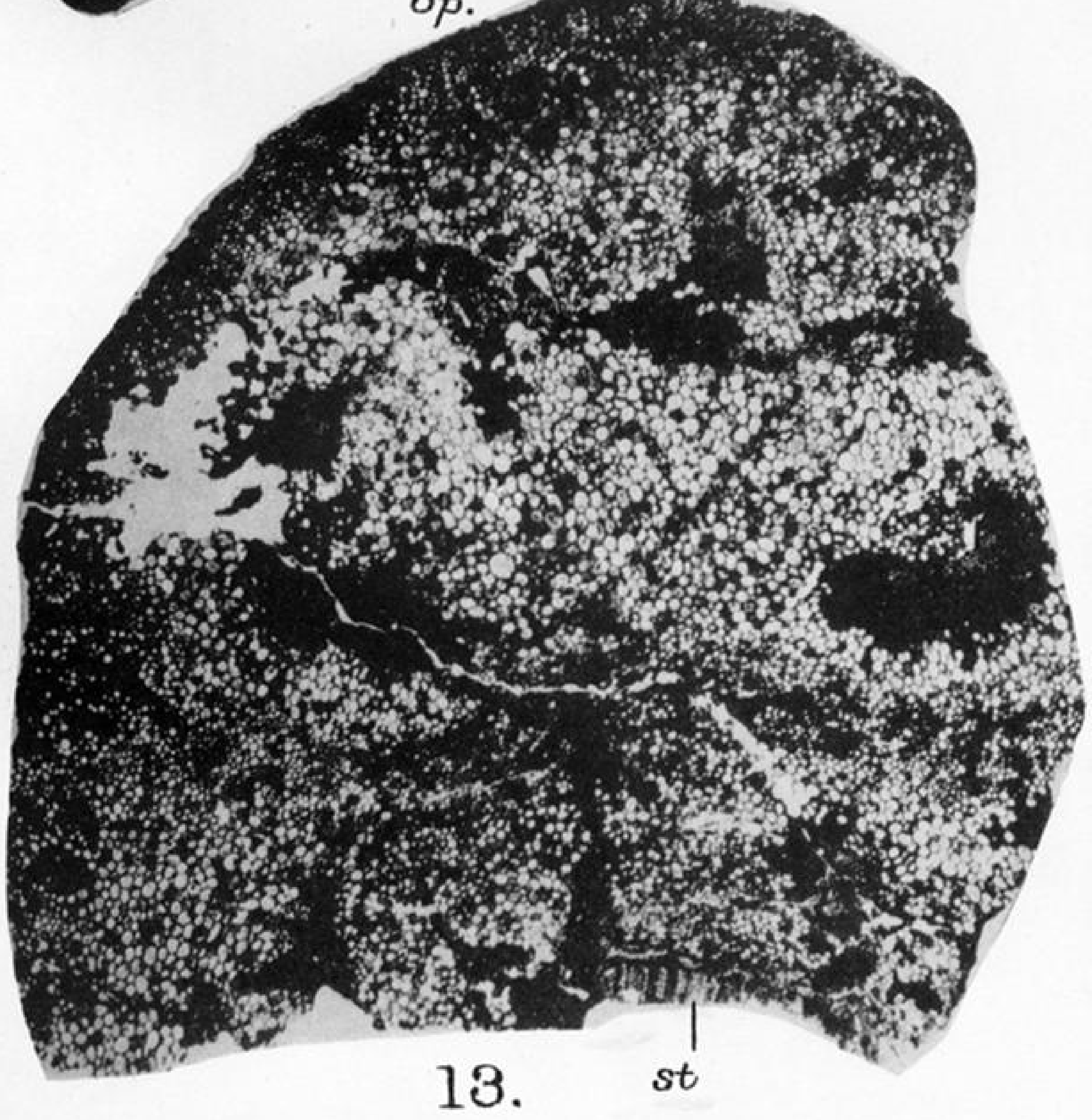

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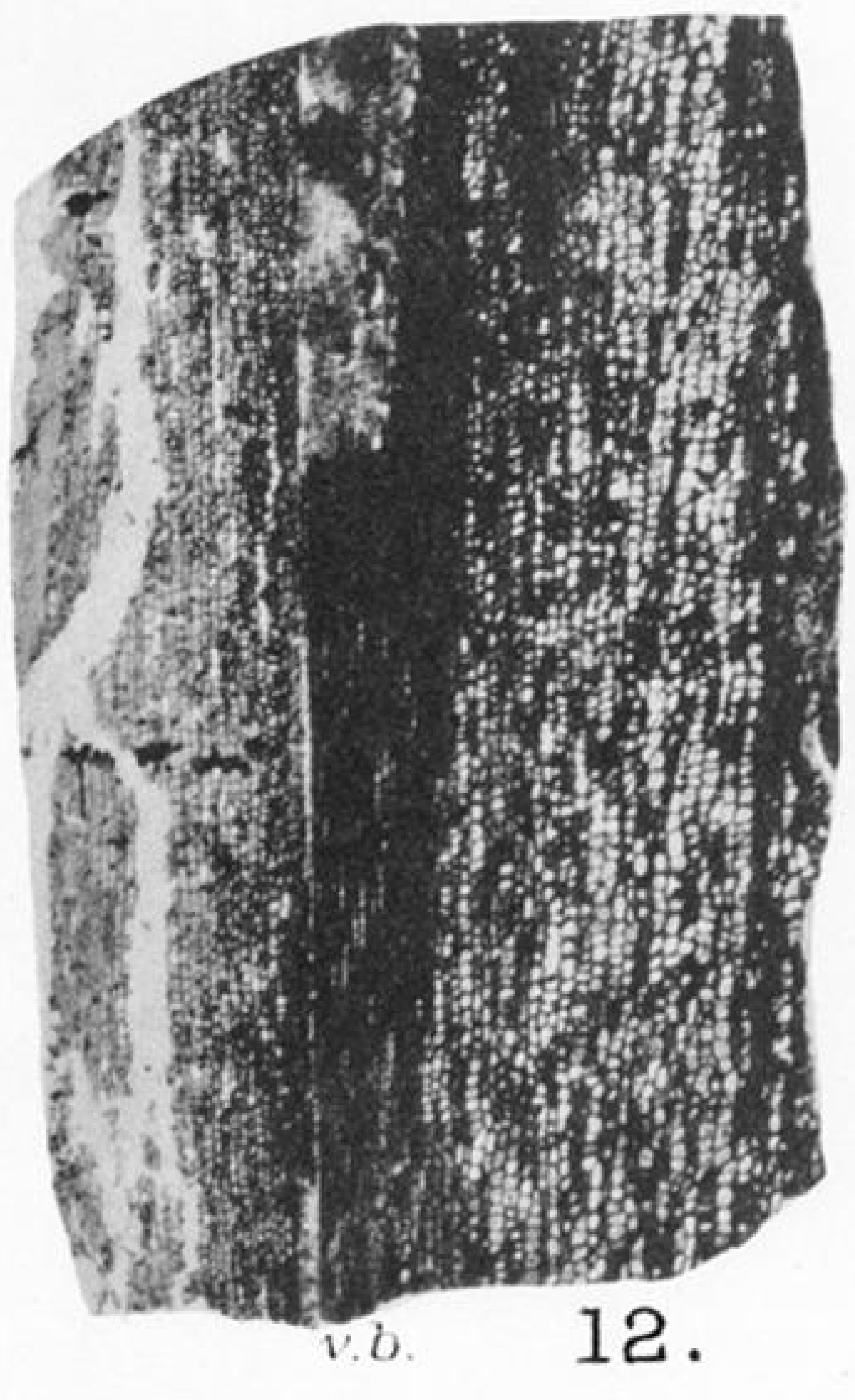

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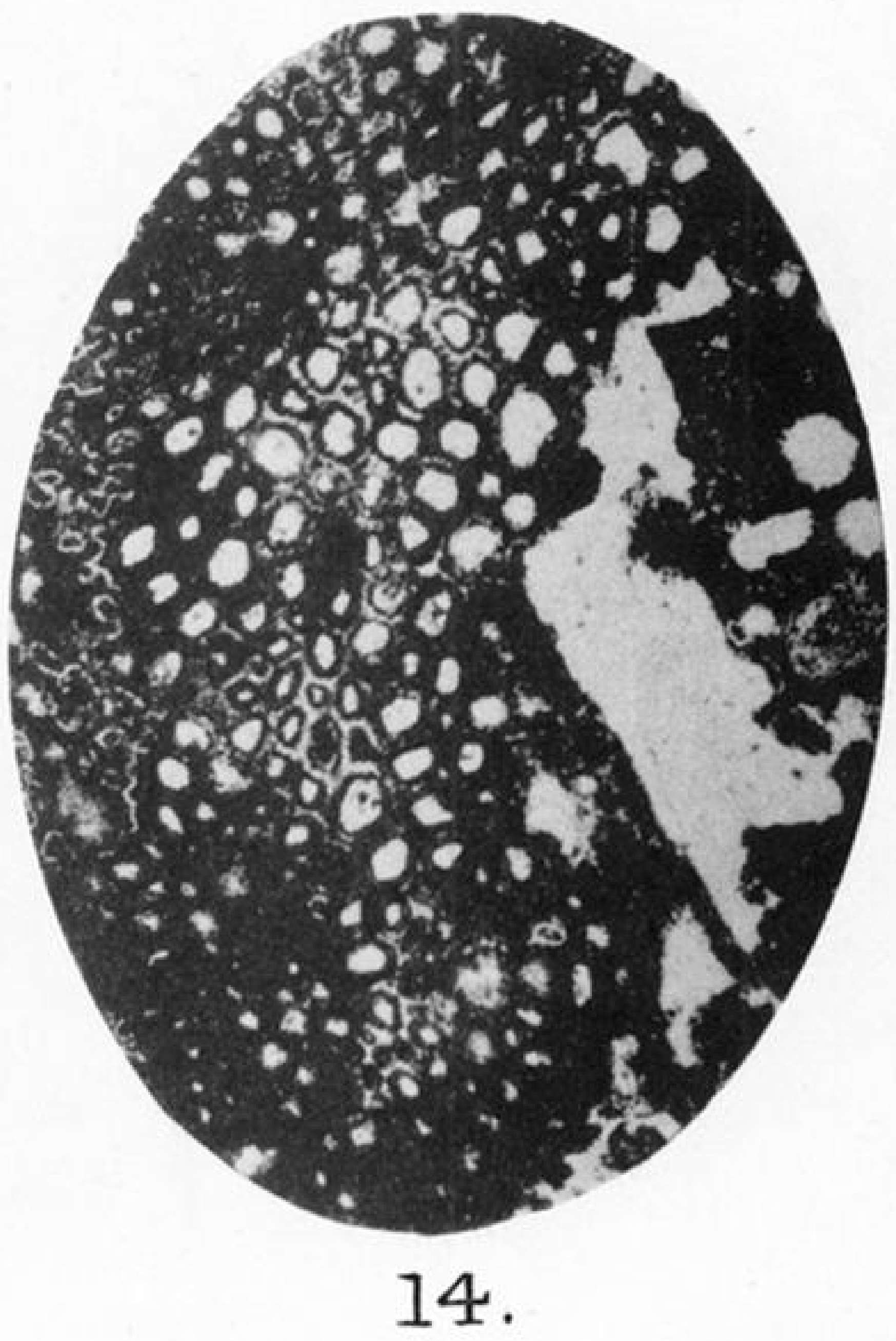


14.

PLATE 28.

Kalymma and Calamopitys.

Phot. 8.—Tangential section of the *Kalymma* in connection with *Calamopitys*, passing on the right through the Sparganum cortex. × about 5. Section K, 5.

Phot. 9.—Approximately radial section of the same specimen, showing the wood of the *Calamopitys* stem towards the right. × about 5. Section K, 4.

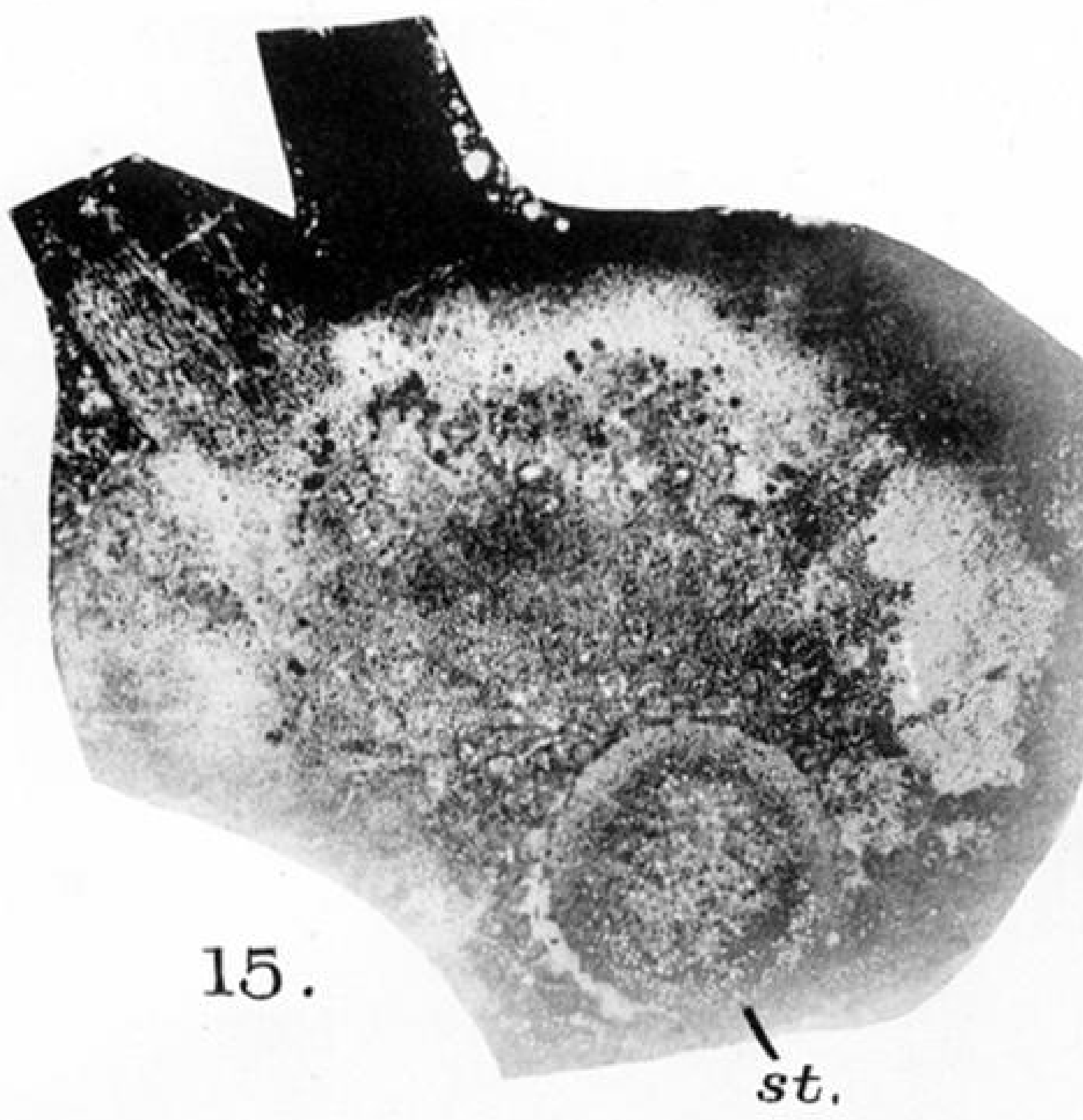
Phot. 10.—Transverse section of a small *Kalymma*, about half of which is preserved. *sp*, part of the Sparganum cortex. The left-hand bundle is shown in detail in Plate 27, Phot. 5. × about 5. Section L, 6.

Phot. 11.—Transverse section of part of a *Kalymma* from Prof. F. O. BOWER'S specimen (Genessee Shales). The left-hand bundle is shown in detail in Plate 27, Phot. 3. This section is chosen for the bundles; it does not show the Sparganum cortex which is present in other sections. × about 5.

Phot. 12.—Longitudinal section, passing through a vascular bundle, *v.b.*, of the small *Kalymma* shown in Phot. 10. × about 5. Section L, 11.

Phot. 13.—*Kalymma* in connection with *Calamopitys*. Another transverse section from the same specimen as in Plate 27, fig. 7. *st*, small portion of the stele of the stem; *Sp*, Sparganum cortex. × about 5. Section K, C.

Phot. 14.—Vascular bundle from right of Phot. 13. × about 50. Section K, C.



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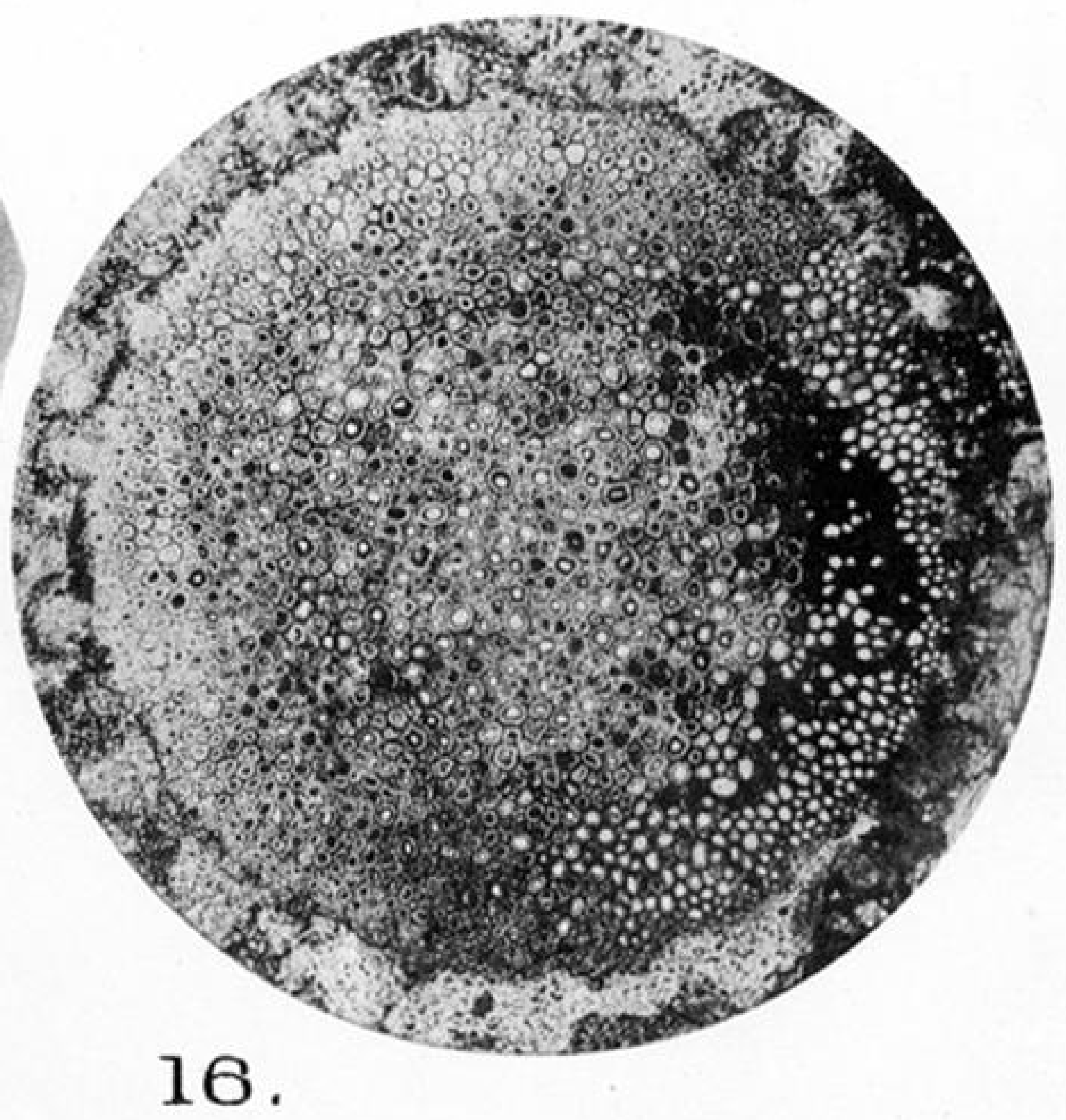

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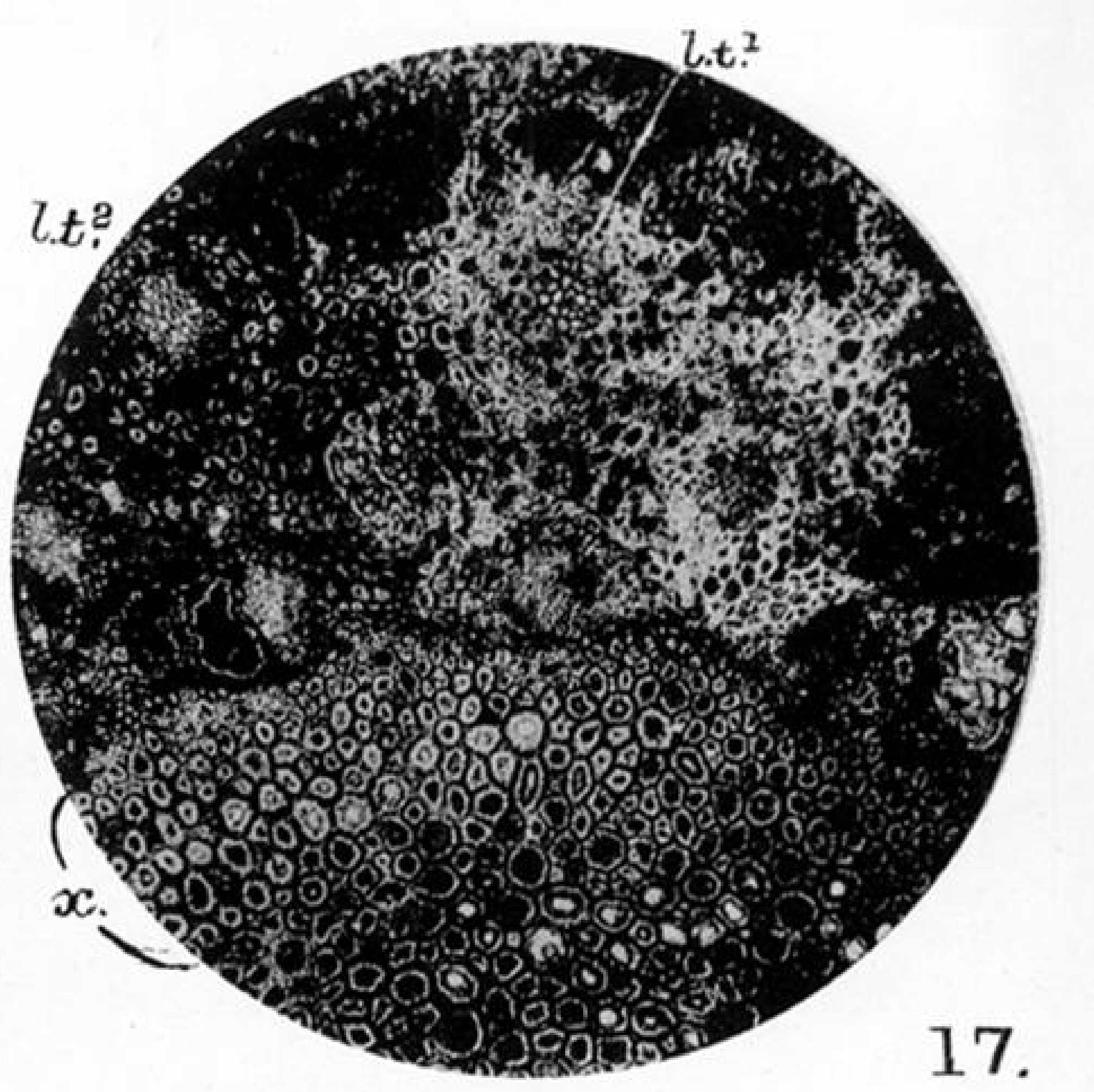

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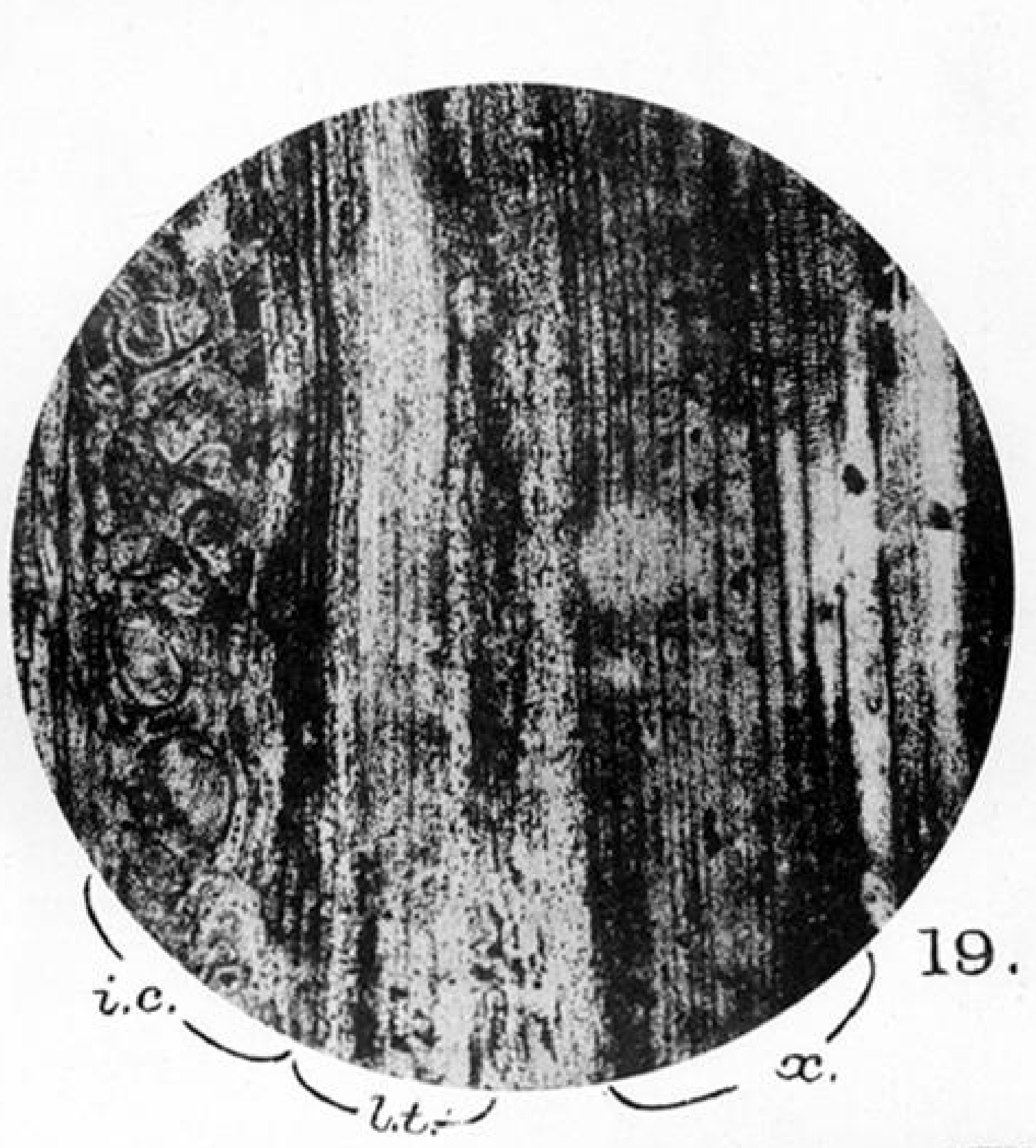

