

XXVII.—On the Fossil Osmundaceæ. By R. Kidston, F.R.S. L. & E., F.G.S., Foreign Mem. K. Mineral. Gesell. zu St Petersburg; and D. T. Gwynne-Vaughan, M.A., Lecturer in Botany at Queen Margaret College, Glasgow University. (Plates I.–VI.)

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PART I.

The two new species of *Osmundites* described in this paper are based upon two fossils from the Jurassic rocks near Gore, Otago district, New Zealand. The one was discovered by Mr ROBERT DUNLOP, and the other by Mr ROBERT GIBB. Both specimens eventually came into the possession of Mr DUNLOP, who generously handed them over to the authors for investigation, with full permission to have them cut for microscopical examination, and to whom we take this opportunity of expressing our indebtedness.

Osmundites Dunlopi, n.sp.

(Plates I., II., and III., figs. 1–16.)

The specimen is preserved in silica, and the plant appears to have suffered a certain amount of decay and attrition before it finally became embedded in the rock. The fossil was collected *in situ*, and impressions of the leaves of *Cladophebis denticulata*, Brongt. sp., were also found in the same bed. The specimen measured 9 cm. across its widest, and 6 cm. across its narrowest part, and contained a portion of the stem about 3 cm. long. The stem itself was to be seen in transverse section on both surfaces of the block; but the greater part of the fossil consisted of a very large number of overlapping leaf-bases packed closely round the axis (Pl. I., fig. 1). The stem itself is about 17 mm. in diameter, and its external limit is indicated by the letter α in the figure. The outer region of the cortex is sclerotic, and stands out clearly even in surface view.

Fig. 2, Pl. I., is a photograph of a transverse section, and it shows that, while the sclerotic tissues are fairly well preserved, the thin-walled tissues had decayed before fossilisation, leaving spaces now filled with finely granular matter in which the cellular structure is only rarely indicated. In no case, however, do these spaces represent actual lacunæ, and it may be safely assumed that in life they were occupied by thin-walled tissues analogous to those present in the corresponding regions in the other species of the order.

The wide central pith is represented by a space that is surrounded by an almost continuous ring of xylem about 5 mm. in diameter (fig. 2, *xy.*), which in the fossil has become accidentally fractured at several points. Neither the inner cortex (fig. 2, *i.c.*) nor the peripheral tissues of the stele have been preserved, but they have left a space traversed by several of the departing leaf-traces. The outer region of the cortex (fig. 2, *o.c.*) was sclerotic, and at certain points, which appear as dark patches, it is still in sufficiently good condition to show that it consisted of narrow, thick-walled fibrous elements. The leaf-traces in this sclerotic region were surrounded by a sheath of parenchyma continuous with that of the inner cortex, but it has decayed away, and the leaf-traces appear to lie loosely in so many cavities in the sclerotic outer cortex. Some other smaller light-coloured spaces are also present in the outer cortex (fig. 2, *R.*), which represent roots cut across in various directions as they pass outwards.

The actual limit of the stem itself coincides with the periphery of the cortical sclerenchyma (fig. 2, *a.*), and this is surrounded by a thick coating of closely adpressed leaf-bases which may have been more or less conerescent in close proximity to the axis. In this region of the fossil, however, each leaf-base is distinguished by a special ring of dense sclerenchyma which is continuous below with the outer cortex of the stem. The space between the separate sclerotic rings is occupied by a large number of small sclerotic strands of irregular and varied form, scattered in a matrix of finely granular matter, to which attention will be presently directed.

At first sight the sclerotic rings of the leaf-bases appear to increase in size gradually towards without, at the same time becoming tangentially flattened and variously twisted and contorted. If, however, the coating of leaf-traces be more closely scrutinised as a whole, four more or less distinctly concentric zones (fig. 2, *sc. L.*) can be made out in which the sclerotic rings are especially ill-developed and small in size. These zones successively interrupt the regularity of the increase in size of the leaf-bases towards without, and no doubt they represent zones of scale-leaves with abortive laminae similar to those occurring in certain of the modern *Osmundaceae*.

DETAILED DESCRIPTION OF THE STEM.

The most important anatomical character of this species is the almost complete absence of leaf-gaps in the xylem ring of the stem. The fact is that most of the leaf-traces, if not all, depart without in any way interrupting the continuity of the xylem ring, so that the "medullary rays" characteristic of the Osmundaceous stele in general are almost or completely absent. The xylem ring is irregularly and rather deeply indented along both its margins (Pl. I., fig. 3), and before or during fossilisation it became crushed at some points and broken right across at others. Most of these breaks in the xylem ring are clearly due to accident, but it is just possible that some of them may have been occupied by thin-walled cells which decayed before fossilisation. Even if such medullary rays actually were present in the living plant, they must

have been extremely narrow and very rare. Figs. 3, Pl. I., and 4 and 5, Pl. II., illustrate the manner in which most of the leaf-traces, if not all, left the stele; and reference to the longitudinal sections (Pl. II., figs. 6–8) will make it clear that no medullary ray is caused by the departure of the xylem of the leaf-trace, and that the continuity of the deeper portion of the xylem ring is undisturbed. The xylem strand of the leaf-trace, when immediately outside the stele, appears to have a median adaxial group of protoxylem, but it is very indistinct, and once the xylem of the leaf-trace has joined on to that of the stem it can no longer be recognised with certainty. It is not accompanied by parenchyma as in the living *Osmundaceæ*, and must have died out almost at once.

The xylem ring consists of tracheides alone, without any admixture of parenchyma. It is on an average about six or seven elements thick, and the tracheides undergo a marked decrease in size towards without. As seen in transverse section (Pl. II., fig. 9), most of the tracheide walls have a curious speckled appearance, owing to the presence of certain small black masses in their substance: two or even three of these black marks may occur in the same wall. The same fact was noted by PENHALLOW in *Osmundites skidegatensis* (1), and he points out that it is also to be observed in *Osmunda* and *Todea*. The examination of the living genera shows at once that these markings are due to the presence of more than one vertical series of pits on the same wall of the tracheide. The solid unpitted parts of the wall between the several series of pits give rise to the marks seen in transverse section. In *Todea barbara*, *Osmunda cinnamomea*, etc., the small outer tracheides show typical scalariform markings, but in most of the larger ones the single series of pits on the vertical walls is replaced here and there by two or even three series (Pl. II., figs. 10–11). In *Osmundites Dunlopi* the pits seem to have been more or less oval, and in one of the leaf-traces which was cut obliquely the general suggestion is of porose pitting (Pl. II., fig. 12), but in the stem the tracheides are not sufficiently well preserved to make sure of the real nature of their marking. Unfortunately, the small fragment which was available for longitudinal sections was the worst preserved portion of the specimen, and the tracheides showed no markings whatever.

There is no trace of cell-structure left in the pith or in the region of the stele just outside the xylem. In one of the sections, however, the stele is surrounded at a short distance from the xylem ring by a circle of small black marks and dots which undoubtedly represents the endodermis, and consists of the remains of the more persistent parts of its walls. A similar endodermis also clearly outlines the leaf-traces as they pass through the destroyed inner cortex (Pl. II., fig. 13). In this region the leaf-trace is elliptic or at most slightly reniform in section, and its xylem strand has the same form with somewhat enlarged ends. The outline of the leaf-trace remains the same even in the sclerotic outer cortex, but its xylem strand becomes rather more curved, and a median adaxial group of protoxylem now becomes quite distinct.

THE BASE OF THE PETIOLE.

Once the leaf-trace has passed into the petiole it increases rapidly in size and becomes much more curved, taking successively the form of a crescent, a semicircle (Pl. III., fig. 14), an arch, and finally of a horse-shoe with deeply incurved ends. The median protoxylem group becomes broader and more prominent as it passes out. Finally it divides into two, and then into several separate groups (Pl. III., fig. 15), twenty or more being present in the outermost leaf-bases. The phloem is nowhere preserved, and only in a few of the outer leaf-bases are any indications to be found of the thin-walled cells that occupied the space between the leaf-trace and the sclerotic ring of the petiole (Pl. III., fig. 14). A number of isolated strands of sclerenchyma occur in this tissue, scattered on all sides of the leaf-trace and also in its concavity (Pl. VI., fig. 3). They are very irregular in size and form, but two of them are very much larger than the rest and are constant in position. They lie in the two bays formed by the incurved ends of the leaf-trace, and in immediate contact with it. These strands are increasingly conspicuous in the outer leaf-bases (Pl. I., fig. 2, *scl.*).

In the actual living plant the sclerotic ring of each leaf-base was surrounded by thin-walled tissue, which was prolonged on either side of the petiole so as to form two stout and wide stipular wings. This tissue does not exist as such in the fossil, but is represented by the matrix that fills up the spaces between the sclerotic rings of the petioles. The stipules also contained a very large number of thick-walled fibrous elements, which were embedded in this parenchyma, and these still remain *in situ*. They occur for the most part as isolated fibres, but they are also grouped together to form so many strands of various shapes and sizes, which are scattered irregularly throughout the substance of the stipule (Pl. III., fig. 16). A general idea of the distribution of all this sclerenchyma may be obtained from Pl. VI., fig. 3, which is a diagrammatic reconstruction of a section of a leaf-base situated at some distance from the stem. Towards below the leaf-bases all appear to become concreescent by their parenchymatous stipules. The sclerotic strands of the stipules are already present even in this region, but those lying within the sclerotic ring of the petiole do not appear until further out.

The smaller leaf-bases that are supposed to represent scale-leaves do not differ from the rest in structure, except that the xylem of the leaf-trace is very poorly developed. It would seem, indeed, that only a very few tracheides in immediate contact with the protoxylem elements ever become fully differentiated, the rest of the metaxylem remaining permanently thin-walled. This actually proved to be the case in the scale-leaves of *Osmunda Claytoniana* and *O. cinnamomea*. A full-sized leaf-trace is laid down by the meristem of the leaf-rudiment, but their protoxylem elements alone appear to be sufficient to meet the diminished water-supply needed by the abortive leaf throughout its life, and except at the very base of the scale the metaxylem elements remain permanently unthickened and unligified. This metaxylem, therefore, provides an unusual and instructive example of an undoubted vestigial tissue. Further, it suggests

that the production of scale-leaves was initially due to certain adverse external conditions which so reduced the vegetative energy of the plant that certain of the leaf-rudiments were unable to attain their full development as foliage-leaves. That these abortive leaves have acquired protective and storage functions is a secondary and an incidental phenomenon.

THE ROOT.

Numerous roots run in all directions through the cortex of the stem and through the coating of leaf-bases (*r.* in Pl. I., fig. 2, and Pl. III., figs. 15–16). They bore their way through the stipular wings of the leaf-bases, but are unable to perforate the sclerotic rings. They arise upon the leaf-traces after the latter have become free from the stele of the stem—one from each margin of the leaf-trace (Pl. II., fig. 13, *r.*). No case was found in which the xylem of the root was directly inserted upon that of the stem. Their xylem strand was diarch in every case observed. The roots obtain a cortex of their own while passing through the outer cortex of the stem (*r.* in fig. 2, Pl. I.). At first it consists of a thin-walled inner and a sclerotic outer zone, but in the peripheral region of the fossil it appears to be all thin-walled.

Osmundites Gibbiana, n.sp.

Plate III., figs. 17–19, and Plate IV., fig. 20.

The single specimen of *Osmundites Gibbiana* that was found had the form of a small oval disc measuring 4·5 by 5 cm. in diameter and slightly under 2 cm. in thickness (Pl. III., fig. 17). It consisted of a portion of the stem of the plant surrounded by a thick coat of compacted leaf-bases. Before mineralisation took place, the softer tissues of the leaf-bases in the immediate neighbourhood of the stem had somewhat decayed, causing this part of the fossil to sink inwards and produce a shallow circular trough surrounding the stem, which projected from the centre of the fossil as shown in the figure. The specimen was found loose, but Mr DUNLOP, who was present when it was discovered, assures us that there can be no doubt that it came from the same bed as *Osmundites Dunlopi*. The stem itself is about 1·5–1·7 cm. in diameter, and its external limit lies about the point marked *a* in fig. 18, Pl. III. In close proximity to the stem the ensheathing leaf-bases are very tightly packed, but further out they become gradually larger and more distinct, the outermost of all being more or less triangular in section. The state of preservation is much the same as in *Osmundites Dunlopi*.

