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III. *Some Fossil Plants of Early Devonian Type from the Walhalla Series, Victoria, Australia.*

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[PLATES 11–13.]

Introduction.

IN 1927 we gave a brief account (LANG and COOKSON, 1927) of the plant-remains that had been found in rocks regarded by the Geological Survey of Victoria as of Upper Silurian age. That account was based on specimens in the Collections of the National Museum, Melbourne, and of the Geological Survey of Victoria, which were sent to Manchester for examination. With the exception of some from Waratah Bay and Rhyll (COOKSON, 1926), the specimens came from a number of localities along the Walhalla geo-syncline in Eastern Victoria. The rocks from which they were derived are distinguished in the local succession (BARAGWANATH, 1925; HERMAN, 1901; WHITELAW, 1916) as the Jordan River Beds below and the Walhalla Beds above; the Yeringian conglomerate is at the base of the Walhalla Series. Both the Jordan River Series and the Walhalla Series are referred to the Yeringian (Upper Silurian).

The stratigraphical sequence of the rocks as determined by the Geological Survey has been recently confirmed by a re-examination of the Walhalla-Wood's Point region by Prof. E. D. SKEATS (1928), who was accompanied on his visit to a number of localities by Mr. F. CHAPMAN and Mr. BARAGWANATH. The alternative view of the succession, advanced on palæontological grounds by Mr. CHAPMAN (1926) and referred to in our previous paper, may therefore be left out of consideration here, and his term Tanjilian will not be employed.

As already mentioned, the Jordan River Beds and the Walhalla Beds are both included in the Upper Silurian. Graptolites are recorded as occurring in the strata below the Yeringian conglomerate, and plant-remains, including some that have been described and figured, are believed to come from this horizon in the Jordan River Beds. Graptolites are also found in beds above the conglomerate, near the base of the Walhalla Series, and some of the plants we described and figured in our previous paper are regarded as coming from this horizon. We have not obtained evidence of the association of recognisable plants with graptolites, although we have seen fragments that are presumably plants on the same piece of rock. The interesting and important questions of the nature of the plants from these lower horizons and their association with Silurian animal fossils must be left, until collecting shall have provided adequate material for investigation. It must be borne in mind that the localities are situated in very difficult country. Further and more critical evidence is required before the geological age of the plant-containing strata can be regarded as clearly established.

We mention these points in order to make it quite clear that in the present paper we are not dealing with these lower horizons. None of the plants we have as yet seen from them are determinable, though some are of striking size and appearance. The present description of some well-characterised and determinable fossil plants from a higher horizon in the Walhalla Series, that of the Centennial Beds, is a contribution of fact, which will require to be taken into consideration along with data regarding the animal fossils in dealing with the stratigraphical question as a whole.

There appears to be general agreement that strata in a number of localities where fossil plants are relatively abundant are situated high in the Walhalla Series. This applies to the Centennial Mines, the beds at Wood's Point and those at Gaffney's Creek, from all of which specimens were recorded in our earlier paper. It applies also to the North Road Quarry, about one mile from Walhalla, from which the fossil plants that form the subject of this paper have been obtained. This locality is thus referred to in Prof. SKEAT's paper (1928, p. 226):—

"No. 4 locality shows the Centennial beds north of Walhalla township, and according to Mr. BARAGWANATH, is 8,000–10,000 feet stratigraphically above the basal conglomerate (Yeringian). At this locality very abundant fossil plants occur which yet await full description."

In relation to the beds at this horizon, it is of interest to note Prof. SKEATS's further remark (1928, p. 221) that "the upper part of the Walhalla series is probably higher in the series than the upper part of the Yeringian in Central Victoria, and it is possible, but not proved, that sedimentation may have been continuous in this Walhalla-Wood's Point region into the Lower Devonian period." The possibility of an Early Devonian age of the plants in these beds, which include the North Road Quarry, would thus appear to be left quite open by geologists. As will be seen later, the nature of the plant-remains strongly supports such a view.

The following account is almost entirely based on a collection of the plant-remains made by one of us from the North Road Quarry. One interesting type was also met with in beds of the same horizon about half a mile up the east branch of Stringer's Creek. Occasional comparisons will be made with remains from the Centennial Mines and from Wood's Point. Preliminary comparisons will also be indicated with plant-remains obtained from Knott, a locality which appears to be lower in the Walhalla series.

It was through Mr. BARAGWANATH, the Director of the Geological Survey of Victoria, that attention was directed to the North Road Quarry. We desire to express our thanks to him and also to the Council for Scientific and Industrial Research (Australia), by which a grant was made to one of us to assist in the collection of specimens. Several visits for this purpose were paid to the quarry and the available fossiliferous rock broken up and examined. We have also to thank Mr. E. ASHBY for the photographic illustration of the specimens and for assistance in other ways during the investigation.

The quarry, which is of small size and not at present worked, is in a relatively coarse sandstone that has, so far, proved unfossiliferous. Interbedded with the sandstone, however, is a finer-grained, sandy mudstone, throughout which abundant fragmentary plant-remains are distributed. Some layers are composed of a still finer-grained mudstone and may have more or less macerated plant-remains on the smooth surfaces exposed on splitting the rock. The general characters of the beds suggest that they are of estuarine or deltaic origin. We may mention that the only animal remains noticed on the pieces of rock containing plant-remains have been a piece of Eurypterid skin and a shell of *Lingula*. The plant-remains may be represented by a black material which, as a rule, is very resistant to treatment with SCHULZE's macerating fluid (HNO_3 and $KClO_3$). This material is often highly cleaved diagonally. In other cases the organic material has largely or wholly disappeared, having been replaced by a brown material which, however, preserves the form of the plant.

A general idea of the mode of occurrence and the abundance of the fragmentary plant-remains is afforded by Plate 11, fig. 1, which represents a surface of the sandy mudstone exposed on splitting the rock. Many portions of plants are, of course, so fragmentary as to be quite indeterminable. For its size, however, the collection is remarkable for the definiteness and instructiveness of the few types of fossil plants it contains. The four main important type of plant-remains that have to be described and considered in detail are :—

(1) branched axes of the general type that has been recognised in Europe under the name *Hostimella* sp. ;
(2) vascular strands showing tracheidal structure ;
(3) a fructification (*Zosterophyllum australianum* n.sp.) ;
(4) a sporogonium-like fossil (*Sporogonites Chapmani* n.sp.).

In addition to these definite types, which are both of botanical interest and of importance as providing evidence on the disputed question of the age of the beds, some more occasional, imperfect or uncertain remains have to be recorded. Two such types that will be dealt with later are spore-like bodies of a considerable range of size, and reticulated incrustations.

The chief remains of vegetative organs, which may of course be derived from more than one kind of plant, are the smooth branched axes of *Hostimella* sp. type, such as are shown in fig. 1. Before dealing with these, however, some indications of the presence of other vegetative remains require brief mention.

Thus, among the fragmentary remains there were some of larger size that suggested comparison with pieces of "fossil wood," often met with in similar deposits elsewhere. Such specimens, showing nothing of the external form of a plant and evidently incomplete, have been seen up to 3 cm. in breadth. In no case, however, has any evidence of the structure been obtained so that this mention of their occurrence will be sufficient.

None of the specimens from the North Road Quarry have demonstrated the presence of axes bearing small leaves or spines, though plant-remains of this type might have been anticipated in association with the types that are found. One or two specimens showed obscure markings on the surface, suggestive of such an interpretation but in no case amounting to evidence. One piece of rock from Wood's Point, bearing brown flattened incrustations, exhibited a clear contrast of smooth axes with another that was marked with small depressions and elevations. A portion of this specimen is represented enlarged 3 diameters in Plate 13, fig. 42. The question as to the occurrence of small-leaved plants can, however, only be decided by the discovery of further and more definite specimens.

A few examples of small branched axes have been met with, which present a longitudinally ribbed or ridged appearance. One of these is shown enlarged 4 diameters in fig. 2. It may be mentioned that a similarly ridged fragment occurred among the plant-remains from Knott.

Hostimella sp. (Plate 11, figs. 1, 3–9).

Description of Specimens.—In our earlier paper certain branched axes were described under this name and their similarity to the correspondingly named remains from the Early Devonian of Europe was pointed out. The best specimens were on a slab from the Centennial Beds at Walhalla, which showed smooth, branched axes without any axillary structures, and also an example demonstrating the presence of the peculiar axillary body found in some, but by no means all, of the European specimens.

The collection from the North Road Quarry has provided ample evidence of the abundance of such smooth, branched axes of various diameters and both without and with the axillary structure. The organic material has mostly disappeared and been replaced by a brown mineral which, however, gives a clear record of the form. The specimens are, as a rule, flattened incrustations. When they enclose a more or less flattened cast composed of the matrix, only the outer layers of the axes had persisted. That this explanation is correct is shown by such specimens as that represented in fig. 8, where a thin black layer, with indications of the cellular structure, bounds an uncompressed, cylindrical cast composed of the materials of the matrix.

A number of such flattened incrustations are seen in fig. 1. Fig. 3 represents an example in which the relatively main axis was about 4 mm. wide. In its length of some 6 cm. this gives off alternately two lateral branches, the lower on the right and the upper on the left, the branches are only some 2 mm. wide. The specimen shown in fig. 4 is 2 mm. wide and in its length of 7·5 cm. gives off one lateral branch, that is about the same width as the main axis. The axes in fig. 1 are more slender, and still thinner specimens have been seen, some of which branched dichotomously. But nothing approaching a complete branch-system has been met with, the fragmentary nature of the remains being represented fairly by the examples figured. None of the examples so far referred to show any trace of an axillary structure and this holds for many other specimens.

On the other hand, a number of specimens from the quarry exhibited this feature very distinctly. The example shown in fig. 5 of natural size is an axis about 2 mm. wide giving off a somewhat narrower branch. In an axillary position and sunk in the tissue is a definitely marked, oval body, slightly over 1 mm. long by 0·5 mm. wide. There is a trace of carbonaceous material on the axillary body, but it is mainly represented by a cast. Fig. 6 represents the region of the departure of a branch in a similar specimen enlarged $5\frac{1}{2}$ diameters, and gives a good idea of the relation of the axillary body to the branching. Another specimen is enlarged 3 diameters in fig. 7; the oval axillary body is represented by a cast of mineral material in the usual position. The main axis in this specimen was 3 mm. wide; it shows the appearance of oblique cleavage in the brown material, which has replaced the carbonaceous remains.

It will be evident from these examples that the axillary structures in the Australian specimens closely resemble those found in specimens from the Middle Devonian of Europe and the Middle Old Red Sandstone of Scotland. The Australian examples, indeed, provide an excellent demonstration of this morphological feature but do not afford any further insight into the structure of the oval body than do the European specimens. From its position it is usually referred to in the literature as a "bud," but this, so far, is only a convenient designation and not based on any demonstration of the construction or behaviour of the axillary body.

In this connection a single specimen from the quarry possesses considerable botanical interest. It is represented, enlarged three diameters, in fig. 8. This specimen has already been referred to as being preserved as an uncompressed cast, bounded by a layer of carbonaceous material representing the peripheral tissues of the axis. It shows in the lower part of the figure a portion of the main axis, which continues somewhat to the right above the place of branching. These parts are preserved as solid casts, as is the extreme base of the branch which departs at an acute angle on the left. But for almost the whole extent of the branch the solid core formed by the cast is lost, and this part of the specimen is represented by a concave impression, the surface of which is black and longitudinally striated.

The great interest of the specimen lies in the presence of the base of another branch, arising at the level of departure of the lateral branch from the main axis but directed obliquely upwards and towards the observer. Although only the base of this, which (though this is not strictly accurate) may be distinguished as the axillary branch, is present, its preservation as an uncompressed cast bounded by a layer of black material renders certain its distinctness from the main axis and the lateral branch. The branching might be described as a trichotomy but, although the direction of the third branch is not strictly axillary, the position of its base relatively to the main axis and lateral branch corresponds to that of the axillary structure in the examples described above. This specimen thus provides a considerable amount of justification for regarding the axillary structures as " buds " in the sense that they were really rudimentary or dormant axillary branches.

What appears to be a second example of this type of branching is among the few specimens as yet obtained from a soft grey mudstone at Knott. The specimen in question (fig. 9) appears as the concave impression of a branched axis, that must have been originally preserved as a cast. There were scattered carbonaceous particles derived from the remains of the peripheral tissues of the axis over the surface of the impression. The main axis and the branch which departs to the left are distinguishable by these features in fig. 9, which represents the specimen enlarged three diameters. In the angle between the main axis and lateral branch there was an oval white area delimited by a thin dark layer. This suggested comparison with the axillary structures, but there were differences sufficient to cause hesitation in identifying the two. In the light of the specimen shown in fig. 8, however, the axillary oval area in fig. 9 appears to be naturally and satisfactorily interpreted as the base of an axillary branch going off obliquely into the stone.