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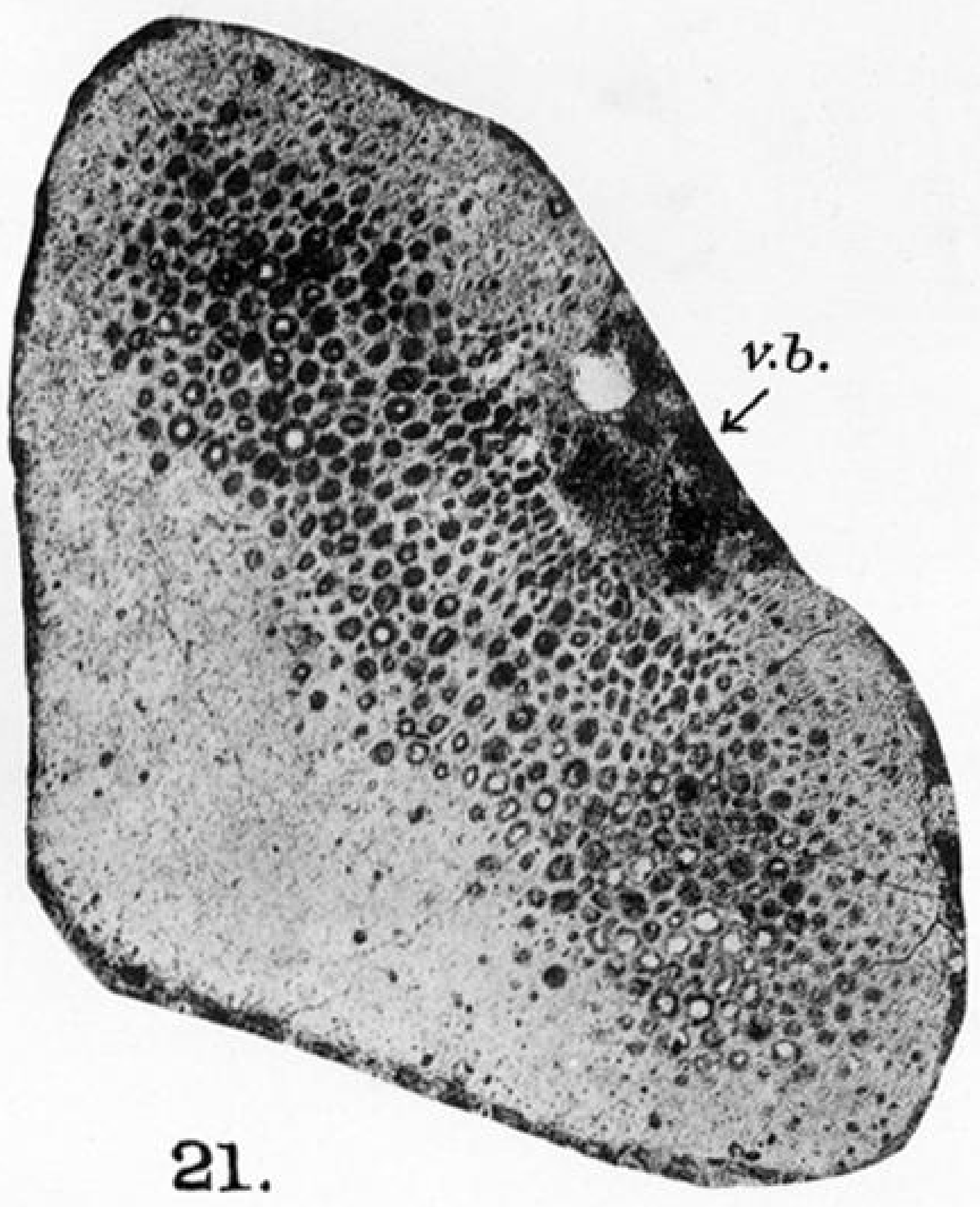

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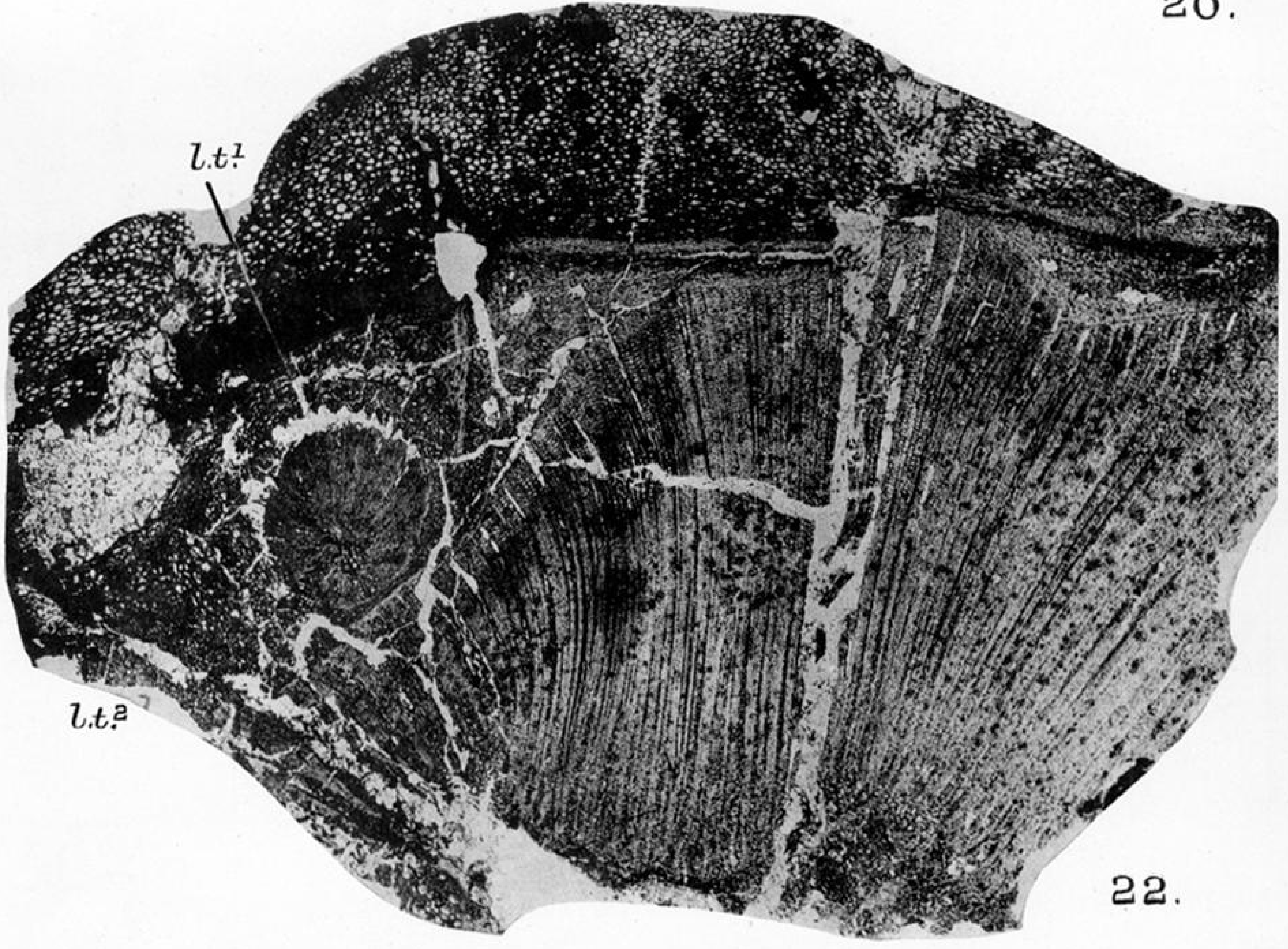


22.

15-21, LEPIDOSTROBUS FISCHERI.
22, CALAMOPITYS AMERICANA.

PLATE 29.

Phots. 15–21, *Lepidostrobus Fischeri.*

Phot. 15.—Transverse section of the axis of the cone, showing the bases of two sporophylls. *st*, stele. The continuous, non-lacunar cortex is the most striking feature. × 10. Section 4.

Phot. 16.—The stele, with leaf-traces being given off. Though so well preserved, the limit between xylem and "pith" is almost unrecognisable. On the left the somewhat lighter zone approximately corresponds to the xylem, while on the right it is indicated by the numerous clear lumina. × 30. Section 4.

Phot. 17.—Portion of stele, with leaf-traces. *x*, xylem-zone. *l.t.*^{1}, leaf-trace showing mesarch xylem clearly; *l.t.*^{2}, leaf-trace with well-preserved sheath. × 56. Section 4.

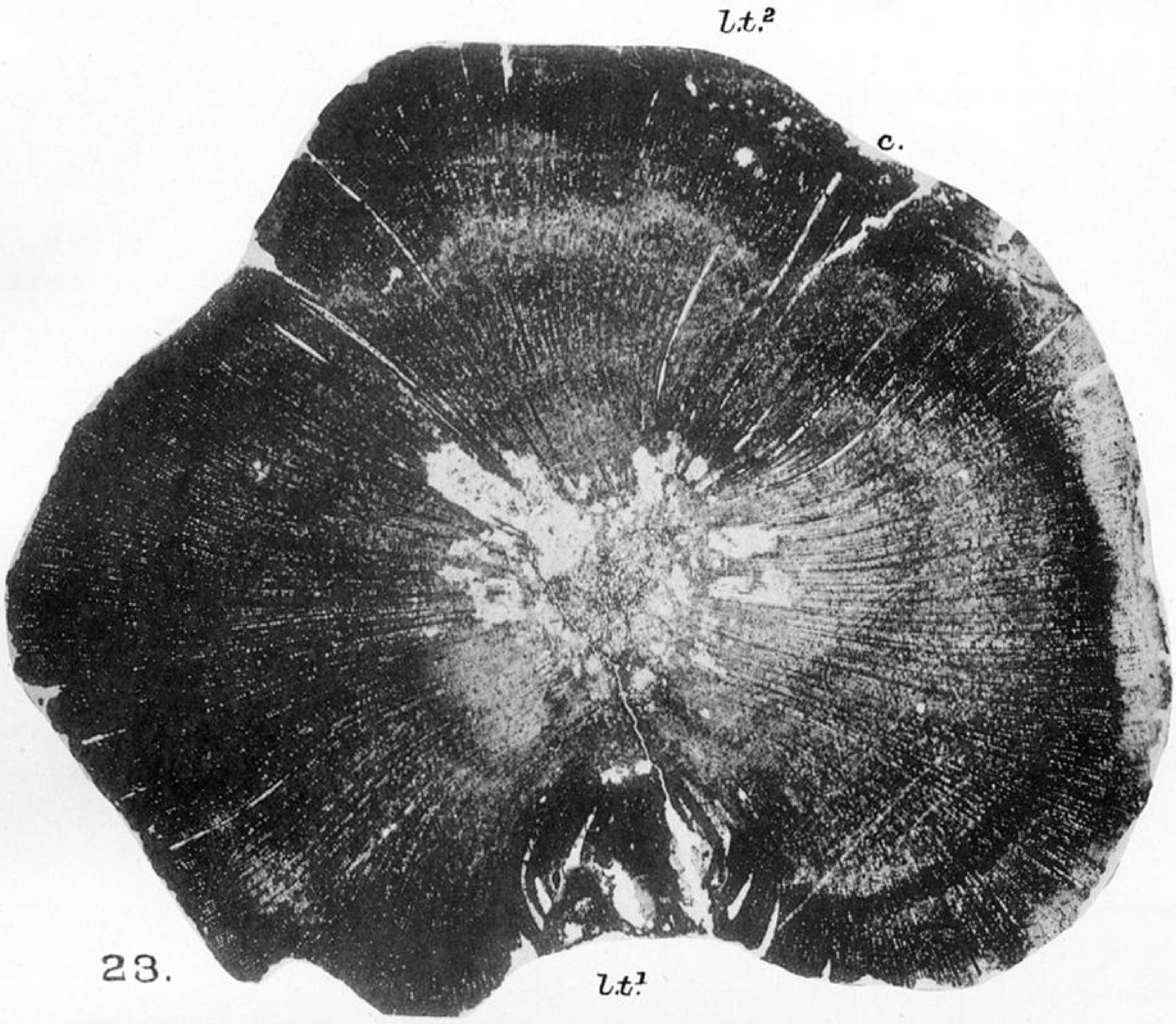
Phot. 18.—Radial section of axis, showing the bases of three sporophylls. *st*, stele; *i.c.*, narrow inner cortex; *o.c.*, wide outer cortex. × 10. Section 5.

Phot. 19.—Part of the same section (reversed) more highly magnified. *x*, xylem-zone; *l.t.*, leaf-trace with its sheath on either side; *i.c.*, inner cortex. × about 56. Section 5.

Phot. 20.—Tangential section, passing through the pedicels of several sporophylls, cut transversely. × 7. Section 6.

Phot. 21.—The right-hand bottom pedicel from the last photograph, more highly magnified. *v.b.*, position of vascular bundle (which has perished) above median ridge. × 37. Section 6.

Phot. 22.—*Calamopitys americana.* Transverse section of a large stem, showing wood and cortex. *l.t.*^{1}, large leaf-trace bundle with secondary wood; *l.t.*^{2}, fragment of the wood of a second bundle. × about 5. Section F, 28.



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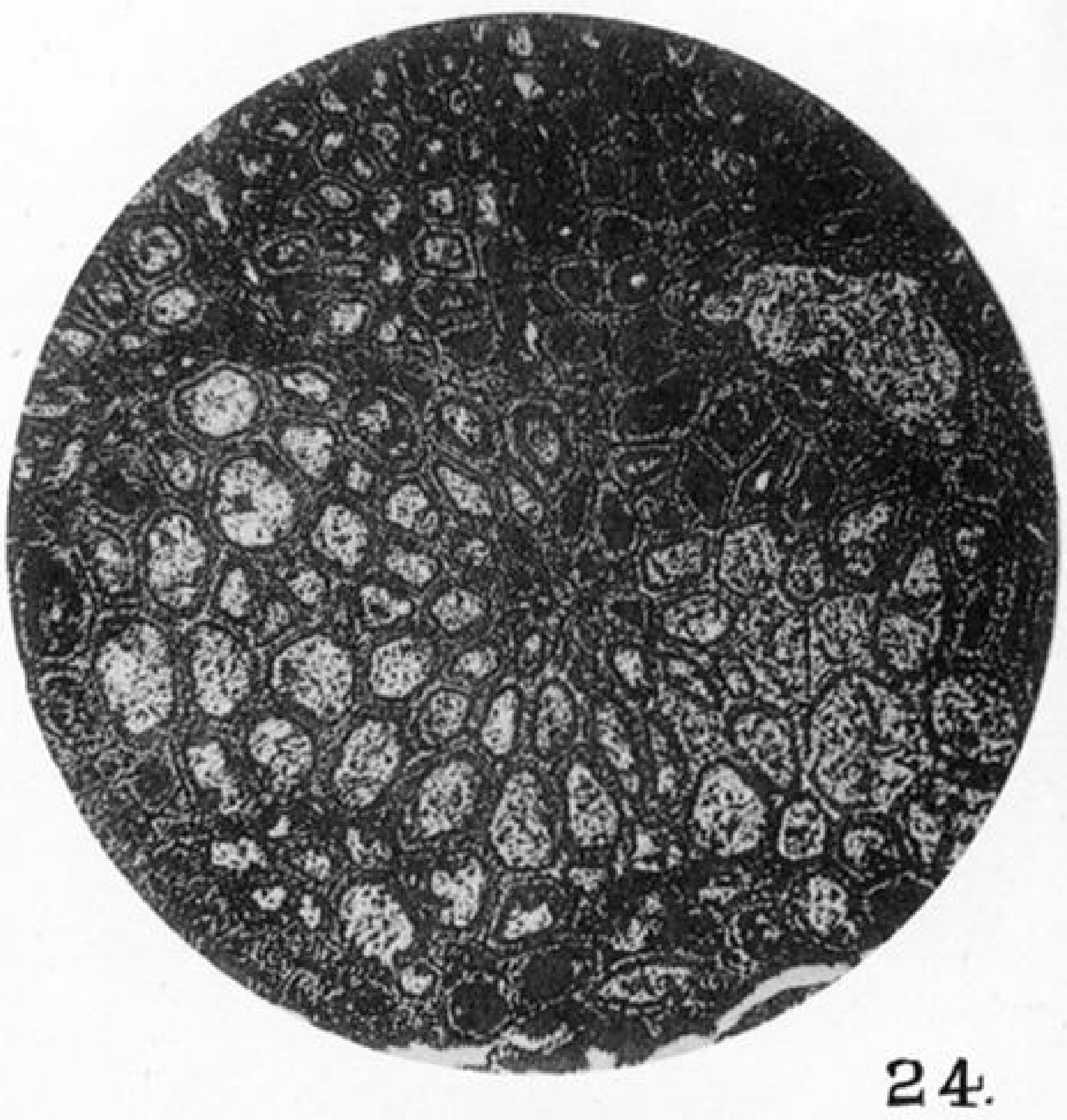

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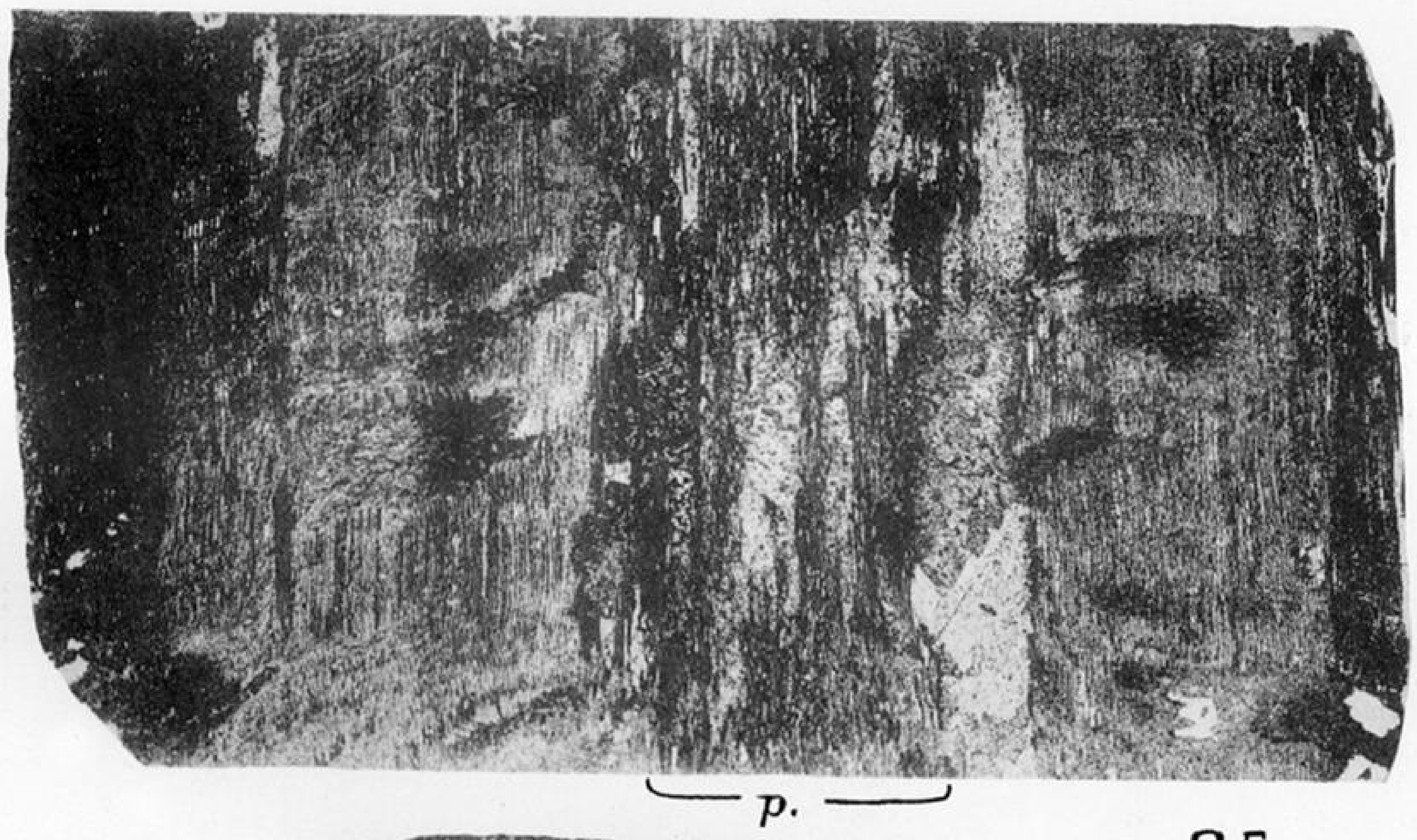

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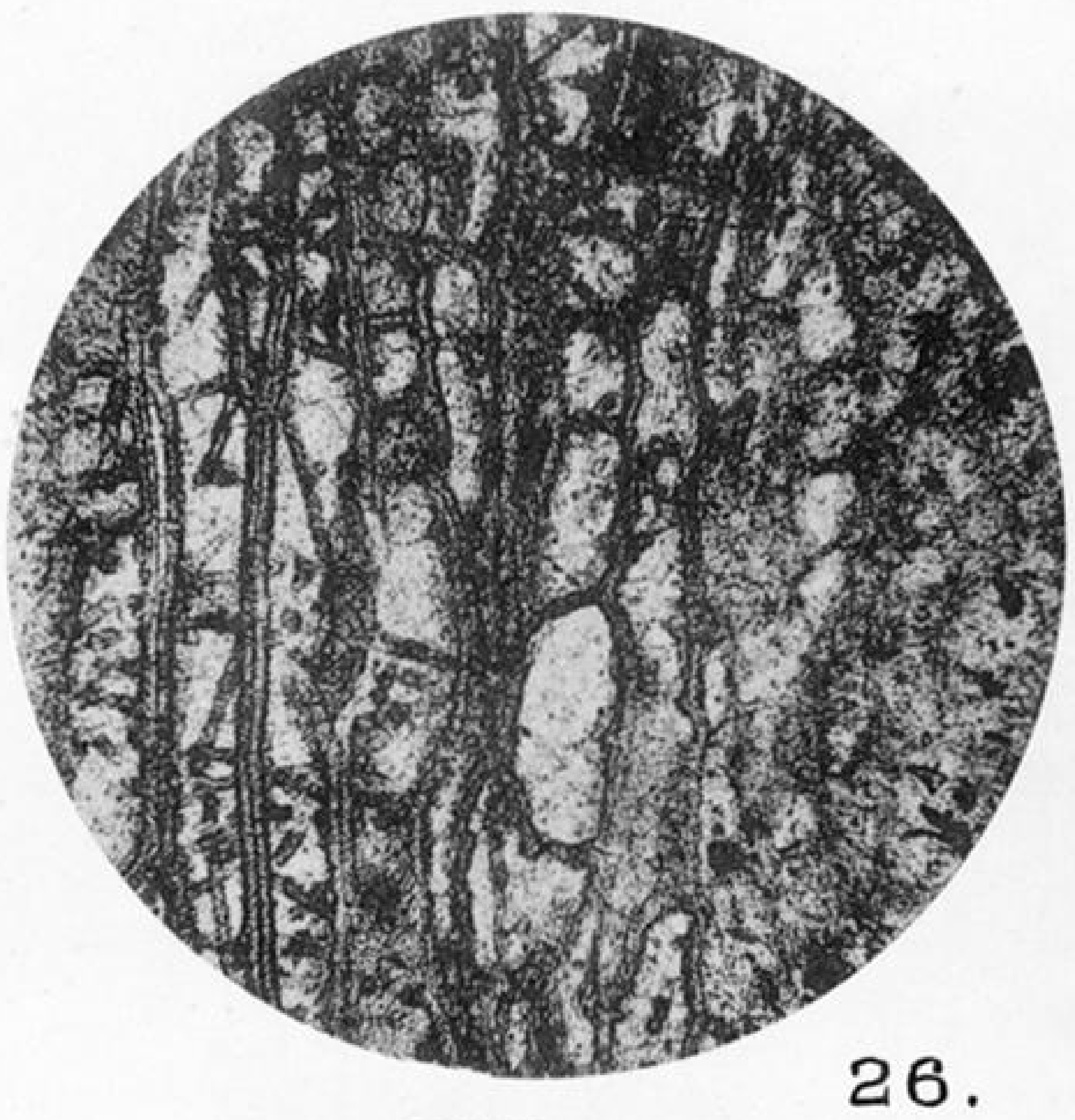

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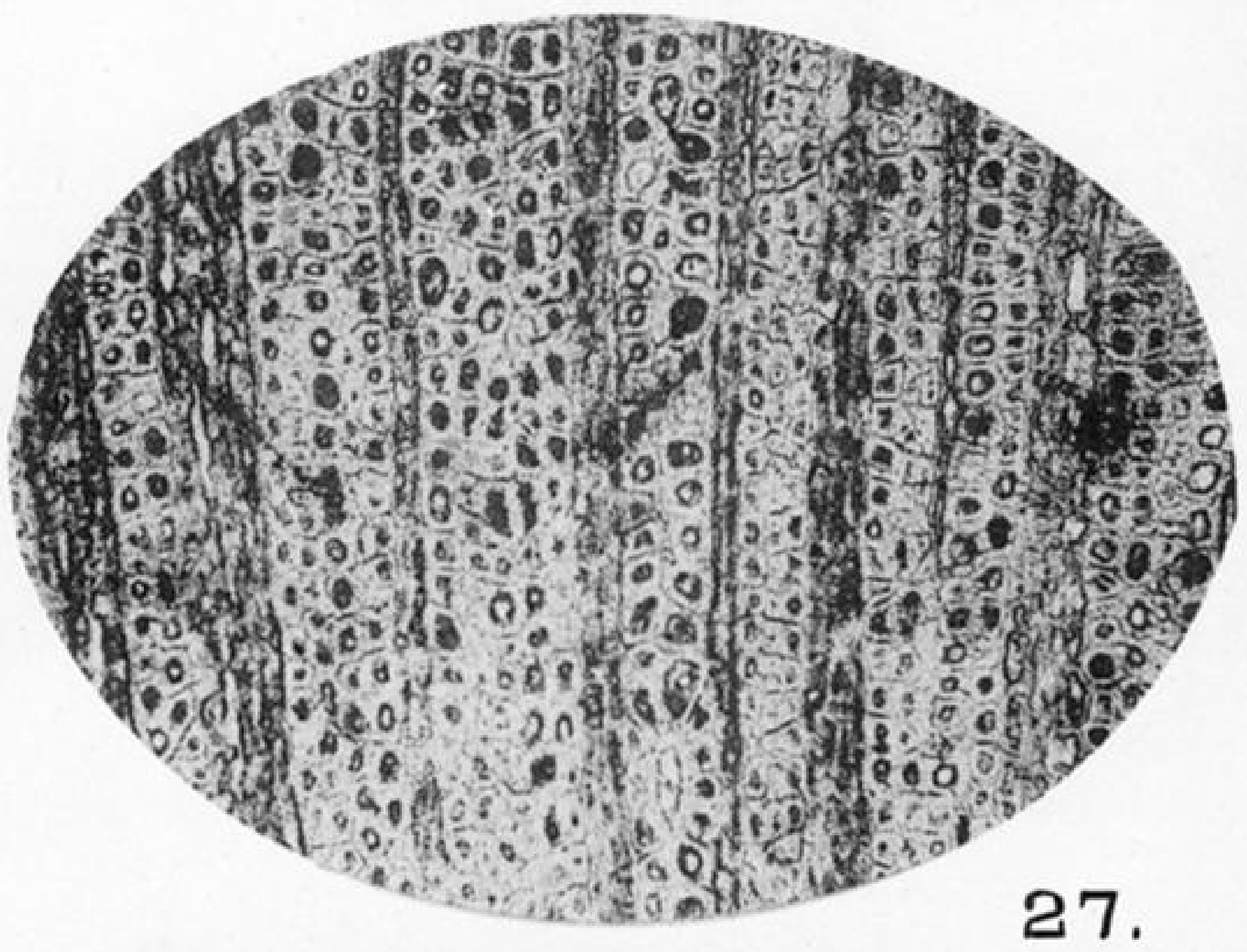

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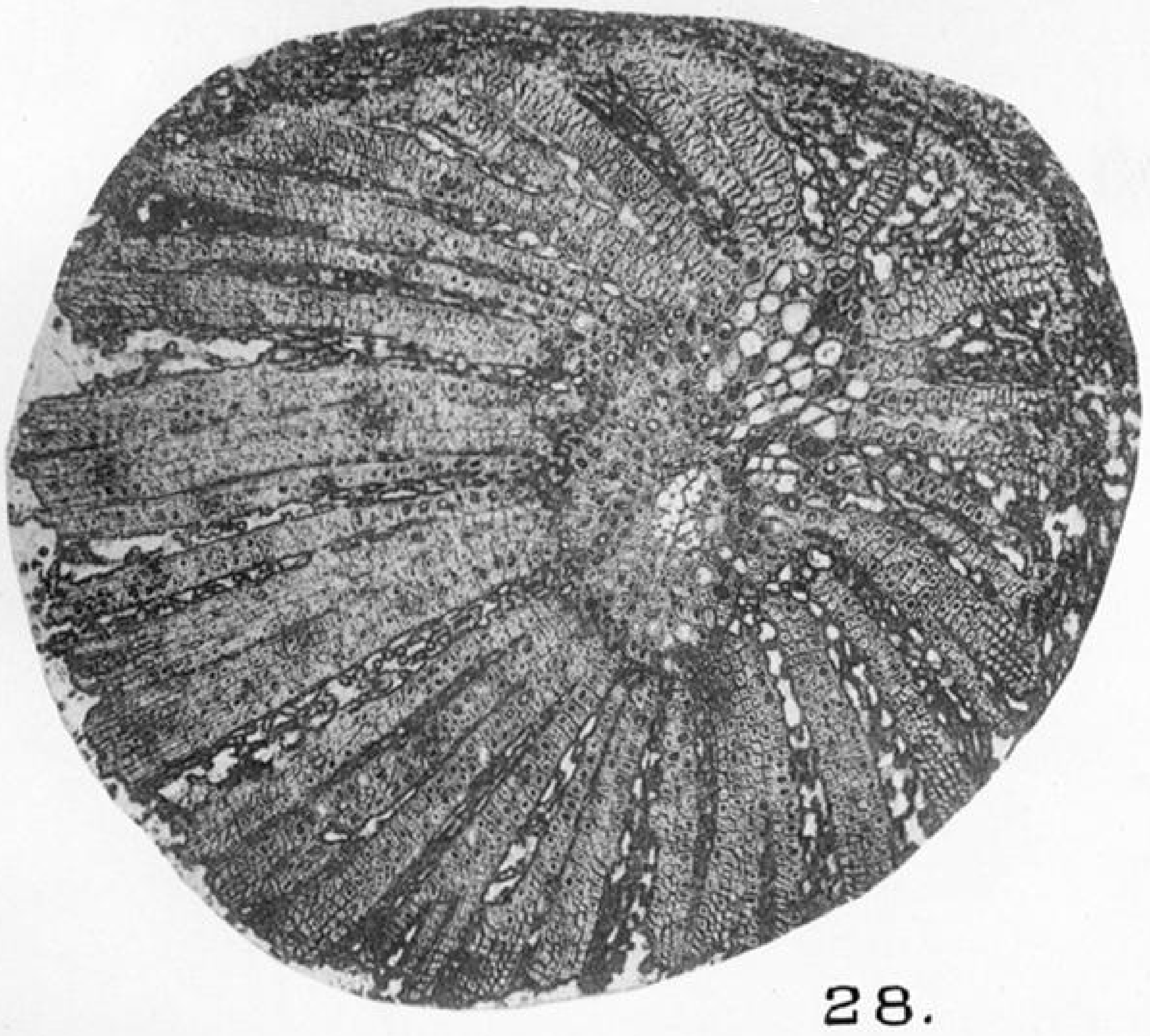