As seen in section, the axis of the stem is occupied by a fairly wide space representing the pith, which is surrounded by a ring of xylem still well preserved. The inner cortex and the peripheral tissues of the stele were greatly decayed before fossilisation, but the fibrous sclerotic elements of the broad outer cortex (*o.c.*, fig. 18, Pl. III.) were

still in good condition. Numerous leaf-traces are seen traversing the cortex, and in the outer sclerotic region they are surrounded by rhomboidal areas formerly occupied by thin-walled tissue. Beyond the limit of the stem itself, each leaf-base is represented by its own sclerotic ring, and, as already described in *Osmundites Dunlopi*, the space between the rings was occupied in the living plant by the tissues of the more or less concrescent stipular wings of the leaf-bases. As represented by their sclerotic rings, the leaf-bases gradually increase in size towards without, with the exception of two more or less distinct concentric zones of especially small and ill-developed rings apparently belonging to scale-leaves (*sc. L.* in fig. 18, Pl. III.).

DETAILED DESCRIPTION OF THE STEM.

The xylem ring is irregularly oval in outline, possibly owing to compression. It is 2.5 by 4.5 mm. in diameter, and consists of about twenty distinctly separate strands. The strands vary much in form and size (Pl. III., fig. 19), and were separated from each other by tracts of thin-walled tissue corresponding to the "medullary rays" of the modern *Osmundaceæ*. In the fossil, however, this tissue has entirely disappeared. The different forms assumed by the xylem strands are dependent upon their relation to the departing leaf-traces and upon their proximity to the points at which they fuse with each other. The effect of these relations upon the form of the strands will be easiest understood by reference to Pl. VI., fig. 1, which is a diagrammatic plan of the xylem system of *Osmunda regalis*.

It is perfectly clear that the xylem system of the fossil constitutes a precisely similar network, the gaps in which are caused by the departure of xylem to the leaf-traces and give rise to the so-called medullary rays. Referring to the diagram, it is seen that when the leaf-trace xylem enters the stele of the stem its ends join on to the backs of two adjacent strands of the xylem ring. A single strand is thus produced, which, seen in section, is shaped like an arch. The concavity of the arch is at first continuous with the pith, and the protoxylem strand of the leaf-trace is continued downwards in the median region of its inner surface (Pl. III., fig. 19, *xy.*¹). If this strand is followed down the stem, the two sides of the arch gradually approach each other until they meet and fuse by their inner ends. A small island of parenchyma is thus enclosed within the concavity of the arch surrounding the protoxylem, which may now be regarded as mesarch. As it passes downward, the island of parenchyma gradually becomes smaller until it disappears altogether. The xylem strand is now solid, with a mesarch protoxylem (Pl. III., fig. 19, *xy.*²), which, however, below this point rapidly becomes unrecognisable. Concurrently with these changes an indentation appears on the outside of the xylem strand, which progresses inwards until the strand is divided into two. Subsequently the entrance of other leaf-traces joins up these strands with those lying next to them in the xylem ring (Pl. III., fig. 19, *lt.*¹), and the same series of changes are again repeated.

The xylem itself is not so well preserved as in *Osmundites Dunlopi*, but on the broader walls of the tracheides dark marks are to be seen which indicate the presence of more than one vertical series of pits. In this species the tracheides are about the same size on the outside of the xylem ring as they are on the inside. There is no parenchyma among the tracheides of the xylem, apart from that surrounding the protoxylem elements.

Although the peripheral tissues of the stele are very much disorganised, distinct indications of the larger sieve-tubes are still to be made out on the outside of the xylem ring (Pl. III., fig. 19, *S.T.*). They occur as wedge-like groups projecting shortly into the medullary rays, and they also form a row on the outside of most of the xylem strands. The outer limit of the stele is clearly defined by the remains of an indubitable endodermis (Pl. III., fig. 19, *en.*), but the structure of the medullary tissue on the inside of the xylem ring is no longer recognisable.

In the inner cortex, just outside the stele, the leaf-traces are elliptic or slightly reniform in section, and their xylem strands are of the same form, with a single median adaxial protoxylem (Pl. III., fig. 11, *lt.*²). The leaf-trace as a whole is clearly delimited by the remains of an endodermis, and there are indications of a row of sieve-tubes on the abaxial side of the xylem. The leaf-trace itself retains the same form until it has passed through the sclerotic outer cortex of the stem, but its xylem strand becomes more distinctly curved.

STRUCTURE OF THE LEAF-BASE.

Passing out towards the periphery of the fossil, the leaf-trace undergoes the same series of changes as in *Osmundites Dunlopi*, until in the outermost leaf-bases it has the form of a horse-shoe with deeply inrolled ends. The xylem strand is thin, and so badly preserved that the protoxylem groups are not to be distinguished (Pl. IV., fig. 20, *lt. xy.*). It is usually surrounded by a sheath of crushed elements in which no distinct tissues can be recognised. The thin-walled elements lying between the leaf-trace and the sclerotic ring of the petiole have left no remains; but several small strands of sclerenchyma are present which are still preserved. They occur on all sides of the leaf-trace and also in its concavity, but the two especially conspicuous strands lying in the bays formed by the incurved ends of the leaf-trace in *Osmundites Dunlopi* are wanting in this species. The leaf-base possessed the same stipular wings as in *O. Dunlopi*, but they are not so thick, and the sclerotic strands they contain are not irregularly scattered, but are arranged in a single series in each wing of the stipule (Pl. IV., fig. 20, *sc. st.*). This is best seen in Pl. VI., fig. 4, which is a diagrammatic restoration of one of the outer leaf-bases. The largest of these strands is nearest the sclerotic ring of the petiole, to which it is often more or less attached, and they gradually decrease in size towards the thin edge of the stipule. The larger strands are distinctly oblong in form, with the long axis at right angles to the surface. The stipular wings were probably more or less

conerescent in close proximity to the stem, as in the modern *Osmundaceæ*. As in *Osmundites Dunlopi*, the xylem strands of the small leaf-bases supposed to belong to scale-leaves were very badly preserved, and it seems probable that those elements only of the metaxylem which were in immediate contact with the protoxylem groups were ever fully differentiated (Pl. IV., fig. 20, *Sc.L.*).

THE ROOTS.

The root steles in this species are very small and delicate, with a diarch xylem strand of very few elements. They arise from the margins of the leaf-traces as they pass through the inner cortex of the stem; apparently not in pairs, but one from each leaf-trace. The root does not obtain a cortex of its own in its passage through the stem, and those that occur in the coating of leaf-bases are so badly preserved that nothing can be made out in them except that they seem to have had no cortical sclerenchyma at all.

AFFINITIES.

The two fossil stems just described agree so exactly in all essential characters with the stems of the modern *Osmundaceæ* that we have no hesitation in including them in this order. Again, they differ from each other so much in detail, they undoubtedly represent two distinct species. On the other hand, it is a very difficult matter to decide whether they belong to the same genus or not, and, in any case, whether they may be identified either with the modern genus *Osmunda* or with *Todea*. In the first place, a careful examination of the stocks of the living representatives of the order only provided a single morphological criterion whereby any given Osmundaceous stock may be definitely assigned to one or the other of the two genera. This distinction is the presence of a transverse commissure formed by the fusion of the upper part of the stipular wings across the adaxial side of the petiole in the Todeas (*T. barbara*, *T. superba*, *T. hymenophylloides*, and *T. Frazeri*), which appears to be entirely absent in the Osmundas (*O. regalis*, *O. Javanica*, *O. cinnamomea*, *O. Claytoniana*). Unfortunately, this does not help us at all with the fossils, because the preservation is not good enough to determine whether a transverse commissure was present or not in either of them.

The only thing to be done, therefore, is to obtain some convenient and reliable anatomical characters which will serve to distinguish between the several living species of the whole order, considered separately and without respect to the genera to which they belong, and then to apply these to the fossils. Such distinctive characters proved, however, to be very difficult to discover; in fact, we have been reduced to the selection of the sclerenchyma in the base of the petiole. The arrangement of the sclerotic tissues in most Ferns is admittedly a variable and insecure feature for such a purpose, but it was found that in the *Osmundaceæ* the various sclerotic strands that occur in the base

of the fully developed petiole are distributed in a manner characteristic of, and practically constant in, each species examined. At the same time, it varies sufficiently from one species to another to render it suitable for the purpose of comparison. The diagrams given in the figs. 6-12, Pl. VI., indicate the arrangement of the sclerenchyma as seen in a section taken about half-way up the stipular region of the petiole in the various living species examined. On comparing them with the fossils, it is seen at once that the leaf-base of *Osmundites Dunlopi* (fig. 3, Pl. VI.) comes very near that of *Todea barbara* (fig. 7, Pl. VI.); while *Osmundites Gibbiana* (fig. 4, Pl. VI.) (although in some respects unique) approaches nearest to *Osmunda regalis* and *O. Javanica* (Pl. VI., figs. 6 and 8.).

While referring to these diagrams, it should also be mentioned that the two American species, *Osmunda cinnamomea* (Pl. VI., fig. 11) and *O. Claytoniana* (Pl. VII., fig. 12) distinguish themselves from all the rest by the fact that their sclerotic ring is not homogeneous, but masses of specially dense and thick-walled elements occur at certain well-defined points in it.

In the stem itself the most important anatomical character that shows any considerable variation in the living species (apart from *Osmunda cinnamomea*) is the extent of the interruption in the continuity of the xylem ring caused by the departure of the leaf-traces. *Osmunda regalis* may be taken to represent one extreme of this variation, in which the xylem ring is broken up into so many distinctly separate strands which are quite free from one another, at any rate over part of their course (Pl. VI., fig. 1). The other extreme is represented by *Todea barbara* and *T. superba*, in which the strands are fused with each other and with the xylem of the leaf-traces, so as to form continuous bands often of considerable extent (Pl. VI., fig. 2). As regards the two fossil species, *Osmundites Dunlopi*, with a practically continuous xylem ring, clearly points in the direction of *Todea barbara*, while *Osmundites Gibbiana* points in the direction of *Osmunda regalis*. So far as our own data permit us to judge, it appears that among the living *Osmundaceæ*, *Todea barbara* shows most resemblance to *Osmundites Dunlopi*, and *Osmunda regalis* to *Osmundites Gibbiana*. Nevertheless, it does not follow that the two fossils actually belong to these two genera, and, until their spore-bearing leaves are also known, it is advisable that both should remain in the comprehensive fossil genus *Osmundites*. The question now to be considered is whether our fossils are identical with any of the three other previously described species of the genus. The first of these was found in the year 1847 by PETTKO (2) in Tertiary quartz in Hungary, and was described by him in 1850 under the name of *Tubicaulis*. It was again briefly described by UNGER (3) in 1854, who correctly named it *Osmundites schemnicensis*. In 1870, *Osmundites Dowkeri* was obtained by CARRUTHERS (4) from the Lower Eocene of Herne Bay, and in 1902 PENHALLOW (5) described *Osmundites skidegatensis* from the Lower Cretaceous in Canada. SEWARD and FORD (6) also refer to a section of an unnamed *Osmundites* preserved in the collection of the botanical department of the British Museum, and labelled "New Zealand." Through

the kindness of Dr Rendle, we have been able to examine this specimen, and we find that it is identical with *Osmundites Dunlopi*. The xylem ring of the stele is poorly preserved, and is much more crushed and broken up than in our specimen, many of the pieces being pushed out of alignment with the rest of the ring; nevertheless, we are satisfied that most, if not all, the gaps that occur in it are really true fractures and not medullary rays. In all other respects it corresponds exactly with our specimen, especially in the distribution of the sclerenchyma in the stipules, which are here clearly delimited from each other by brown lines. Seven zones of scale-leaves are visible in the coating of leaf-bases, and, as in our specimen, their xylem strands are very poorly developed. Another fossil stem with structure preserved has been referred by SOLMS LAUBACH to *Osmundites* (*Fossil Botany*, p. 172). It was found loose in the alluvium of the lower course of the Lena, in Siberia, and has not yet been fully described.