Discussion.—Smooth axes with dichotomous branching, or with lateral branching that is suggestive of the production of a sympodium from dichotomy, are among the most frequent plant-remains in Devonian rocks from various regions. They do not characterise any one kind of plant but are known to be portions of diverse plants, the morphology of some of which is fairly completely known. Such fossils, when occurring in the detached condition, may conveniently be kept under the name *Hostimella* sp. It is impossible to draw a sharp line between them and remains that have been termed *Aphyllopteris*. The name *Pteridorachis*, on the other hand, may be taken to imply that the somewhat similar specimens are portions of the branch-systems of fronds of Ferns or Pteridosperms.

On our present knowledge such fossils are not a feature of the Carboniferous flora and when met with are probably in all cases portions of the fronds of highly organised plants. The same remark applies, though perhaps less completely, to the occurrence of such specimens in rocks of Upper Devonian age. On the other hand, remains of this type are abundant and characteristic in Early Devonian deposits. Even at this lower level they may be portions of frond-like structures, but a number of types of plants in the Middle and Lower Devonian are now known with sufficient completeness to show that their whole vegetative body was composed of a branch-system of cylindrical axes of various diameters. Fragmentary remains of the type under consideration are abundant in the Middle Old Red Sandstone of Scotland, the Middle Devonian of Bohemia, the Middle Devonian of Germany, and the Middle Devonian of Norway. Remains that come under the same general type are known from the Lower (or Middle) Devonian of Canada, the Lower Devonian of Spitzbergen and the Lower Devonian of Norway. There is no reason to doubt that they are all portions of vascular plants and in some cases there is direct evidence of this.

There is no clear evidence of the occurrence of such plant-remains from rocks earlier than the Lower Devonian. Slender branched specimens, probably vascular axes, though there is as yet no demonstration of vascular elements, are met with in the Downtonian of England, but these beds are now placed in the Devonian. Fragmentary axes, some showing the vascular structure, were recorded by DAWSON (1871) from the limestones underlying the Gaspé sandstones, and he regarded these limestones as equivalent to the Lower Helderberg group of New York and of Upper Silurian age. But the Helderberg limestone is now classed with the Lower Devonian and this is also the case for the beds below the sandstones in the Gaspé peninsula. Thus, this region does not provide evidence for the extension of such remains of vascular plants back into the Silurian period. In this connection it should, however, be mentioned that black incrustations of branched axes have more recently been described and figured from the Bertie Water Lime (GOLDRING, 1925), at Buffalo ; these beds are near the summit of the Upper Silurian. There is no proof that they are remains of vascular plants.

The preceding references show that the presence, especially in abundance, of smooth branched axes is, on our present knowledge, indicative of rocks of Early Devonian age, without being distinctive of the Middle or Lower Devonian. The presence of an oval structure, sunk in the angle between the relatively main axis and the branch, in some examples of such smooth branched axes, provides us with a more definitely characterised fossil type, on which to base stratigraphical comparisons. Specimens of this type were first recorded from the Middle Devonian beds of Bohemia (POTONIÉ and BERNARD, 1904). POTONIÉ and BERNARD, in their account of this flora, distinguished these structures as " bourgeons," and explained them as due to a rapid dichotomy of the branch, the one resulting branch having developed while the other had aborted or remained dormant. They showed that such structures were characteristic of the remains they distinguished as *Hostimella hostimensis*, but only occurred at some of the branchings, even of one branch-system. Their account is illustrated by numerous drawings of specimens of the forms they distinguish as *Hostimella hostimensis* (a) *typica* and (b) *rhodeaeformis*. All these remains are fragmentary, the complete plant not being known, so that they come under the general name of *Hostimella* sp. as employed here. Specimens with the oval axillary body typically present have been found, along with other similar smooth branched axes that do not exhibit this feature, in the Middle Old Red Sandstone of Scotland (LANG, 1925). They are also recorded from the Middle Devonian of Germany (KRAÜSEL and WEYLAND, 1923). So far as we know, this character has not been found in any of the smooth branched axes met with in Lower Devonian rocks.

No exactly similar specimens are described from the Upper Devonian, but NATHORST (NATHORST, 1902, Plate 11, fig. 3) figures an isolated specimen with a projecting oval axillary structure from Bear Island. Thus, on our present knowledge, specimens of the *Hostimella* sp. type exhibiting a definite axillary structure are specially characteristic of Middle Devonian deposits. While this is so, too much weight should not be attached to them as decisive of a Middle rather than a Lower Devonian age.

The outcome of the preceding survey of our knowledge of the occurrence of fragmentary branched smooth axes (*Hostimella* sp.) in other regions when applied to the abundant remains of this type from the North Road Quarry can be put very briefly. The Australian remains, considered comparatively on the basis of our present knowledge, suggest an Early Devonian age for the rocks of this horizon of the Walhalla Beds. The specimens with the oval axillary structure are closely similar to those known from Middle Devonian rocks in Europe and, taken by themselves, would appear to indicate this age for the Australian beds. The associated fossils of other types to be described below must, however, be taken into consideration before such a conclusion is drawn.

Another comparison must be mentioned which, so far as it goes, lends weight to a possible Lower Devonian age; it is based on the specimens with remains of an actual branch arising at the level at which an axillary structure is found in other specimens. The two Australian specimens of this type described (figs. 8, 9) provide a new piece of evidence that has evident bearings on the nature of the axillary structure (" bud "), even if it does not completely settle the nature of this structure. The relative position of the branch is probably essentially similar to that of the axillary structure, though it must be noted that the branch does not lie in the axillary plane but projects diagonally. So far as we can ascertain, no corresponding specimens are described from the various Middle Devonian deposits in which specimens of *Hostimella* sp. with axillary structures are known.

In this connection, however, reference must be made to Dr. HEARD's account (HEARD, 1927) of plant-remains from the Lower Old Red Sandstone (Senni beds) of Breconshire. Among the remains on which his new genus and species *Goslingia breconensis* is based are sympodially branched axes, and in some cases " special branches which emerge from immediately below the bifurcation of the stems on the sympodial main axis " are described. While this comparison of the Australian branched specimens of *Hostimella* sp. with a Lower Devonian plant is of interest, further information as to the morphology of *Goslingia* is required before it can be regarded as more than suggestive.

Vascular strands showing tracheidal structure.—(Plate 13, figs. 30–36.)

Description of Specimens.—None of the specimens of branched axes with recognisable external form such as those described above have shown evidence of their vascular structure, although there is no reason to doubt that they are all portions of vascular plants. On the other hand, some fragmentary remains have proved to be portions of vascular strands and have shown the structure of their component elements. It would be a reasonable supposition that some or all of these macerated vascular strands belonged to the *Hostimella* sp. type, but this has not been demonstrated.

Such remains, more or less linear and measuring from $\frac{1}{2}$ to 3 mm. in breadth, were especially abundant on some of the smooth, fine-grained surfaces of the rock, where they had evidently been sorted out during sedimentation. The carbonaceous material was often of an intense black, with a graphitic appearance and split by diagonal lines of cleavage. Only occasionally could indications of structure be recognised under reflected light as a longitudinal striation.

Numerous film-transfers and cellulose film-pulls have been made from such material. In most cases the results were negative, the black material removed on the film being opaque, and showing as little structure as when examined on the stone. But in a number of instances preparations were obtained demonstrating the vascular nature of some of the remains and allowing the inference to be extended to others. The connection between the extreme cases was made by examples in which the bulk of the wood had been converted into homogeneous and opaque carbonaceous material, but a few vascular elements were still recognisable at the edge of the strand. The soft tissues that originally surrounded the woody strands have as a rule wholly disappeared.

In a few instances the tracheidal structure of the compressed strand was clearly evident and fairly well preserved throughout. The study of such specimens, and of isolated tracheides occurring in the rock, has enabled the nature of the thickening to be ascertained. A portion of such a well-preserved strand that was about $\frac{1}{2}$ mm. wide is represented at a magnification of 100 diameters in fig. 30. The strand of primary xylem is seen to be composed of similar, elongated, tubular elements, with no admixture of parenchyma. These elements were doubtless tracheides, although the terminations have not been observed. The appearance of the xylem and of the thickening of the tracheides is more clearly shown in fig. 31, which represents a portion of the same strand under a higher magnification. The thickening, which is fairly well preserved although there is always some alteration due to decay, appears as bars of dark carbonaceous material, that are narrow relatively to the interspaces between them. This gives rise to the transversely barred appearance evident in figs. 30 and 31. The nature of the thickening is more readily understood when isolated tracheides such as those in figs. 32, 33, are taken into consideration. It is not scalariform. At first sight it gives the impression of a close spiral, but the thickening bands prove on closer examination to be almost or quite transverse. Occasionally a band is connected with the next, but no case of a continuous spiral has been seen; it is, of course, quite possible that this modification may sometimes occur. The natural conclusion is that we are dealing with a type of annular thickening. The thickening rings are not very broad. Even when most closely placed, as in the case of the isolated tracheide in fig. 33, the portions of unthickened wall separating the thickening bands are as broad as the latter; usually the interspace is considerably wider than the thickening ring (fig. 31).

The preservation of the tracheide shown in fig. 34 is peculiar. Numerous such tracheides were dissolved out from the matrix in making a cellulose transfer from a portion of the third specimen of *Zosterophyllum australianum*. The isolated tracheides were very delicate and did not appear to have any wall remaining. The dark bands evident in fig. 34 are broader than the clear interspaces. They are composed of fine granular material which, though probably organic in origin, belongs to the matrix. The rings of thickening are represented by the clear intervals. The explanation of the specimens thus appears to be that we are dealing with casts of tracheides.

The thickening bands do not necessarily, or indeed usually, come opposite to one another on the two sides of a wall between two tracheides. They may be opposite, but, when the common wall is seen in profile as in section, they usually appear to alternate.

The tracheides, throughout the few vascular strands which have shown them clearly, appear similar, and it is evident that the type of thickening was the same in them all. No evidence has been obtained of any distinction of protoxylem and metaxylem, even on the ground of the width of the elements. It is, of course, possible that further specimens might show this. The diameter of the tracheides has been found to range from 25 μ to 50 μ.

Even in the case of the fairly well-preserved tracheides so far considered, there are indications of the material of the thickening bands having commenced to break down. This is shown by the outline of the bands becoming irregular. In many cases this goes much further, and the rearrangement of the organic material leads to an appearance of numerous small circular areas between the remains of the bars, or extending uniformly over the wall. These circular areas may give an appearance of pitting, but intermediate stages of the disintegration show that this is always to be regarded as an artefact. The commencement of this change was present in the strand represented in fig. 30, as is shown in the tracheide on the left in fig. 31. In its extreme form, when all trace of the original bars is lost, it is shown in fig. 35.

The type of annular tracheide described above is characteristic of practically all the fragments with vascular structure that have been met with in the rock. One very small fragment, however, showed narrow tracheides, a few of which were well-preserved and the clear interspaces between the thickenings were more suggestive of uniseriate, large oval pits. A portion of one of the film-pulls from this fragment is represented in fig. 36.

Discussion.—Although they cannot be referred to any particular plant, the vascular strands described above are so definitely characterised, even taken by themselves, as to provide a sound basis for comparative discussion. The solid strands have been seen to be composed wholly of tracheides with annular thickening. Metaxylem of this type can be contrasted with that composed of tracheides with scalariform or rounded bordered pits, such as is found in most existing and extinct Pteridophyta or Gymnosperms.

Primary xylem of the latter type is known for many of the vascular plants of the Middle Devonian. Thus scalariform tracheides are described for a number of plants, including the *Hostimella*-like branches from Germany that are regarded as parts of *Asteroxylon elberfeldense* (Kraüsel and Weyland, 1923), while tracheides, with bordered pits of various types compose the wood of *Palæopitys Milleri* and that of *Schizopodium Davidi* (HARRIS, 1929), the latter from Queensland. The type of metaxylem under special consideration here, composed wholly of annular or spiral tracheides, is only known for some plants from the Middle and Lower Devonian. Thus it occurs in *Asteroxylon Mackiei* (KIDSTON and LANG, 1920), and in somewhat different form in *Rhynia Gwynne-Vaughani* and *Hornea*, all from the Rhynie Chert of Middle Old Red Sandstone age. It has been found in *Psilophyton Goldschmidti* (NATHORST, 1913), and apparently in *Psilophyton princeps* and *Arthrostigma* also, from the Lower Devonian of Norway. Xylem of this type is figured as belonging to *Goslingia breconensis* (HEARD, 1927) from the Lower Old Red Sandstone of Wales and the xylem of *Zosterophyllum myretonianum* (LANG, 1925) from the lower horizon of the Caledonian Lower Old Red Sandstone is composed of annular elements.