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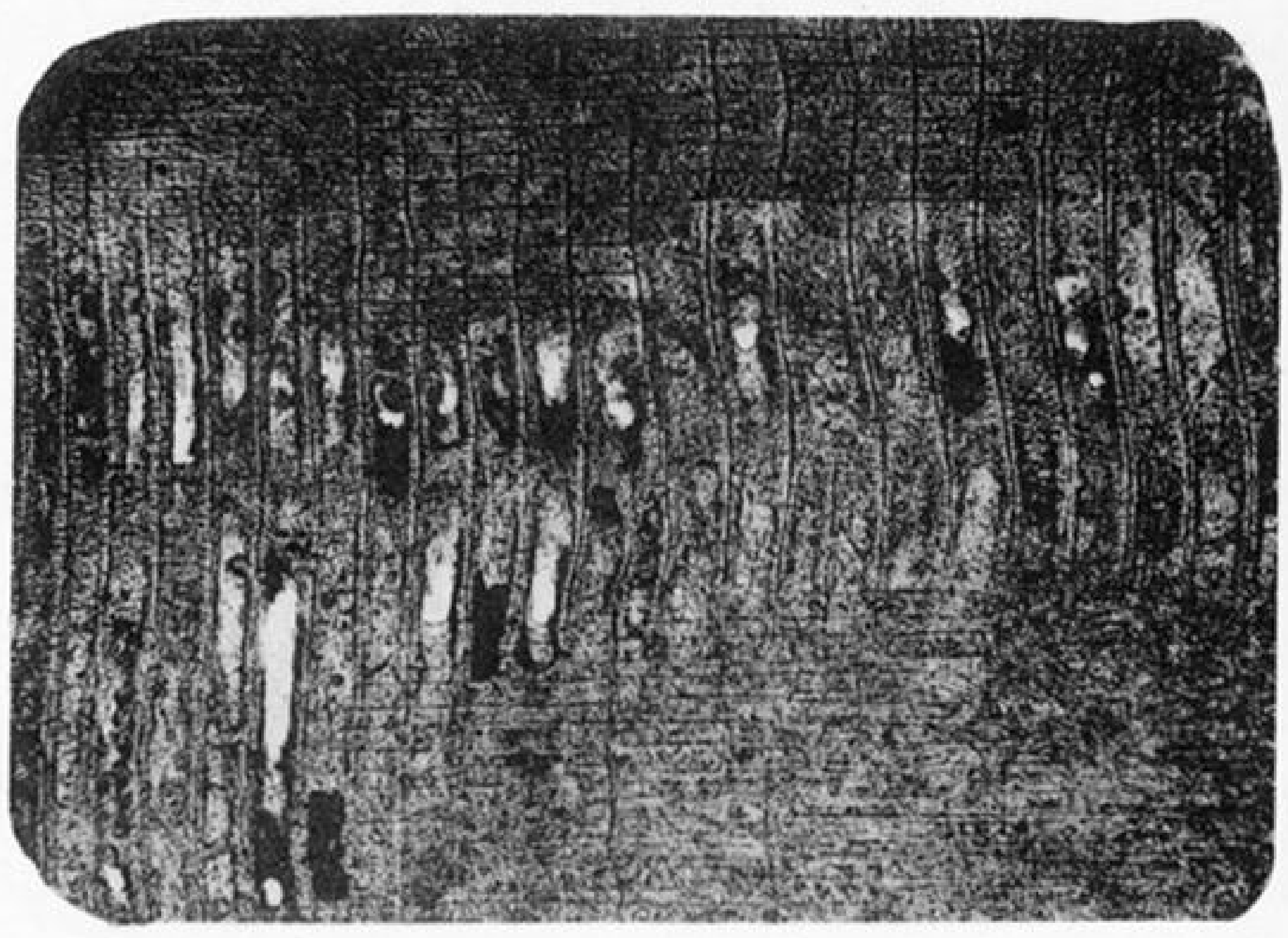

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PLATE 30.

Calamopitys americana.

Phot. 23.—Transverse section of a small stem, showing mixed pith, wood, and some slight remains of cortex, *c.* *l.t.*^{1}, leaf-trace passing through wood. *l.t.*^{2}, leaf-trace bundle outside wood. × about 5. Section C, 13.

Phot. 24.—Mesarch xylem-strand at the edge of the pith in the same section. The secondary wood is above, the pith below. *Cf.* Plate 35, fig. 1. × 56. Section C, 13.

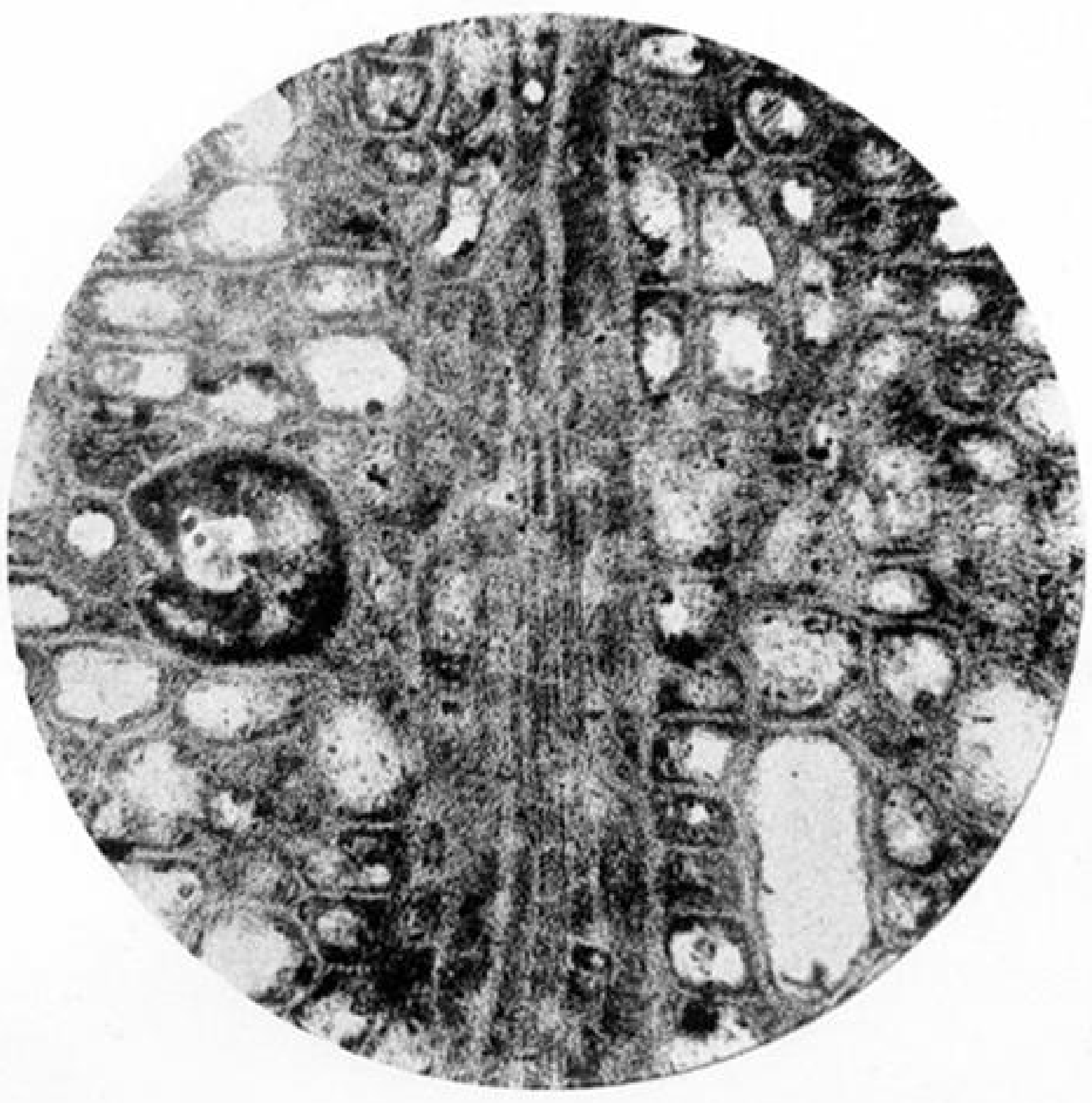
Phot. 25.—General radial section of the same stem, showing mixed pith (*p*) and wood with medullary rays. × about 5. Section C, 16.

Phot. 26.—Part of the pith in longitudinal section, showing trabeculæ in the tracheides and cells. × 56. Section C, 16.

Phot. 27.—Transverse section of part of the secondary wood of the stem shown in Plate 29, Phot. 22. × 37. Section F, 28.

Phot. 28.—Leaf-trace bundle (*l.t.*^{1}) from the same section, showing primary and secondary wood. × about 20. Section F, 28.

Phot. 29.—Part of secondary wood in radial section (same stem as Phot. 25) showing medullary rays. × 37. Section C, 16.



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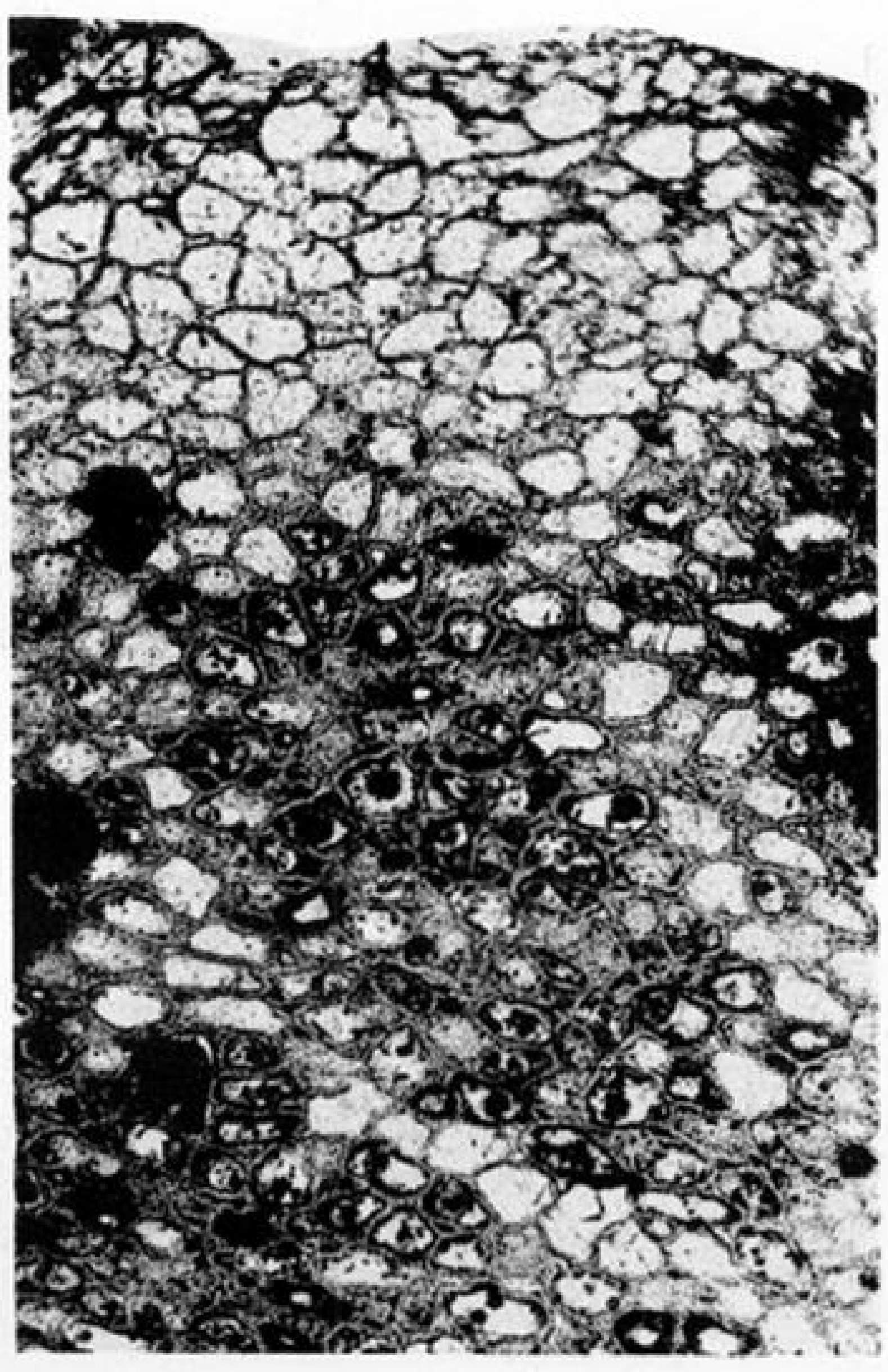

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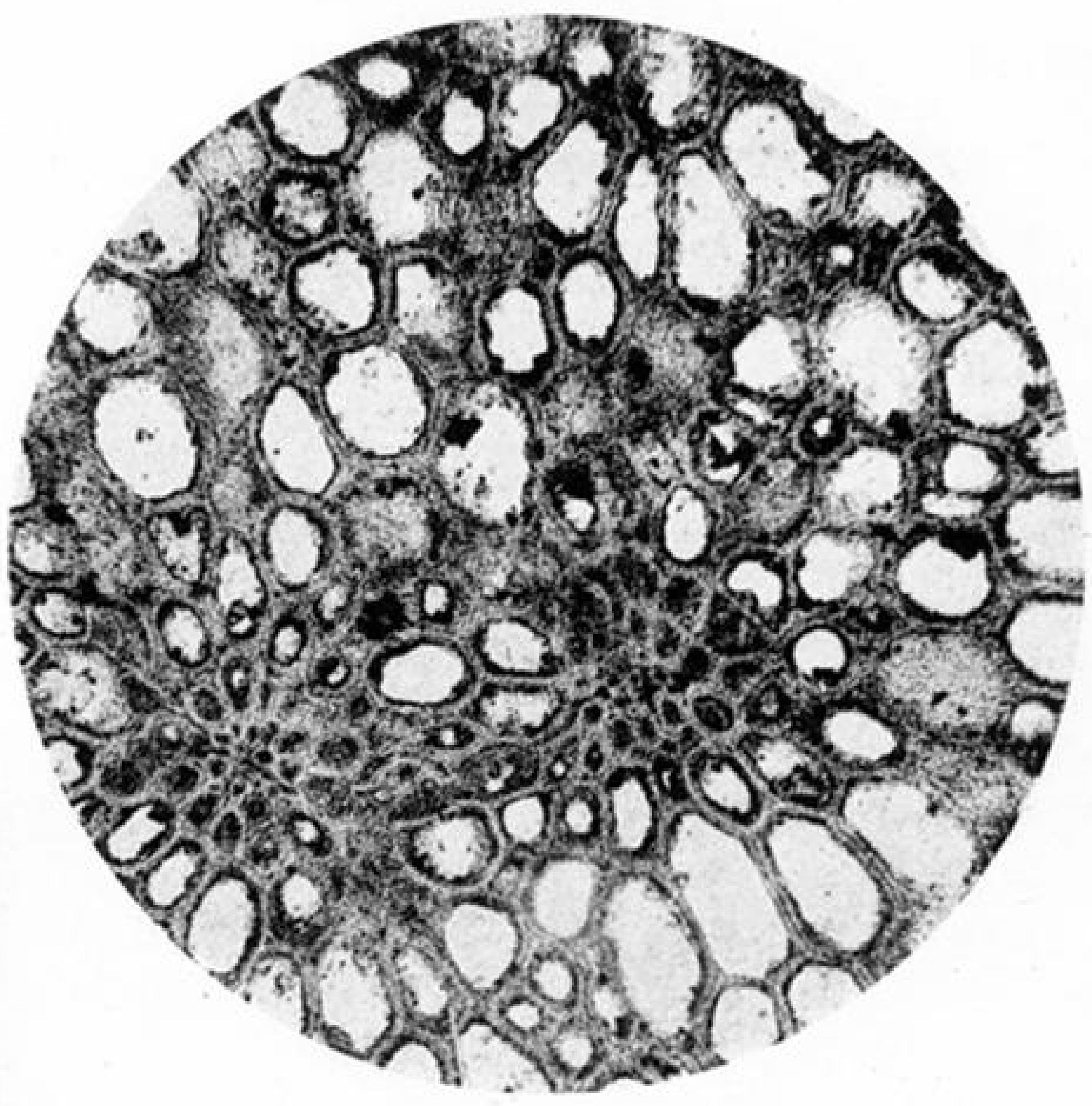

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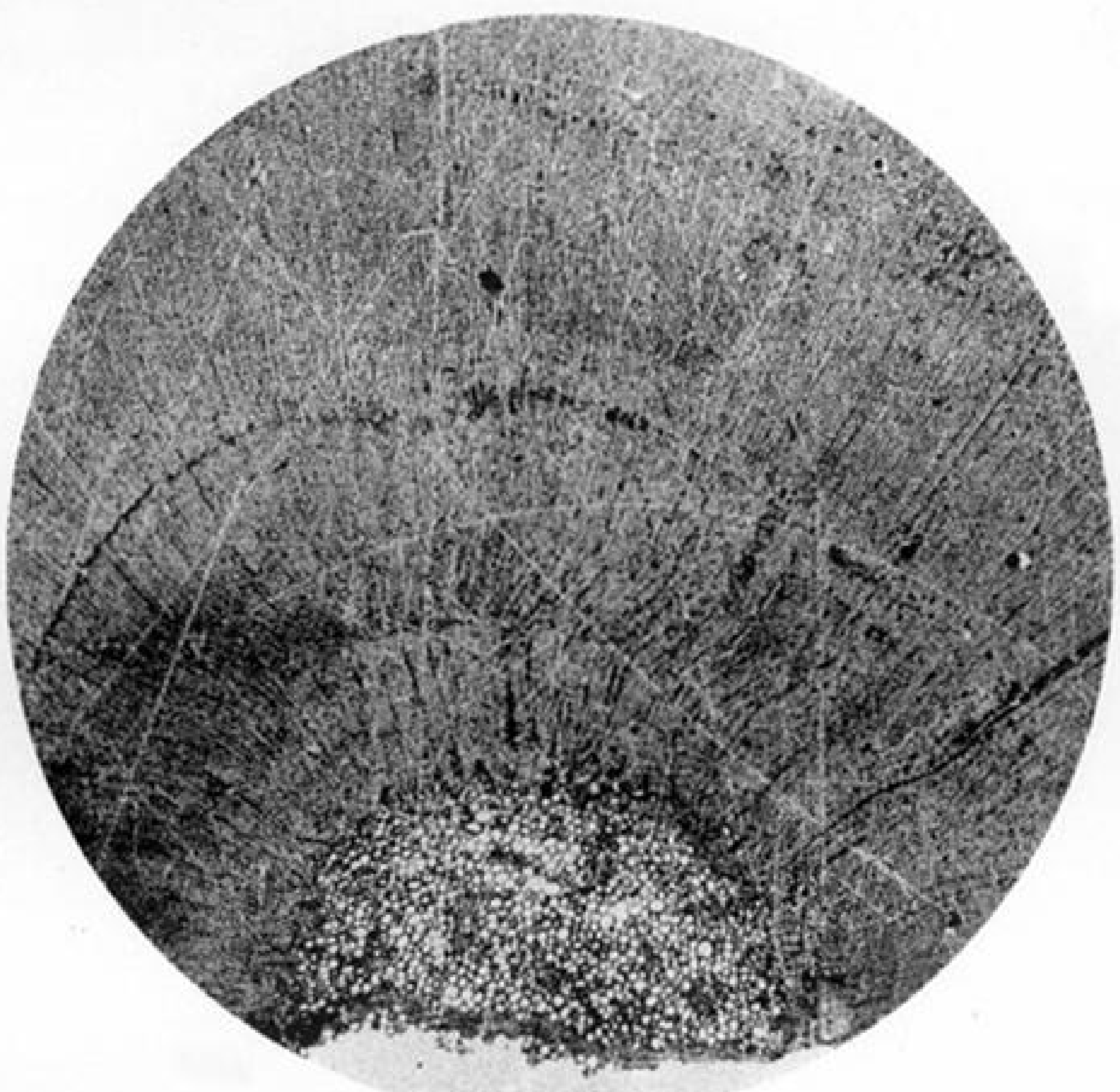

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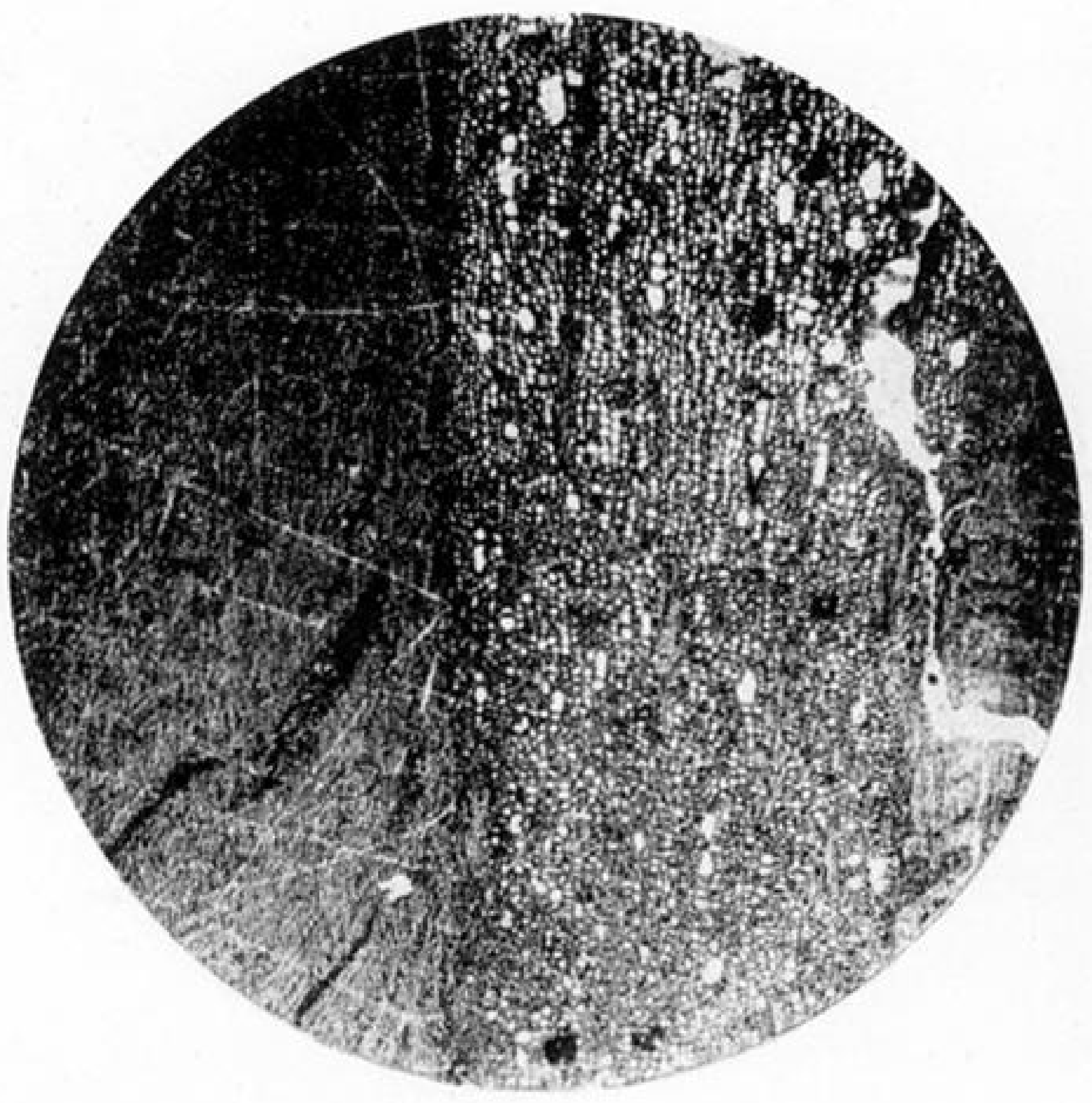

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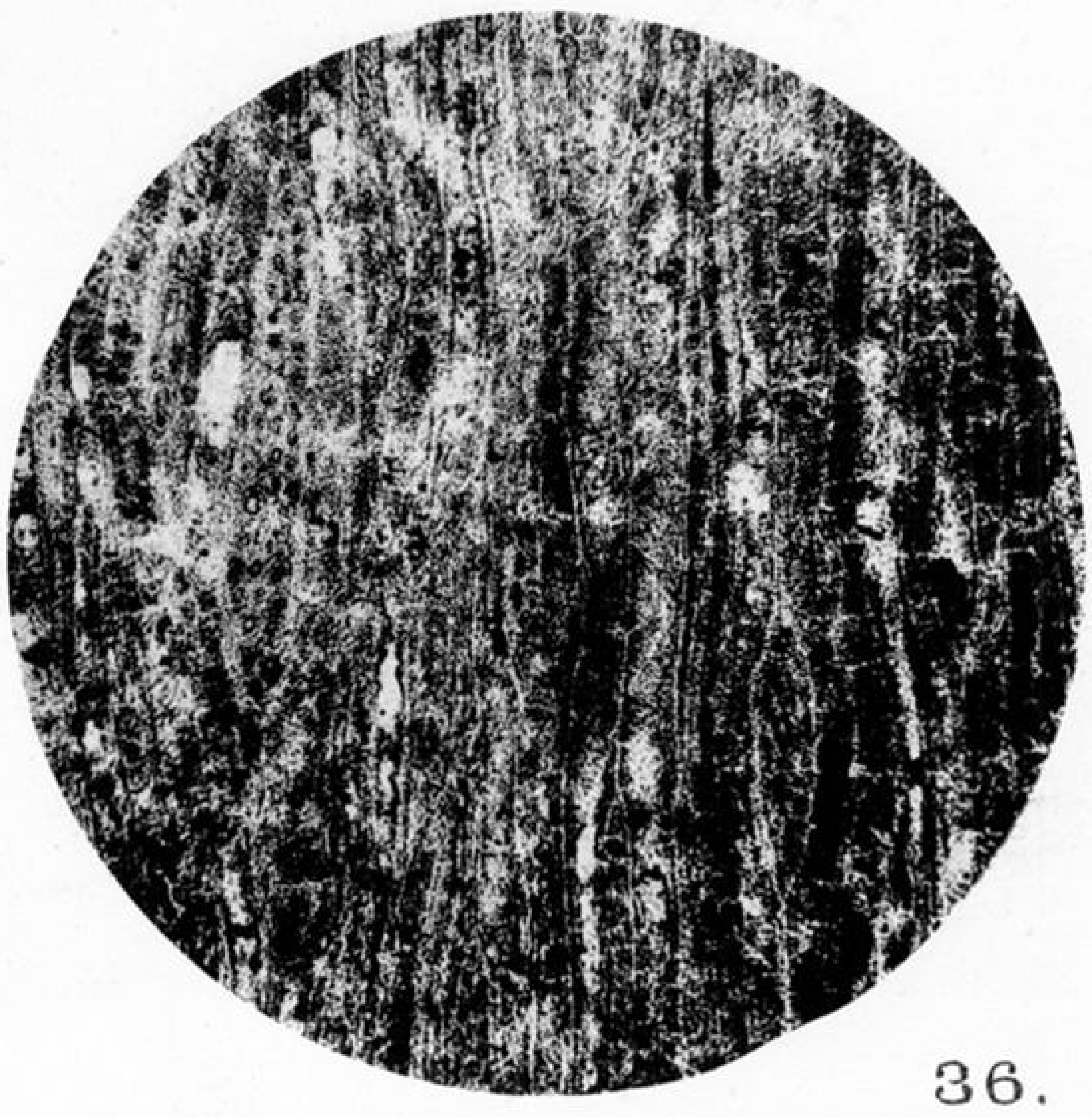


36.

30, CALAMOPITYS AMERICANA.
31–36, ARCHAEOPITYS EASTMANII.

PLATE 31.

Phot. 30.—*Calamopitys americana.* Part of cortex, transverse, from the stem shown in Plate 29, Phot. 22. × 20. Section F, 28.

Phots. 31–36, *Archæopitys Eastmanii.*

Phot. 31.—Longitudinal section of part of pith, passing through a primary xylem-strand, *x*. A large sac or cavity is seen on the left. × 56. Section 9·3, 2. Radial.