So far as our fossils are concerned, *Osmundites skidegatensis* may at once be removed from the comparison, for its structure is so unique and extraordinary that it will have to be dealt with apart and in some detail later on. Both *Osmundites Dowkeri* and *O. schemnicensis* clearly belong to the type of xylem ring represented by *Osmunda regalis* and *Osmundites Gibbiana*, and therefore *Osmundites Dunlopi* stands alone, and is undoubtedly a distinct and a new species.

Through the courtesy of Dr A. SMITH WOODWARD, F.R.S., we have been able to examine a section of CARRUTHERS' specimen of *Osmundites Dowkeri*, and, as will be presently shown, so many points of difference are to be found between it and *O. Gibbiana* that they must clearly be held to represent two separate species. As regards *Osmundites schemnicensis*, the descriptions given by PETRKO and UNGER are not detailed enough for an accurate comparison; but, so far as may be judged from their figures, it appears to be distinct from *O. Gibbiana*, while it is very near to, possibly even identical with, *O. Dowkeri*.

Osmundites Dowkeri, Carruthers.

(Plate IV., fig. 21.)

1870. *Osmundites Dowkeri*, Carr., *Quart. Jour. Geol. Soc. Lond.*, vol. xxvi. p. 349, pl. xxiv. figs. 1-3, and pl. xxv. figs. 1-4.

A strong dissimilarity in general appearance is at once apparent between *Osmundites Gibbiana* and *O. Dowkeri*, if fig. 18, Pl. IV., be compared with fig. 21, Pl. IV., which is a photograph of a section of the latter. The numerous differences in detail which also exist will now be pointed out. Unfortunately, from our point of view, CARRUTHERS' specimen had been attacked by the mycelium of a fungus which had wrought so great destruction among the tissues, before fossilisation set in, that accurate interpretation of their original structure is rendered somewhat difficult. The delicate septate hyphæ of the fungus are most beautifully preserved, and at certain points they seem to have

formed numbers of small, oval, dark-coloured spores. The stele of *Osmundites Dowkeri* in all essentials closely resembles that of *O. Gibbiana*. There are about thirty separate strands in the xylem ring, and many of the tracheides have more than one vertical series of pits on their broader walls. The phloem is too badly preserved to show whether there was a porose layer or not. The pith is still intact and fairly well preserved (Pl. IV., fig. 21, *P.*). It consisted of rather thick-walled parenchymatous cells with conspicuous coarse, irregular reticulate markings on their walls. The elements at the periphery of the pith are smaller and more sclerotic than the rest, and some of the central cells appear to be thin-walled, but this may be an accident of preservation. A marked feature of *Osmundites Dowkeri* is the strong curve taken up by the xylem of the leaf-trace almost immediately it has left the stele (Pl. IV., fig. 21). In *O. Gibbiana* the curve is only very slight until the leaf-trace has left the cortex of the stem. The coating of leaf-bases is well preserved in *Osmundites Dowkeri*; even the parenchymatous tissues of the stipules are still present. Towards the periphery of the section the limits between the separate stipules are clearly marked out by brown lines, although in close proximity to the axis they are all concrescent. The diagram text fig. 5 represents a restoration of a section of the leaf-base of *Osmundites Dowkeri*, showing the distribution of the sclerenchyma, and it is altogether distinct from that of *O. Gibbiana* (Pl. VI., fig. 4). The stipule as a whole is much thicker in proportion to its length, and, in particular, the single series of oblong sclerotic strands in the wing of *Osmundites Gibbiana* are here replaced by a number of more or less rounded strands scattered irregularly and at different levels in the thickness of the stipule. In both species isolated strands of sclerenchyma occur within the sclerotic ring, but the stout band of sclerenchyma that lies in contact with the concave surface of the leaf-trace in *Osmundites Dowkeri* was not to be found in *O. Gibbiana*.

THE ROOT.

The roots arise one at a time, or possibly sometimes in pairs, at the angles of the leaf-gap, before the leaf-trace is yet free from the stele of the stem. The xylem strand is always diarch, and the root obtains a cortex of its own while passing through the outer cortex of the stem. The outer zone of this cortex is at first heavily sclerotic, but as the root passes outward it becomes all more or less thin-walled. The number of roots that occur among the leaf-bases is very large, and they differ considerably in size and structure. The smallest roots are exceedingly delicate, with a very small stele. The endodermis consists of some six to nine rather flattened cells, and these are surrounded by the same number of especially large cortical cells filled with some finely granular matter. There is no reason, however, to believe that these smaller roots belong to some other plant. They are very probably branches borne by the larger main roots; indeed, one case of branching was actually observed. Moreover, excellent examples of branching roots within the coating of leaf-bases are provided by *Osmunda Claytoniana*.

and *O. cinnamomea*. In these plants the young roots that arise near the growing point of the stem are not able to bore their way straight out through the coating of leaf-bases. The older leaf-bases near the outside appear to be too tough for them to penetrate. So they eventually turn upwards and become flattened out between the closely packed leaf-bases. At the same time they branch copiously in a distichous manner. Many of these roots never reach the soil until the old leaf-bases lying outside them rot away. Some of them, however, may do so by growing on upwards until they have over-topped the coating of leaf-bases.

Osmundites skidegatensis, Penhallow.

Plate IV., figs. 22, 23, and Plate V., figs. 24-28.

1902. *Osmundites skidegatensis*, Penhallow, *Trans. Roy. Soc. Canada*, ser. 2, vol. viii. p. 3, pls. i.-iv., figs. 1-8.

1902. *Osmundites skidegatensis*, Penhallow, *ibid.* p. 32, pls. vii.-xi.

Our attention was first drawn to the remarkable structure of this plant by the inspection of the admirable photographs given by Professor PENHALLOW in his original description of the species, and on communicating with him he at once most generously presented us with a transverse section of his fossil. A photograph of this section is shown on Pl. IV, fig. 22. The section includes but little more of the stem than the stele itself, and since this alone measures as much as 2.4 cm. in diameter, it follows that the whole stock, with its coating of leaf-bases, must have been very much larger than that of any known member of the *Osmundaceæ*. The structure of this plant has such an important bearing upon the discussion of the vascular morphology of the order that it is necessary, even at the risk of some repetition, to deal with it here in full detail, in order that a proper appreciation of its relation to the other species may be attained.

STRUCTURE OF THE STEM.

The xylem ring of the stele contains about fifty very distinctly separate strands, and, so far as the relation of these strands to one another and to the entering leaf-traces is concerned, it clearly belongs to the type represented by *Osmunda regalis*. The xylem ring surrounds a very wide pith (Pl. IV., figs. 22 and 23, *P.*), which consists partly of thin-walled and partly of thick-walled sclerotic cells. The latter occur in scattered groups of various forms and sizes. The most startling point in its anatomy, however, is the fact that the departure of each leaf-trace interrupts the continuity of the whole vascular ring. Not only is there a gap left in the xylem ring, but also in the phloem, and through this gap the tissue of the pith becomes perfectly continuous with that of the cortex in the axil of the leaf-trace (Pl. IV., fig. 22, *b.*, fig. 23, *lg.*, and Pl. V., fig. 25). But this is not all, for the inner margin of the xylem is surrounded by a ring of internal phloem (Pl. IV., fig. 23, *int. ph.*, and Pl. V., figs. 24, and 27, *int. ph.*), and at the

departure of each leaf-trace this internal phloem becomes continuous with the external phloem along both sides of the leaf-gap (Pl. V., figs. 24, 25, and 26, *l.g. ph.*). The external phloem presents the same peculiarities as that in the modern *Osmundaceæ*. The sieve-tubes of the metaphloem are plentiful and large, and they are separated from the tracheides of the xylem by a broad stratum of parenchyma four to five cells thick (Pl. V., figs. 25 and 26, *par.*). There is no true protophloem, but the metaphloem is immediately followed towards without by eight to ten layers of cells strongly elongated in a tangential direction (Pl. V., figs. 25 and 26, *p.l.*). Their walls sometimes show clear indications of a pitted or sieve-plate marking, and beyond doubt they correspond to the porose layers first mentioned by ZENETTI (7) in the living *Osmundaceæ*. The more peripheral elements of this porose zone are narrower and less tangentially elongated than the rest, and they may perhaps be counted as a normal pericycle. No layer resembling an endodermis can be distinguished in the fossil, and, as stated by PENHALLOW, it is practically impossible to set a definite limit to the stele.

The internal phloem consists of metaphloem alone (Pl. V., fig. 27, *int. ph.*), and as before the sieve-tubes are separated from the inner margin of the xylem by about five layers of parenchyma (Pl. V., fig. 27, *par.*). The porose cells are entirely absent on the inside of the xylem ring, nor are there any tissues present that can be identified with a pericycle or an endodermis.

The internal and external metaphloems are connected above the point of departure of each leaf-trace by two bands of sieve-tubes extending along the two sides of the leaf-gap (Pl. V., figs. 24, 25, and 26, *l.g. ph.*). These sieve-tubes are, as elsewhere, separated from the xylem by about five layers of parenchyma (Pl. V., figs. 25 and 26, *par.*). The median region of the leaf-gap is occupied by a large mass of starch-bearing sclerenchyma, which extends inwards directly into the pith and outwards into the cortex in the axil of the leaf-trace (Pl. V., figs. 24-26, *l.g. sc.*). Above the leaf-departure the porose layers very soon extend again across the leaf-gap so as to close it up on the outside (Pl. V., fig. 26, *p.l.*). The sclerenchyma in the middle of the leaf-gap is separated from the two bands of sieve-tubes that line the sides by about four layers of thin-walled parenchyma (Pl. V., fig. 25, *par.*²). As the leaf-gap becomes narrower towards above (*cf.* the diagram of *Osmunda regalis*, Plate VI., fig. 1), the sclerenchyma gradually diminishes in quantity until at length the two lateral bands of phloem come into contact in the median region of the gap (Pl. V., fig. 24, *lg.*¹ and *lg.*²). Still higher up, the two xylem strands themselves fuse together to form a single one. The fusion is at first only partial, beginning in their more central regions, so that the single strand thus formed has a deep groove on its external surface that is still filled by the remains of the median connecting band of phloem (Pl. IV., fig. 23, *xy.*¹ and *xy.*²).

In order to complete the description of the stele, it is necessary, first of all, to give an account of the structure of the leaf-trace, and then to deal with the disposition of the tissues in the regions lying below the leaf-gap after their entry with the leaf-trace. The leaf-trace itself is very large, and it is already strongly curved, even while still in

the parenchymatous inner cortex of the stem (Pl. IV., fig. 23, *lt.*¹). The concavity of the curve is entirely occupied by a mass of dark sclerenchyma. The leaf-trace is completely surrounded by phloem, which is separated from the xylem strand by about four or five layers of parenchyma (Pl. V., fig. 28). A true and perfectly distinct protophloem is present on the abaxial side of the trace, lying on the outside of the clearly centripetal metaphloem. The protophloem elements are particularly conspicuous at two points: one on each side of the back of the leaf-trace (Pl. V., fig. 28, *pr.ph.*). This rather curious arrangement is also present in the leaf-traces of the modern *Osmundaceæ*. In the young leaf-rudiment, it is at these points also that the protophloem is first differentiated; and further, when mucilage sacs are present in the pericycle of the leaf-trace, these are the only points on the abaxial side of the leaf-trace where they occur. To return to the fossil, there is no protophloem at all on the abaxial side of the leaf-trace, but the metaphloem is continued round the ends of the xylem by a layer of fairly large sieve-tubes that extends across the whole concave surface (Pl. V., fig. 28, *ad. ph.*). These sieve-tubes are separated from the sclerenchyma in the concavity of the trace by about three layers of thin-walled cells, which may be regarded as pericycle (Pl. V., fig. 28, *par.*²), but no endodermal layer can be made out on any side of the trace.