It is unnecessary to enter into details regarding these various plants, but an addition may be made to the previous description of the xylem of *Asteroxylon Mackiei* (KIDSTON and LANG, 1920), and a figure given of what is the most perfectly preserved example of wood of this type (Plate 13, fig. 43). In the original description in the memoir on this plant, it was pointed out that (except for a difference in diameter of the protoxylem elements) the xylem was composed of similar tracheides; these were termed spiral, and it was emphasised that no scalariform or pitted tracheides were present. This description holds, with the modification that, while spiral tracheides can be clearly demonstrated, the thin bands of thickening of most of the elements form unconnected rings; on the whole, the thickening is annular. The piece of xylem represented in longitudinal section in fig. 43 is exceptionally well preserved, the tracheides not being as is usually the case, isolated by maceration of the middle layers of their walls. The middle lamella, secondary and tertiary layers can be distinguished in the walls separating adjoining tracheides. Further there seems to be no indication of a spiral course of the thickening in most of the tracheides shown; they appear to have narrow rings of thickening projecting into the lumen. But the narrow tracheide on the extreme right showed distinct spiral thickening in the upper part of the figure, and equally distinct annular thickening lower down.

While *Asteroxylon Mackiei* is an example of this type of wood from the Middle Devonian, the fragment of xylem removed from *Psilophyton Goldschmidti* (NATHORST, 1913, Plate IV, fig. 6), and described by NATHORST as showing annular tracheides, is a clear example from the Lower Devonian. The stratigraphical indications afforded by the presence of this type of xylem in the North Road Quarry are thus clearly in favour of an Early Devonian Age for the Australian flora, without being decisive between Lower and Middle Devonian.

Zosterophyllum australianum, n.sp.—(Plate 12, figs. 15—29.)

The collection from the North Road Quarry includes three specimens of what has proved to be a new fructification. This is not in connection with vegetative organs so that nothing can be said as to the morphology of the plant as a whole. The stalk of the fructification resembles the fragments of axes in the rock but has no detailed characters that warrant an identification. Above the naked, unbranched stalk comes a region in which the axis is hidden by a number of spirally placed appendages which have proved to be sporangia. A number of detached appendages (sporangia) have been met with in the rock and can be referred to the same plant. One such isolated sporangium was obtained from Wood's Point and is of interest as a record of the plant from a second locality; this detached sporangium has been selected for illustration (fig. 29). The main source of our information regarding this new and distinctive plant, however, has been the study of the three, fairly complete incrustations.

As the descriptions will show, the organisation of the fructification as an axis bearing shortly stalked, large sporangia, that are extended tangentially and dehisced by a slit running along the extended distal edge, corresponds to that found in *Zosterophyllum myretonianum* Penh. from the Lower Old Red Sandstone of Scotland. The Australian plant can, therefore, be placed as a new species in this genus.

The first specimen is represented of natural size in fig. 15 and enlarged two diameters in fig. 16; the counterpart is shown in fig. 17. As was the case for many of the branched axes described above, the organic material had wholly disappeared, and the form of the plant is represented by a cast of a fine-grained brown material. Though flattened in the rock the specimen has retained considerable thickness and reveals the form of its component parts by the modelling. In figs. 15, 16 the stalked fructification is viewed from one side and has not been split through. The counterpart (fig. 17) shows concave impressions corresponding to the convexities in fig. 16; these concavities are lined by a thin layer of the brown material. The main thickness of the lower part of the stalk has come away on the counterpart.

The specimen is clearly an axis, bearing around its upper portion the spirally arranged and closely-crowded appendages, that will be shown to be large tangentially expanded sporangia. This specimen measured about 3·5 cm. in length and its breadth in the upper spike-like portion was about 12 mm.; the lower half is a brown flattened incrustation of an axis, about 5 mm. wide and destitute of appendages. This axis evidently continued into the upper portion, but is completely hidden by the closely-placed appendages that are viewed from the outside of the fertile spike in fig. 16. Seven of these appendages are clearly distinguishable. Their position indicates a spiral arrangement and the differences in outline they present can be understood as depending on this. Those in the middle line are viewed from the abaxial side and show their full breadth, while those more laterally placed are only partially visible. They evidently widened from a stalk-like basal portion into the distal portion that has a rounded margin or summit; in other words, there is the short stalk and the tangentially extended sporangium. The largest, seen from the abaxial side, is 8 mm. across at its widest part, but some of the upper appendages viewed similarly are only 5·5 mm. across. It is impossible to give a measurement of length owing to the gradual passage of the upper portion into the stalk and of the latter into the axis bearing it; it may be said approximately that the expanded portion (sporangium) may be 4 or 5 mm. in this direction.

Two of the appendages above and to the left in fig. 16 are viewed obliquely, only portions of their distal regions being visible, and the lowest appendage on the left is seen similarly, but in its whole length. Almost opposite to the latter appendage the lowest appendage on the right side is viewed from its edge and has an evident thickness of some 2 mm. This thick edge gives the appearance of two ridges with a groove between. The thickness of this appendage is the only indication in this specimen of the radial measurement of the sporangium.

The counterpart (fig. 17) confirms the features referred to above, but does not add any particular information. The appearance of a rim around the convexity of some of the appendages is only indistinctly marked, and will be better considered in connection with the second specimen in which this feature is more evident.

The size of the second specimen will be evident from fig. 18, which represents the counterpart of natural size and is, therefore, comparable with the adjacent figure of the first specimen (fig. 15). The proportions of the second specimen are throughout much more slender than in the case of the one described above. Its total length was about 2·5 cm. The lower 12 mm. of this is a naked axis about 1·5 mm. wide. The fertile spike measures about 4·5 mm. across. The appendages themselves are also small, relatively to those of the first specimen, measuring about 3 mm. across the widest part of the sporangium. The morphological agreement between the two specimens is, however, so close that there seems no reason at present to draw a specific distinction on the ground of size only, though the difference must be borne in mind.

The specimen is enlarged $5\frac{1}{2}$ times in fig. 19, and its counterpart in fig. 20. Like the first specimen, it is represented by brown mineral material that has replaced the organic substance of the plant. There are 6 or 7 appendages, clearly shown or indicated. These are seen in the solid so far as they emerge from the matrix in fig. 19, while they are represented by corresponding depressions in fig. 20. The second appendage from the top in the middle line of fig. 19 is viewed from the abaxial side, but (in contrast to those in fig. 16) so as to give the impression of a solid edge. This gives the appearance of a marginal rim, a feature that is also evident in the counterpart. The appendage below and to the right of this in fig. 19 and also the incomplete appendage below and to the left of these are viewed obliquely from the side. They give a definite impression of thickness, as if they were solid casts. The convex edge of the solid body in both these cases presents the appearance of two lips with a groove between; this edge of the lower incomplete sporangium is photographed at a higher magnification in fig. 21.

The interpretation which the casts of appendages in this specimen, taken together with the information obtained from the first specimen, suggested was that we were dealing with large sporangia that had opened by a slit along the summit and had become filled with matrix. These sporangia, being borne spirally on short stalks around the main axis, would present diverse appearances according to the point of view. The interpretation was thus consistent with the directly abaxial view, as well as with views in which the side or the free distal margin of a sporangium is more or less turned to the spectator, showing the thickness of the sporangium and the line of dehiscence. It would thus further lead to an explanation of the marginal rim, evident in some of the impressions.

It did not appear likely that further work on these two specimens, from which the carbonaceous material had wholly disappeared, would throw enough further light on the morphology to justify injury of them as type-specimens. The interpretation indicated above was therefore especially tested by the examination of the third specimen which has now to be described. This was utilised for detailed examination by various methods, in order to ascertain as much as possible regarding its structure and morphology.

The preservation of the third specimen of this type of fructification was in some respects different from that of the two so far described. While the stalk and in part the appendages were represented by brown material similar to that forming the other two incrustations, a considerable proportion of black carbonaceous material remained. The specimen further differed from those described above, in that, while the splitting of the rock had provided two surfaces showing impressions of the axis and spike (figs. 22, 23), these were not strictly a fossil and its counterpart, but impressions of opposite sides of the flattened spike. The bulk of the spike (fig. 24) had come away with a little of the matrix when the block was split and had fortunately been preserved. The two impressions on the rock are represented, enlarged two diameters, in figs. 22 and 23 and the larger piece of flattened spike at the same magnification in fig. 24. There was another small piece of the spike which is not figured. The surface of the piece shown in fig. 24 is that which would fit on to the rock-surface in fig. 22.

As the figures enlarged two diameters (figs. 22, 23), show when compared with figs. 16, 17, the third specimen corresponded in proportions with the first. The whole specimen (*cf.* fig. 22) had a length of about 4 cm.; the flattened axis was some 2 cm. long and about 3·5 mm. broad, while the portion of the spike-like region preserved represents another 2 cm. It is unnecessary to go into a detailed description of the two impressions on the rock. The stalk was represented by brown material showing oblique cleavage; the spike is represented by the impressions of a considerable number of appendages. Probably because the spike itself was less flattened than in other cases, most of the stalked sporangia had evidently projected obliquely outwards from it so that the impressions are due to their distal ends somewhat flattened. Without describing the impressions individually, it can be noted that they tend to show an oval or diamond-shaped outline; they are further characterised by a linear mark, extending horizontally and usually nearer to the upper than to the lower edge of the whole impression. This linear mark appears as two lines separated by an interval. It evidently corresponds to the impression of the thick margin of the appendage or sporangium, but seen in this case as if from within. These impressions are to be seen in both figs. 22 and 23, but most clearly in the former figure. The presumption that has to be further examined is that the linear mark represents the line of dehiscence of the large sporangium.

Before considering the further investigation of the impressions the surface of the flattened spike shown in fig. 24 must be described. In this case we are looking at a spike as if from the outside. The upper portion of the stalk is seen at the lower part of the fragment on its left side. Above this are seen the convex ends of a number of sporangia which show a linear mark, corresponding to that referred to above in commenting on the impressions. The sporangia at the left edge of the fragment are imperfect, but a little consideration will show that the whole could be turned over and fitted on to the impression on the rock shown in fig. 22. In other words, the detached spike shows the ends of the sporangia from the outside, the impression on the rock shows them as if from the inside.

Cellulose film-pulls, without previous etching of the surface, were taken of the impressions on the rock and provided further information. Only that from the surface shown in fig. 22 need be considered, and this is shown, reversed, in fig. 25. By reversing the film the sporangia are viewed as if from the outside and they now correspond to those seen on the surface of the spike (*cf.* fig. 24). This correspondence was shown by similar film-pulls taken from the surface of the piece in fig. 24, but not reversed. Such pulls have removed both the yellow and black material; if treated with hydrofluoric acid only the latter remains undissolved. Other films were thus treated to show the remains of the organic material alone.

It is unnecessary to describe the sporangia as shown in the film-pull individually. Some of those in fig. 25 are represented at a higher magnification in fig. 26. A consideration of these will show the clear demonstration of the line of dehiscence that is obtained by this method. A considerable portion of the abaxial wall of the sporangium is shown below the slit and a smaller portion of the adaxial wall above it.

It has been mentioned that the first pulls from this flattened spike in fig. 24 gave a picture of the same sporangia so like that given by figs. 25 and 26 that it is unnecessary to figure the pull. In both cases, the surface removed included the remains of the sporangial wall above and below the slit of dehiscence, and thus gave a picture of the summit of the sporangium. A succession of film-pulls was now made from the spike in fig. 24, the surface being treated with hydrofluoric acid before each pull was made. In this way, successively deeper sections were, as it were, cut into the flattened spike. In the early pulls the slit widened out to the cavity of the empty sporangium. This then took on a tangentially extended oval shape and diminished in size as the plane of section cut deeper. A fairly deep pull is shown in fig. 27 at the same magnification as the adjacent fig. 26. In fig. 27 the sporangia are represented by the thin black layer of the carbonaceous wall, which is complete, since the plane of section is below the level of the slit of dehiscence. The sporangial cavity is empty, or rather was so at the time of fossilisation, and has become filled with matrix rather different in type from that of the rest of the rock. Evidence is thus afforded that we are dealing with flattened cones in which the empty sporangia are represented by casts of the cavity with remains of the wall on the surface.