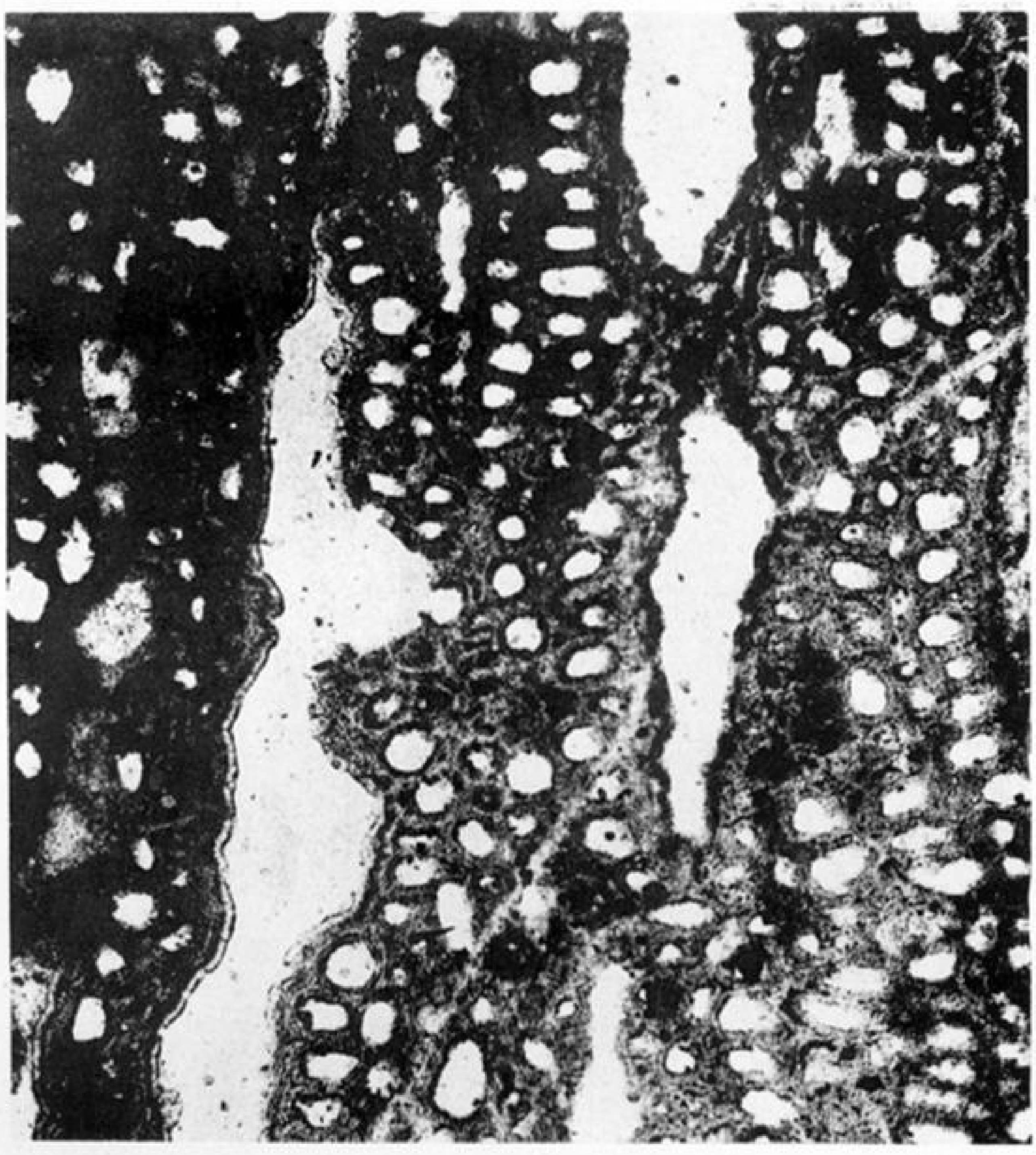
Phot. 32.—Transverse section of part of pith, showing two medullary mesarch xylem-strands, which fuse in the succeeding sections. × 56. Section 9·3, 1. Lomax.

Phot. 33.—General transverse section showing the pith with the primary xylem-strands, and part of the secondary wood. × about 5. Section 9·3, 1. Lomax.

Phot. 34.—General radial section, showing the pith with some primary xylem-strands, and part of the secondary wood. × about 5. Section 9·3, 2. Radial.

Phot. 35.—Tangential section of part of the secondary wood, showing "knots," possibly connected with the neighbourhood of an appendage. × 22. Section 9·3, 3. Tangential.

Phot. 36.—Tangential section of the normal secondary wood, showing some medullary rays. × 66. Section 9·3, 3. Tangential.



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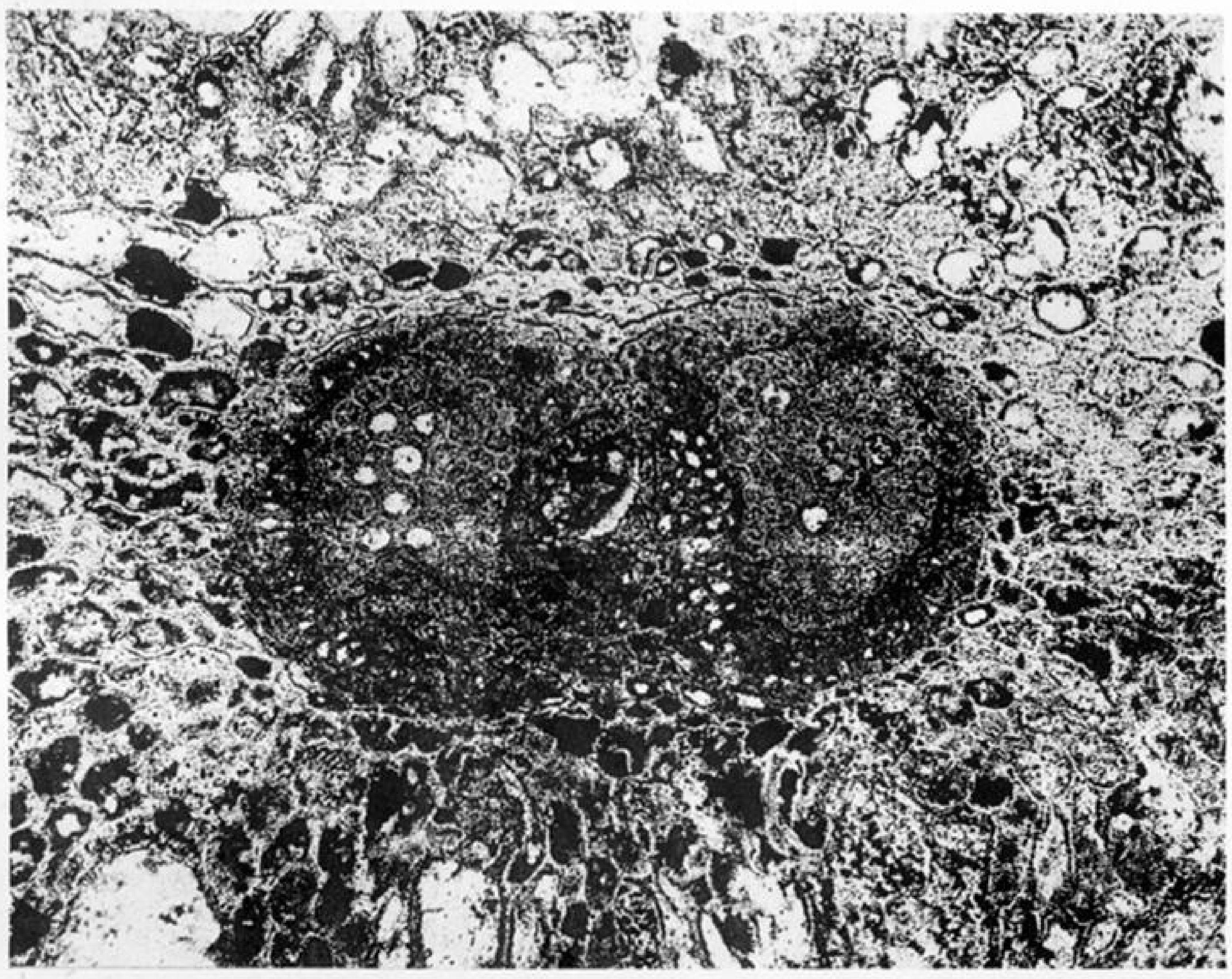

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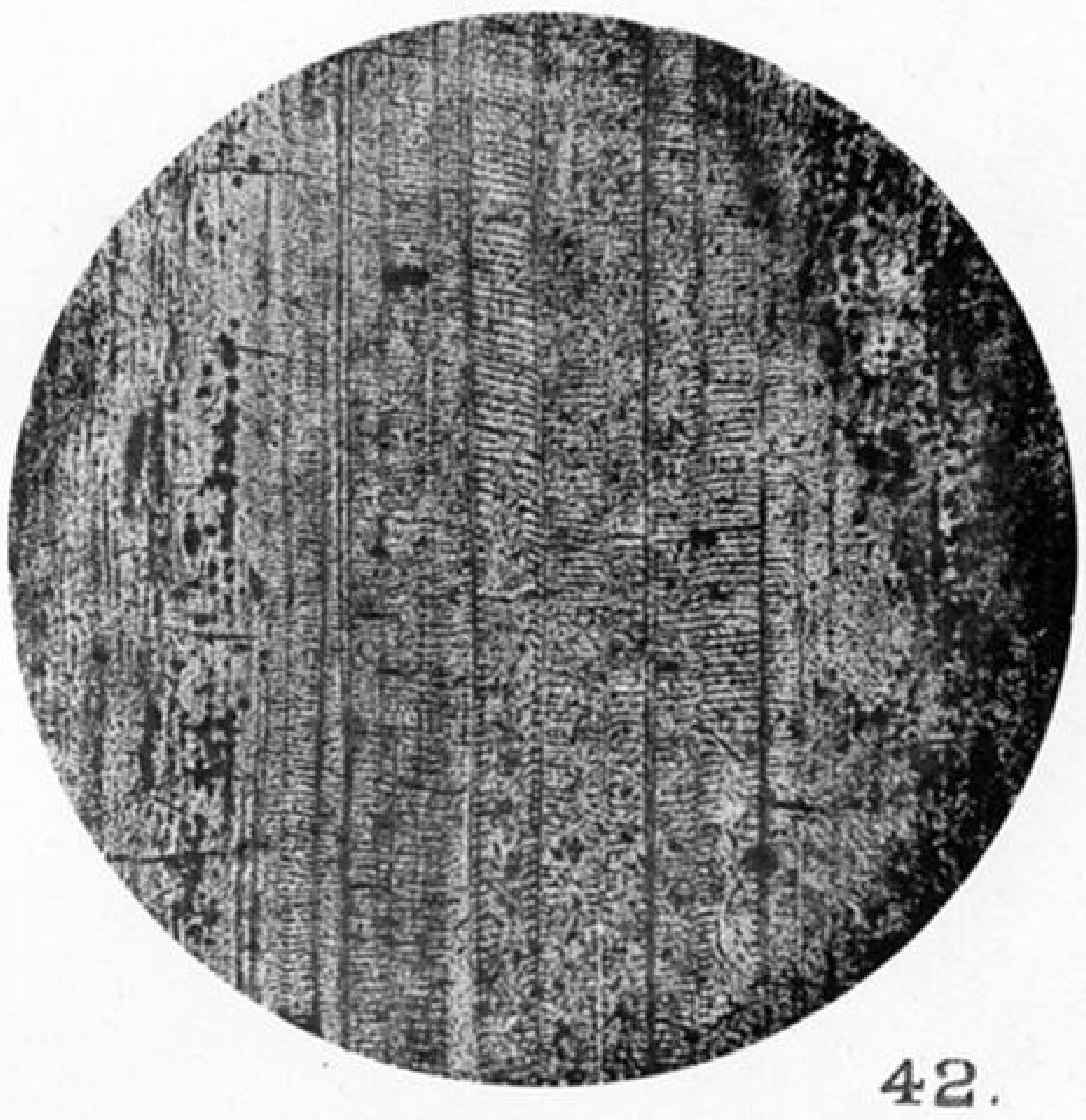

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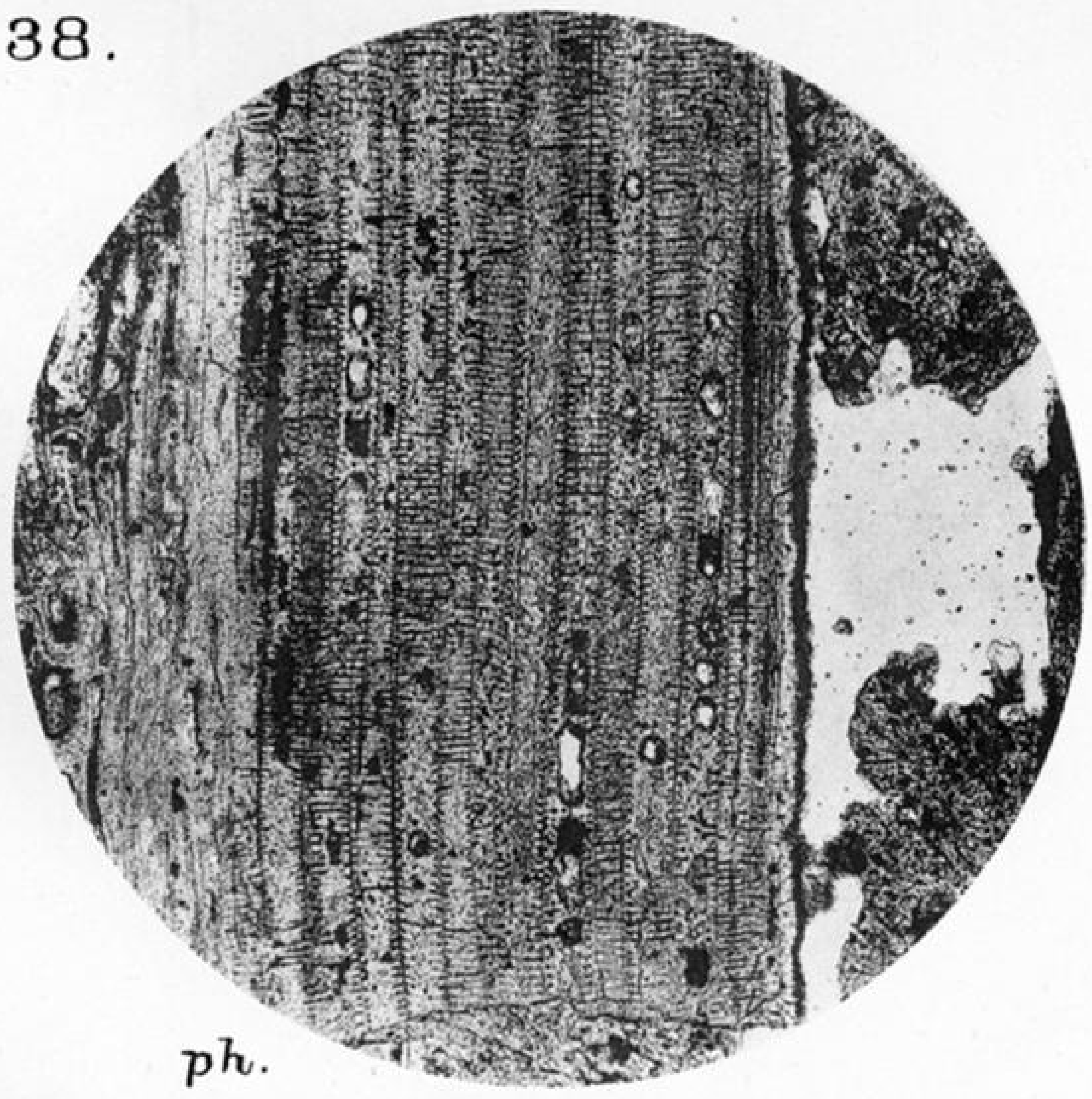

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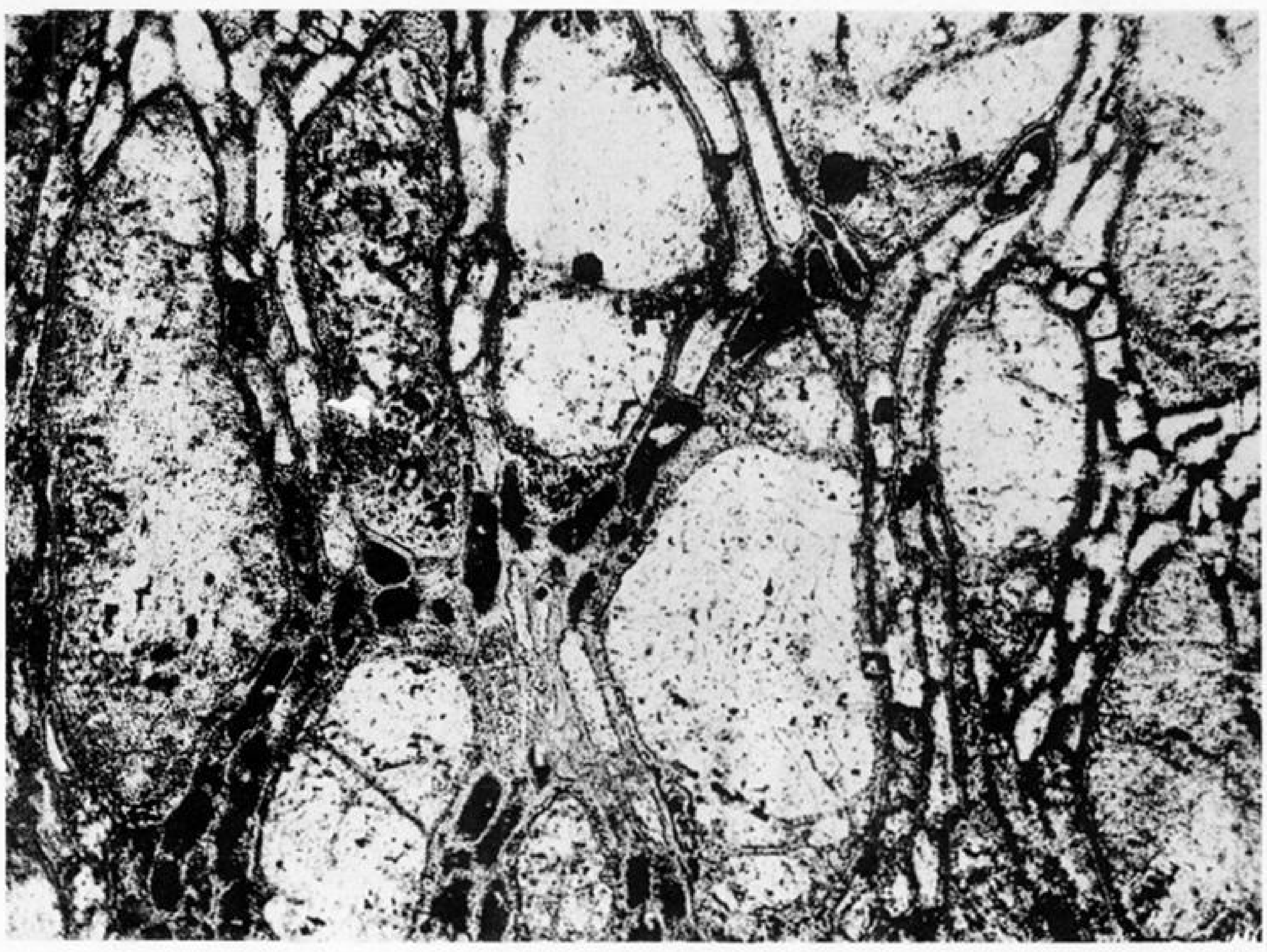


39.

37–41, PERIASTRON PERFORATUM.
42, STEREOPTERIS ANNULARIS.

Plate 32.

Phots. 37–41, *Periastron perforatum.*

Phot. 37.—General transverse section of petiole; *v.b.*, the median row of bundles; the two middle pairs and three bundles to the right are clearly shown; also one to the left, damaged. On either side is the wide lacunar zone, and at the top the outer cortex. × $7\frac{1}{2}$. Section E, 23.

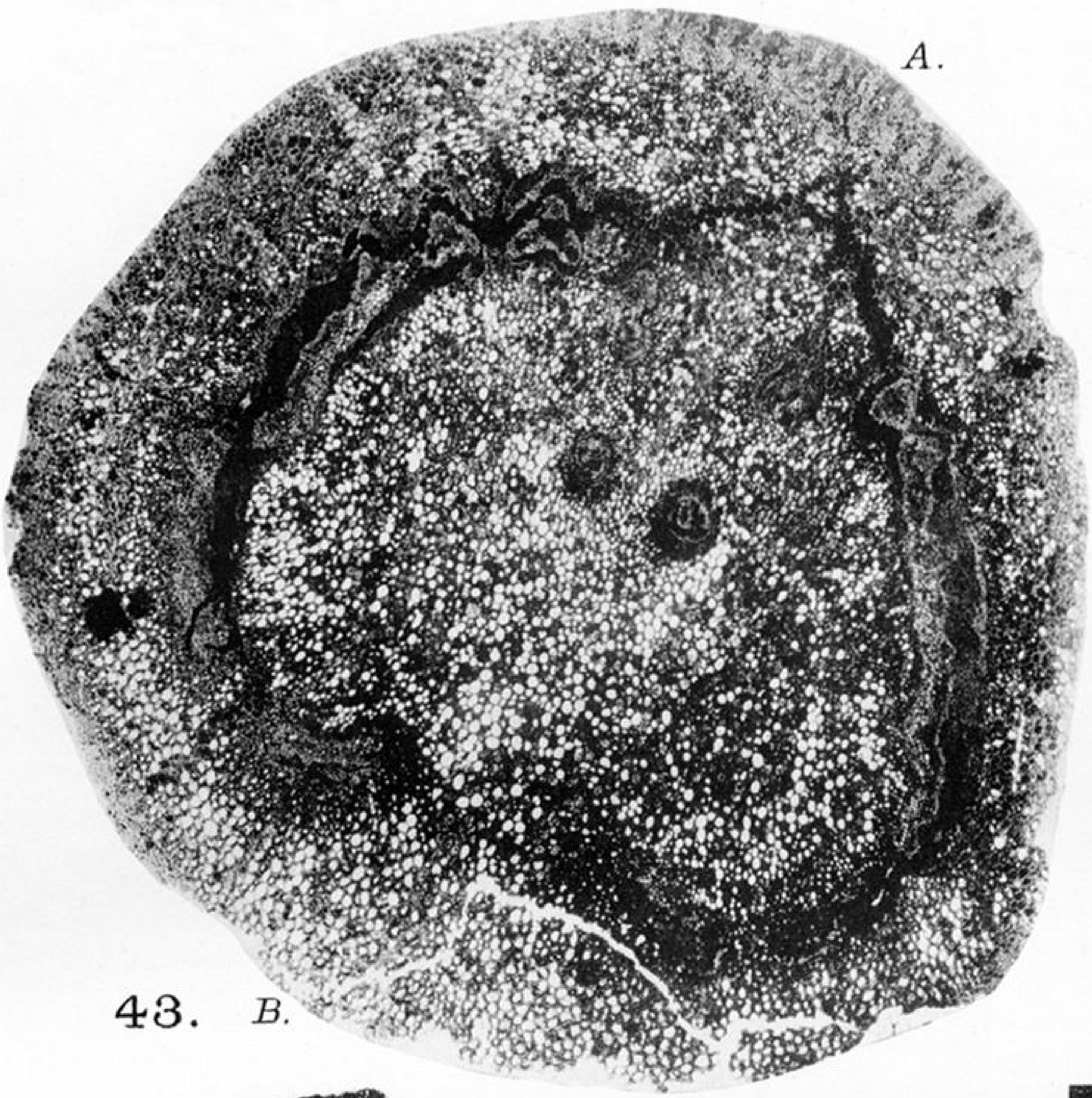
Phot. 38.—Transverse section of one of the middle pairs of bundles with the surrounding tissue. *Cf.* Plate 37, fig. 12. × 37. Section E, 23.

Phot. 39.—Transverse section of part of the lacunar zone. × 37. Section E, 23.

Phot. 40.—Vascular bundle in longitudinal section, showing the scalariform tracheides, with phloem (*ph*) on the left. × 37. Section P, 14.

Phot. 41.—Tangential section through the outer part of the lacunar zone. × 37. Section P, 13.

Phot. 42.—*Stereopteris annularis.* Radial section through the xylem, showing scalariform tracheides. × about 56. Section B, 10.



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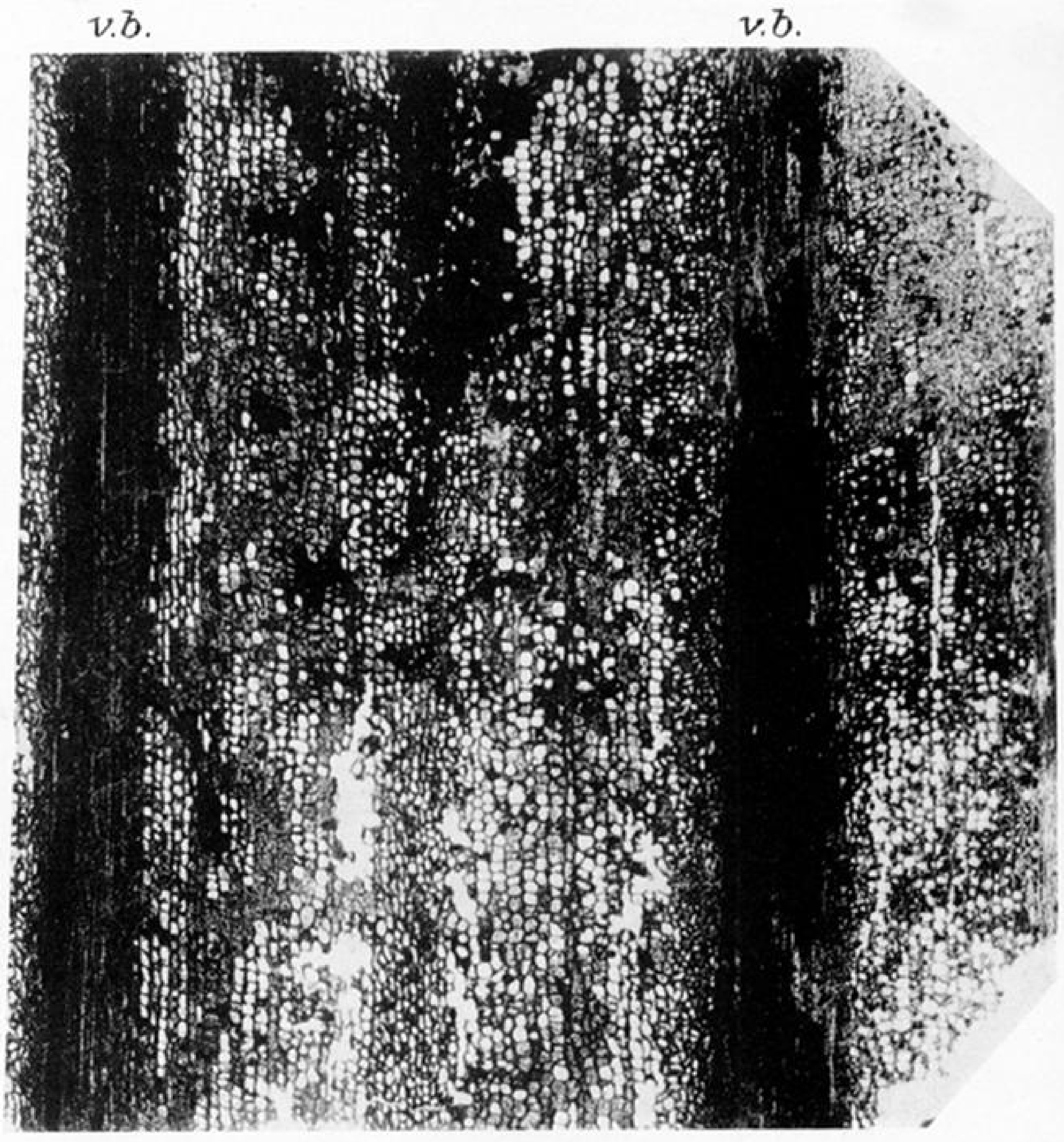