When the leaf-trace enters the stele, the ends of its curved xylem strand fuse with the outer surfaces of two adjacent xylem strands of the stele, so as to form a wide and a very deep arch (Pl. IV., fig. 23, *lt.*³). The metaphloem in the concavity of the leaf-trace joins on to that lining the sides of the leaf-gap above, and the median region of the arch is occupied by sclerenchyma continuous with that in the leaf-gap above and with that in the concavity of the leaf-trace (*cf.* text fig. 1). Towards below the inner ends of the xylem arch gradually approach each other (Pl. IV., fig. 23, *lt.*⁴), but before they actually fuse all the phloem lining the concavity of the arch has disappeared. After the fusion, therefore, the xylem strand includes only an island or pocket of sclerenchyma, separated on all sides from the tracheides by several layers of thin-walled parenchyma (Pl. V., fig. 24, *l.g. sc.*). This sclerenchyma is, of course, continuous above with that in the axil of the leaf-trace, but it dies out rapidly towards below, leaving a pocket of parenchyma only (Pl. IV., fig. 23, *xy.*¹ and *xy.*²; *cf.* text fig. 1). This in turn eventually disappears, leaving a comparatively narrow strand of solid xylem, with a mesarch group of protoxylem elements near its external periphery (Pl. IV., fig. 23, *xy.*³), which may be traced upwards into the endarch protoxylem of the leaf-trace, but when traced downwards finally disappears.

Reference must now be made to a very disconcerting phenomenon that occurs in our section of the fossil—to wit, the presence of a certain amount of internal vascular tissue lying in the pith near to one side of the stele, and just within the normal vascular ring (Pl. IV., figs. 22 and 23, *int. str.*). It consists of about seven radially elongated strands of xylem, lying close together and more or less parallel to one another. The more central ends of these xylem strands are surrounded by phloem similar in structure to that in the corresponding position at the inner margin of the normal xylem ring.

This phloem also projects into the spaces separating the internal xylem strands, and in two cases the adjacent strands were further separated by a broad tract of sclerenchyma (Pl. IV., fig. 23, *scl.*). It was not possible to make out definite protoxylem elements

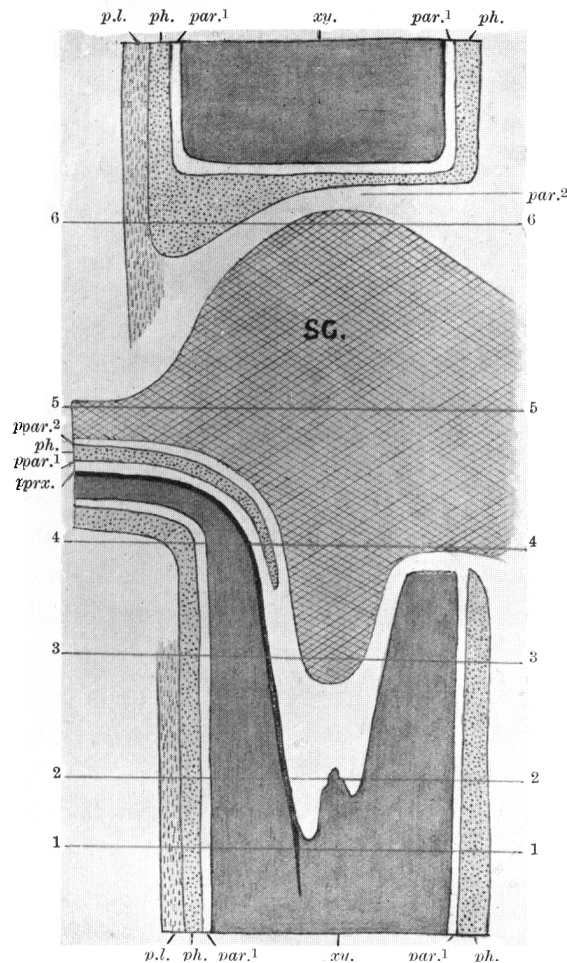


FIG. 1.—Diagrammatic representation of a longitudinal section through the median region of a departing leaf-trace of *Osmundites skidegatus*. The xylem (*xy.*) is evenly shaded; the protoxylem (*prx.*) is dead black; the metaphloem (*ph.*) is dotted; the porose layers (*p.l.*) are shaded with short lines; the sclerenchyma (*sc.*) is cross-hatched, and the parenchyma (*par.*¹ and *par.*²) is left unshaded.

A transverse section taken at the level 1-1 corresponds to the xylem strand *xy.*⁴ in fig. 23, Pl. IV.; at the level 2-2 to the strand *xy.*² in fig. 23, Pl. IV.; at the level 3-3 to the strand marked *Lg. sc.*¹ in fig. 24, Pl. V.; at the level 4-4 to the departing leaf-trace *lt.*³ in fig. 23, Pl. IV.; at the level 5-5 to the leaf-gap *lg.* in fig. 23, Pl. IV.; and at the level 6-6 to the leaf-gap marked *Lg. sc.* in fig. 24, Pl. V.

in the strands, but in one of them there was a group of small tracheides near its outer end which possibly represents protoxylem.

These internal vascular strands have to be accepted as actually present in the living plant, for the continuity of their elements with those of the pith is too perfect for their occurrence to be accidental, or for them to be due to the displacement of a broken-off portion of the normal ring which has slipped down from above, as, at first sight, seemed to be the obvious explanation. At the same time, a letter which we have received from Professor PENHALLOW informs us that this internal vascular tissue is not to be found

in a section taken about 5 mm. above the one we possess, nor in another taken about the same distance below. In face of these facts, we are only able to regard it as an unaccountable anomaly.

The thin-walled inner cortex of the stem is beautifully preserved, and is surrounded by a comparatively narrow sclerotic outer cortex (Pl. IV., figs. 22 and 23, *i.c.* and *o.c.*), but the fossil only includes a very small portion of the coating of leaf-bases. Each petiole has a sclerotic ring of its own, and a few isolated strands of sclerenchyma are scattered in the parenchyma lying between it and the leaf-trace. The concave surface of the latter is also bordered by a broad zone of the same sclerotic tissue (Pl. IV., fig. 23, *lt.*¹). The leaf-bases certainly possessed parenchymatous stipular wings, but even the outermost is cut too near the stem to show the arrangement of the stipular sclerenchyma—if, indeed, they contained any at all.

THE ROOT.

The roots arise directly upon the xylem of the stem, just below the angles of the leaf-gaps. The xylem strand of the root appears to run downwards within the phloem for some distance before it becomes free from the stele of the stem. The xylem of the root is at first rounded in section, and without definite protoxylem elements, but further out it becomes elliptic and diarch. The root obtains a cortex of its own before it has left the tissues of the stem. It consists of two zones, an inner cortex of thin-walled cells and a broad sclerotic outer cortex.

THEORETICAL CONSIDERATIONS.

According to JEFFREY (8) and FAULL (9), the *Osmundaceæ* present a series of reduced structures, so far, at least, as their vascular systems are concerned. This opinion is based upon an attempt to explain the presence of the internal phloem and endodermis discovered by FAULL at the inner margin of the xylem ring of *Osmunda cinnamomea*. The vascular system of this plant is supposed by these authors to have degenerated from a dictyostelic cylinder, the leaf-gaps in which have been reduced to the so-called medullary rays. In *Osmunda cinnamomea*, the internal phloem and endodermis of the confluent meristemes is still retained at any rate in the neighbourhood of the branchings. In the other species of the order, the reduction has gone so far that these tissues have entirely disappeared; except, perhaps, in *Todea hymenophylloides*, where, according to SEWARD and FORD (*l.c.*, p. 249), indications of the internal endodermis are still occasionally to be found. This theory has met with strong opposition from subsequent writers, BOODLE (10), SEWARD and FORD (*l.c.*, p. 255), and CHANDLER (11), who base their objections chiefly upon the absence of confirmatory evidence in the stem of the young plant. We entirely agree with their criticisms, and prefer to regard the Osmundaceous type of vascular system as directly derived from a primitive

stele possessing a true pith, surrounded by a stout and perfectly continuous ring of xylem. The leaf-traces departed from this stele in a protostelic manner, *i.e.* without leaving any depression or gap into which the external tissues could subside. Further, it is possible to regard this stele as derived in turn from a still more primitive protostele with a solid central mass of xylem.

The evidence provided by the fossil *Osmundaceæ*, so far as it goes, may be taken as distinctly in favour of this point of view. For the requisite perfect continuity of the xylem ring is almost, or, as we believe, actually, realised in *Osmundites Dunlopi*, one of the oldest representatives of the order as yet recognised.* This theory is also in full agreement with the ontogenetic evidence. For in several species it has been shown that a continuous ring of xylem is maintained for some distance upwards in the stem of the young plant (*Todea hymenophylloides*, SEWARD and FORD, *l.c.*, p. 241; *T. Frazeri*, CHANDLER, *l.c.*, p. 398; *Osmunda Claytoniana* and *O. cinnamomea*, FAULL, *l.c.*, p. 387). Indeed, the leaf-trace occasionally departs in a protostelic manner, even in the mature stem of *Todea barbara* and *T. hymenophylloides*, as we have ourselves observed; and, judging from the description given by SEWARD and FORD (*cf.* fig. 29, *l.c.*), the same holds good also in *Todea superba*.

It should be noted here that both JEFFREY's view and our own are opposed to the idea accepted by DE BARY (12), that the vascular system of the *Osmundaceæ* is merely a sympodium formed by the lower ends of the leaf-traces. On the contrary, as already pointed out by LACHMANN (13) and by ZENETTI, the xylem strands undoubtedly constitute a cauline network proper to the stem itself.

Although protesting against the application of a theory of reduction to the order as a whole, we do not, of course, reject, *a priori*, the possibility of its occurrence in any one particular species. In fact, each case must be considered on its own merits, and it is obvious that the structure exhibited by *Osmundites skidegatensis* will have an important bearing upon the discussion. This plant at first sight appears to provide something very like the dictyostelic ancestor postulated by JEFFREY's theory, and it certainly establishes the fact that the *Osmundaceæ* in the past have reached a far higher degree in complexity than is represented by any of the living species.

In face of this, the possibility that some of the existing species—*Osmunda cinnamomea*, for instance—are reduced can no longer be summarily rejected even by those who are unwilling to apply a theory of reduction to the order as a whole. While admitting this, we venture at the same time to advance an alternative view. In the first place, we would suggest that the type of dictyostely exhibited by *Osmundites skidegatensis* may have been attained by a "cladosiphonic" and not by a "phyllosiphonic" method. That is to say, the internal phloem may have originated by the subsidence of the external phloem into the pith through gaps in the stele produced by the branching of the stem, and not through the gaps due to the departure of the leaf-traces—as

* Since this paragraph was written we have obtained a fossil Osmundaceous stem which indisputably shows a perfectly unbroken ring of xylem.

appears to have been the case in most of the other Pteridophyte dictyosteles and solenosteles.

This idea leads us to regard *Osmunda cinnamomea* as illustrating one of the simpler stages in an ascending series of cladosiphonic structures that have culminated in the complexity of *Osmundites skidegatensis*, and certain points in the anatomy of the former plant seem distinctly in favour of this view. For instance, the internal phloem does not occur in all regions of the stem, but is more or less closely confined to the neighbourhood of the points of branching. Even at these points it is sometimes wanting, as in those cases when the stele branches by a simple median constriction without forming a gap in the xylem ring. Indeed, it seems that it is never present under such conditions; but existing observations on this point are not conclusive. Again, whenever the internal phloem actually is present it is invariably continuous with the external phloem through a gap caused by the branching of the stele; and further, the amount of internal phloem present is closely related to the extent of the opening in the stele. The significance of these facts is accentuated by the phenomena that we observed in a case of branching in *Todea barbara*. Here the xylem ring of the stele opened up in the sinus between the two branches, and the external phloem subsided through the gap for a considerable distance into the medulla of the main axis below the branching. It should be mentioned that in this case neither the porose layer nor the endodermis was decurrent. It is possible, however, that further developments on this line might be met with if other cases of branching could be obtained.