It may be mentioned that observations with reflected light and also some of the film-pulls have shown indications of the elongated cells of the sporangial wall radiating between the stalk and the line of dehiscence. The wall is not, however, sufficiently preserved for detailed description or figures.

Even had no further evidence been obtained it would be justifiable to regard the sporangial nature of the appendages as established by the consistent body of facts regarding their shape and the presence of the line of dehiscence. A fortunate preparation, however, enables us to add the conclusive fact of the presence of spores in the sporangia. The sporangium in question is the lower one on the left in fig. 26. On examining the carbonaceous material in the film-pulls a distinction had been drawn between homogeneous opaque portions that were apparently remains of the sporangial wall and more or less rounded or oval areas with a reticulate structure. The latter were suggestive of being remains of the walls of spores but it was not possible to identify them with certainty.

The next film-pull to that shown in fig. 26 was treated with hydrofluoric acid, to remove the yellow mineral matter and leave only the carbonaceous remains. In the position of the dark mass seen on the left-hand side of the incomplete sporangium this treatment revealed an indefinite mass of such possible spores and a few more isolated groups. The appearance of these groups was significant and characteristic, as is shown in the case of two of them photographed in fig. 28. While the preservation of the individual spores is not good, their outline can be distinguished and the groups are clearly tetrads. In the lower tetrad two spores are seen in focus and a third more dimly. In the upper tetrad portions of three spores are seen against the film while the fourth is pulled off, and appears as an opaque black body. It is this association of the spores in tetrads that affords the final proof of their nature and, since they are met with within the enlarged hollow appendages, of the correctness of identifying the latter as sporangia.

None of the isolated spores have had their walls preserved as continuous bituminised membranes. The fragments into which the carbonised wall has broken fall apart when the rock is dissolved by hydrofluoric acid, so that this method does not serve to obtain isolated spores. Thus, although there is reason to believe that isolated spores occur within some of the sporangia and in the matrix, it is safer to rely for evidence on those found united in tetrads. From these it appears that the spores were moderately large, measuring about 75 μ. There is no reason to think that there were spores of two sizes and the plant was presumably a homosporous Vascular Cryptogam.

Discussion.

The results of the investigation of this fructification, which has been named *Zosterophyllum australianum*, can be briefly summarised. The detached fructifications must be considered by themselves for, apart from the naked unbranched axes which bear the spirally arranged sporangia above, the vegetative organs are unknown. The sporangia are apparently terminal on short stalks; they are of large size, tangentially extended and opened by a slit extending along the convex summit. The presence of spores, about 75 μ in diameter, and still united in tetrads has been demonstrated in the sporangia. Most of the sporangia are empty and filled with mineral material, giving rise to solid casts covered by remains of the walls. This holds also for sporangia without stalks found isolated in the rock.

The arrangement of the short-stalked appendages on the axis and their form suggested comparison with *Zosterophyllum myretonianum*, from the Carmyllie beds of the Lower Old Red Sandstone of Scotland (Lang, 1925). The characters of this plant, including some new features of importance that have been ascertained as a result of comparison with the Australian plant, must therefore be summarised.

Zosterophyllum myretonianum is now one of the most completely known of Lower Devonian plants, although all our information has been obtained from flattened incrustations that are for the most part poorly preserved. It was a relatively small plant, consisting, so far as is known, of a branch-system of leafless axes, which were traversed by a central vascular strand composed of annular tracheides. There is evidence that erect branched axes, the terminal regions of which bore more or less closely associated, stalked, reniform appendages, sprang from a rhizomatous region. The characteristic branching, in which the branch divided at once into an upwardly growing and a downwardly growing axis, may have been mainly in the rhizomatous region.

For our present purpose, attention may be concentrated on the terminal regions bearing the shortly stalked appendages. A branch of the vascular strand of the main axis passes into the stalk and the distal region of the appendage is expanded tangentially with a convex margin. These distal regions are frequently met with isolated and then have a reniform shape, a basal depression marking the place of separation from the stalk. There is often an appearance of a marginal rim to the appendage.

The arrangement in a loose spike and the general appearance of the appendages were highly suggestive of their being reniform sporangia. But, while a difference between the remains of the internal tissue and the boundary wall was recorded, the presence of spores was not demonstrated. The conclusion reached was that, "It would be an assumption to identify the reniform appendages as sporangia, though this may ultimately prove to be their nature." (Lang, 1925, p. 450.)

The work on the Australian fructification, where the sporangia were preserved as casts, led to a further attempt to demonstrate the sporangial nature of the similar, though flattened, structures in *Zosterophyllum myretonianum*. Two critical preparations are illustrated in figs. 44, 45, on Plate 13, which completely justify identifying the reniform appendages as sporangia. Fig. 44 shows a portion of an isolated sporangium removed on a film-transfer. The interest of this preparation is that, though the sporangium was empty, the line of dehiscence is clearly evident with portions of the halves of the sporangial wall to either side of it. This preparation explains the appearance of a marginal rim so often met with. Fig. 45 is a photograph of the contents of another flattened sporangium removed from the rock on the same film-transfer. While most of the contents form a black layer in which no structure can be detected, thin portions or intervals reveal that this is made up of spores. In the figure a number of the isolated spores, 25—30 μ in diameter, are clearly shown. The same spores have been found in film-pulls of a number of other specimens.

There is thus complete proof that the upper region of the branches of *Zosterophyllum myretonianum* bore spirally arranged, large, shortly-stalked sporangia, opening by a slit along the tangentially extended upper or outer edge, and containing spores.

The above account of *Zosterophyllum myretonianum* indicates, without further comment, how close the morphological comparison is between its terminal fertile regions and the Australian fructifications. The agreement justifies placing the latter plant, the vegetative organs of which are as yet unknown, in the same genus, under the name *Zosterophyllum australianum*.

This clear comparison with a plant from the lower fossiliferous horizon in the Lower Old Red Sandstone of Scotland is in favour of attributing a Lower Devonian* age to the Australian beds.

Sporogonites Chapmani, n.sp.

A specimen from the North Road Quarry appears to be so closely comparable in form with the incrustations of *Sporogonites exuberans*, Halle, from the Lower Devonian of Röragen, Norway, that it can be placed under the same generic name. There is no evidence to show whether or not the Australian plant had the internal construction that was demonstrated in a single petrified example of the Norwegian species and in any case it is better to keep it specifically distinct. We have pleasure in naming it after Mr. F. Chapman, A.L.S., who has been a pioneer in recognising the significance of the plant-remains in these strata as possibly indicating the Devonian age of some of the rocks.

A second specimen of the same general type, though considerably smaller, was found in a disused quarry about ½ mile up the east branch of Stringer's Creek, Walhalla. The horizon, being that of the Centennial beds, is the same as that of the North Road Quarry. It will require separate description but, for the present at least, may be kept under the same specific name as *S. Chapmani*, forma *minor*.

* It may be further noted that reniform bodies, similar to those of *Z. myretonianum* are, recorded from the Senni beds (the upper horizon of the Lower Old Red Sandstone of Wales) by Heard. He regarded them as sporangia belonging to *Goslingia breconensis*. (Heard, 1927, Plate XV, fig 4.)

One of the incrustations of *S. Chapmani* from the North Road Quarry is represented of natural size in fig. 10, and figs. 11 and 12 show the fossil and the counterpart enlarged $5\frac{1}{2}$ diameters. The total length of the specimen was about 2·5 cm. The slender unbranched stalk is straight and about 0·75 mm. wide. It widens gradually to form a basal region to the terminal capsule-like structure. This is about 5 mm. long, or, if the widened upper region of the stalk is included, about 7·5 mm. The capsule-like structure is 2·5 mm. wide in its lower part where the sides are parallel and above this tapers to a somewhat rounded point. These features are best shown in the magnified photographs (figs. 11, 12) and the various regions may be further described with reference to these two corresponding exposures of the one specimen.

The slender stalk gives a smooth linear impression on the rock. Fragmentary remains of black carbonaceous material persist on this, but nothing can be learnt as to the structure. The stalk widens gradually to form the base to the terminal capsule, and just beneath this is about 2 mm. wide. The widened region of the stalk exhibits longitudinally running ridges separated by shallow grooves, four ridges being visible on the surface exposed in fig. 11. These ridges die out gradually on passing downwards to the narrow stalk.

There is a fairly definite and apparently natural boundary between the base of the capsule-like body and the widened end of the stalk, the line indicating this being slightly convex downwards. There is an appearance of a transverse limit between the cylindrical portion of the capsule and the conical terminal region, but it is by no means clear that this indicates a natural boundary. The main thickness of the terminal region has come off on the half shown in fig. 11, while the main thickness of the middle region of the capsule is on the half shown in fig. 12; the suggestion of an upper transverse boundary is perhaps better explained as due to this. The appearance of the cylindrical region differs according to the lighting. In some lights, as in fig. 11, the outermost ridges of the widened region of the stalk seem to continue into the boundary wall of the capsule on either side, while the region between shows three low ridges. These are not continuous with the two central ridges of the stalk. In other lights the distinction that is most evident is that between a fairly thick boundary wall on either side and a uniformly expanded central region. There is a certain amount of black, opaque, carbonaceous material over the surface in fig. 12. The thickness of the wall can be followed around the terminal pointed region but nothing can be said as to the organisation of the inner region here. Probably, in spite of the apparent demarcation, it is merely the continuation of the region below. This interpretation of the whole capsule-like structure as composed of a thick wall enclosing a continuous cavity is, on the whole, supported by a film-pull made from the surface shown in fig. 11, although the pull did not reveal any detailed structure. The presence of spores has not been demonstrated, though there is no reason to doubt that we are dealing with a spore-containing structure.

The specimen of *S. Chapmani*, f. *minor*, from Stringer's Creek, though similar in general type, is much smaller than the specimen of *S. Chapmani* described above. The total length is 9 mm., the capsule-like structure, including the widened end of the stalk, representing about 5 mm. of this. The capsule itself may be estimated as about 3 mm. long. It is about 1·5 mm. broad, while the narrow lower part of the stalk is under 0·5 mm. This specimen is not represented of natural size, but figs. 13, 14 show it enlarged $5\frac{1}{2}$ diameters, and are thus comparable with figs. 11, 12 of *S. Chapmani*. Fig. 13 shows the slender stalk, the widened upper end of this, and the capsule-like structure with its bluntly pointed upper end. In the case of the counterpart shown in fig. 14 the stalk and lower portion of the capsule are correctly shown, but the terminal region had been injured and mended.

There are indications of ribbing on the enlarged upper region of the stalk and the line of demarcation between this and the capsule is fairly evident, though not sharply defined. The sides of the capsule are slightly convex, but its shape was fairly cylindrical; the pointed upper end is well seen in fig. 13. In this specimen (fig. 13) the outline of the wall of the capsule can be traced, but little or no carbonaceous material remains; the middle region was a hollow, the substance from which had come off on the other half. In this region of the counterpart (fig. 14) there was a considerable amount of dull black material, apparently representing the contents of the capsule. It was impossible to decide whether this had completely filled the cavity, but no evidence of the presence of a columella was obtained.

The general appearance of the dull black material contained in the capsule of this specimen was strongly suggestive of its being derived from a mass of small spores. A small piece when macerated became fairly translucent and appeared to be composed of granules of organic material that at places were arranged as if derived from curved portions of cell-walls, but no evidence of well-preserved spores was obtained.

Discussion.

The figures of these two specimens, *i.e.*, of the single example of *Sporogonites Chapmani* (figs. 10–12) and of the single example of *S. Chapmani* f. *minor* (fig. 13, 14) show all the features that can be definitely recognised. The distinction of stalk, enlarged upper region of stalk, and capsule-like terminal structure is clear. The distinction of a thick boundary wall from a central region, that presumably contained the spores, is on the whole established. It is doubtful whether the terminal region differed in its construction from the main part of the capsule; on the evidence it is best regarded as the bluntly pointed upper end of this.

It is noteworthy that two specimens of this type should have been found in two distinct exposures of the same stratigraphical horizon. This justifies the hope that further specimens may be discovered which will lead to the details of the morphology of *S. Chapmani* being more fully ascertained. For the present, comparisons must be based on the features summarised above.