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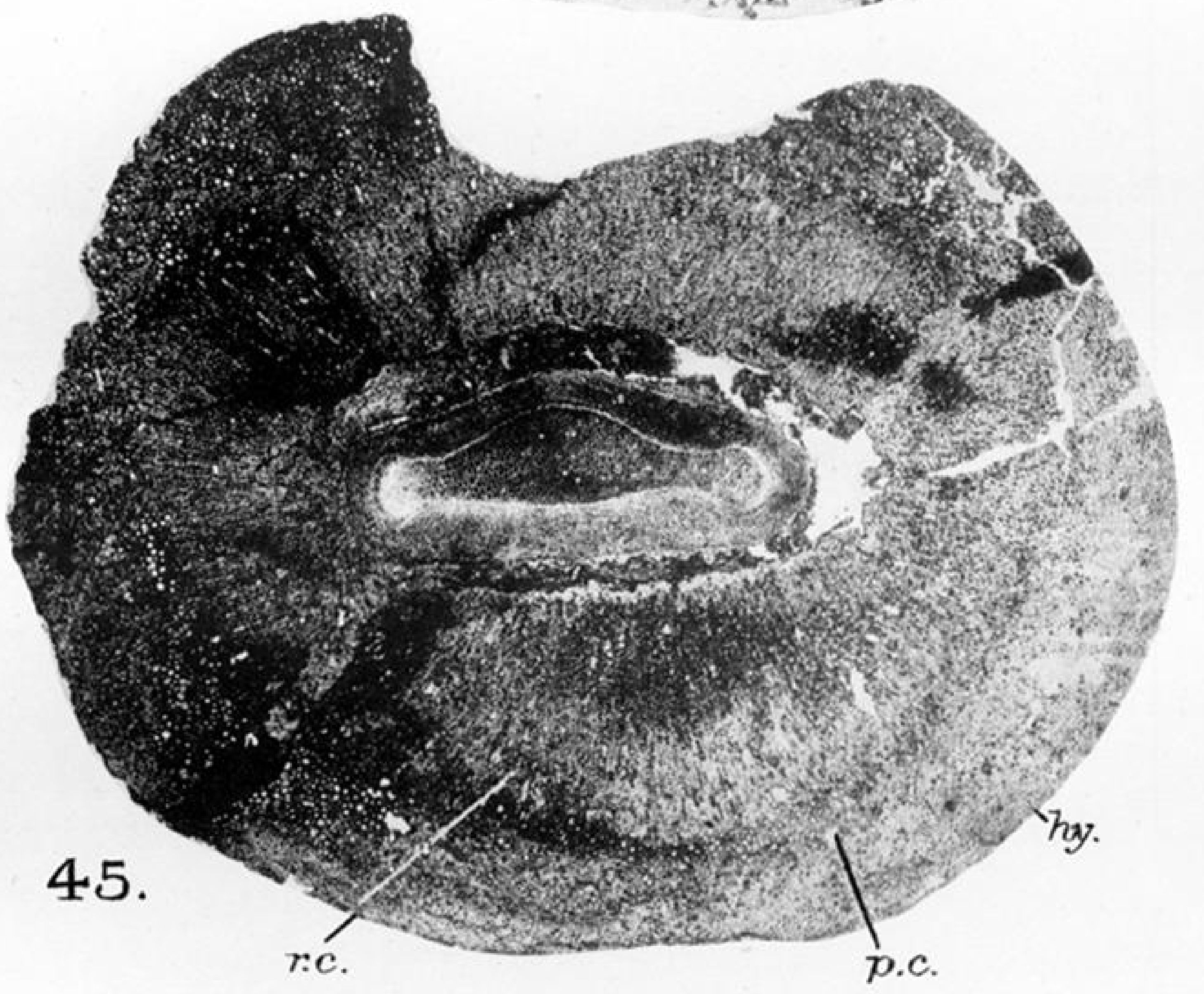

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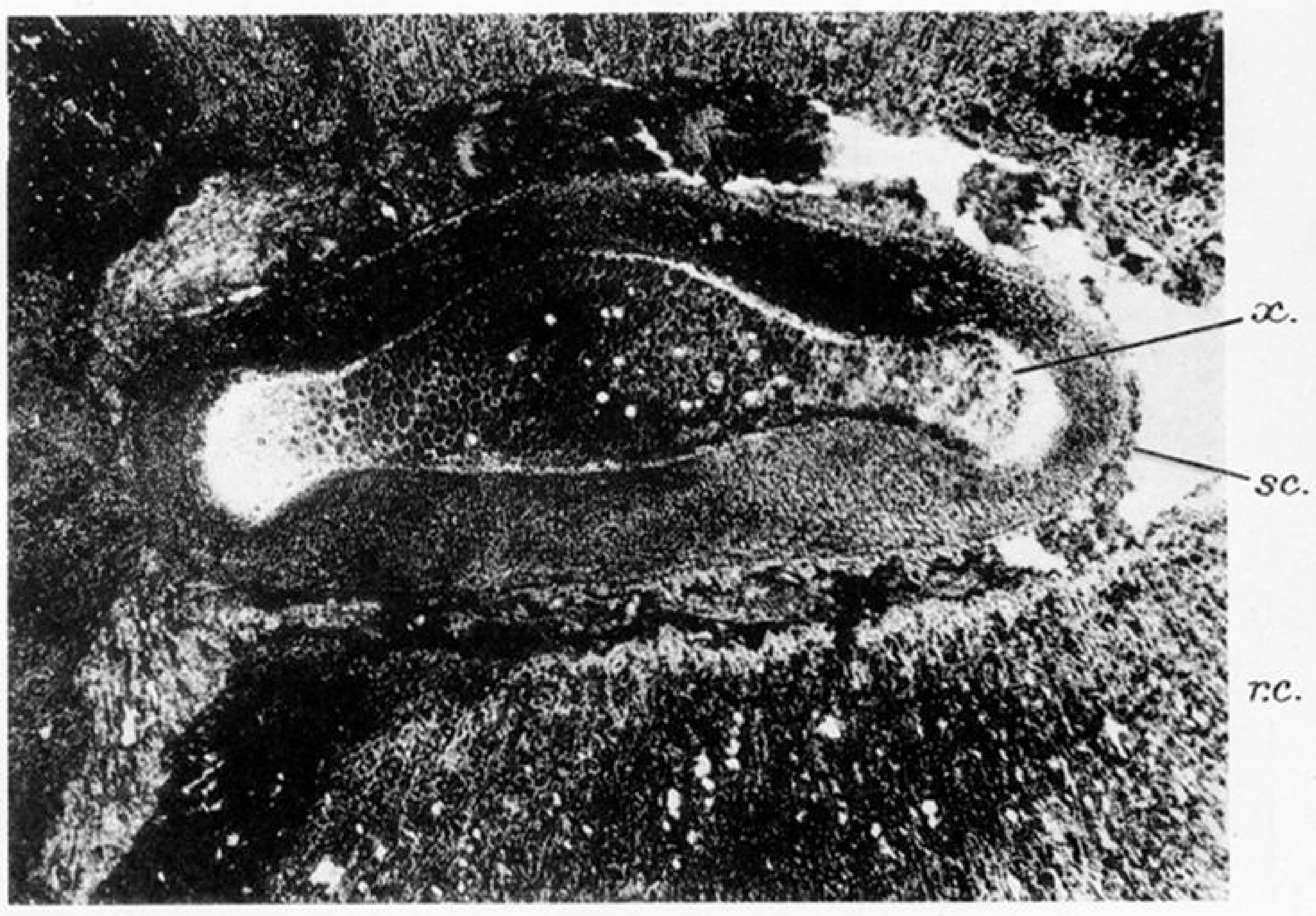

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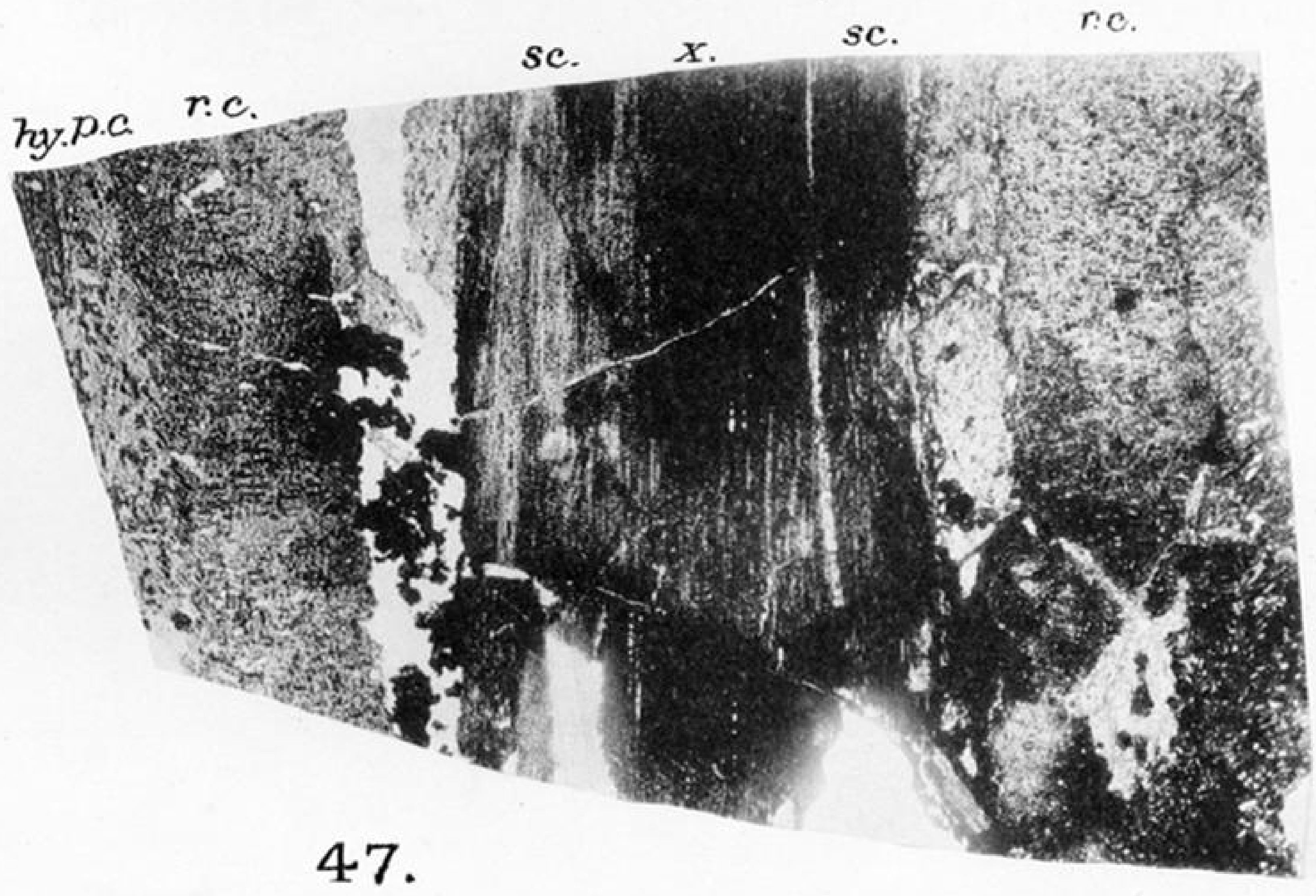

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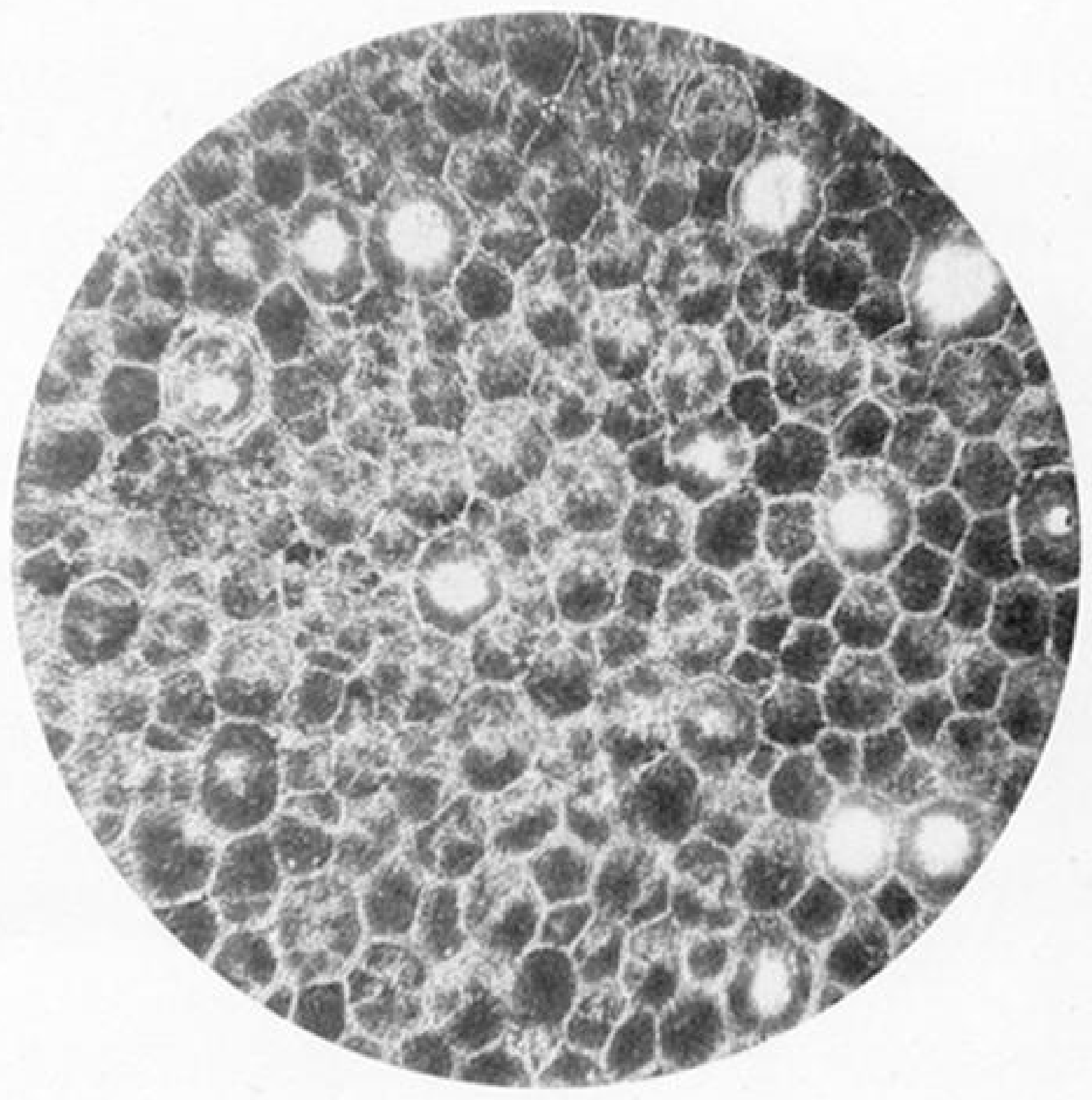


48.

43, 44, CALAMOPTERIS HIPPOCREPIS.
45–48, STEREOPTERIS ANNULARIS.

PLATE 33.

Phots. 43, 44, *Calamopteris Hippocrepis*.

Phot. 43.—General transverse section of the petiole, showing the horseshoe arrangement of the partially confluent bundles, *cf.* the diagram, text-fig. 1. The letters A and B give the orientation. × $6\frac{1}{2}$. Section A, 1.

Phot. 44.—General radial section, passing through the zone of bundles (*v.b.*) and showing the short-celled ground-tissue. × 7. Section A, 4.

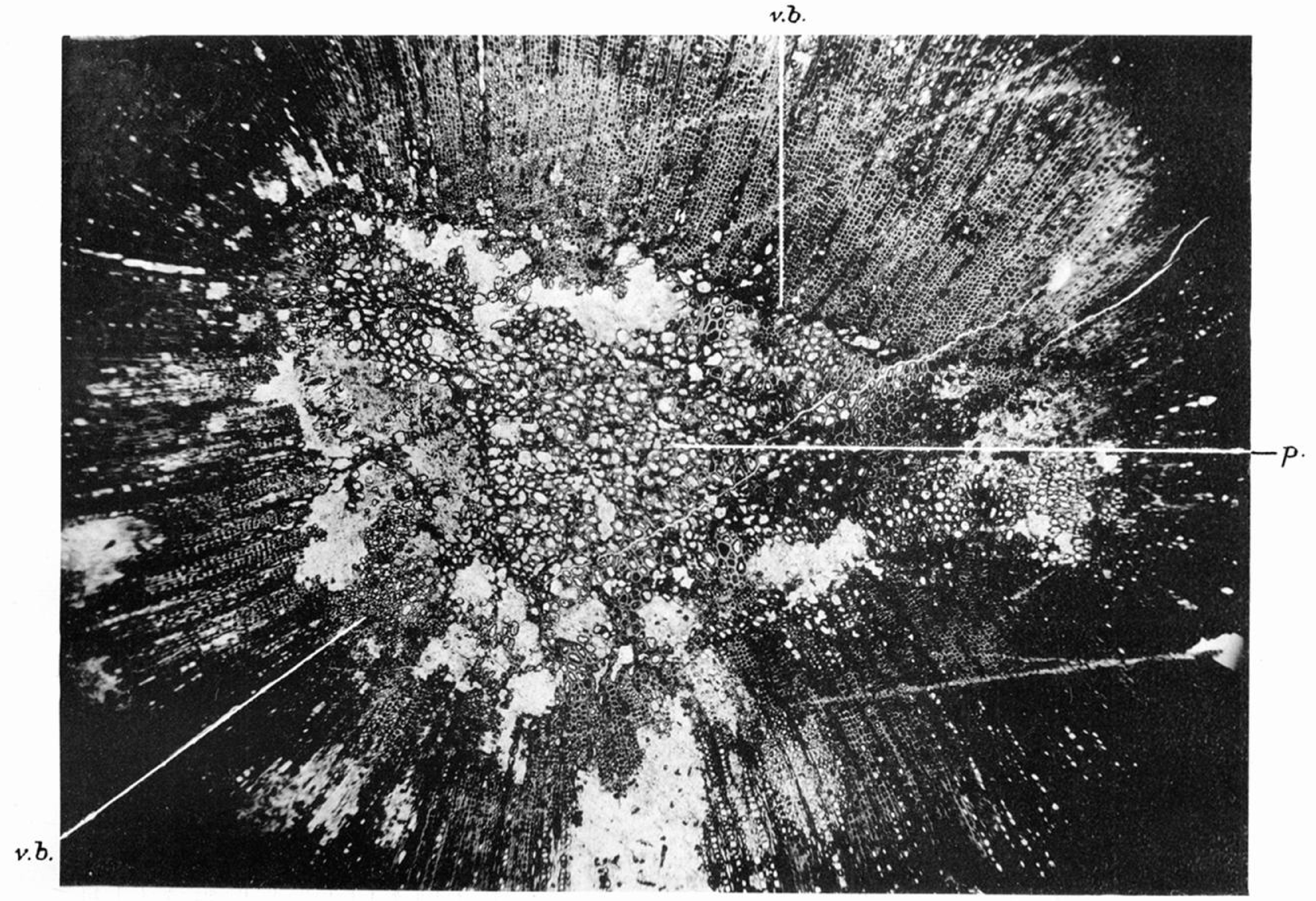
Phots. 45–48, *Stereopteris annularis*.

Phot. 45.—General transverse section of the petiole, showing the vascular bundle and the whole of the cortex. *r.c.*, radiating zone of cortex ; *p.c.*, parenchymatous cortex ; *hy*, hypoderma. × about 5. Section B, 6.

Phot. 46.—Vascular bundle and surrounding tissue, more highly magnified. *x*, xylem ; *sc*, sclerenchymatous zone ; *r.c.*, radiating zone of cortex × 11. Section B, 6.

Phot. 47.—General radial section, in the plane of the long axis of the bundle. The various cortical layers are well shown, specially on the left. Lettering as above. × about 5. Section B, 10.

Phot. 48.—Part of the xylem in transverse section. × 56. Section B, 6.



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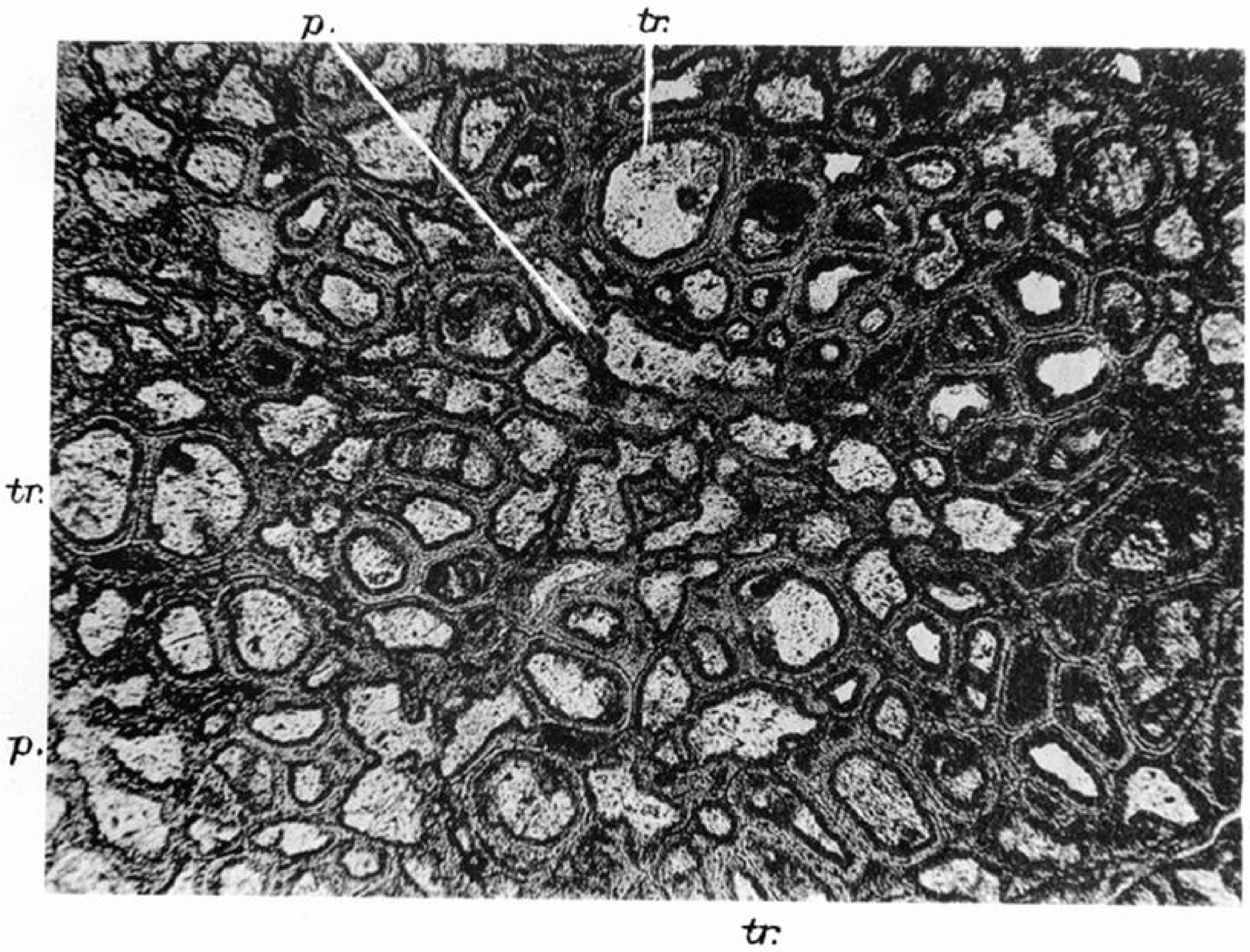

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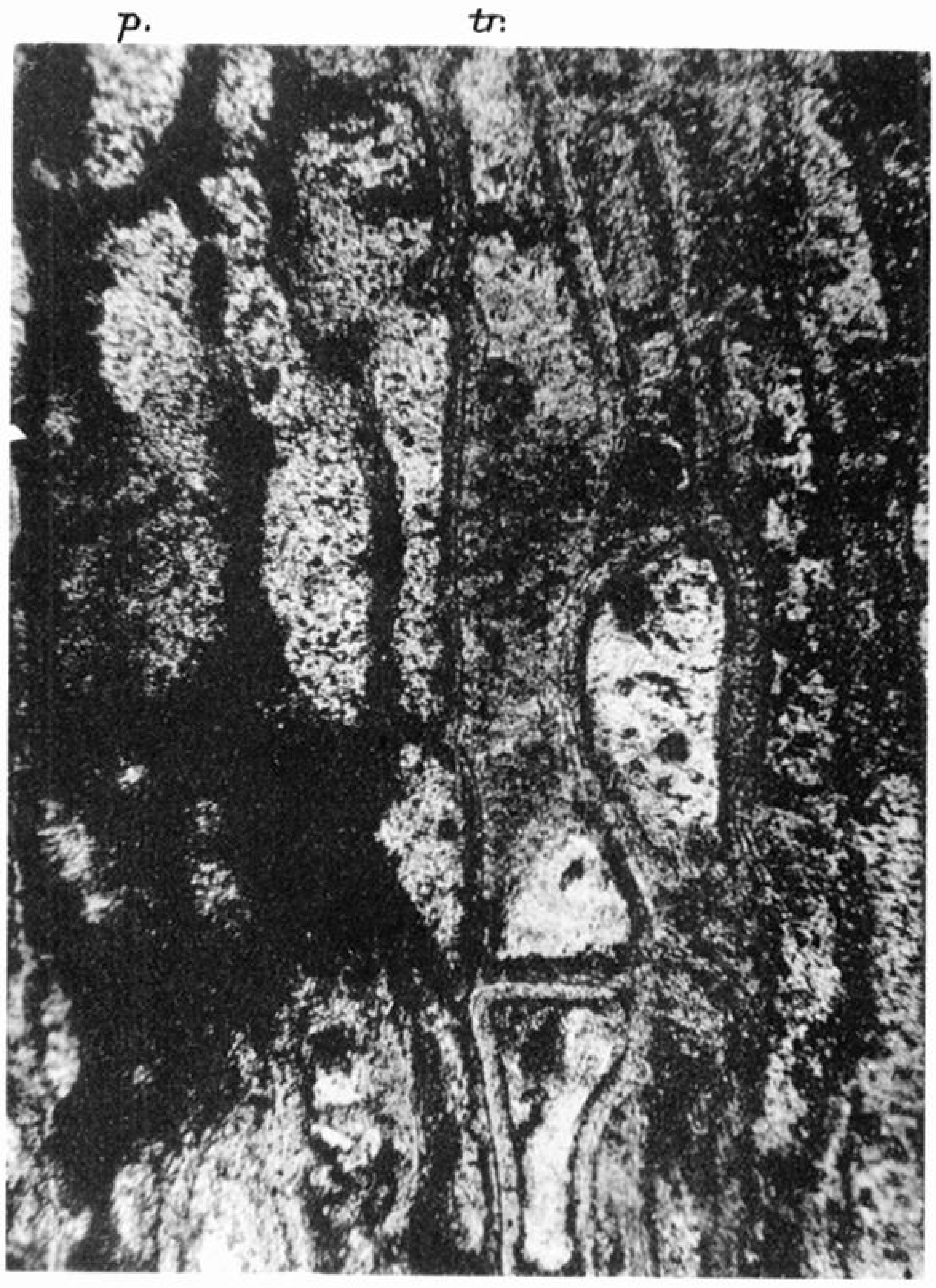


51.

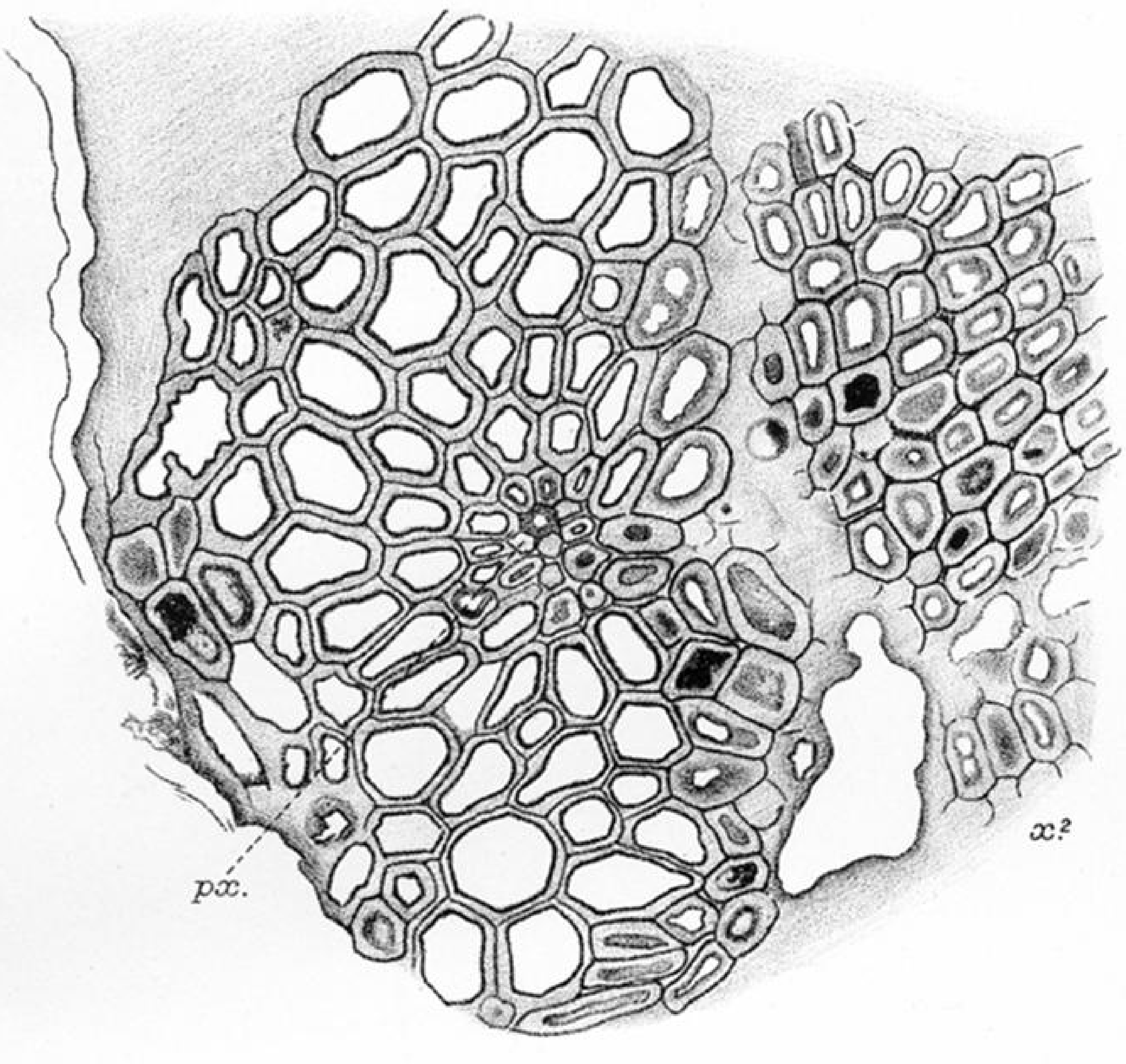
PLATE 34.