If it were once conceded that the internal phloem obtained admission in this cladosiphonic manner, it is easy to conceive of the subsequent changes that would result in the structure of *Osmundites skidegatensis*. Concurrently with the distension of the stele and the widening of the leaf-gaps incidental to the departure of such large leaf-traces as are possessed by this plant, the phloem would tend to project more and more deeply into the medullary rays both from the inside and from the outside. In fact, according to JEFFREY and FAULL it is already beginning to do so in *Osmunda cinnamomea*. Then the internal and external phloems would meet so as to form a phloem ray, and later the central ground-tissue would project into the median region of this phloem, separating it into two layers lining the sides of the leaf-gap. The two strips of parenchyma lying between these layers of phloem and the xylem now represent all that is left of the original medullary ray tissue. A still further outward extension of the internal ground-tissue would cause the complete disruption of the peripheral tissues of the stele at the level of the departing leaf-trace (*cf.* text fig. 1), and the structure of *Osmundites skidegatensis* would now be attained. Regarded in this light, the continuity of the internal ground-tissue with the external is a secondary and not a primary phenomenon.

The fact that an internal endodermis is always present in *Osmunda cinnamomea*, even in those parts of the stem where no phloem is to be found, may possibly be advanced as an objection to this theory. However, there is, in the first place, no necessity whatever to assume that the internal endodermis actually originated in

continuity with the outer. It is quite probable that the medullary endodermis was already present before ever the stele opened at a branch-gap. In fact, SEWARD and FORD's discovery of an occasional internal endodermis in *Todea hymenophylloides* (l.c., p. 249) that never comes into contact with the external endodermis seems to give support to this view. If, on the other hand, we assume that the two endodermes are really homologous, it is true that initially the phloem must have found its way into the medulla before the endodermis; but it by no means follows that the two tissues should subsequently keep pace with each other in their downward extension. The endodermis may have outstripped the phloem.

However it may eventually be settled, the whole question discussed above provides an instructive example of the importance that should be attached to the proper determination of the morphological status of the various tissues of the stem. The question as to whether the internal ground-tissue of the *Osmundaceæ* is to be held as stelar or not may at first sight appear to be a distinction of merely academic interest; but, nevertheless, the settlement of this point decides whether the order as a whole is to be regarded as an ascending or a descending series.

THE ANCESTRY OF THE OSMUNDACEÆ.

The presence of several vertical series of pits on the broader walls of the tracheides of both modern and fossil *Osmundaceæ* becomes a matter of considerable importance when considering their ancestry, especially since in the primitive fossil species *Osmundites Dunlopi* the tracheides suggest the presence of a reticulate or even porose pitting. It is clear, in fact, that the presence of such markings on the tracheides of any particular fossil can no longer be regarded as an objection to an Osmundaceous affinity. According to the views already expressed above, the stele of such an ancestral type would have a continuous ring of solid xylem, or, in a still more primitive form, even a solid central xylem mass. In both cases the leaf-trace would depart in a protostelic manner, without interrupting the continuity of the xylem, and the protoxylems of the leaf-traces would be more or less decurrent into the xylem of the stem as a mesarch strand. It is further probable, in the more primitive forms, that there would be a peripheral exarch protoxylem of small elements proper to the stem, and apart from the mesarch protoxylem of the leaf-traces. In many of the species already known, the tracheides of the xylem ring diminish markedly in size towards the periphery (*Osmunda regalis*, *Osmundites Dunlopi* and *O. skidegatensis*); although it must be admitted that in the living *Osmundaceæ* the differentiation of the metaxylem elements takes place quite irregularly after the decurrent leaf-trace protoxylems are once fully developed.

If a fossil stem possessing the more primitive of the above-described characters were ever to be found, it would very probably be classed at first sight with the *Botryopterideæ*. This is a conclusion with which we would at once agree, for we regard the

Osmundaceæ as directly descended from an ancestral stock from which at least two other types of structure also arose—that of *Botryopteris* and that of *Zygopteris*.

As far as can be gathered from RENAULT's meagre description of the fossil, it appears to us that *Grammatopteris Rigoletti*, B. Ren. (14), possesses a type of structure that may be regarded as primitively Osmundaceous.

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DESCRIPTION OF FIGURES.

Figs. 1-2, 6-12, 14-18, and 20-24 are untouched photographs. Figs. 3-5, 13, 19, and 24-28 have been made from lightly printed bromide prints, which were used as camera lucida tracings.

The following lettering is used throughout:—*xy.*, xylem strand; *prx.*, protoxylem; *ph.*, phloem; *prph.*, protophloem; *S.T.*, sieve-tubes; *i.c.*, inner cortex; *o.c.*, outer cortex; *p.*, pith; *l.t.*, leaf-trace; *l.g.*, leaf-gap; *r.*, root.

PLATE I.

Fig. 1. *Osmundites Dunlopi*. Surface view of the specimen. *a.*, outer limit of stem. (Natural size.)

Fig. 2. *Osmundites Dunlopi*. A transverse section of the specimen. *a.*, outer limit of stem; *xy.*, xylem ring of the stele; *S.L.*, zones of scale-leaves; *scl.*, conspicuous sclerotic strands in the outer leaf-bases. (\times about 3.) Slide in the collection of Mr R. Dunlop.

Fig. 3. *Osmundites Dunlopi*. Portion of the xylem ring showing the departure of the leaf-trace xylem. ($\times 36$.) Slide K/1242.*

PLATE II.

Figs. 4 and 5. *Osmundites Dunlopi*. Portion of the xylem ring showing the departure of the leaf-trace xylem. (Fig. 4, $\times 31$, slide K/1243; fig. 5, $\times 36$, slide K/1242.)

Figs. 6, 7, 8. *Osmundites Dunlopi*. Longitudinal sections of the xylem ring showing the departure of the leaf-trace xylem. *st. xy.*, stem xylem; *lt. xy.*, leaf-trace xylem. ($\times 9$.) Slides K/1246, K/1244 (figs. 7–8).

Fig. 9. *Osmundites Dunlopi*. Transverse section of small portion of the xylem ring showing the pit-markings on the walls of the tracheides. ($\times 90$.) Slide K/1243.

Figs. 10 and 11. *Osmunda cinnamomea*. Longitudinal sections of the xylem showing the multiseriate pitting of the tracheides. (Fig. 10, $\times 144$; fig. 11, $\times 155$.)

Fig. 12. *Osmundites Dunlopi*. Oblique section of a leaf-trace passing through the inner cortex to show the apparently porose pitting of the tracheides. ($\times 63$.) Slide K/1243.

Fig. 13. *Osmundites Dunlopi*. Transverse section of a leaf-trace passing through the inner cortex to show the origin of the root steles. *en.*, endodermis. ($\times 20$.) Slide in the collection of Mr R. Dunlop.

PLATE III.

Fig. 14. *Osmundites Dunlopi*. Transverse section of four leaf-bases in close proximity to the stem. ($\times 16$.) Slide K/1243.

Fig. 15. *Osmundites Dunlopi*. Transverse section of leaf-trace (A) in fig. 14 more highly magnified. *scl.*, sclerotic ring of the petiole. ($\times 33$.) Slide K/1243.

Fig. 16. *Osmundites Dunlopi*. Portion of the coating of leaf-bases to show the sclerotic stands (*sc. st.*) scattered in the spaces once occupied by stipular parenchyma. *scl.*, sclerotic rings of the petioles; *lt. xy.*, xylem of leaf-trace. ($\times 33$.) Slide K/1243.

Fig. 17. *Osmundites Gibbiana*. Surface view of specimen. (Natural size.)

Fig. 18. *Osmundites Gibbiana*. A transverse section of the specimen. *a.*, outer limit of the stem; *xy.*, xylem ring of stem; *S.L.*, zones of scale-leaves. ($\times 2.5$.) Slide K/1249.

Fig. 19. *Osmundites Gibbiana*. Portion of xylem ring of stele. *en.*, endodermis. ($\times 33$.) Slide K/1249.

PLATE IV.

Fig. 20. *Osmundites Gibbiana*. Portion of coating of leaf-bases to show the sclerotic strands (*sc. st.*) in the spaces once occupied by stipular parenchyma. *scl.*, sclerotic rings of the petioles; *lt. xy.*, xylem of leaf-trace; *S.L.*, scale-leaf. ($\times 14$.) Slide K/1249.

Fig. 21. *Osmundites Dockeri*. Transverse section of the stock. *a.*, outer limit of stem; *xy.*, xylem ring of stele. The pith (*p.*) is still preserved. (\times about 2.) Slide K/1248.

Fig. 22. *Osmundites skidegatenensis*. Transverse section. *xy.*, xylem ring of stele; *p.*, the pith (still intact); *int. str.*, internal vascular strands. ($\times 2.4$.) Slide K/1251.

Fig. 23. *Osmundites skidegatenensis*. Portion of the vascular ring of the stem. *ext. ph.*, external phloem; *int. ph.*, internal phloem; *int. str.*, internal vascular strands; *scl.*¹, sclerenchyma between xylem strands of normal vascular ring; *scl.*², sclerenchyma between the internal vascular strands. ($\times 14$.) Slide K/1251.

* Slides indicated by a "K" in the collection of Mr R. Kidston.

PLATE V.

Fig. 24. *Osmundites skidegatensis*. Portion of the vascular ring from (A) in fig. 22 more highly magnified. *ext. ph.*, external phloem; *int. ph.*, internal phloem; *l.g. ph.*, metaphloem lining the leaf-gap; *p. l.*, porose layers; *l.g. sc.*, leaf-gap sclerenchyma. ($\times 27$.) Slide K/1251.

Fig. 25. *Osmundites skidegatensis*. Portion of the vascular ring from (B) in fig. 22 showing the departure of a leaf-trace. *lt.*, the departed leaf-trace; *lt. ph.*, phloem of the leaf-trace; *par.*, parenchyma of xylem sheath; *par.*², parenchyma separating the phloem from the sclerenchyma of the leaf-gap. Other lettering as in fig. 24. Note the pitmarks on the tracheide wall. ($\times 110$.) Slide K/1251.

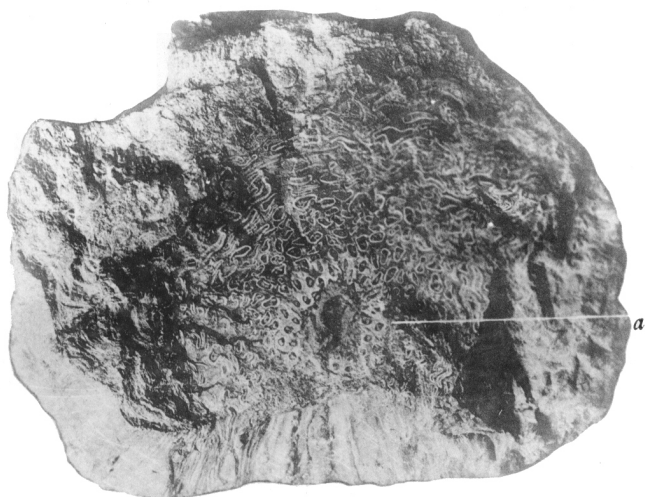
Fig. 26. *Osmundites skidegatensis*. Portion of the vascular ring from (C) in fig. 22 showing a leaf-gap some little distance above the departure of a leaf-trace. Lettering as in fig. 25. ($\times 105$.) Slide K/1251.

Fig. 27. *Osmundites skidegatensis*. The inner margin of a portion of the vascular ring showing the internal phloem (*int. ph.* of fig. 23). Other lettering as in fig. 25. ($\times 110$.) Slide K/1251.

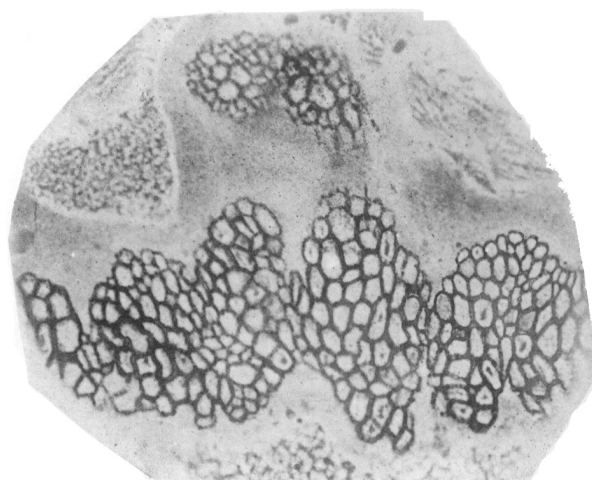
Fig. 28. *Osmundites skidegatensis*. Portion of a transverse section of a leaf-trace passing through the outer cortex of the stem. *ab. ph.*, abaxial metaphloem; *ad. ph.*, adaxial metaphloem; *prph.*, protophloem on abaxial side only; *par.*, parenchyma of xylem sheath; *par.*², parenchyma between phloem and sclerenchyma; *sc.*, sclerenchyma mass in concavity of leaf-trace. ($\times 84$.) Slide K/1-51.