In 1916 Halle (Halle, 1916), described under the name *Sporogonites exuberans* a remarkable fossil from the plant-bearing deposits of Lower Devonian age at Röragen, Norway. A number of specimens were preserved as flattened incrustations, while a single petrified specimen afforded more precise information as to the construction of the capsule. The presence of spores was demonstrated, not only in the latter specimen but in one of the incrustations. Only the petrified specimen, however, showed that the spore-sac was dome-shaped, curving over the summit of a central, sterile columella. Outside the spore-sac came the fairly thick wall of the capsule.

The incrustations of *Sporogonites exuberans* showed a capsule-like body borne on the end of a straight, slender stalk that was 5 cm. long in the most complete specimen. The stalk was 0·5 mm. in diameter and faintly striated longitudinally. The capsule was 6–9 mm. long by 2–4 mm. in diameter at the thickest part; it had a rounded apex and a tapering base gradually merging into the thicker upper end of the stalk. The basal part of the capsule (or widened upper end of the stalk) shows longitudinal furrows passing down into those of the slender stalk; the main part of the capsule is also striated, with alternately broad and narrow furrows. These features are further described and fully illustrated in Halle's paper.

When the Australian specimens are compared with the incrustations of *Sporogonites exuberans* from Norway, a very striking general resemblance is at once evident as well as differences in details. The regions of stalk, widened base, and capsule correspond. There is an appearance of ribbing in the base and capsule in both cases, although the details of this differ. A more important difference is found in the pointed upper end in the Australian specimens which contrasts with the rounded or dome-shaped top of *S. exuberans*. In both sets of specimens there is evidence of a thick outer wall to the capsule. It must be borne in mind that had Halle not obtained the single petrified specimen there would be no evidence (from the incrustations) of the presence of a columella in *S. exuberans*.

The resemblances appear to justify the inclusion of the Australian specimens in the genus *Sporogonites*. On the other hand, the differences in details warrant specific distinction of *S. Chapmani* from *S. exuberans*.

The recognition of this new type of fossil plant was, perhaps, the most striking result of the study of the fossil flora preserved at Röragen. It has so far not been met with elsewhere in Europe. It is thus remarkable that closely similar specimens should be discovered in a small flora in Australia. At Röragen *S. exuberans* is associated with such characteristic Lower Devonian plants as *Arthrostigma gracile* Daws. and *Psilophyton princeps* Daws. and the age of the deposit is thus clearly shown. The indication afforded by the presence of *Sporogonites Chapmani* in the Centennial beds of the Walhalla series is therefore in favour of ascribing a Lower Devonian age to these beds.

As regards the systematic position of *Sporogonites*, the Australian specimens do not provide any further evidence. In discussing the nature of *S. exuberans* in 1916 Halle regarded it as a structure agreeing closely with the sporogonia of the Bryophyta, though not to be referred to any of the existing groups of that phylum. It seemed most comparable with sporogonia of the Bryales. While inclining to this interpretation, he made another important suggestion. "The sporogonium has not been found attached to the gametophyte; and the possibility must be faced that it may represent only the upper part of a more highly developed sporophyte, perhaps on the line of the pteridophytes." (HALLE, 1916, p. 40). One consideration that weighed with him in this was the uncertainty of any records of palæozoic Bryophyta.

The discovery shortly afterwards of the existence of simply organised Vascular Cryptogams, the large sporangia of which terminated straight leafless branches of the thalloid plant-body, appeared to render HALLE's alternative suggestion as to the nature of *Sporogonites* the more probable one. This was especially so because the sporangia of *Hornea* (in contrast to those of *Rhynia*) possessed a columella surrounded by a dome-shaped spore-sac.

On the other hand, the existence of Bryophyta in the Carboniferous rocks may now be regarded as definitely established. In addition to the stem, bearing moss-like rhizoids, described by LIGNIER a number of types of Hepaticæ, both thalloid and leafy, have been recognised and described by WALTON (WALTON, 1925, 1928). The improbability of the occurrence of Bryophyte sporogonia in palæozoic rocks is thus lessened.

The two alternative views as to the systematic position of *Sporogonites*, stated by HALLE, apply to the Australian specimens of *S. Chapmani* as they did to *S. exuberans*. There is neither direct evidence that the structures are sporogonia nor proof that they represent the terminal fertile regions of simple Vascular Cryptogams. It may perhaps be said that the discovery, in a widely distant locality, of further specimens that present striking general resemblances to moss sporogonia on the whole strengthens the case for HALLE's original interpretation of the nature of *Sporogonites*. This morphological and systematic question still remains, however, an open one.

Spore-like bodies, *incertæ sedis* (Plate 13, figs. 37–39).

With the exception of the spores of *Zosterophyllum australianum*, which could be identified with certainty owing to their association in tetrads and their position in the sporangia, little satisfactory evidence of the occurrence of isolated spores of vascular plants distributed through the rock has been obtained. Some bodies that are probably of this nature have been noticed in film-transfers, but the membrane is represented by carbonaceous fragments and they afford no further information.

The most marked and abundant spore-like bodies cannot be regarded with any likelihood as spores of a vascular plant. Isolated specimens are found throughout the rock, but they are met with in greatest number where they have accumulated on the fine-grained surfaces of mud-stone that bore the macerated vascular strands. They then appear as small, round or oval, black bodies, which, even with the naked eye or a lens, can be seen to exhibit a considerable range in size. They can be removed from such rock-surfaces by film-transfers. Portions of such transfer preparations, magnified 75 diameters, are shown in figs. 37, 38, and give an adequate idea of the general appearance of these bodies.

These spore-like bodies have a wide range in size; specimens from 250 μ to 50 μ have been measured. Sometimes they appear as if slightly shrunken from a somewhat larger original cavity in the matrix. They further exhibit a range in appearance from opaque black bodies, limited by a thick wall, to a reticulate structure, the black network forming a hollow sphere. Two small examples in the latter condition are shown more highly magnified in fig. 39.

The most natural view appears to be to regard the opaque examples as the better preserved specimens, and to interpret them as spore-like bodies with a thick wall. Sometimes specimens show this wall more or less fragmented or shattered. More frequently, however, a hollow network takes the place of the thick wall. This can be interpreted as derived from the latter by a process of decay, perhaps somewhat comparable to what has been seen to occur in the case of the carbonised woody strands. On this view the reticulate structure, which exhibits differences in the width of the meshes, would be no part of the original structure, though it might depend on the nature of the thick wall.

Even if the above interpretation of these bodies as spore-like is adopted, their nature and affinities remain quite obscure. The range in size is against their being regarded as spores of any higher plant, and they exhibit no positive features in favour of this. A distant comparison may, perhaps, be made with the spore-like bodies distributed through rocks of various ages (*e.g.*, the Upper Devonian shales in North America) which were termed *Sporangites* by DAWSON. The nature of these is also obscure. They exhibit a range in size, but are preserved as compressed, thick walls, that are brown and translucent. The wall shows no indication of breaking down to form a reticulum.

The nature of the bodies in the Australian rock is so obscure that an alternative interpretation has been considered. On this the network would represent a cellular structure forming a hollow sphere and the thick dark wall would be a secondary derivation from a layer of mucilage. No sufficient evidence for such a view, on which the structures would be looked on as isolated algal colonies, has, however, been obtained.

With this illustrated record of these bodies they may be left for the present, without naming them, in the hope that further field work may throw light on their nature and origin.

Reticulate incrustation, *incertæ sedis* (Plate 13, figs. 40, 41).

Two specimens of an irregular black incrustation were met with. A portion of one of these is represented of natural size in fig. 40, and another portion is shown, enlarged two diameters, in fig. 41. The latter portion was transferred to a cellulose film and mounted in canada balsam, without, however, adding to the information obtained by inspection of the specimen on the rock. The two figures show the general appearance of the network, the various sizes of the oval meshes and the differences in the width of the carbonaceous boundaries separating the latter.

The fossil is of quite uncertain nature; it is not even clear that it is of vegetable origin. It naturally suggested a comparison with specimens of *Parka*, that have lost the discoid spore-masses from the cavities. But careful examination and comparison has led us to the opinion that there are no grounds for regarding the Australian specimen as of this nature.

Conclusion.

The plants described in this paper are few in number, but of considerable botanical interest. They also provide definite palæobotanical evidence bearing on the geological age of the Centennial beds in the Walhalla series. The two questions to be dealt with in these concluding remarks thus concern the botanical and the stratigraphical significance of this small collection of plants from the North Road Quarry, Walhalla. The consideration can be brief, since the various types of plant-remains have been discussed individually from these standpoints in the body of the paper.

The remains of uncertain nature can be omitted from the discussion, which can be profitably limited to the four types of well-characterised remains. These are: (1) the smooth-branched axes, with or without "buds" (*Hostimella* sp.); (2) vascular strands showing the tracheidal structure; (3) *Zosterophyllum australianum*, n. sp.; (4) *Sporogonites Chapmani*, n. sp.

The indications as to geological age afforded by these remains are fortunately clear and free from any serious lack of agreement. Individually and still more strongly, when taken together, they involve close comparisons with Early Devonian floras and particular plant-remains known from Europe. The term Early Devonian has been used to emphasise the contrast with the Upper Devonian and to leave the decision between Middle and Lower Devonian to some extent open. On the whole, however, the comparisons are closer with Lower Devonian remains. It is true that, so far, branched axes with the peculiar and very recognisable axillary "buds" have only been met with in Middle Devonian deposits in Europe. The general type of smooth, branched axes, apart from this character, is a feature of both Middle and Lower Devonian floras and the same can be said as to the type of vascular tissue, with the metaxylem composed of annular tracheides. On the other hand, the stalked, sporogonium-like incrustations are so similar to some of those of *Sporogonites exuberans* from the Lower Devonian of Norway that the Australian specimens can be placed in the same genus under the name *Sporogonites Chapmani*. While this comparison is based on close general resemblance of imperfectly-preserved remains, that which justifies placing the Australian fructification, as *Zosterophyllum australianum*, in a genus hitherto only including a form (*Zosterophyllum myretonianum*) from the Lower Old Red Sandstone of Scotland is based on clear morphological characters. It is, therefore, botanically more important. It is, of course, true that such generic types as *Zosterophyllum* and *Sporogonites* need not have been confined to the Lower Devonian, but may, for example, have extended into the Middle Devonian. Stratigraphical comparison must, however, be based on our present knowledge and these two generic types in Europe are clearly Lower Devonian. The evidence from the flora of the North Road Quarry might be consistent with the beds being Middle Devonian, but since the direct generic comparisons are mainly with plants so far known only from Lower Devonian beds, the latter age is on the whole more strongly indicated.

We feel justified in regarding this evidence from the fossil plants as important and significant, and to be such as must be given full weight in the consideration of the geological age of the Centennial beds. These beds are at present included in the Walhalla series, which is regarded by the Geological Survey of Victoria as forming the upper part of the Upper Silurian (Yeringian). The evidence afforded by the fossil plants indicates the need of reconsidering this conclusion, at least in so far as it applies to the horizon of the Centennial Beds. The statements as to the occurrence of graptolites along with highly-organised vascular plants do not appear to apply to the upper beds of the Walhalla series such as those forming the North Road Quarry. So far as this locality, and the Centennial beds generally, are concerned, the palæobotanical evidence is unequivocally in favour of an Early Devonian age.

This conclusion regarding the upper part of the Walhalla series points to the need of very critical re-examination of the evidence for the association of graptolites with highly-organised plants, which has been stated to hold for the lower part of the Walhalla series and the underlying Jordan River series. Before this can be accepted and the Silurian age of any of the highly-organised plants regarded as established, good specimens of plants associated with graptolites will require to be collected and critically studied. As was explicitly pointed out in the introduction, however, this paper does not deal with the plant-remains from these lower horizons.

The botanical interest of the various plant-remains has been dealt with in relation to the description of each type. Only the points that definitely add to our knowledge need be touched on here. In connection with the clear examples of branched axes with axillary "buds," two specimens with an actual branch in the neighbourhood of the branch-axil have been described. The developed branch does not stand strictly in the axil, but occupies a position that may be compared generally with that of the presumably dormant "buds" in other specimens. Knowledge as to the structural features of the latter is still lacking, but it can be readily conceived how such a structure could arise in development. The specimens with a branch in this position probably do not indicate a resumption of growth on the part of a dormant bud, but rather the development of a branch in place of this which may have taken place at the time of the primary development of the branch-system. The knowledge of these branched specimens is another step towards understanding the morphology of the axes with the axillary structures but does not fully elucidate them.