Calamopitys americana.

Phot. 49.—Transverse section of small stem showing the mixed pith and part of the secondary wood. *v.b.*, two of the primary xylem-strands; *p.*, middle point of part of mixed pith enlarged in Phot. 50. × 17. Section B 1, A.

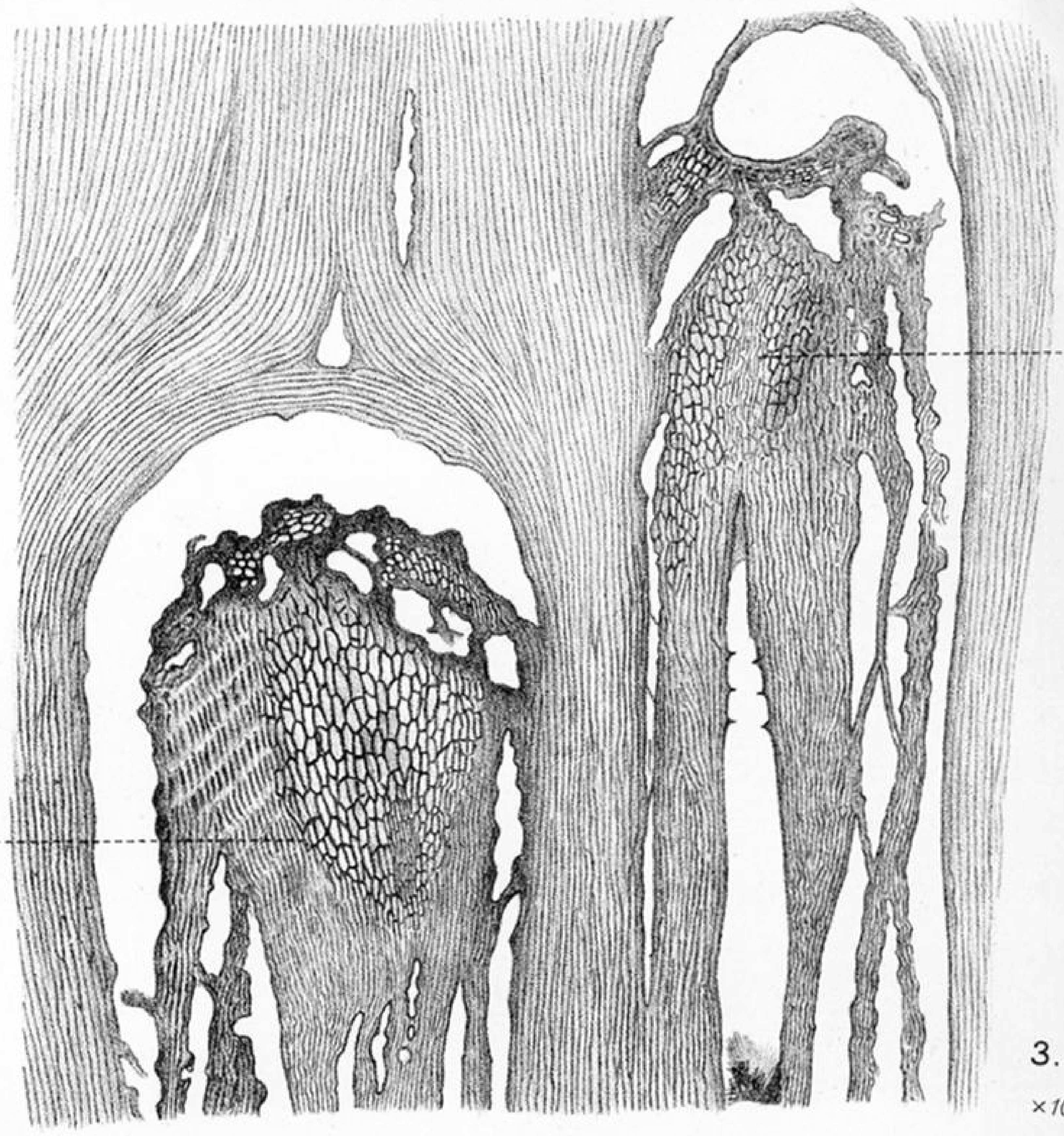
Phot. 50.—Part of the mixed pith from the same section, more highly magnified to show the medullary tracheides, *tr.* *p*, parenchyma. × 80. Section B 1, A.

Phot. 51.—Medullary tracheides in longitudinal section, from the same stem, to show the multiseriate pits. *tr*, a medullary tracheide; *p*, parenchyma. × about 100. Section B1, y, C.



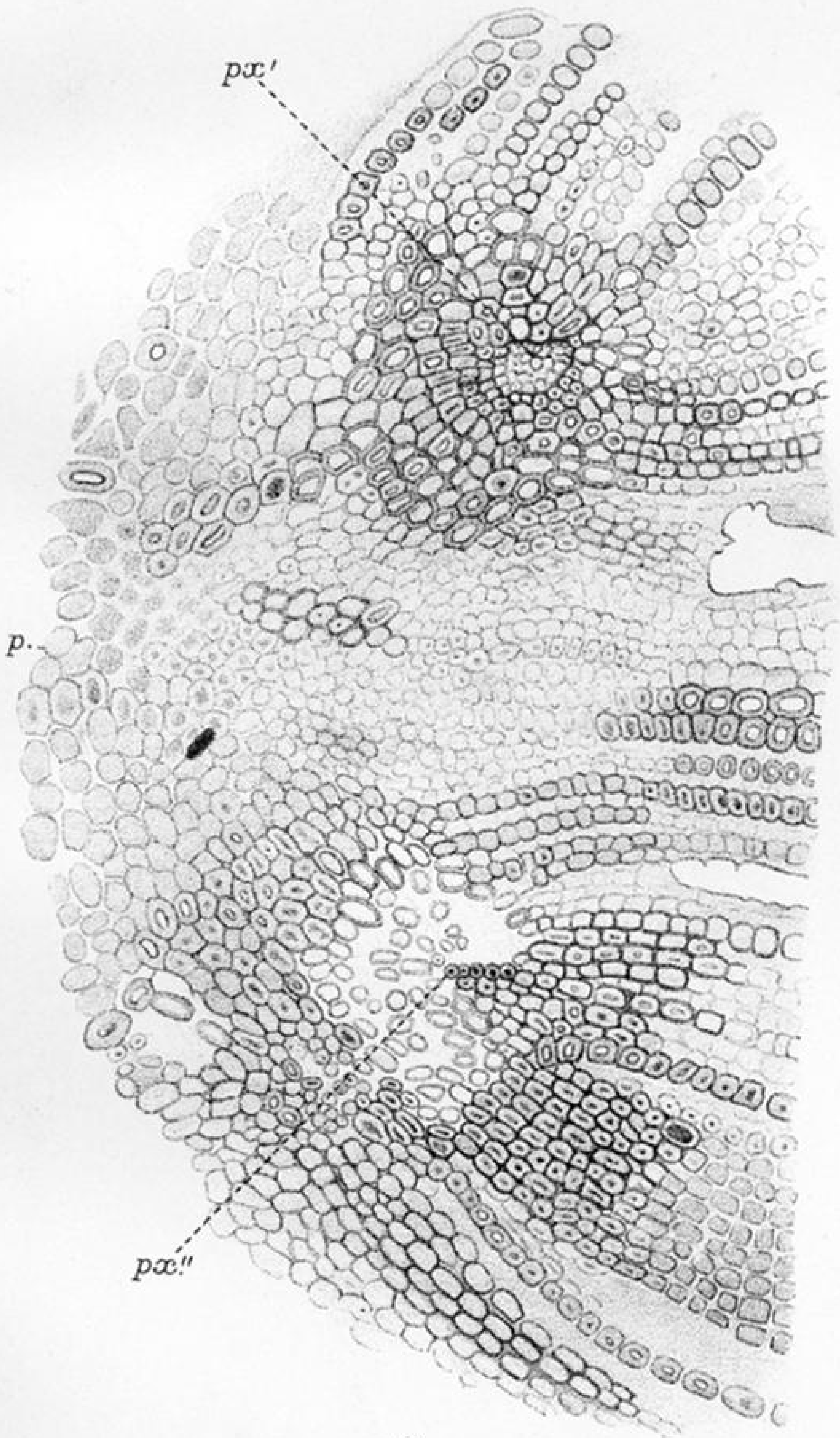
1.

×73



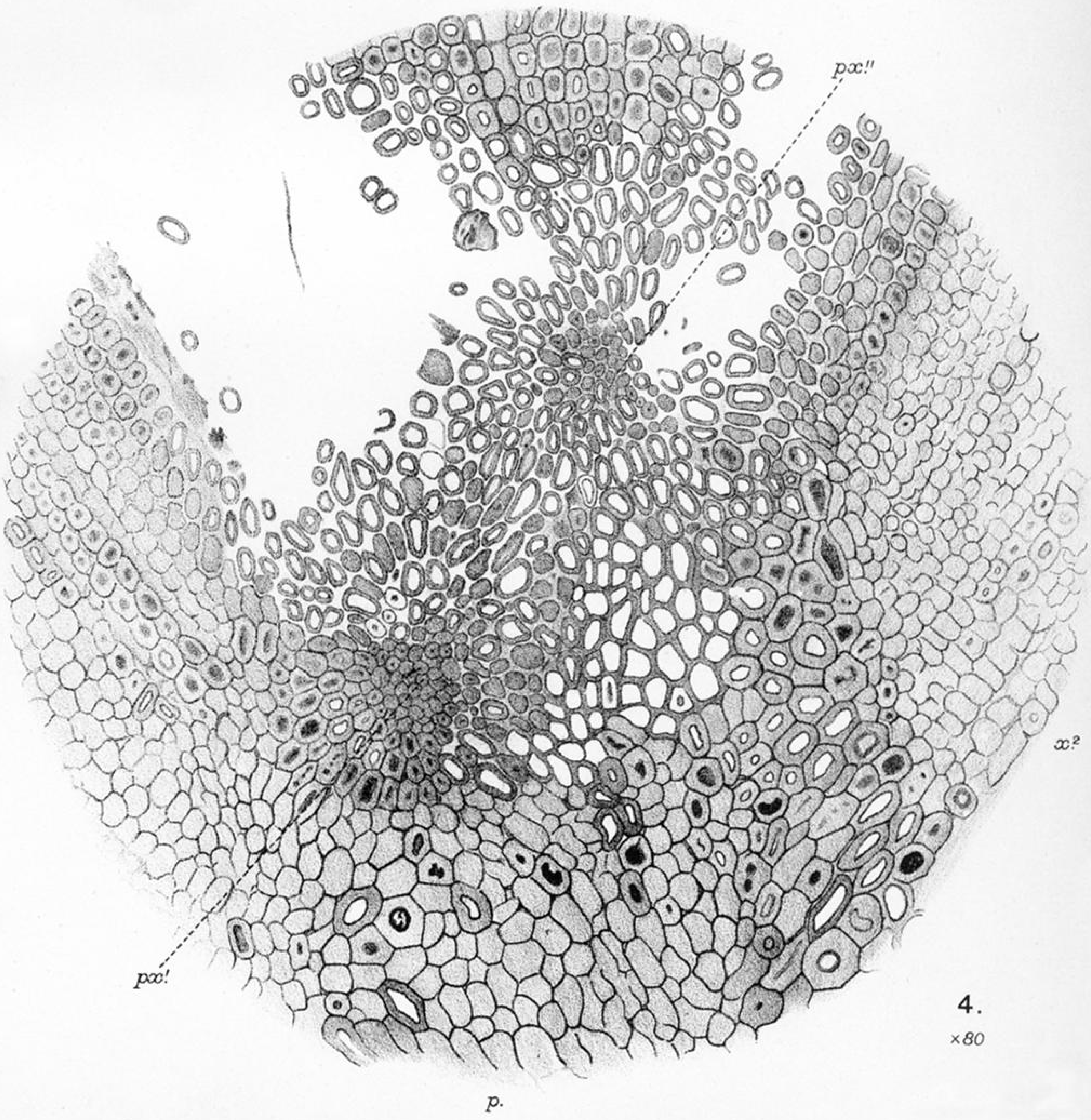
3.

×10



2.

×32



4.

×80

PLATE 35.

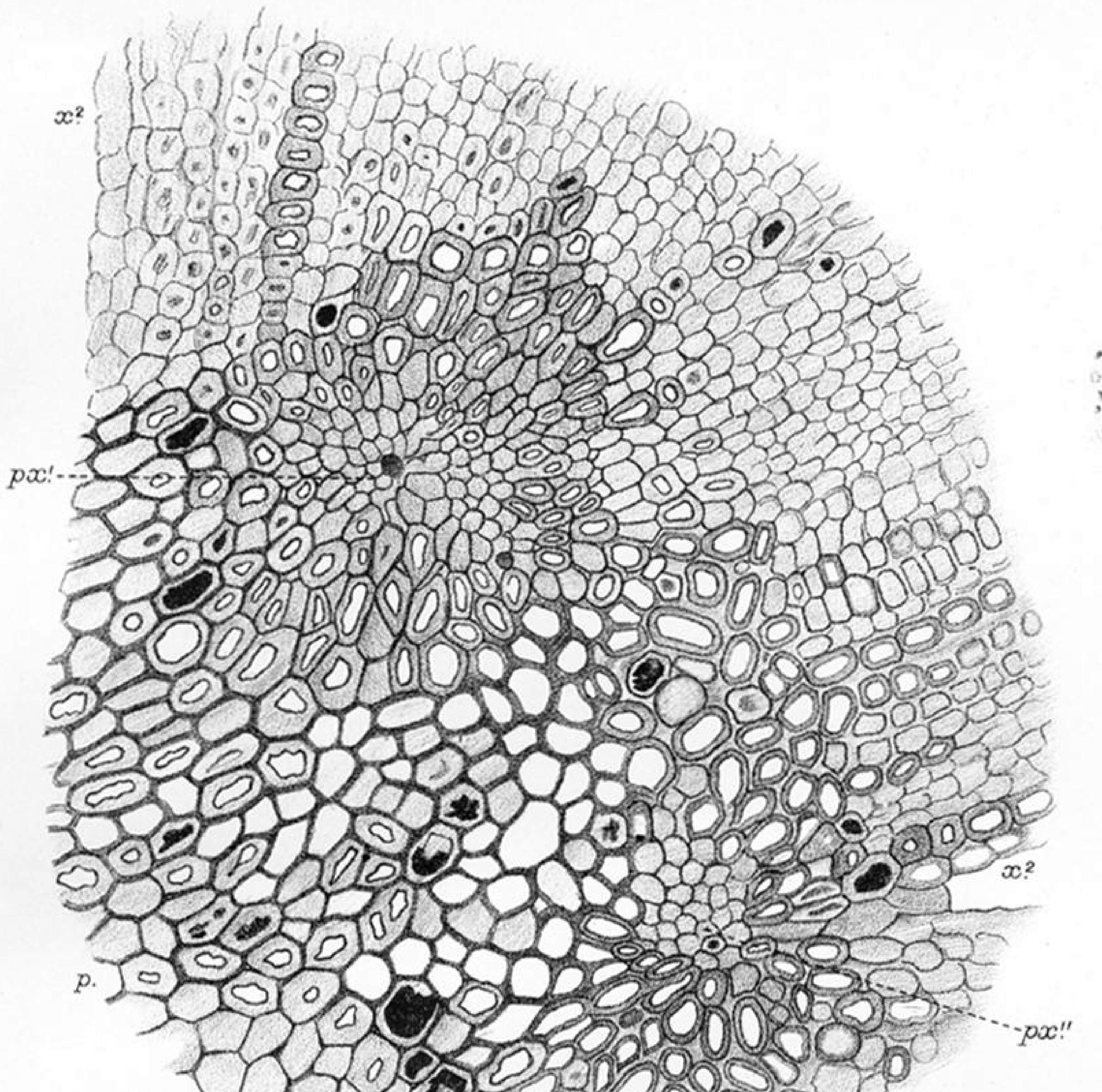
Calamopitys americana.

Fig. 1 (G. T. G.).—Primary, mesarch xylem-strand in transverse section. See also Plate 30, Phot. 24. *px*, protoxylem; x^2, secondary wood. × 73. Section C, 13.

Fig. 2 (G. T. G.).—Transverse section showing a double leaf-trace passing out. *px′*, *px″*, protoxylem groups of the two strands; *p*, pith. × 32. Section B 2, I.

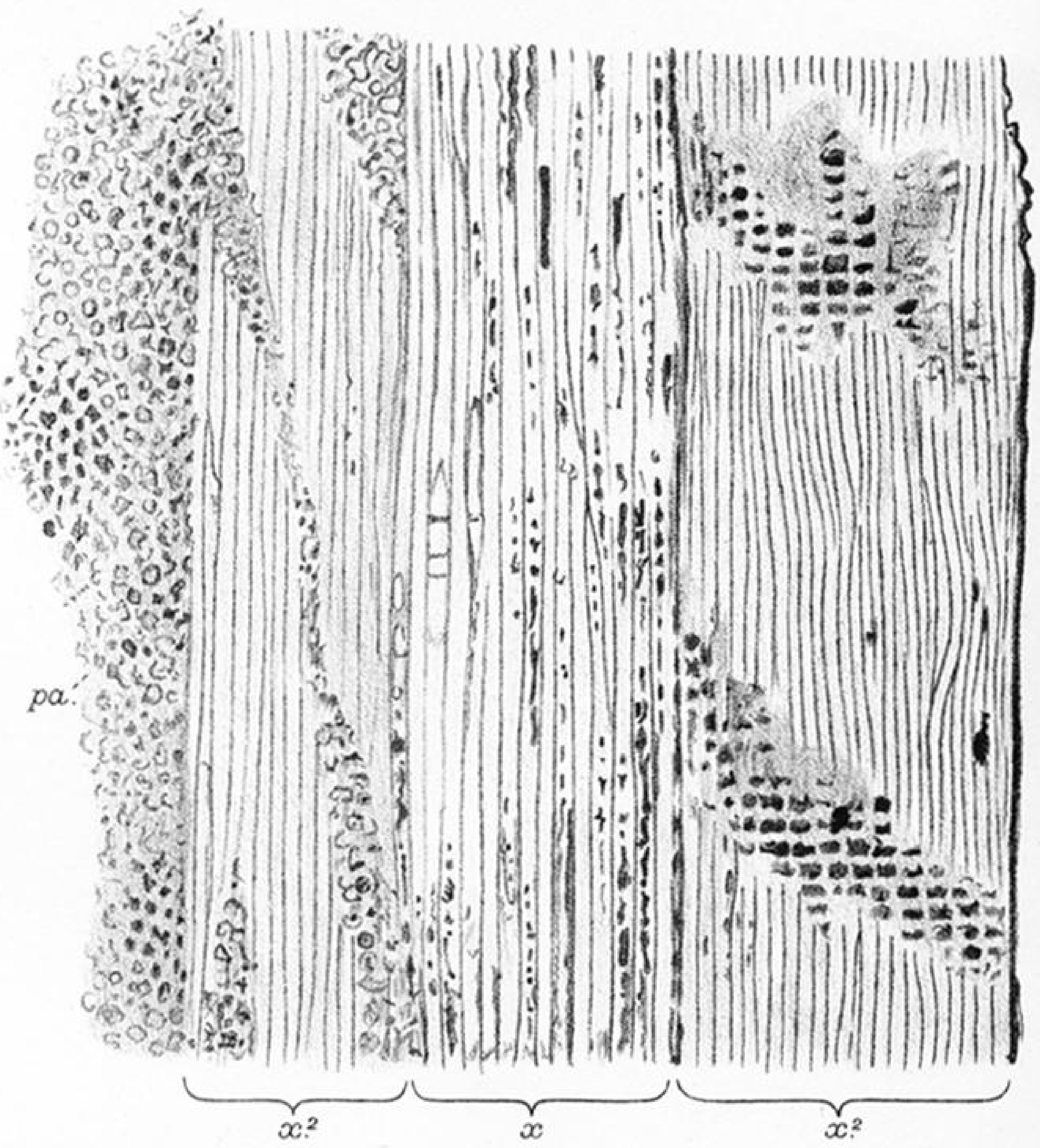
Fig. 3 (G. T. G.).—Tangential section of the wood, showing a double leaf-trace passing out. *x′*, *x″*, primary xylem of the two strands. × about 10. Section C, 14.

Fig. 4 (G. T. G.).—Transverse section, showing a double bundle. *px′*, *px″*, protoxylem-groups of the two strands; x^2, secondary wood; *p*, pith. × about 80. Section B 1, E.



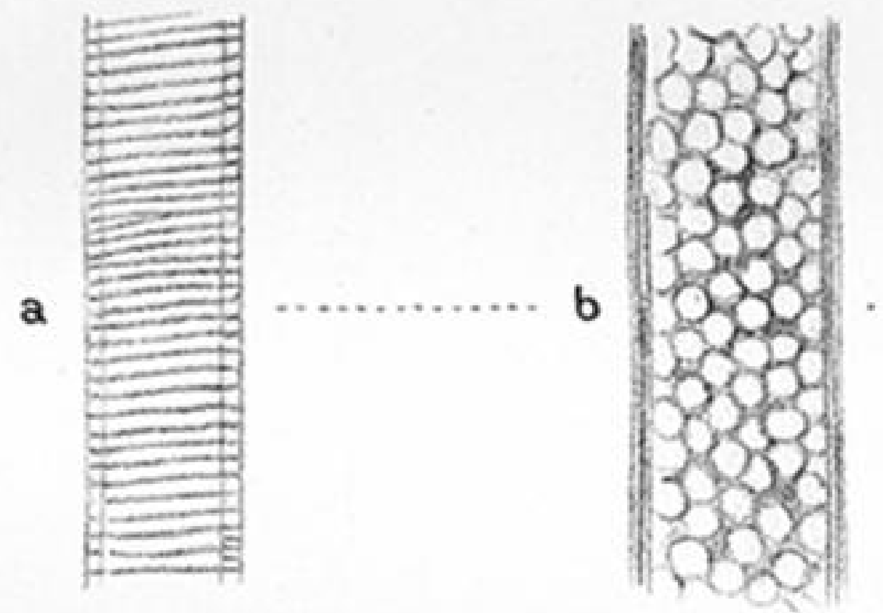
5.

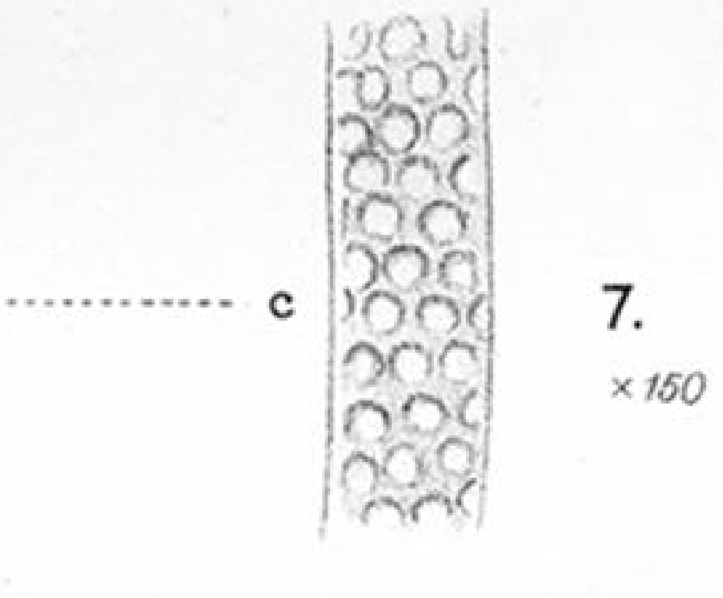
×70



6.

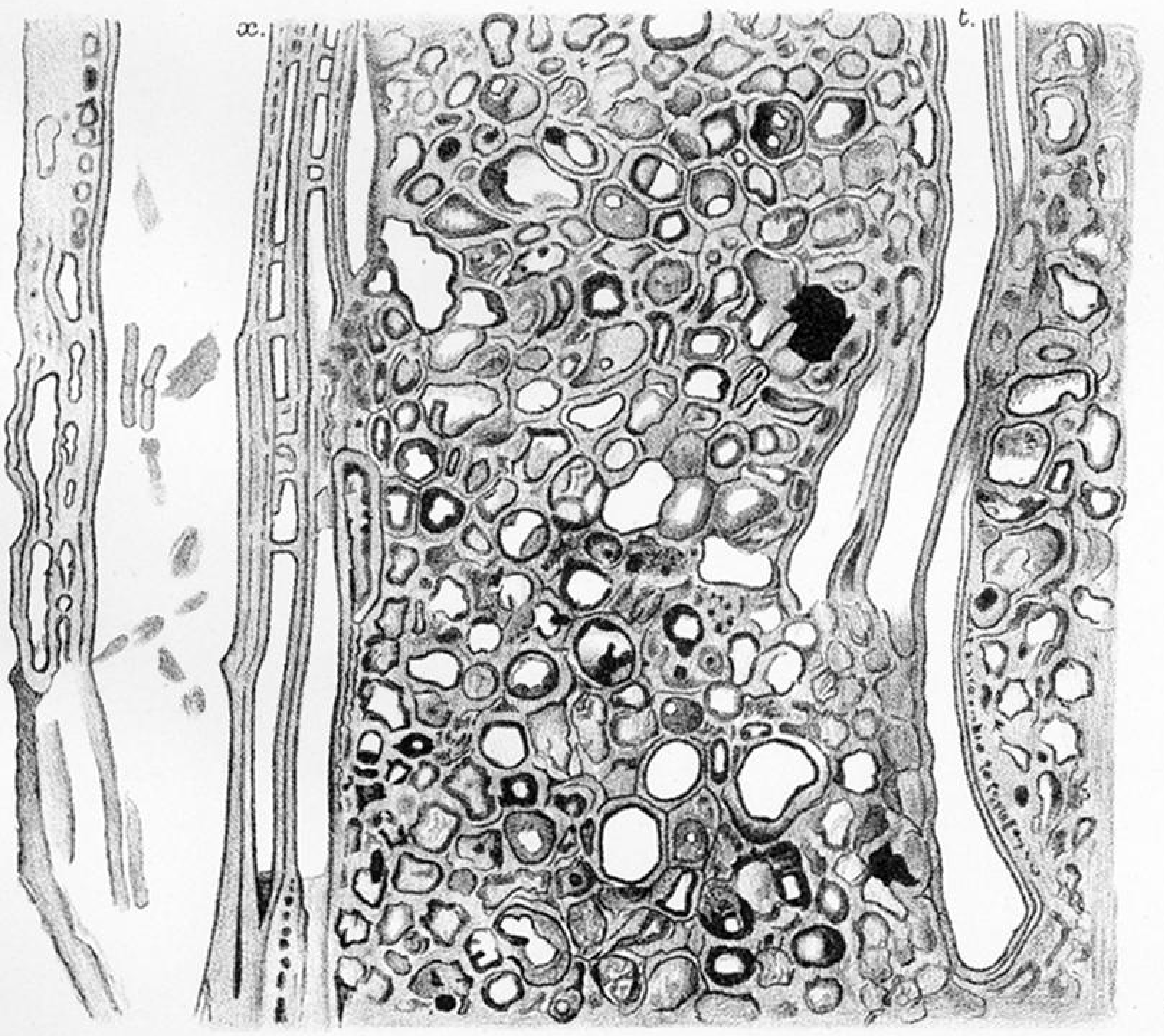
×20





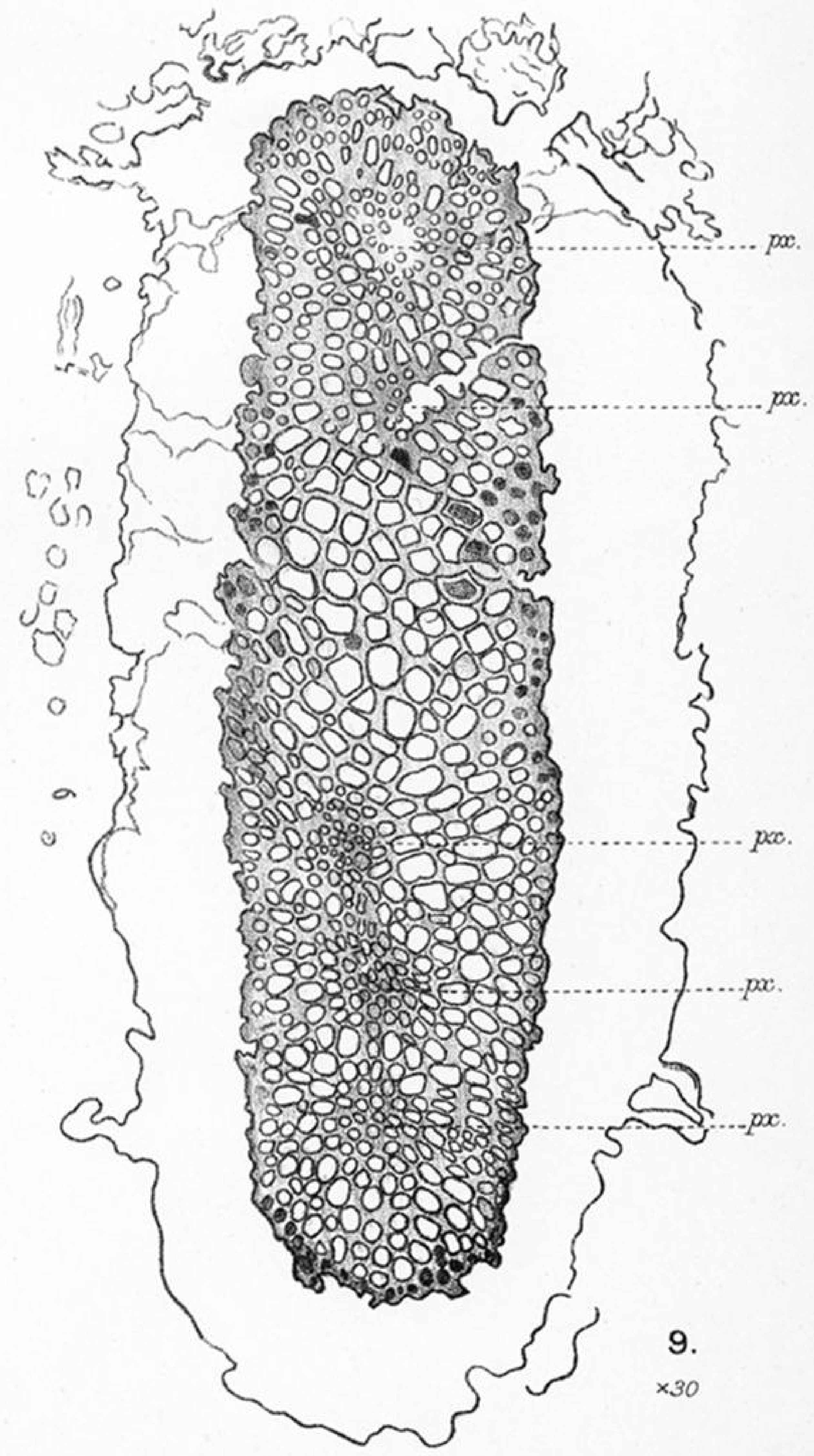
7.