PLATE VI.

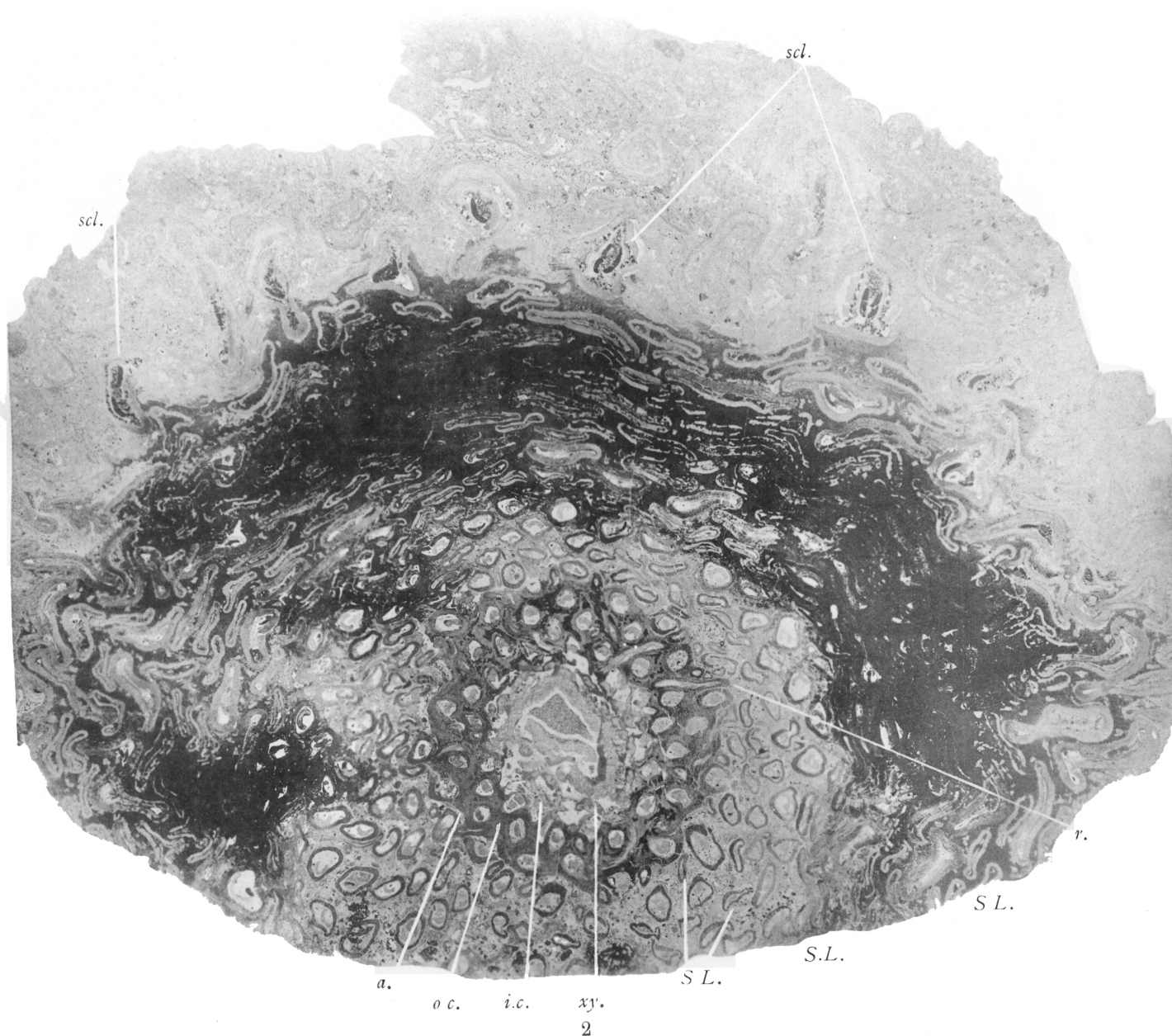
Diagrams; description on plate.