The information obtained as to a particular type of vascular strand and tracheidal structure extends, but does not fundamentally affect, our previous knowledge. The same may be said as to the specimens of *Sporogonites Chapmani*, although the discovery of further specimens of this general type in a new and distant locality is itself a fact of great interest. On the other hand, the discovery of a new species of *Zosterophyllum*, as determined by the fructification, is not only of interest for the same reason, but because it has led to a completion and deepening of our conception of the morphology of this type. Not only do the specimens of *Zosterophyllum australianum* enable us to picture this fructification in the solid, but they have led to a fuller understanding of the corresponding region of *Zosterophyllum myretonianum*. In both we have clear proof, by the discovery of spores that the shortly stalked, tangentially extended appendages were sporangia of large size. These sporangia dehisced by a split extending along the tangentially extended summit. In this character they resembled the much smaller sporangia of some species of *Lycopodium*. But in *Zosterophyllum*, the stalked sporangia formed a close or lax spike and no sporophylls or leaves were present.

Since in the case of *Zosterophyllum myretonianum* the rhizome and erect axes, the vascular structure, the arrangement and structure of the sporangia and the spores are now known, this leafless and rootless Lower Old Red Sandstone plant is the most ancient fully-known plant. It is therefore of peculiar interest to have the morphology of this type of fructification confirmed and extended by the discovery of the Australian species.

Not only is the flora as a whole of stratigraphical importance, but it is of very considerable botanical interest to meet with an assemblage of plants of Early Devonian type in Australia. It has long been known that there was agreement in general features and in generic types between the Upper Devonian flora of Australia and those of the northern hemisphere. But there are still comparatively few data as to the composition of the still earlier floras in the southern hemisphere. A few plants, including the recently described *Schizopodium Davidi*, HARRIS, that are regarded as of Middle Devonian age are recorded from Queensland (DAWSON, 1871 ; HARRIS, 1929). The only other Early Devonian forms are some rather obscure remains from the Falkland Islands (HALLE, 1911 ; SEWARD and WALTON, 1923) ; the most interesting of these are slender branched axes with what appear to be terminal sporangia. Thus the flora described in this paper, small as it is, is the most extensive and definite assemblage of plants of Early Devonian type yet known from the southern hemisphere.

It is of great interest to find that the plants are so clearly comparable with Early Devonian plants from Europe. It may be hoped that the further collection and study of fossil plants from these strata in Victoria will not only reveal new forms, but add to our knowledge of the geographical distribution of early land plants.

Diagnoses of New Species.—Zosterophyllum australianum, n. sp.

Axis or stalk of strobilus naked below; concealed above by the spirally arranged, short-stalked sporangia. Sporangia tangentially extended, 3-8 mm. across, and about 2 mm. thick; dehiscence by a slit running along the convex upper edge; spores about 75 µ.

Horizon.—Centennial beds of Walhalla series.

Locality.—North Road Quarry, Walhalla, and Wood's Point, Victoria, Australia.

Agrees with *Zosterophyllum myretonianum*, Penh., in the shape and mode of dehiscence of the sporangia; in *Z. australianum* the latter are more closely placed to form a strobilus and the spores are larger.

Sporogonites Chapmani, n. sp.

Slender stalk, 0·75 mm. wide, widening to form a basal region to the cylindrical, capsule-like structure, which tapers to a somewhat rounded point above. Capsule 2·5 mm. wide, 5 mm. long, or, including the widened region of the stalk, 7·5 mm.

Horizon.—Centennial beds of Walhalla series.

Locality.—North Road Quarry, Walhalla, Victoria, Australia.

S. Chapmani, forma *minor*.

Smaller, capsule, including widened region of stalk, about 5 mm., breadth 1·5 mm.

Horizon.—Centennial beds of Walhalla series.

Locality.—Stringer's Creek, Walhalla, Victoria, Australia.

Agrees in general appearance with the incrustations of *Sporogonites exuberans*, Halle; differs in details of ridging and especially in the more pointed terminal region. Internal construction and spores not known.

Summary.

1. A small flora of fossil plants is described from the North Road Quarry, Walhalla, Victoria, Australia. The quarry is in the Centennial beds, a high horizon of the Walhalla series. While the possibility is entertained by some geologists that these beds might be Lower Devonian, the Geological Survey of Victoria regards the whole Walhalla series and the underlying Jordan River Series as constituting the Upper Silurian (Yeringian).

2. The chief plant-remains are: *Hostimella* sp., smooth branched axes, without and with axillary "buds," occasionally with a branch in this position; vascular strands, composed of annular tracheides; *Zosterophyllum australianum*, n. sp.; *Sporogonites Chapmani*, n. sp.; remains of uncertain nature, including a reticulate incrustation and spore-like bodies.

3. The various plant-remains mentioned under (2) are fully described and figured. In the case of *Zosterophyllum* additional facts required for comparison are recorded for the British species (*Z. myretonianum*).

4. These fossil plants are comparable with some known from the Early Devonian (Middle and Lower Devonian) of Europe. They clearly indicate such an age for the Centennial beds, and since two forms can be placed in Lower Devonian genera this age appears the more probable. While this conclusion at present applies only to the horizon of the Centennial beds in the Walhalla series, it indicates the need of caution in ascribing a Silurian age to plant-remains from lower horizons in the Walhalla series and in the Jordan River series.

5. The botanical interest of the individual plants and of the flora as a whole is enhanced by their occurrence in the southern hemisphere, and yet presenting numerous features of agreement with plants of the Early Devonian floras of Europe.

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Explanation of Plates.

(All the figures are from untouched negatives. Except where otherwise stated the specimens are from the North Road Quarry, Walhalla. C before a specimen number refers to the Cookson Collection, and L to the Lang Collection.)

Plate 11.

Fig. 1.—Piece of the sandy mudstone, showing the abundance of fragmentary plant-remains (*Hostimella* sp.) nat. size. (C 95.)

Fig. 2.—Small ribbed branched axis. × 4. (C 1.)

Fig. 3.—*Hostimella* sp. Smooth axis, represented by a brown incrustation, with two lateral branches placed alternately. Nat. size. (C 100.)

Fig. 4.—*Hostimella* sp. Axis with one lateral branch. Nat. size. (C 91.)

Fig. 5.—*Hostimella* sp. Axis with one branch and a clearly marked axillary structure. Nat. size. (C 11.)

Fig. 6.—Smooth axis with a lateral branch to the left and the oval axillary structure (" bud ") sunk in the angle between axis and branch. × $5\frac{1}{2}$. (C 103.)

Fig. 7.—*Hostimella* sp. Another example of a branched axis showing the axillary structure. × 3. (C 90.)

Fig. 8.—*Hostimella* sp. Cast of small branched axis; the main axis continues from below to the right, while the branch is represented by a concave impression of its cast to the left. A third axis represented by the base of its cast comes out laterally from an axillary position. × 3. (C 28.)

Fig. 9.—*Hostimella* sp. Branching specimen from Knott apparently similar in type to the preceding specimen; description in text, p. 6. × 3.

Fig. 10.—*Sporogonites Chapmani*. Nat. size. (C. 14.)

Fig. 11.—*Sporogonites Chapmani*. Upper portion of the stalk with the terminal, capsule-like structure. × 5½. (C 14.)

Fig. 12.—*Sporogonites Chapmani*. Counterpart of the specimen represented in the previous figure. × 5½. (C 14A.)

Fig. 13.—*Sporogonites Chapmani* f. *minor*. From Stringer's Creek. × 5½. (C 15A.)

Fig. 14.—*Sporogonites Chapmani* f. *minor*. Counterpart of the specimen represented in the preceding figure; the upper part of the capsule is damaged. × 5½. (C 15.)

Plate 12.

All the figures are of *Zosterophyllum australianum*. Full description in the text.

Fig. 15.—Incrustation of the first specimen. Nat. size. (C. 87.)

Fig. 16.—Incrustation of the first specimen. × 2. (C 87.)

Fig. 17.—Counterpart of the same specimen. × 2. (C 87A.)

Fig. 18.—Second specimen; counterpart to show size compared with fig. 15. Nat. size. (C 86A.)

Fig. 19.—Second specimen. × 5½. (C 86.)

Fig. 20.—Same specimen, counterpart. × 5½. (C 86A.)

Fig. 21.—Part of single sporangium from the specimen shown in fig. 19, to show the thick edge and the line of dehiscence as they appear in the cast. × 14.

Fig. 22.—Third specimen; impression on one rock-surface. × 2. (C 88.)

Fig. 23.—Impression on other rock-surface ("counterpart") of the third specimen. × 2. (C 88A.)

Fig. 24.—Piece of rock, with flattened incrustation of axis and sporangia, of third specimen that came from between the surfaces shown in figs. 22 and 23. × 2.

Fig. 25.—Cellulose film-pull from the surface of the impression shown in fig. 22. This is viewed from the reverse side and therefore corresponds to the surface of the piece in fig. 24. × 2.

Fig. 26.—Portion of the film-pull in fig. 24 to show details of two sporangia which exhibit the line of dehiscence clearly. × 10.

Fig. 27.—A deep film-pull obtained from the specimen shown in fig. 24, showing the sporangia, which were viewed from their ends in fig. 26, in section. × 10.

Fig. 28.—Two tetrads of spores from one of the sporangia shown in fig. 26. × 250.

Fig. 29.—Isolated sporangium, showing the solidity of the cast and the line of dehiscence running along the upper convexity. From Wood's Point. × 3. (C 23.)

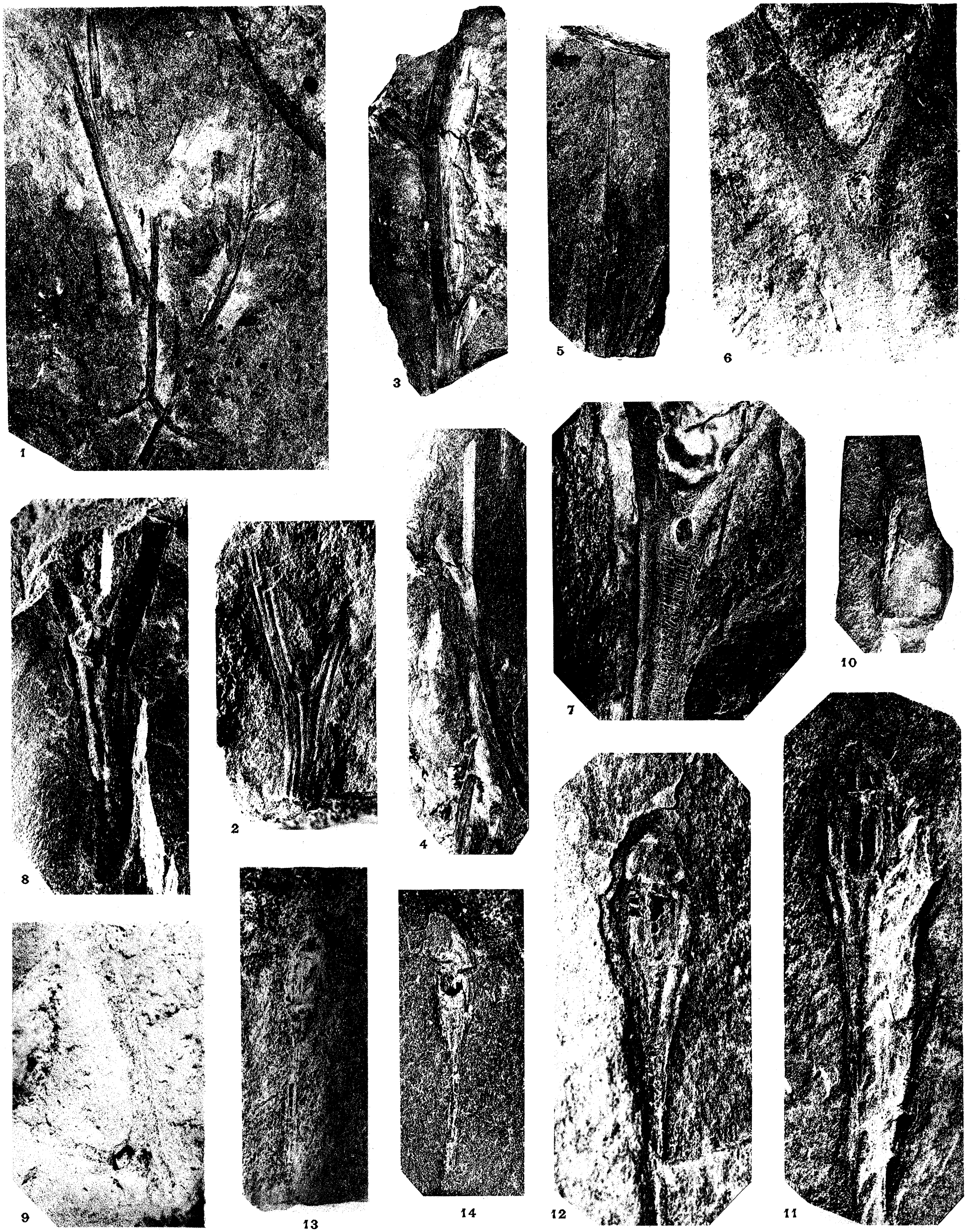
Plate 13.