×150



8.

×35



9.

×30

5-8, CALAMOPITYS. 9, KALYMMA.

PLATE 36.

Figs. 5–8, *Calamopitys americana*.

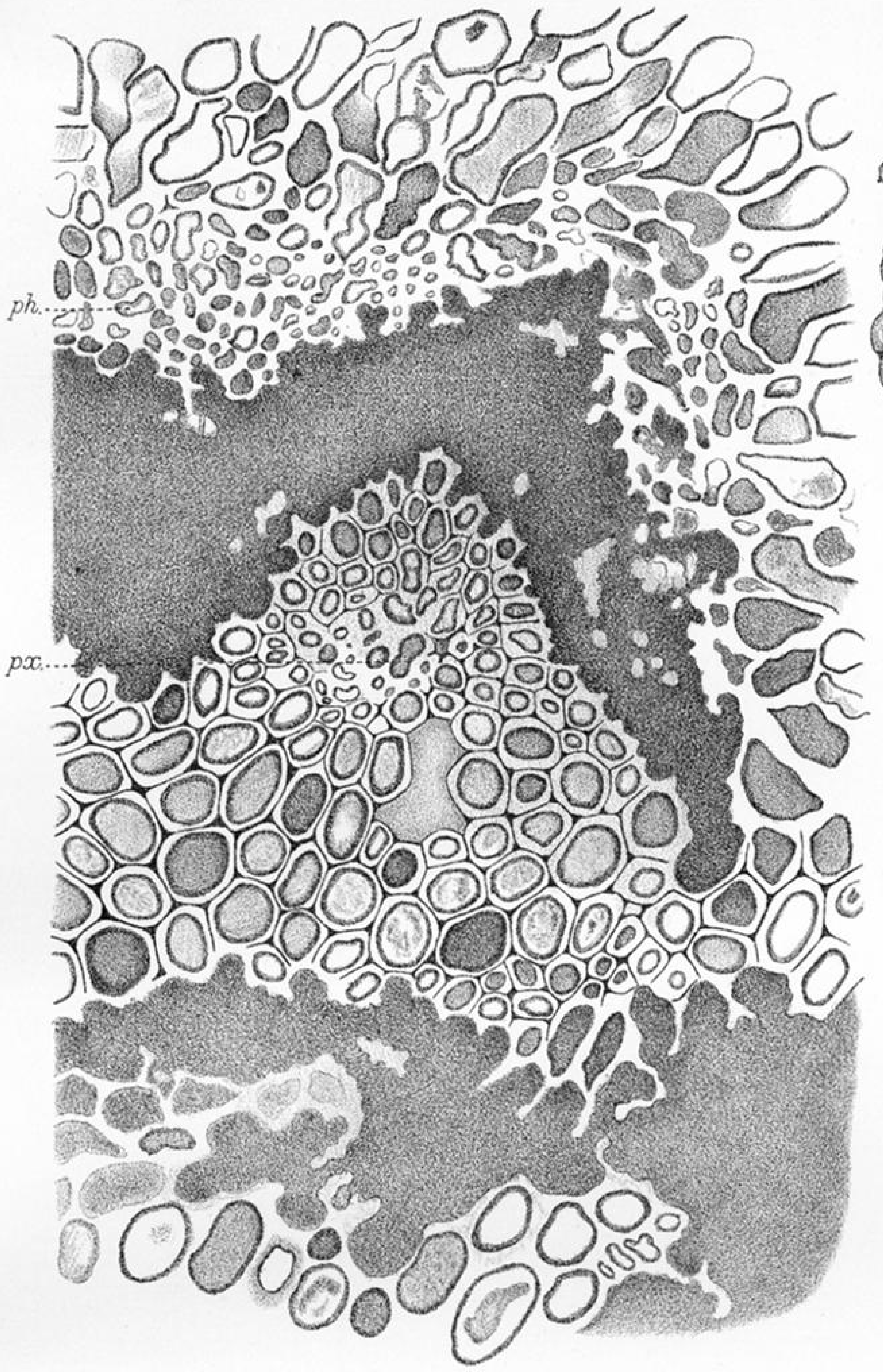
Fig. 5 (G. T. G.).—Transverse section of the outer strand of the double bundle shown in fig. 4, farther out in its course, where it has itself divided into two. Lettering as in fig. 4. × about 70. Section B 1, *y'*.

Fig. 6 (J. A.).—Longitudinal section of a leaf-trace bundle with secondary wood, after it has left the stele. The same bundle is shown in transverse section in Plate 29, Phot. 22, and Plate 30, Phot. 28. *x*, primary xylem, x^2, secondary xylem of strand; x^2 shows the medullary rays; *pa*, surrounding parenchyma. × 20. Section F, 31.

Fig. 7 (J. A.).—Details of tracheides from last section. A, scalariform primary tracheide; B, pitted ditto; C, pitted secondary tracheide. × about 150. Section F, 31.

Fig. 8 (G. T. G.).—Longitudinal section showing tracheides embedded in the pith, and part of a xylem-strand. *t*, medullary tracheides; *x*, part of a xylem-strand. × about 35. Section 6·5. Radial.

Fig. 9 (G. C. H.).—*Kalymma*. Transverse section from a large petiole, showing a single bundle with five protoxylem-groups, *px*. × 30. Section O, 11.



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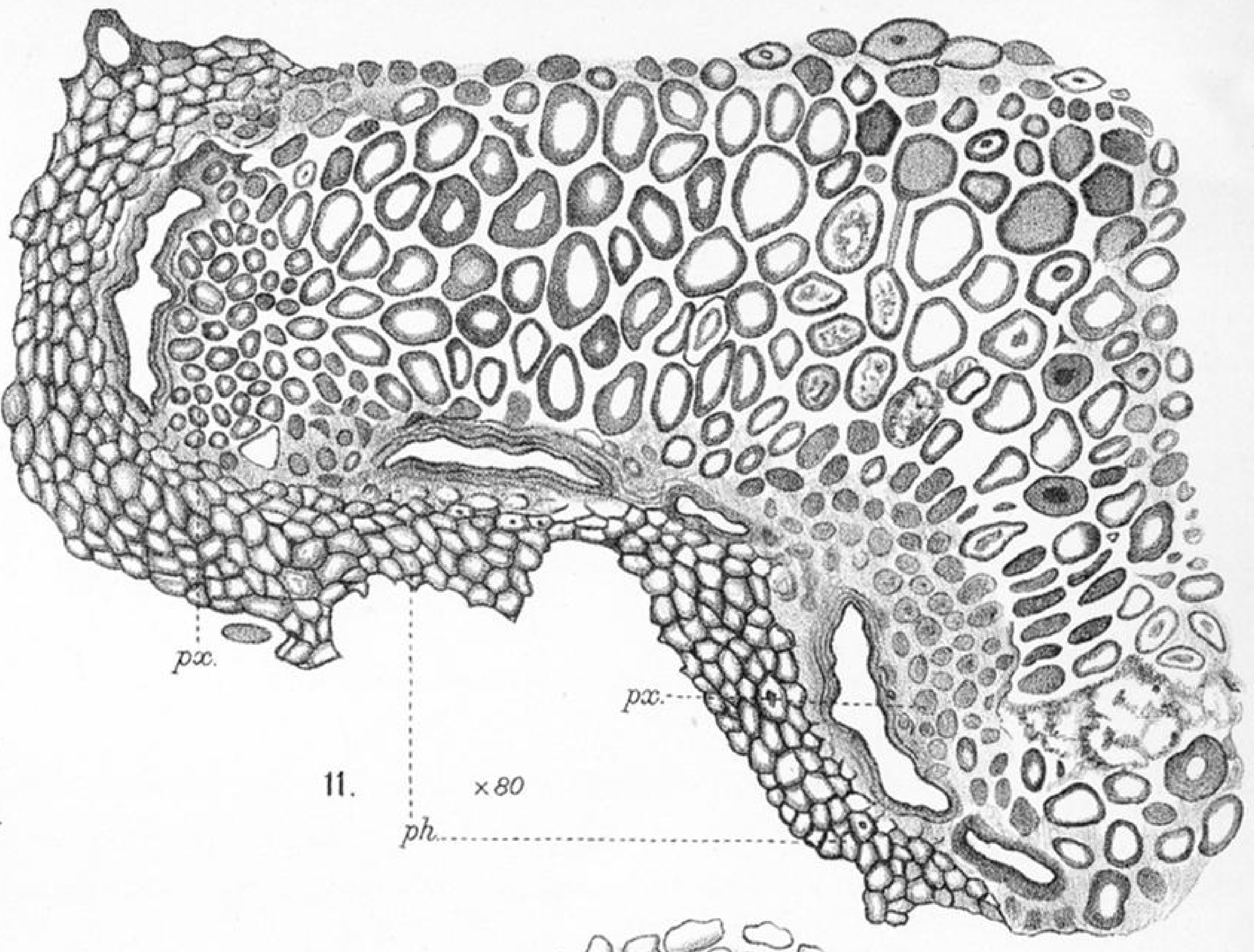
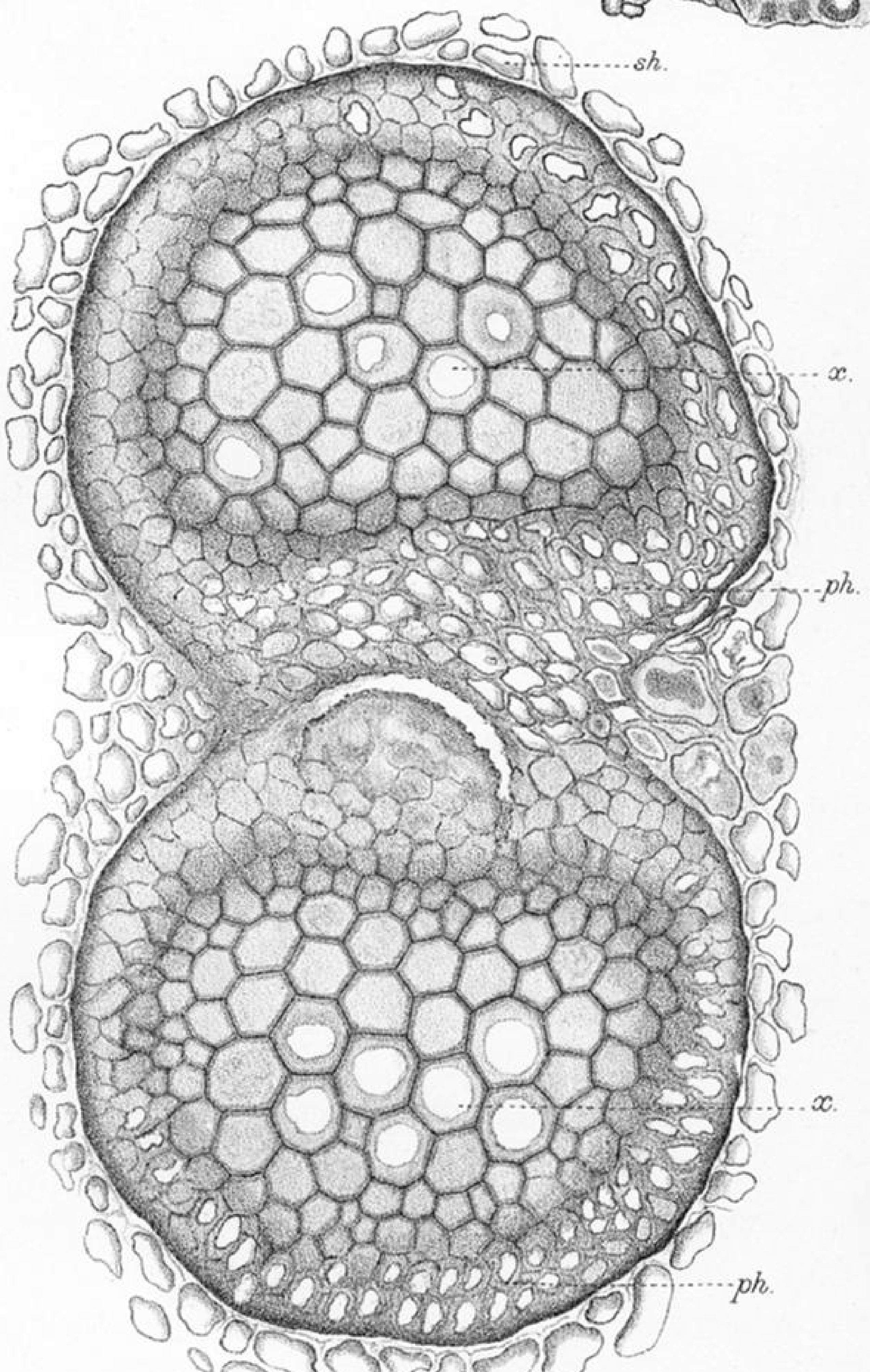


11.



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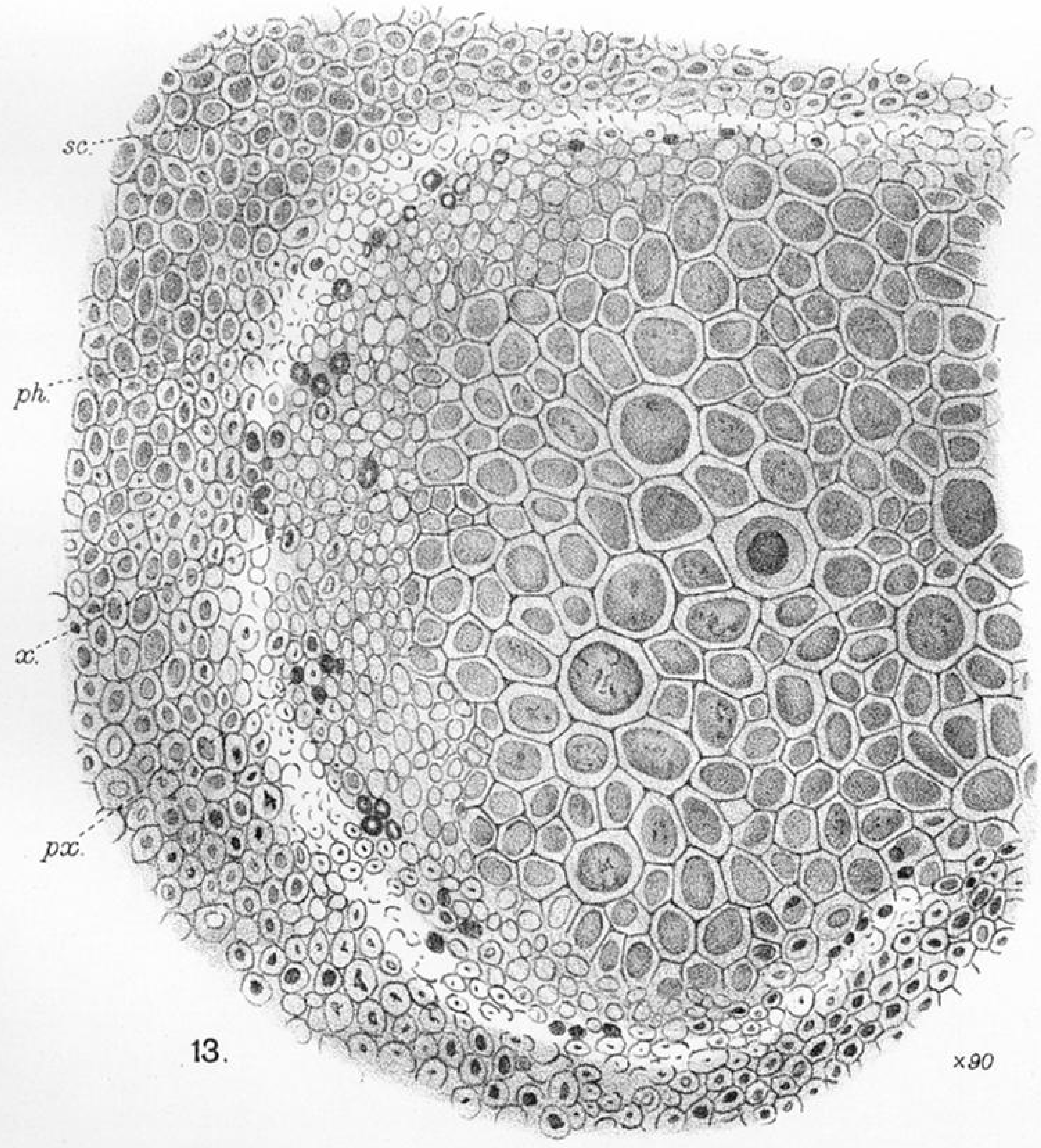
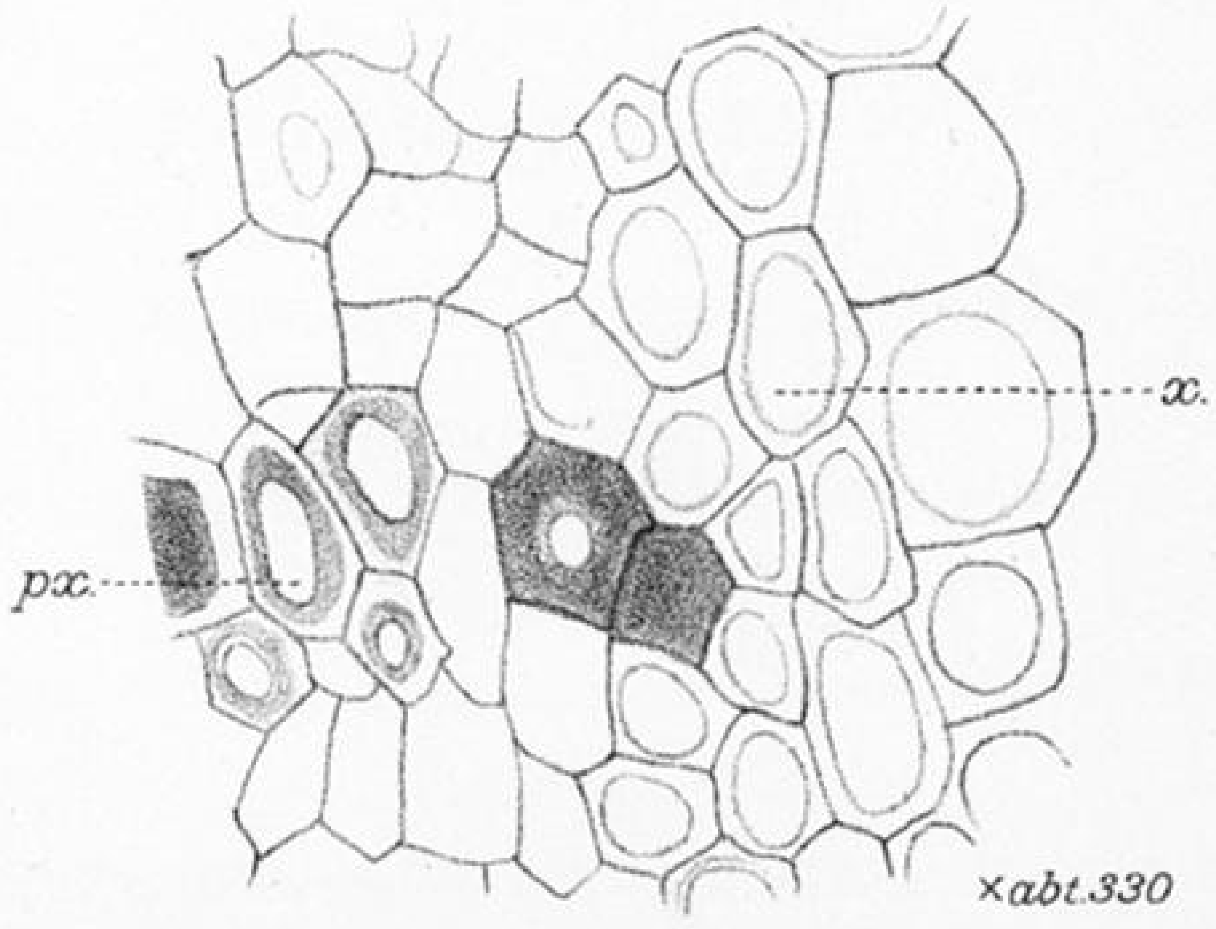


13.



14.

10, CALAMOPTERIS HIPPOCREPIS. 11, C. DEBILIS.
12, PERIASTRON 13, 14, STEREOPTERIS.

PLATE 37.

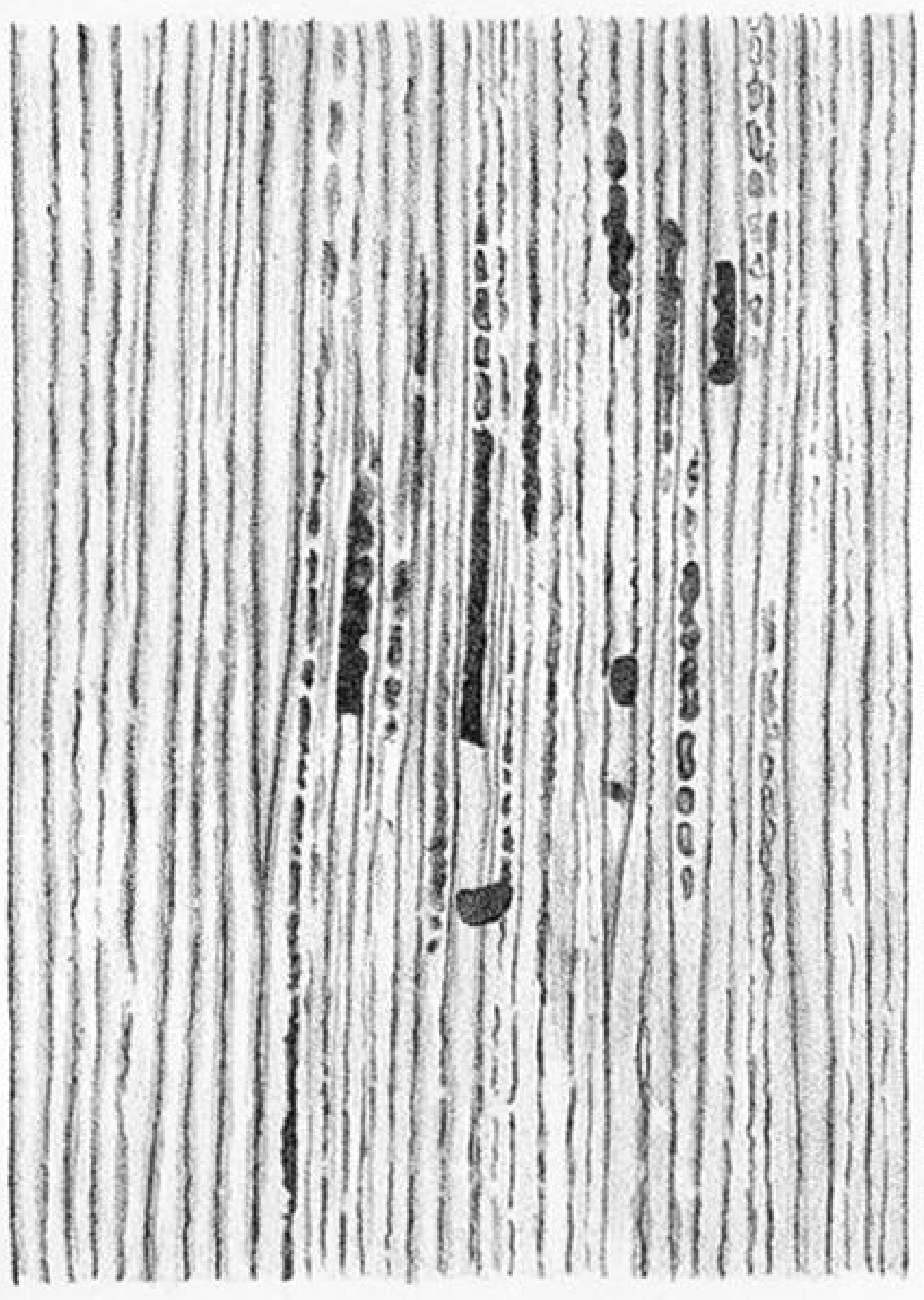
Fig. 10 (G. T. G.).—*Calamopteris Hippocrepis.* Transverse section of part of the bundle-zone, indicated by an arrow in text-fig. 1. *px*, protoxylem; *ph*, remains of phloem. × about 100. Section A, 2.

Fig. 11 (G. T. G.).—*Calamopteris debilis*, Unger. Transverse section of a vascular bundle (indicated by an arrow in text-fig. 2). *px*, *px*, approximate positions of the protoxylem; *ph*, phloem; all the part above this is xylem. × 80. Section 435, Solms collection.

Fig. 12 (G. T. G.).—*Periastron perforatum.* Transverse section of a middle pair of bundles. See also Plate 32, Phot. 38. *x*, *x*, xylem; *ph*, *ph*, phloem of the two bundles; *sh*, sheath. × 73. Section E, 23.

Fig. 13 (J. A.).—*Stereopteris annularis.* One end of the vascular bundle, transverse. *x*, xylem; *px*, approximate position of protoxylem; *ph*, probable phloem; *sc*, sclerenchyma of pericycle (?). × 90. Section B, 6.

Fig. 14 (R. S.).—Transverse section of part of the same, showing probable protoxylem. *px*, protoxylem; *x*, elements of the xylem mass. × about 330. Section B, 6.