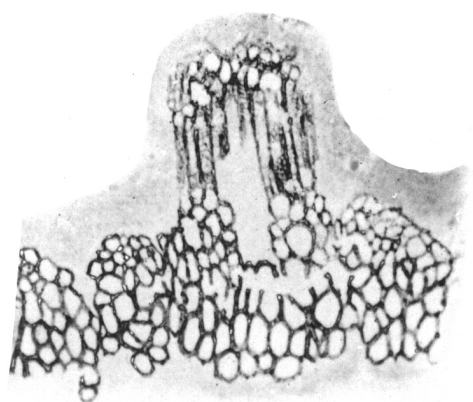
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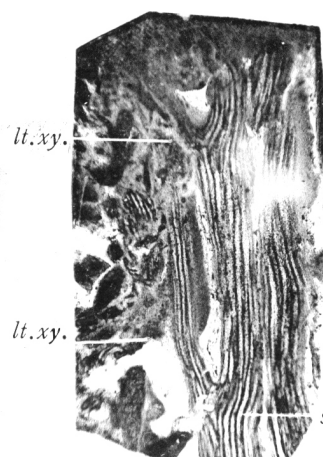
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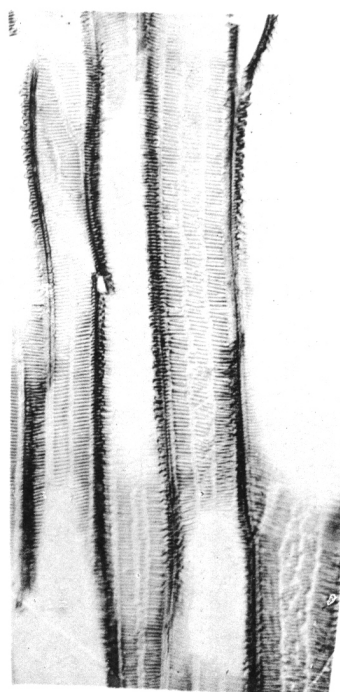
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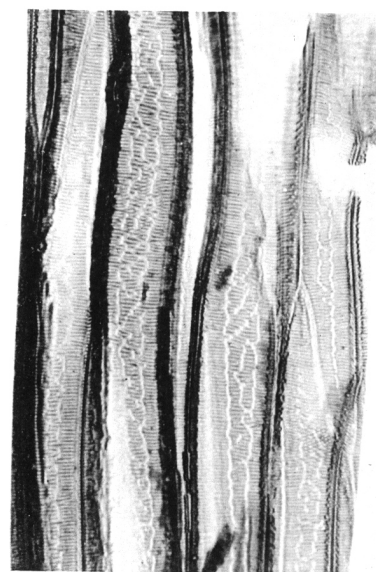
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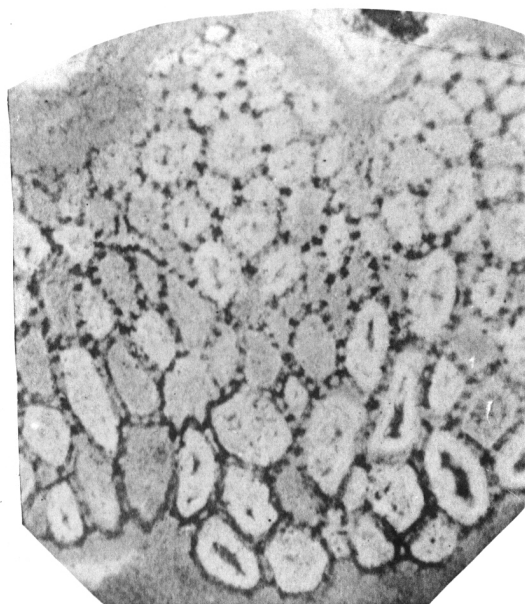
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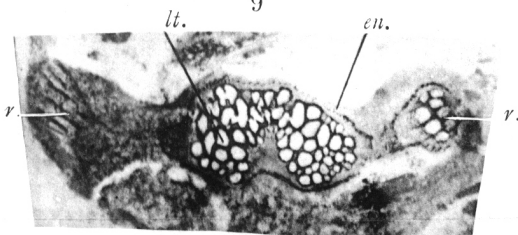
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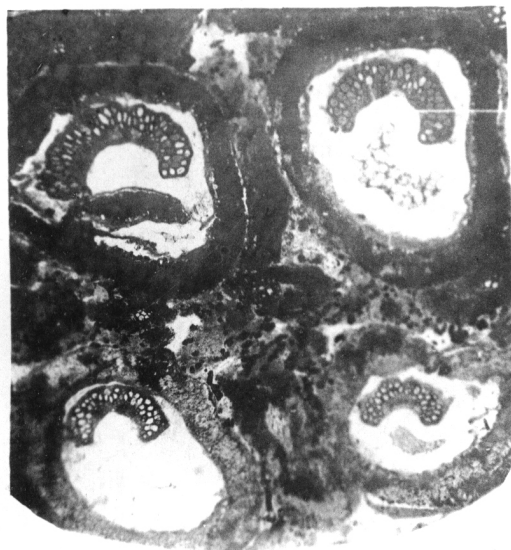
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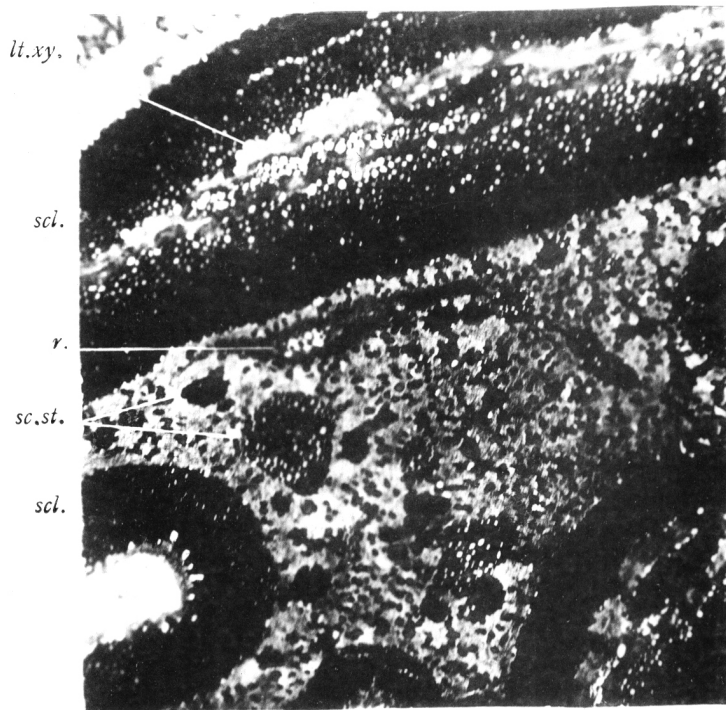
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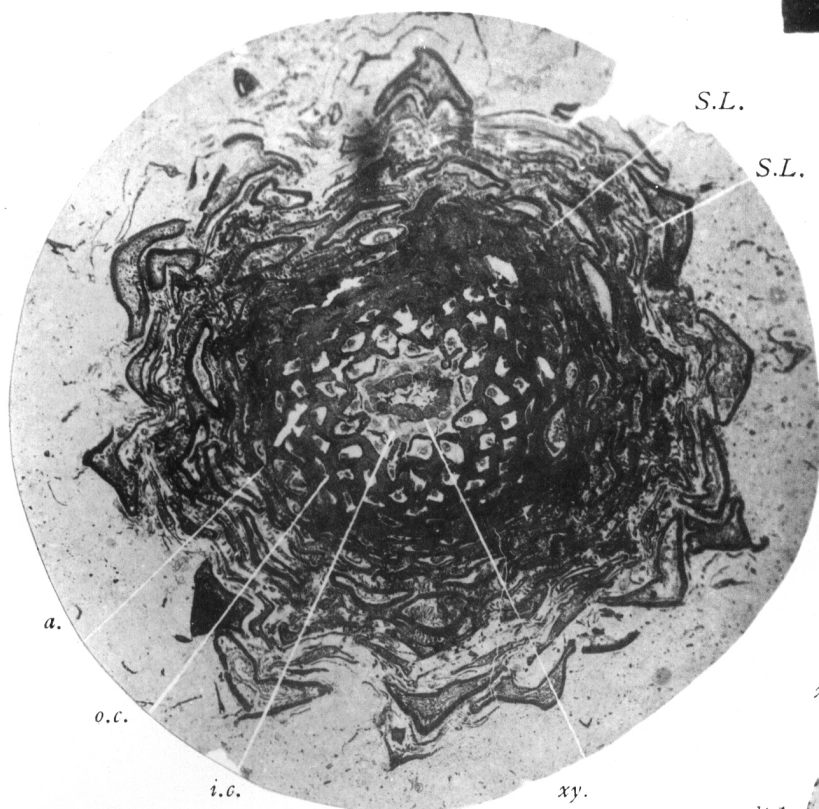
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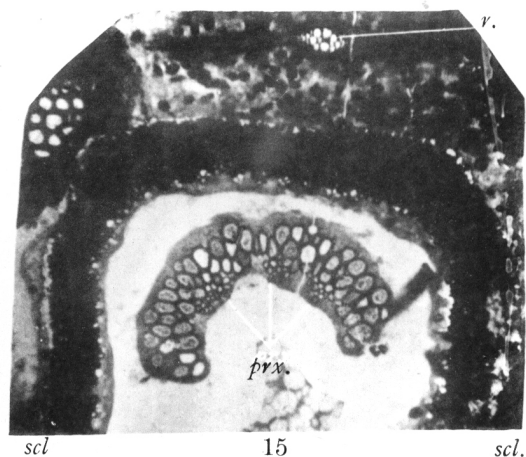
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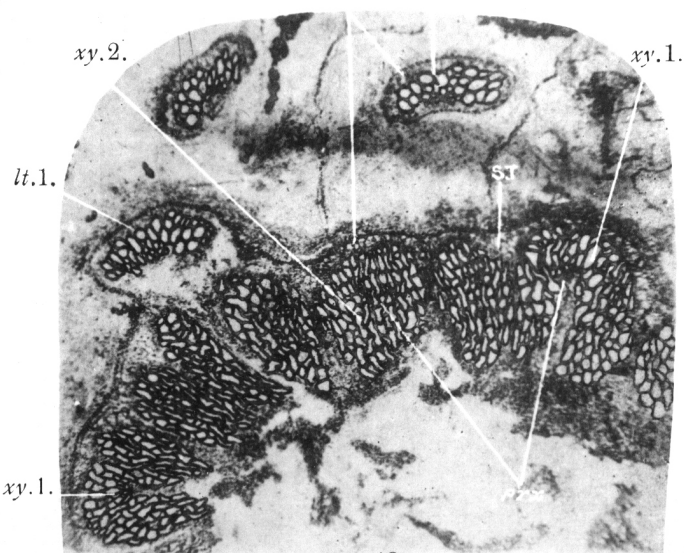
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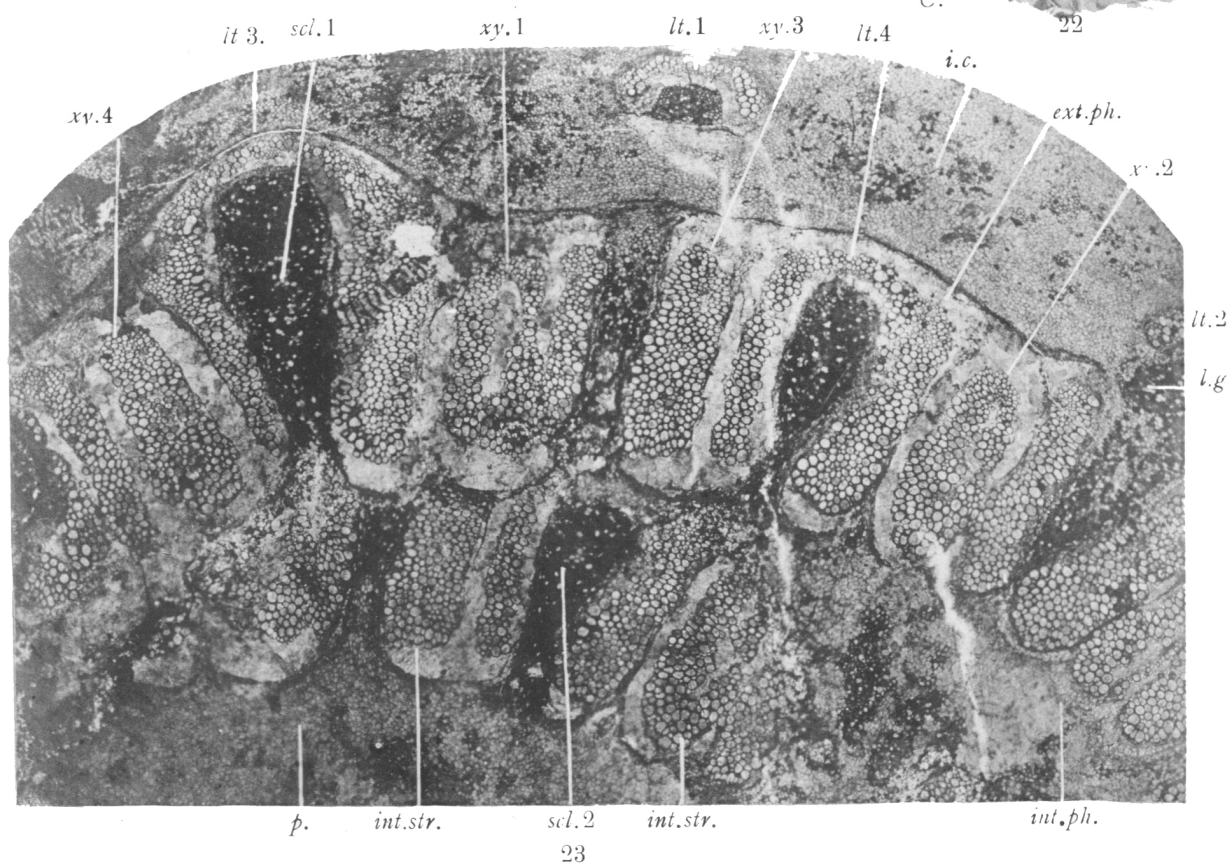
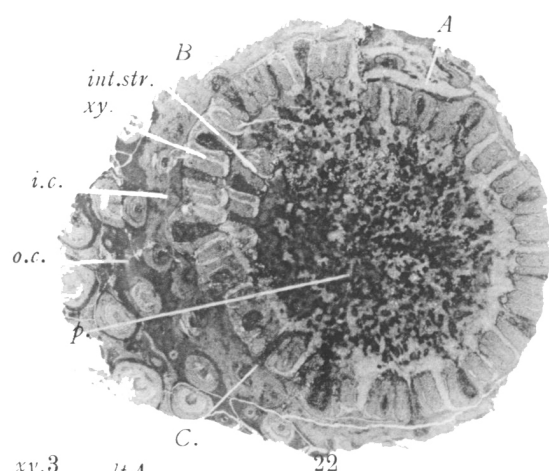
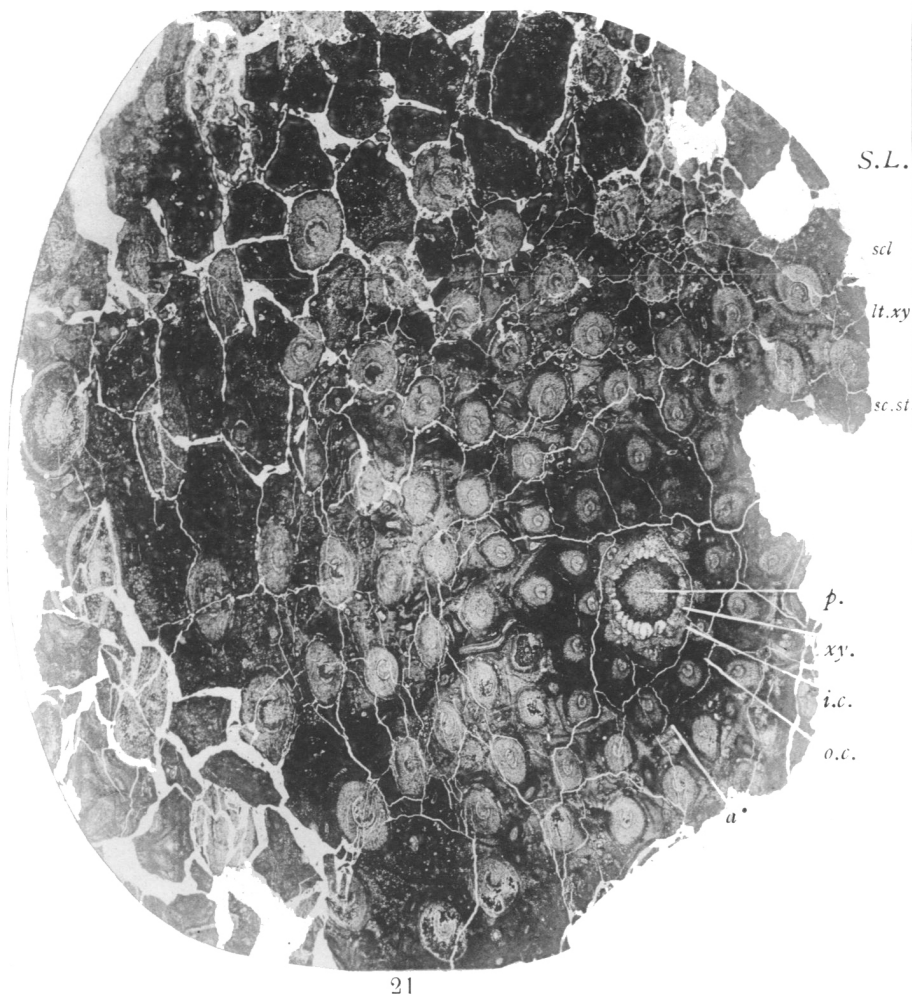
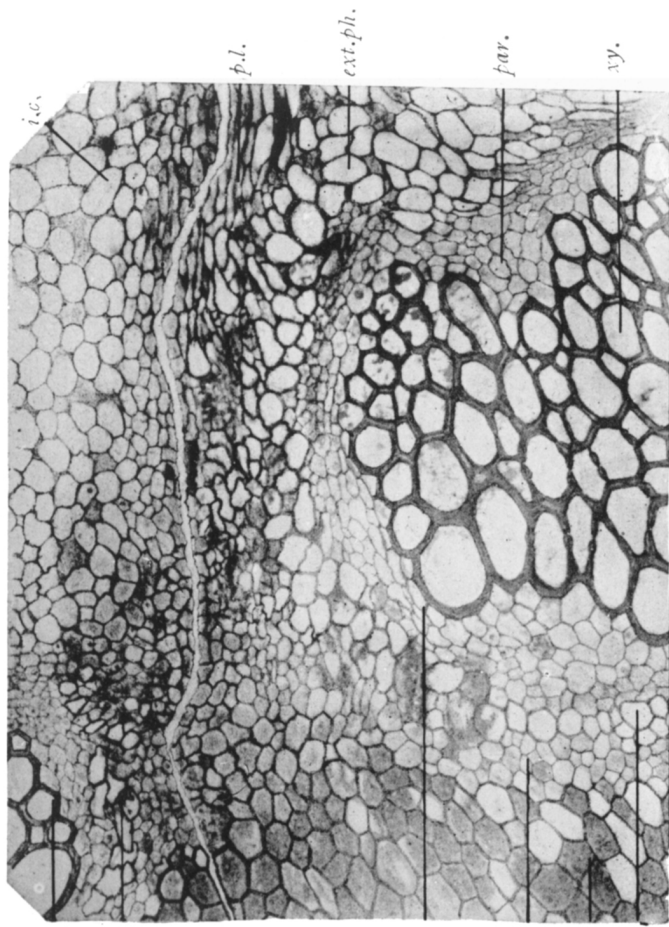
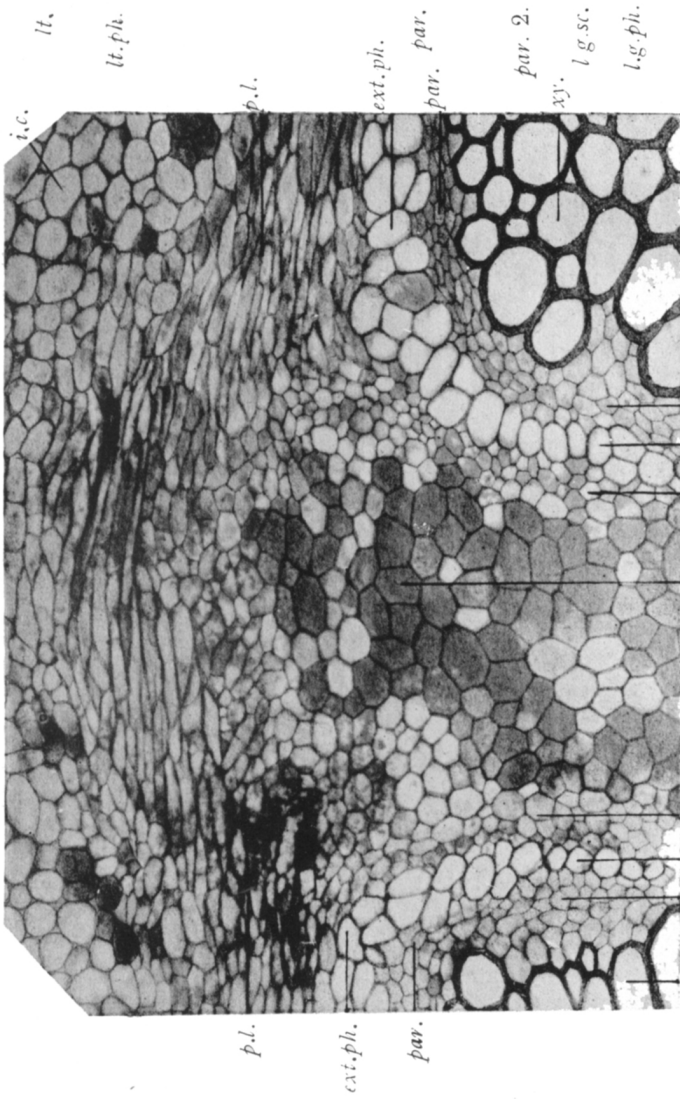