Fig. 30.—Strand of tracheides, flattened on a smooth surface of the rock and removed by a cellulose film-transfer. × 100.

Fig. 31.—Portion of the strand of tracheides in fig. 30 to show the thickening more clearly. × 250.

Fig. 32.—Isolated tracheide of exceptional width, removed from the rock on a film-transfer. × 250.

Fig. 33.—Another isolated tracheide from a similar preparation. × 250.



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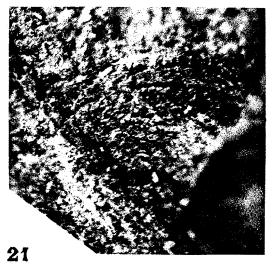
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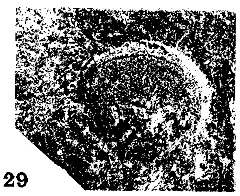
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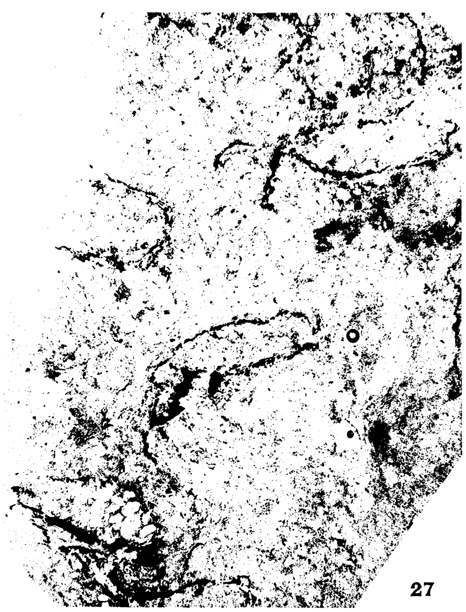
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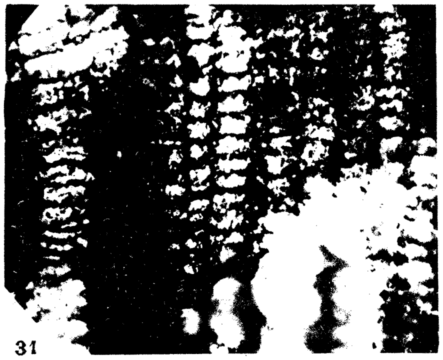
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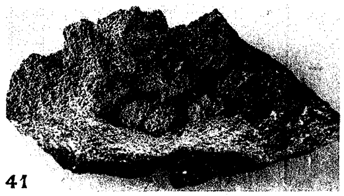
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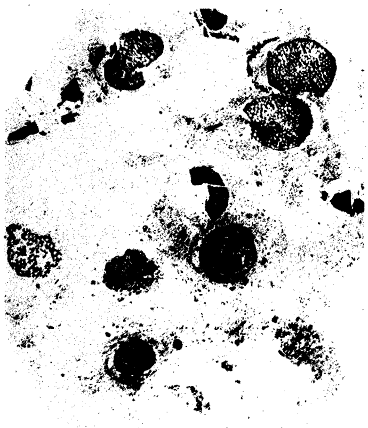
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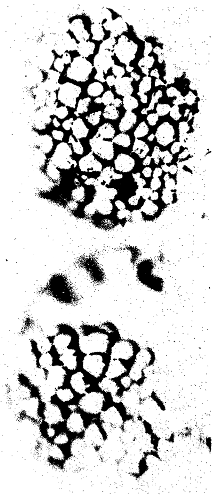
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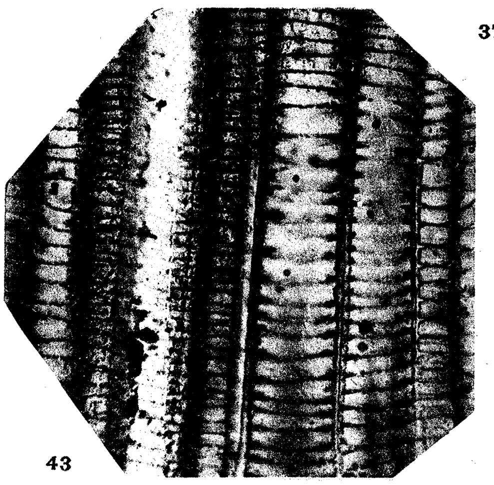
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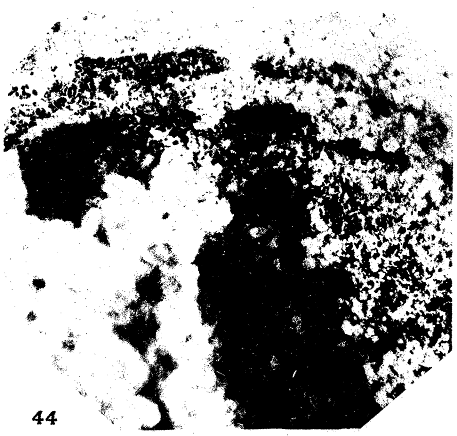
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Fig. 34.—Cast of a tracheide isolated from the rock by solution of the matrix in hydrofluoric acid; the dark bands represent the interspaces between the rings of thickening. × 250.

Fig. 35.—Portion of macerated wood from a similar preparation to that which provided fig. 30, to show the further breaking down of the organic material and the pattern produced as the result. × 250.

Fig. 36.—Slender tracheides with a somewhat different type of thickening from a cellulose film-pull of a small fragment in the rock. × 400.

Fig. 37.—Group of spore-like bodies removed from a smooth surface of the rock on a film-transfer. × 75.

Fig. 38.—Two spore-like bodies to show the condition with a thick black wall, and the range in size. × 75.

Fig. 39.—Two small specimens of the spore-like bodies in the condition with reticulate walls. × 250.

Fig. 40.—Reticulate incrustation. Nat. size. (C 92.)

Fig. 41.—Another portion of the reticulate incrustation. × 2.

Fig. 42.—Portion of specimen from Wood's Point showing smooth axes and an axis with markings suggestive of the presence of small leaves. × 3. (C 21.)

Fig. 43.—*Asteroxylon Mackiei*, from a section of Rhynie Chert; showing very perfectly preserved tracheides in longitudinal section. × 250. (L 1001.)

Fig. 44.—*Zosterophyllum myretonianum*, from Carmyllie beds of the Lower Old Red Sandstone of Scotland. Edge of a flattened sporangium, showing the line of dehiscence and portions of both valves of the wall. × 50. (L 704.)

Fig. 45.—*Zosterophyllum myretonianum*, from the Carmyllie beds. Spores from a film-transfer of a flattened sporangium. × 250. (L 704.)

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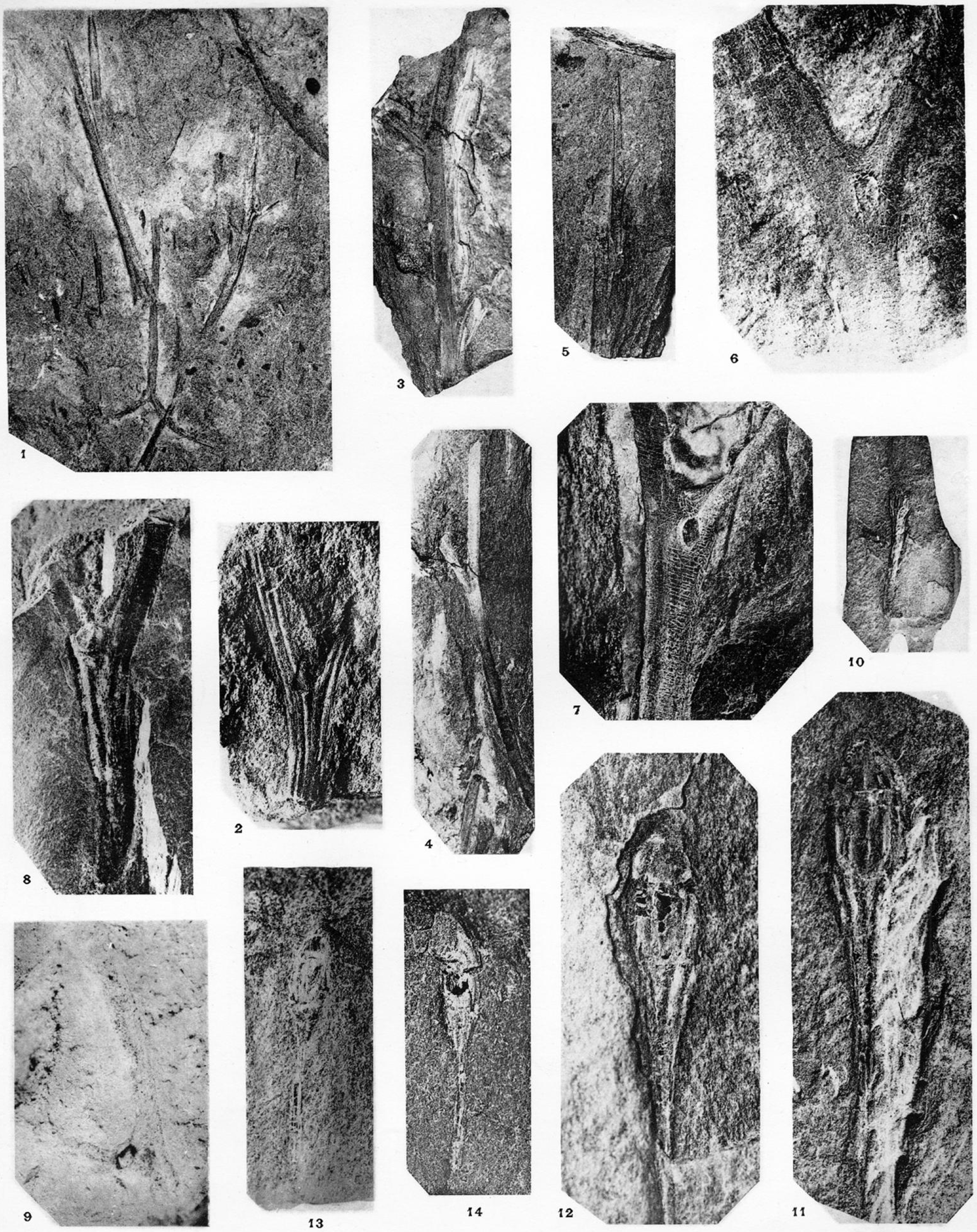

PLATE 11.

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FIG. 11.—*Sporogonites Chapmani*. Upper portion of the stalk with the terminal, capsule-like structure. × 5½. (C 14.)

FIG. 12.—*Sporogonites Chapmani*. Counterpart of the specimen represented in the previous figure. × 5½. (C 14A.)

FIG. 13.—*Sporogonites Chapmani* f. *minor*. From Stringer's Creek. × 5½. (C 15A.)

FIG. 14.—*Sporogonites Chapmani* f. *minor*. Counterpart of the specimen represented in the preceding figure; the upper part of the capsule is damaged. × 5½. (C 15.)