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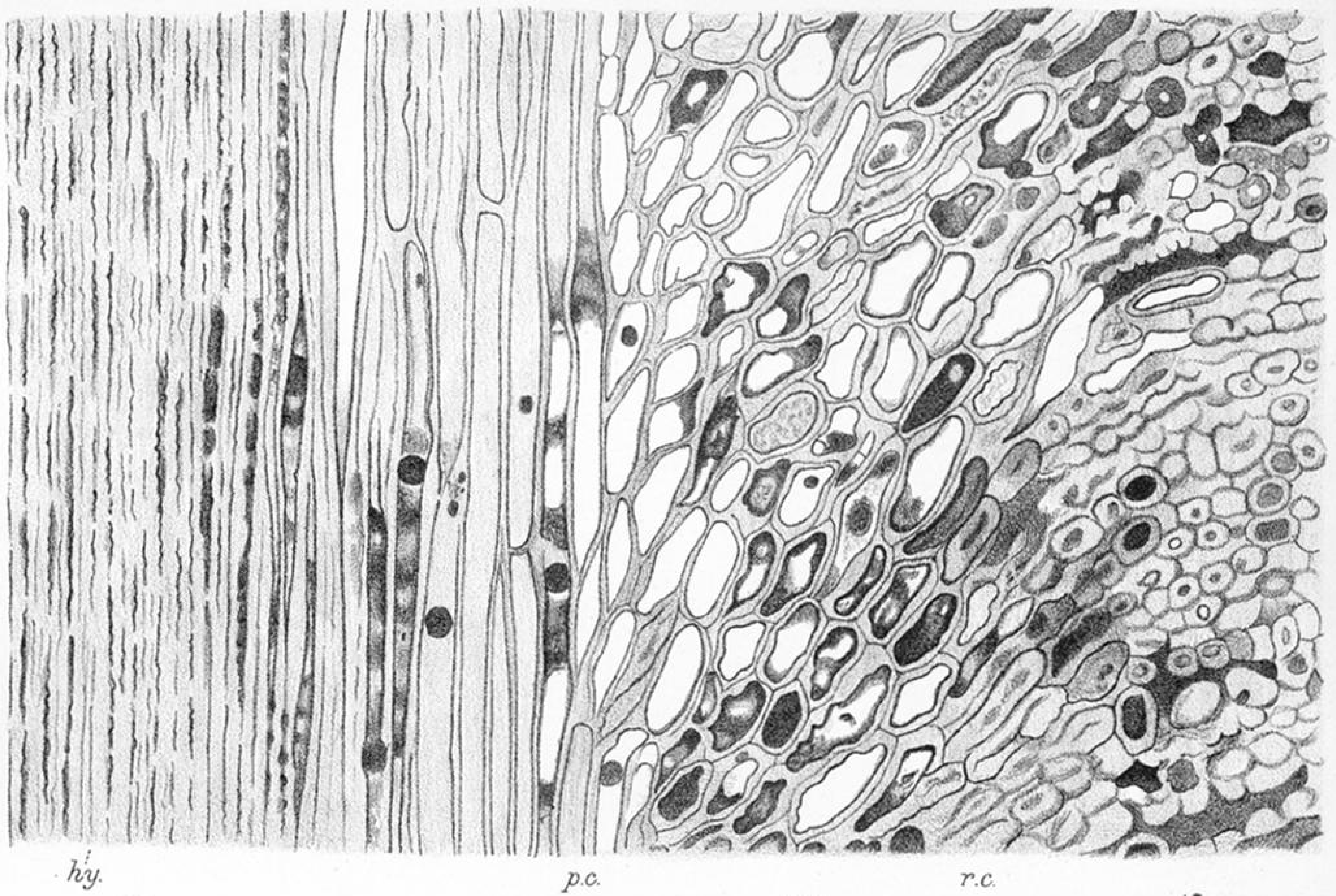

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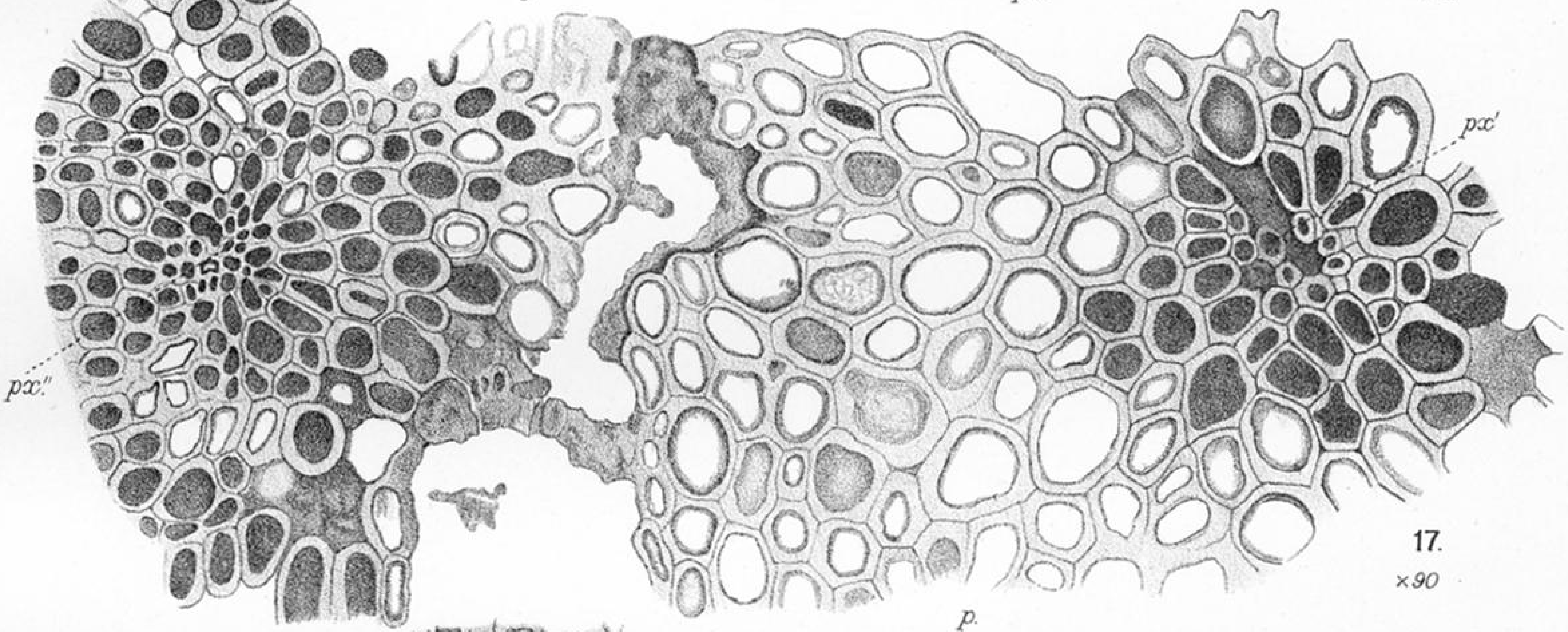

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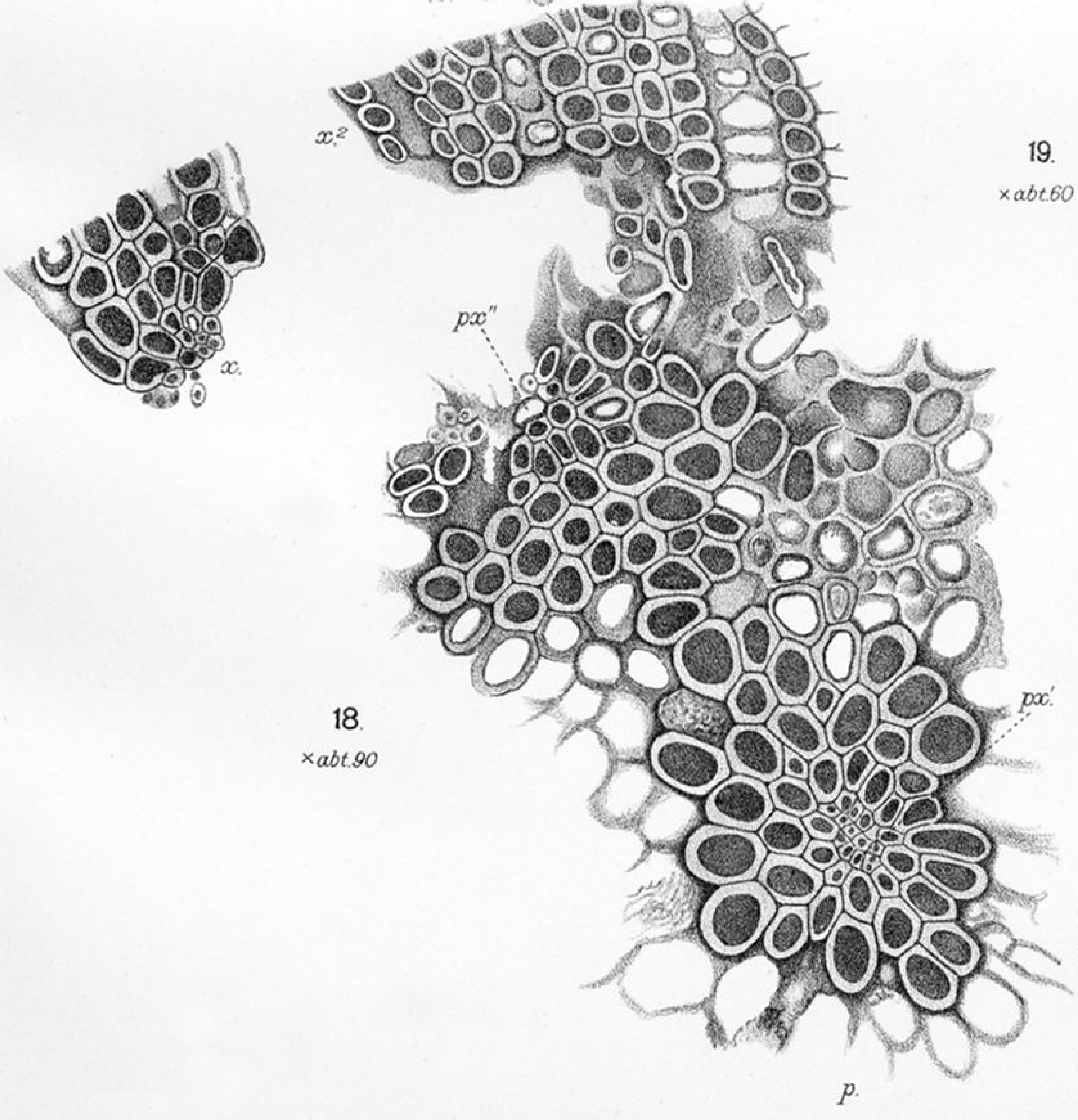

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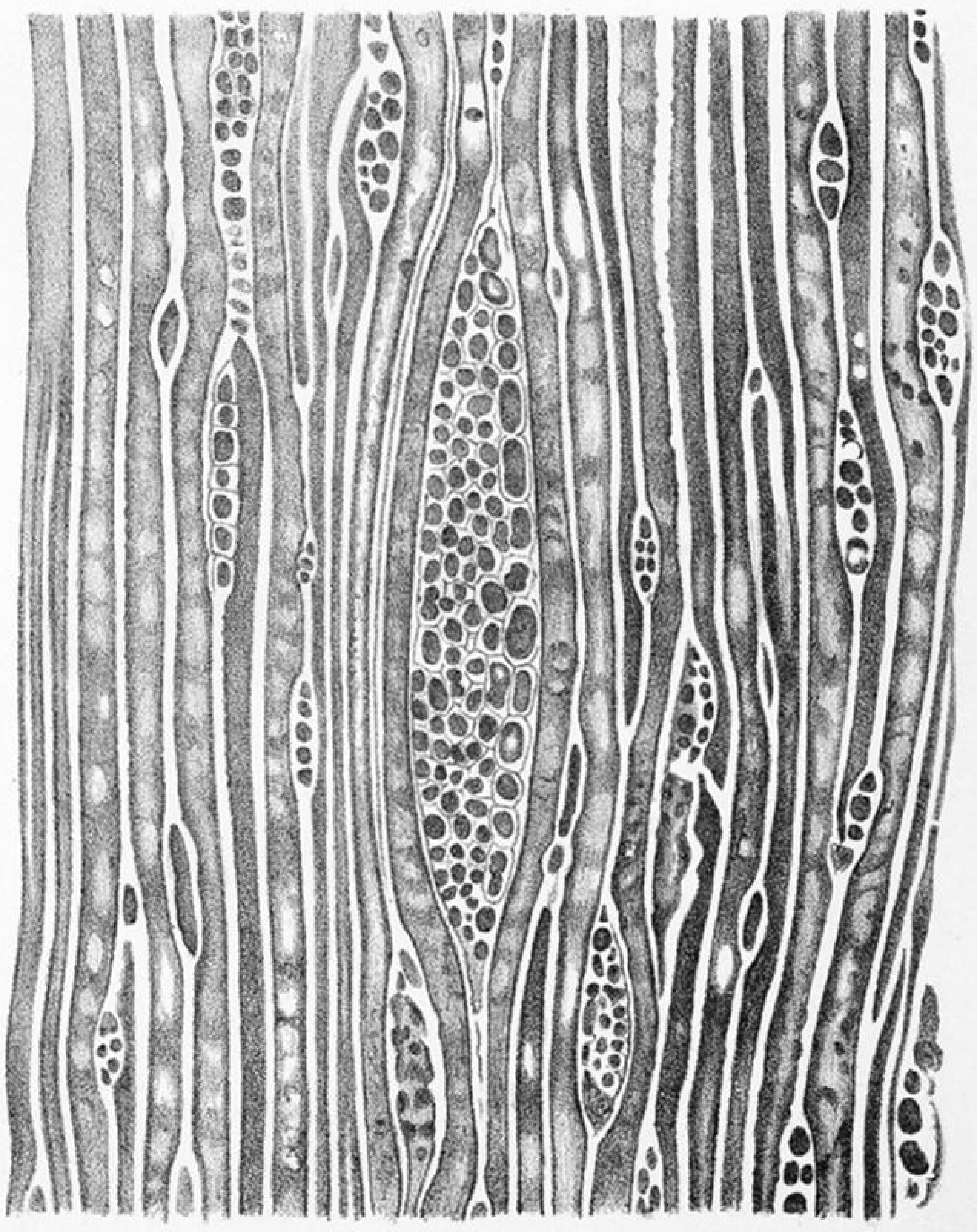


19.

15, 16, STEREOPTERIS. 17–19, ARCHÆOPITYS.

Plate 38.

Figs. 15 and 16, *Stereopteris annularis.*

Fig. 15 (G. T. G.).—Tangential section through the sclerenchymatous zone (pericycle?) surrounding the bundle. × about 35. Section B, *a*.

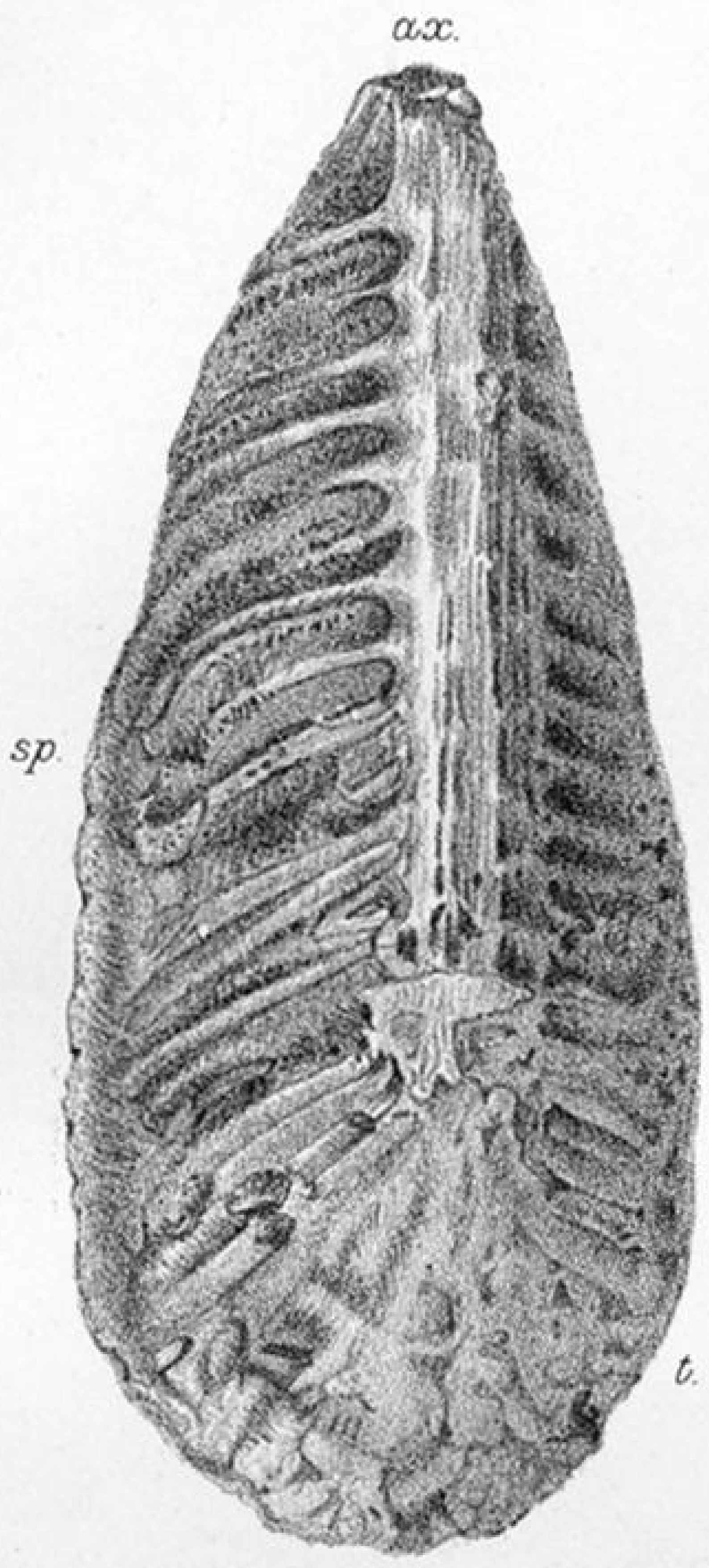
Fig. 16 (G. T. G.).—Approximately radial section through the outer part of the cortex. *r.c.*, part of radiating zone; *p.c.*, parenchymatous cortex; *hy*, hypoderma. × about 40. Section B, *a*.

Figs. 17–19, *Archæopitys Eastmanii.*

Fig. 17 (G. T G.).—Transverse, showing two xylem-strands (marked 7 and E in text-fig. 4), one in the pith, the other in contact with the wood. *px'*, *px''*, protoxylem of the two strands; x^2, secondary wood; *p*, pith. × about 90. Section 9·3, 13. Hemingway.

Fig. 18 (G. T. G.).—The same two strands beginning to fuse (see text-fig. 5, E 7). *px'*, *px''*, protoxylem of the two strands; *x*, detached fragment of primary xylem of outer strand; x^2, secondary wood; *p*, pith. × about 90. Section 9·3, 21. Hemingway.

Fig. 19 (G. T. G.).—Tangential section through secondary wood, showing the medullary rays. × about 80. Section 9·3, D. Lomax.



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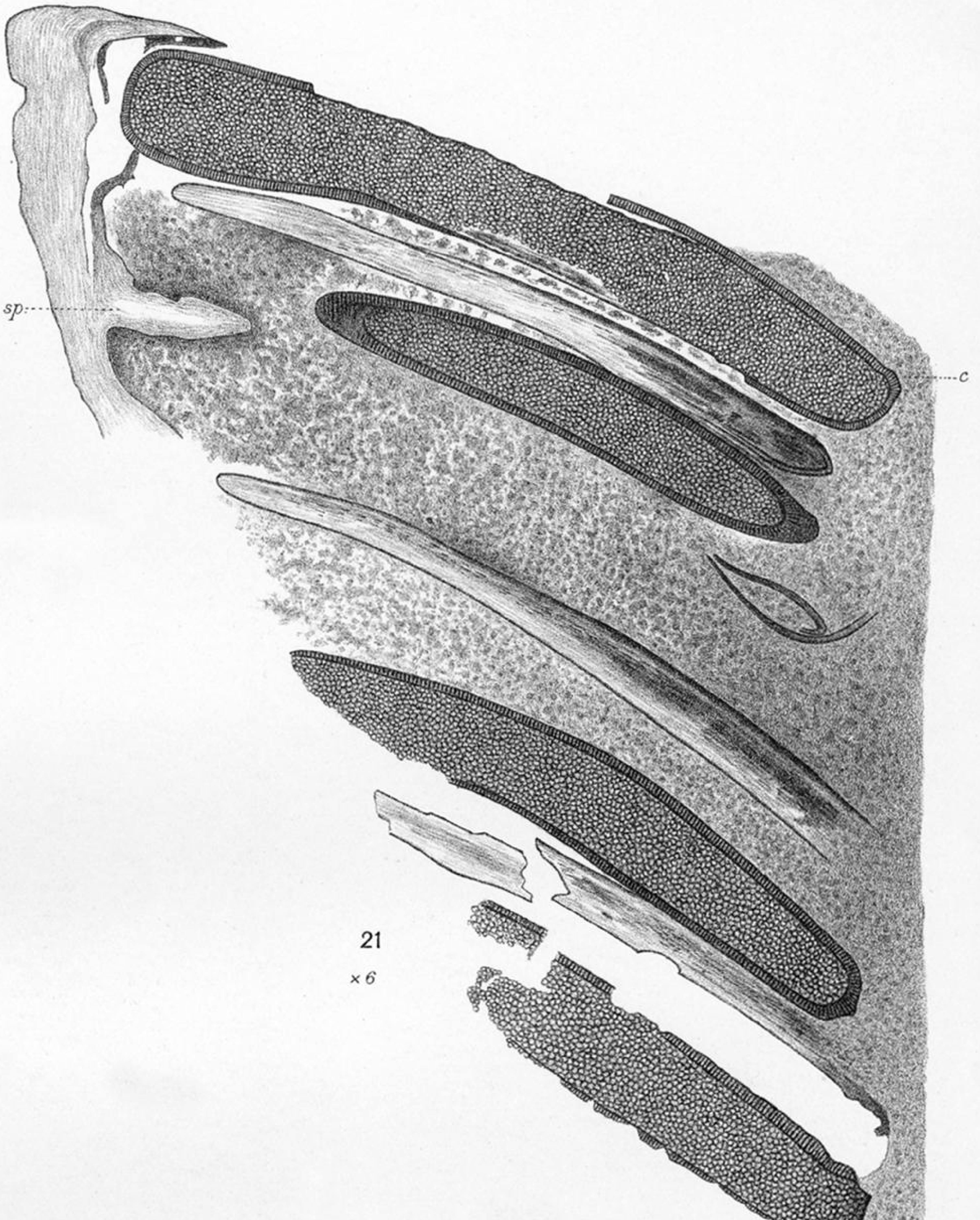
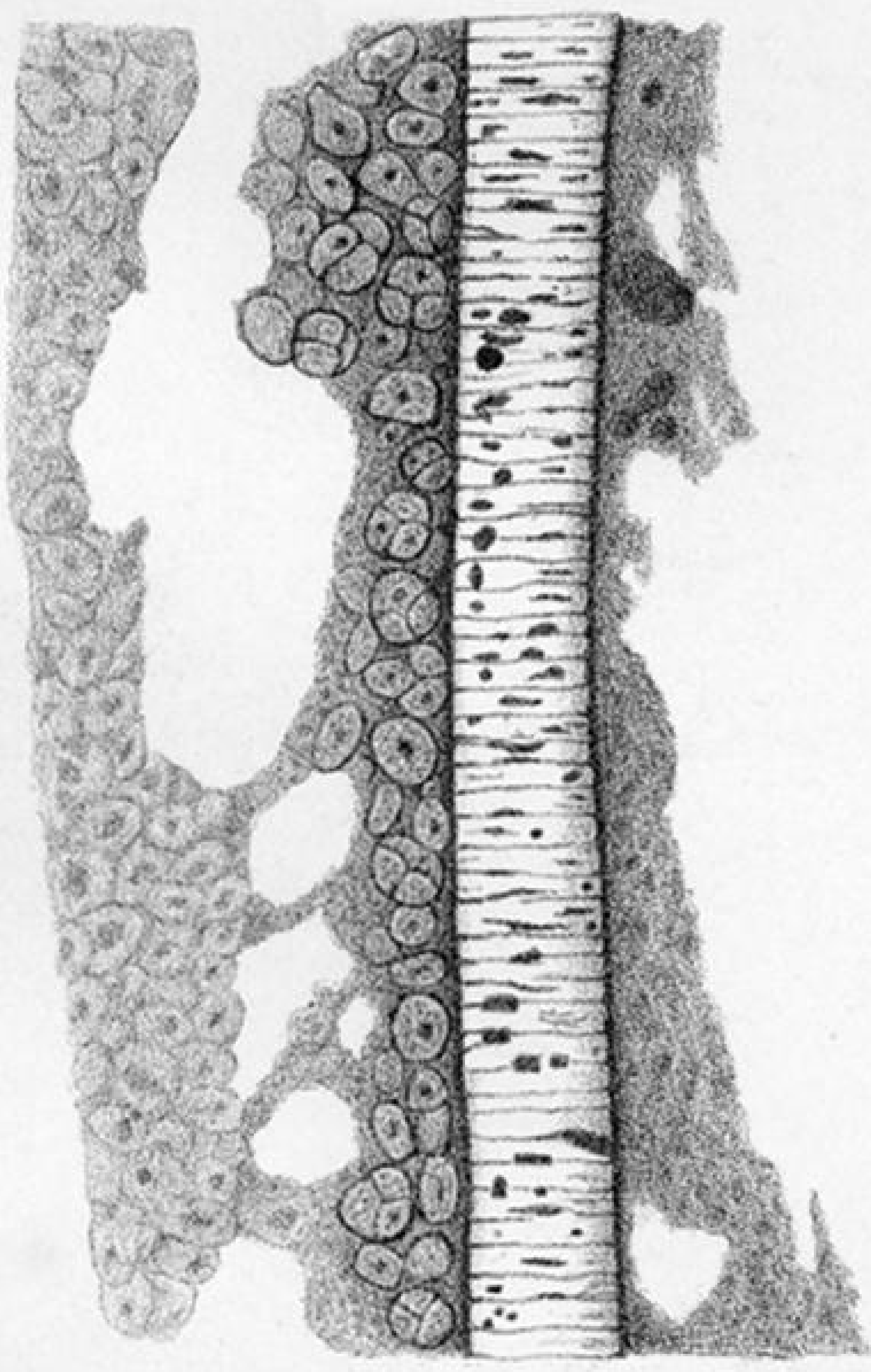


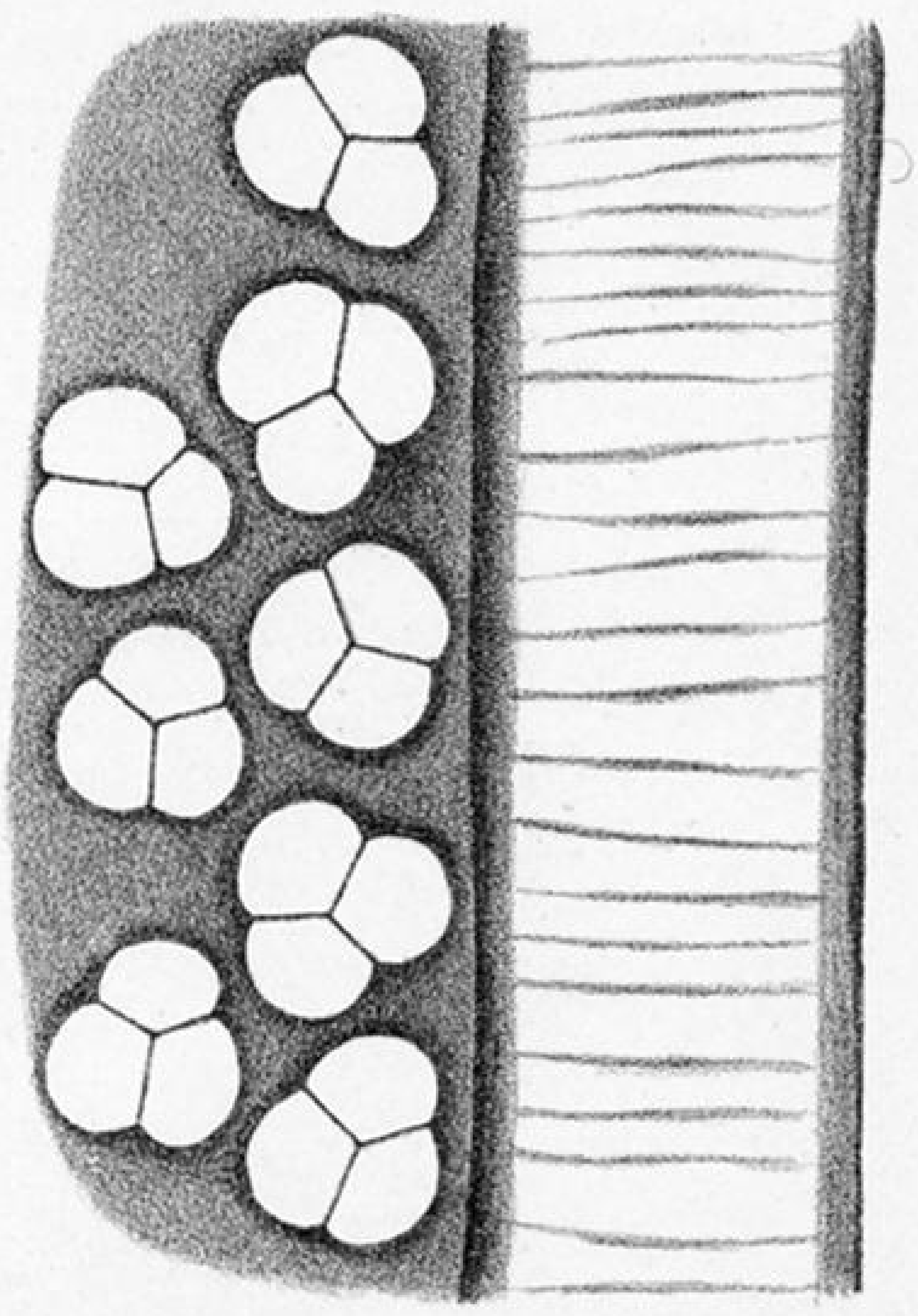
21

× 6



22

× 50



23

× 115

PLATE 39.

Lepidostrobus Fischeri.

Fig. 20 (G. C. H.).—General view of the specimen before any sections were cut. The radial fractures and the oblique terminal fracture (*t*) are shown. *ax*, axis; *sp*, sporophylls. Natural size.

Fig. 21 (G. T. G.).—Radial section, showing a fragment of the axis, sporophyll-pedicels and four sporangia. *sp*, sporophyll base, showing groove on upper surface; *c*, distal crest of the uppermost sporangium. × 6. Section 1.

Fig. 22 (G. T. G.).—Part of a sporangial wall and numerous spore-tetrads. × 50. Section 1.

Fig. 23 (G. T. G.).—Part of another sporangial wall, with a few tetrads; more highly magnified. × about 150. Section 1.