FIG. 20. OSMUNDITES GIBBIANA. KIDST. & G.-V. FIG. 21. OSMUNDITES DOWKERI. CARR.
FIGS. 22-23. OSMUNDITES SKIDEGATENSIS. PENHALLOW.

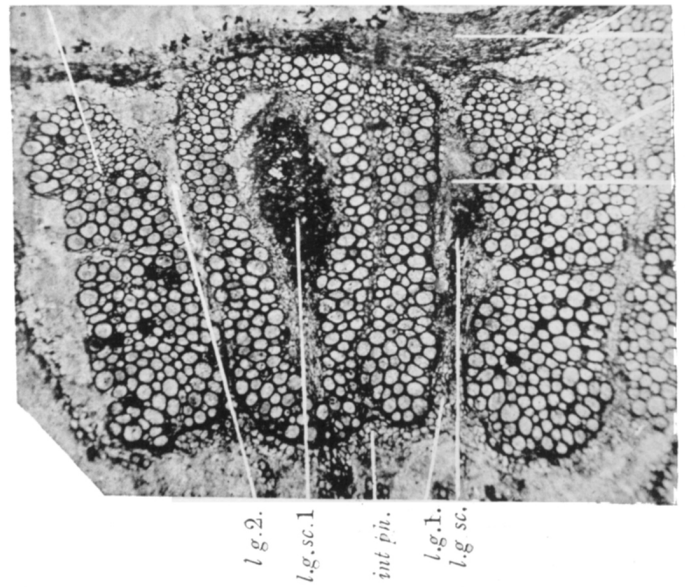
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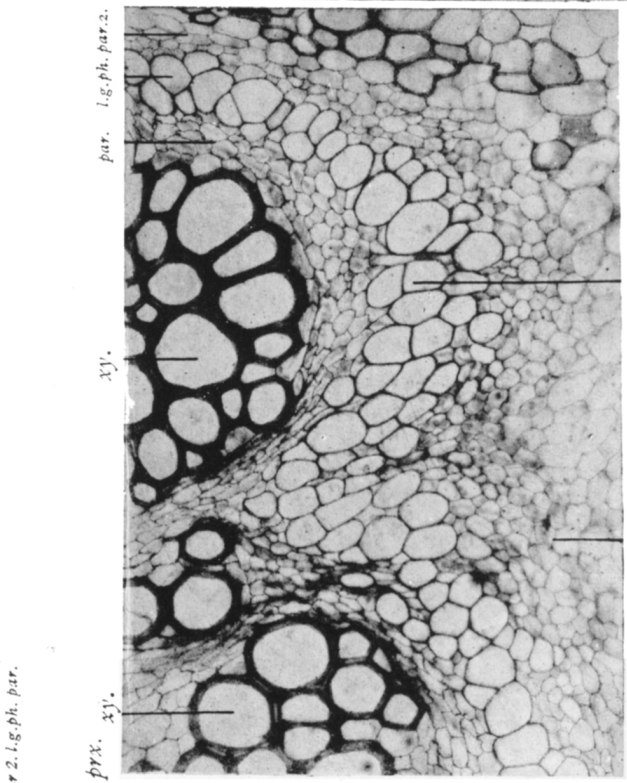
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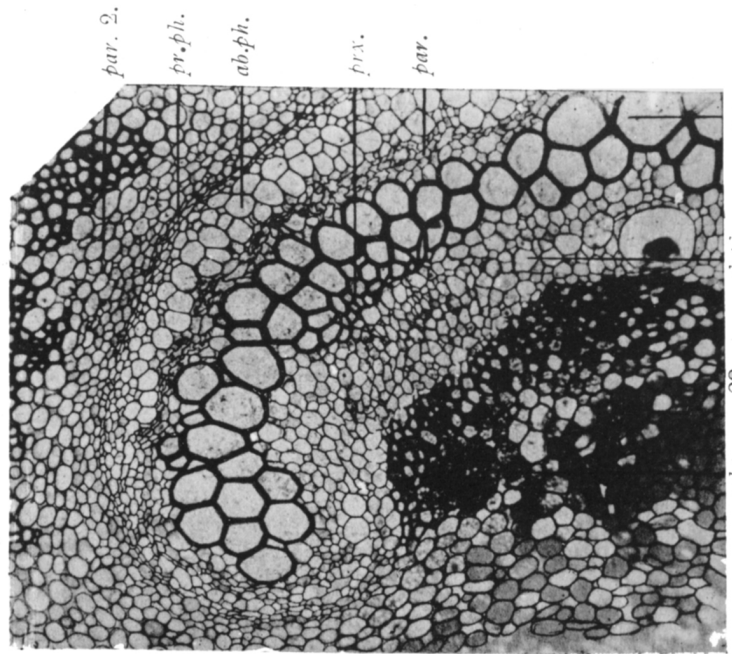
xy. par. l.g.ph. par. 2. l.g.sc.



24 l.g.ph. prx. p.l.

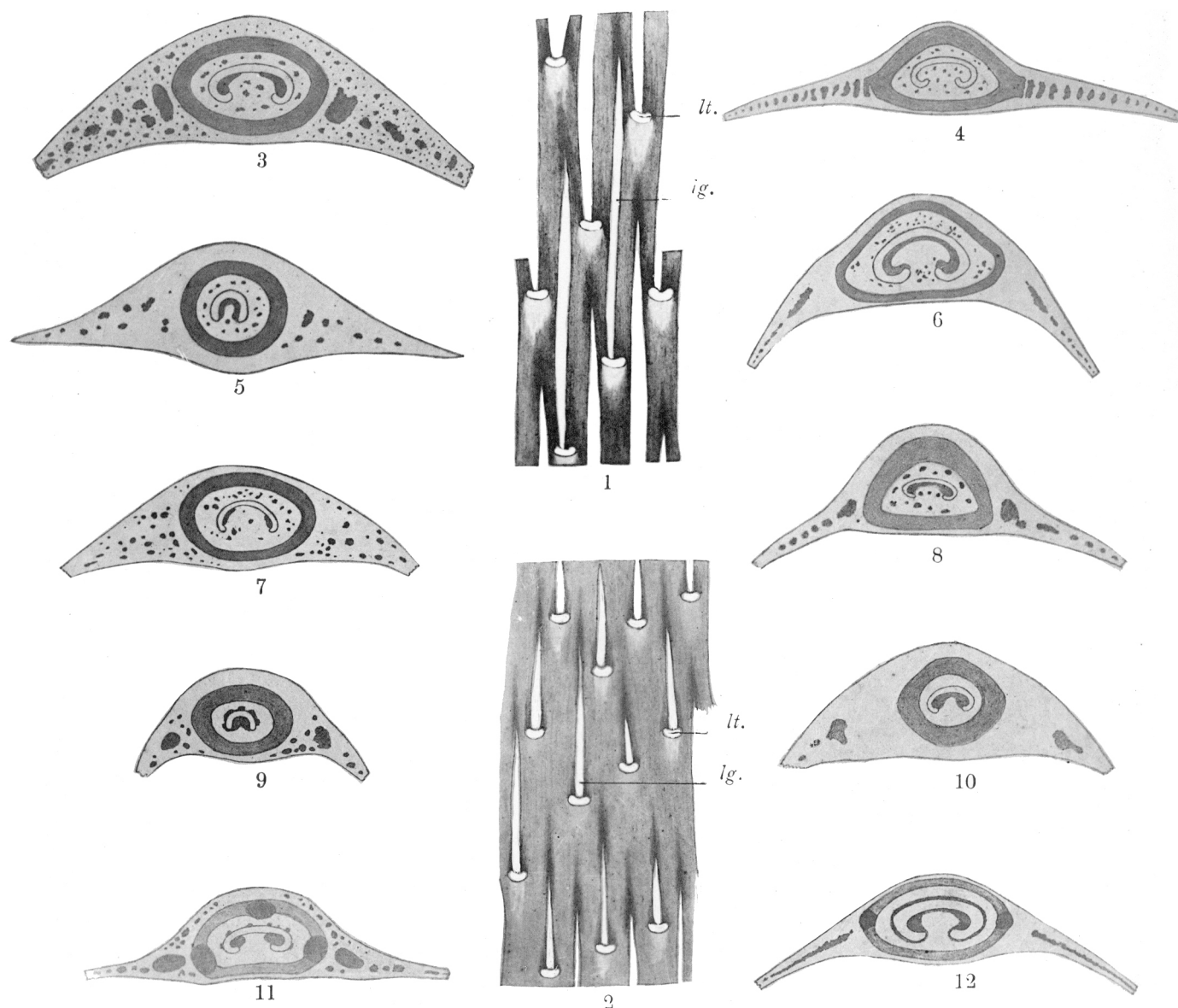


prx. xy. par. l.g.ph. par. 2. p. int.S.T.



par. 2. pr.ph. ab.ph. prx. par. scl. ad.l. xy.

OSMUNDITES SKIDEGATENSIS. PENHALLOW



DESCRIPTION OF DIAGRAMS.

1—A representation of a portion of the xylem ring of *Osmunda regalis* seen from without. lt., cut end of a departing leaf trace; lg., leaf gap., (after Lachmann).

2—A representation of a portion of the xylem ring of *Todea barbara* seen from without. Lettering as above. (After Seward & Ford).

3-12—Diagrams of transverse sections taken about the middle of the stipular leaf-bases of various *Osmundaceae* showing the distribution of the sclerenchyma:—The leaf-trace is unshaded.—3, *Osmundites Dunlopi*; 4, *Osmundites Gibbiana*; 5, *Osmundites Doweri*; 6, *Osmunda regalis*; 7, *Todea barbara*; 8, *Osmunda javanica*; 9, *Todea hymenophylloides*; 10, *Todea superba*; 11, *Osmunda cinnamomea*; 12, *Osmunda Claytoniana*.