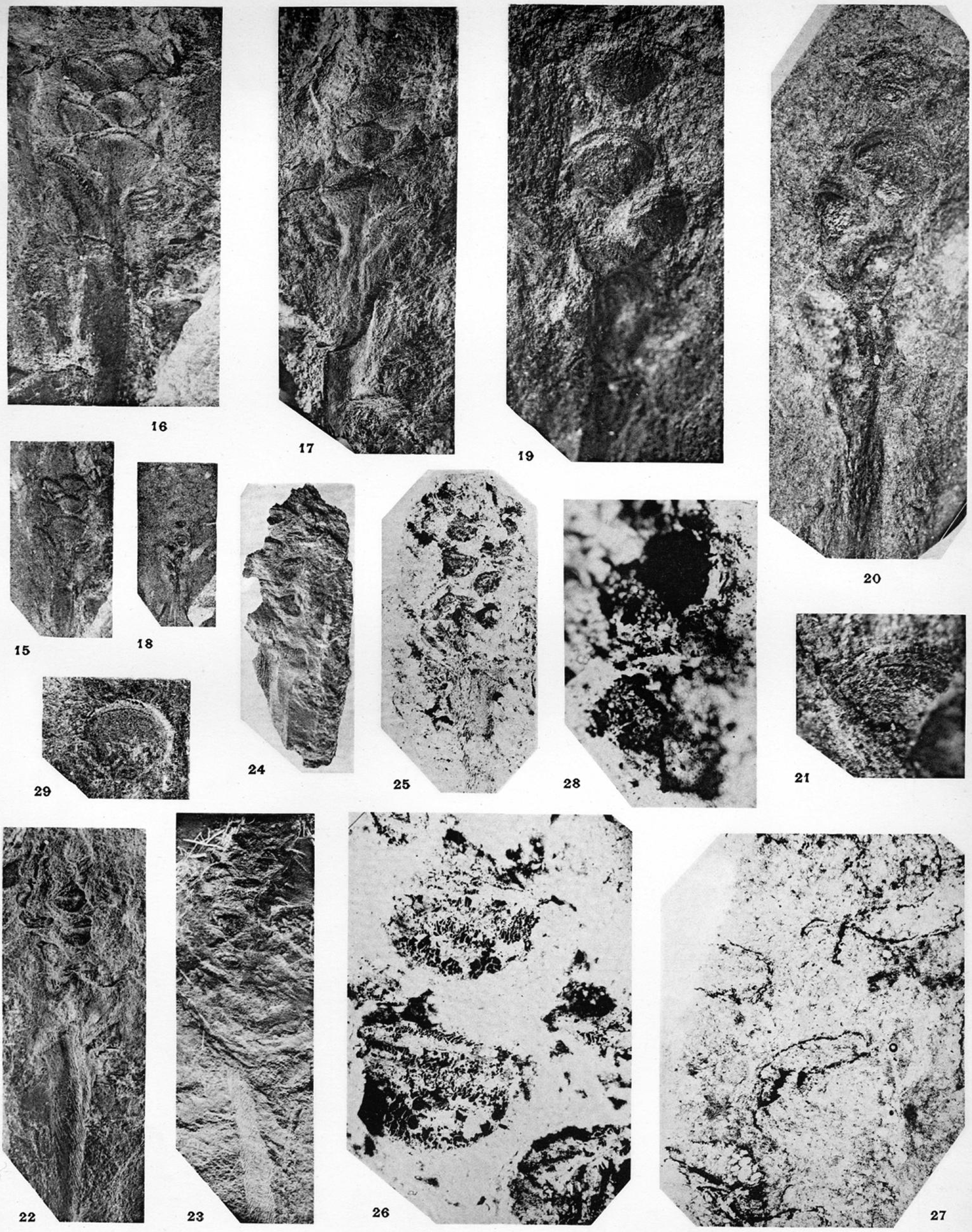

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FIG. 23.—Impression on other rock-surface (" counterpart ") of the third specimen. × 2. (C 88A.)

FIG. 24.—Piece of rock, with flattened incrustation of axis and sporangia, of third specimen that came from between the surfaces shown in figs. 22 and 23. × 2.

FIG. 25.—Cellulose film-pull from the surface of the impression shown in fig. 22. This is viewed from the reverse side and therefore corresponds to the surface of the piece in fig. 24. × 2.

FIG. 26.—Portion of the film-pull in fig. 24 to show details of two sporangia which exhibit the line of dehiscence clearly. × 10.

FIG. 27.—A deep film-pull obtained from the specimen shown in fig. 24, showing the sporangia, which were viewed from their ends in fig. 26, in section. × 10.

FIG. 28.—Two tetrads of spores from one of the sporangia shown in fig. 26. × 250.

FIG. 29.—Isolated sporangium, showing the solidity of the cast and the line of dehiscence running along the upper convexity. From Wood's Point. × 3. (C 23.)

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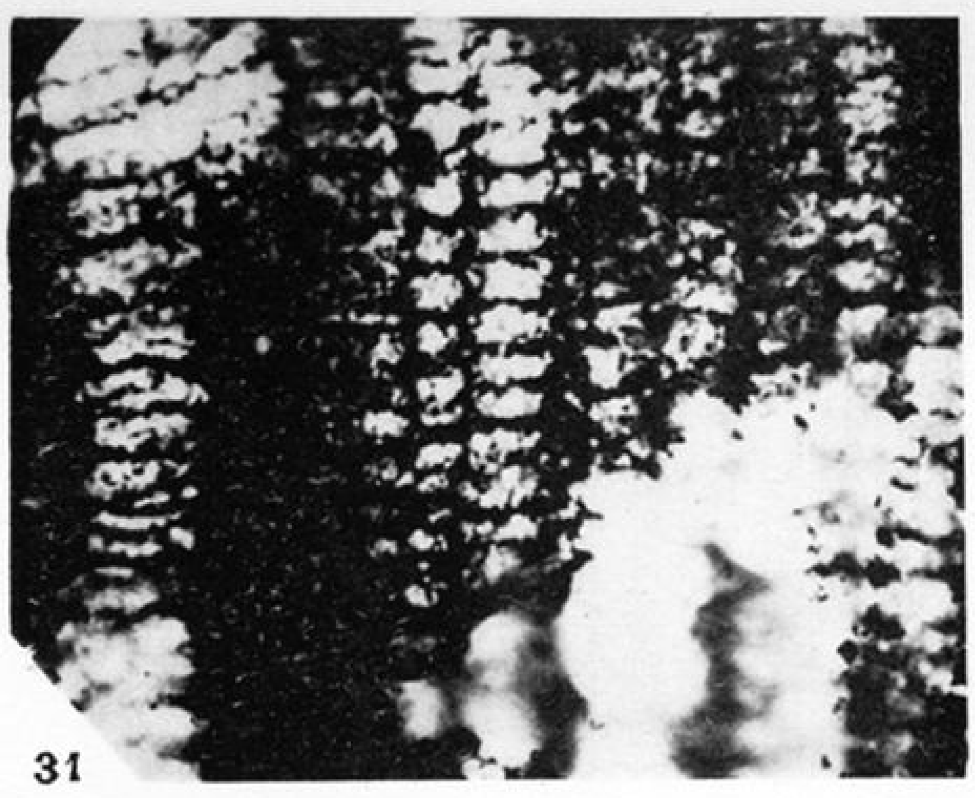

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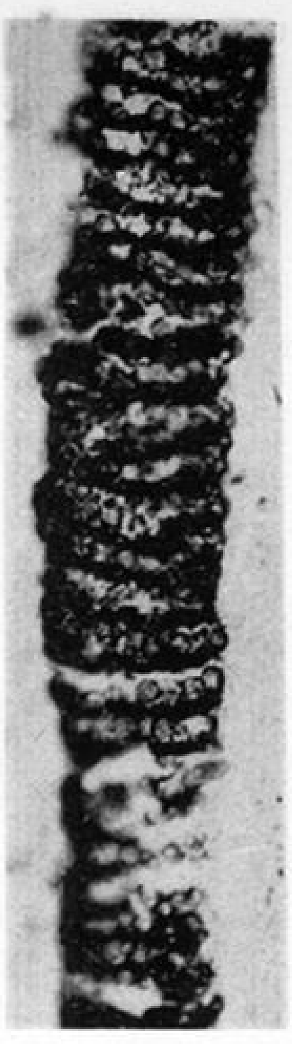

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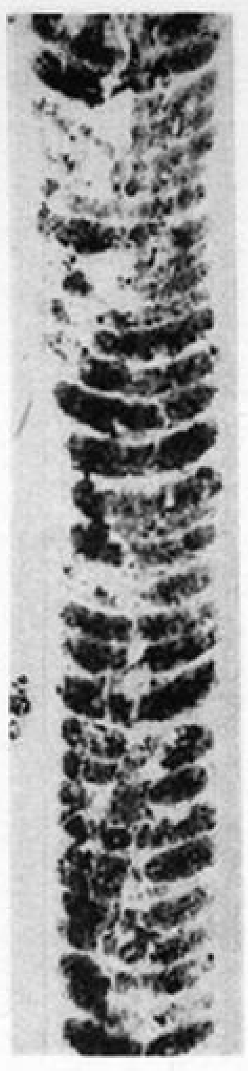

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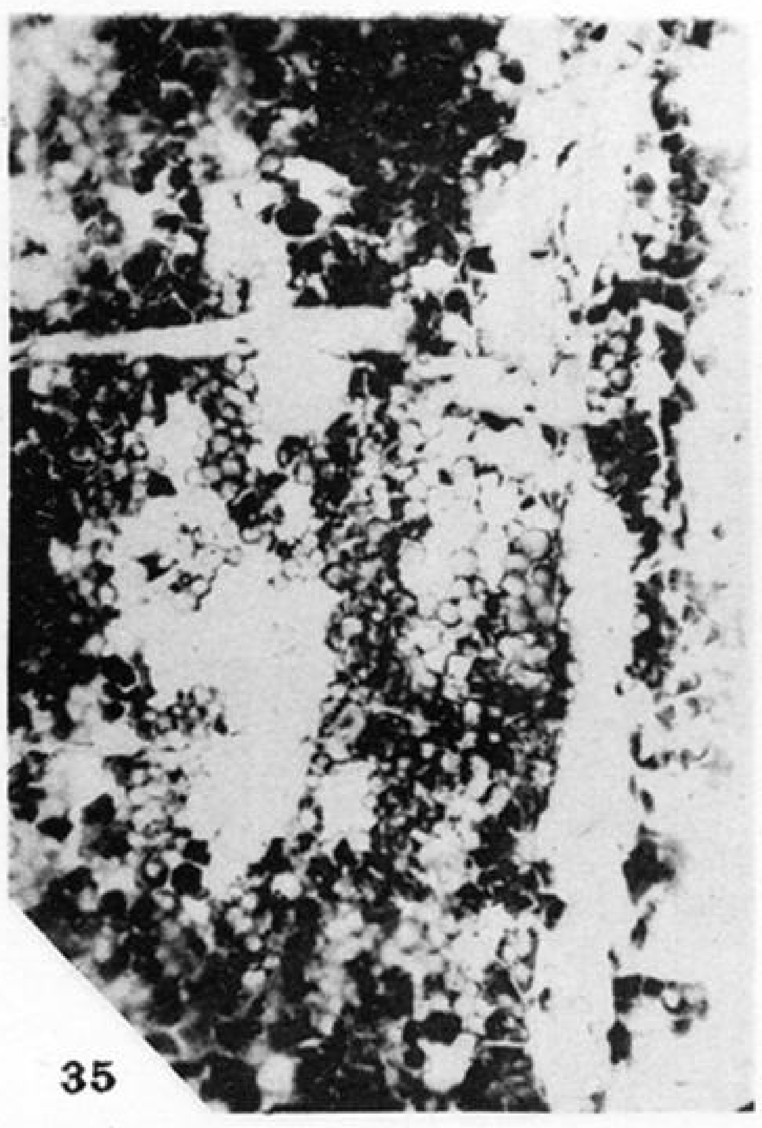

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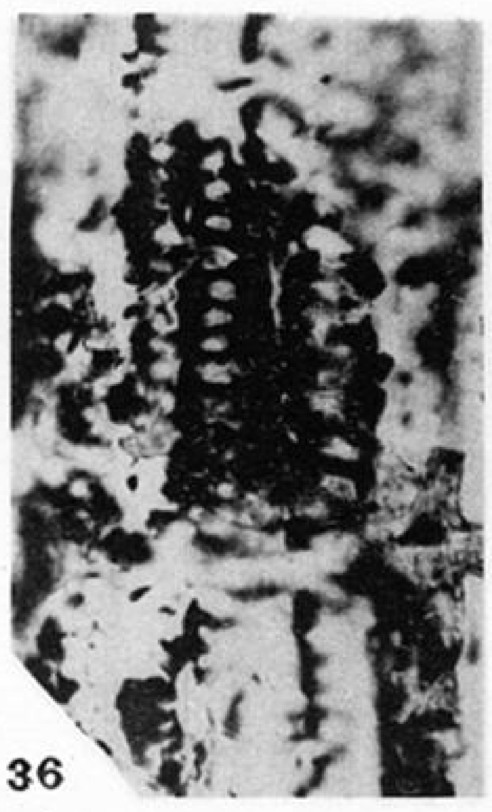

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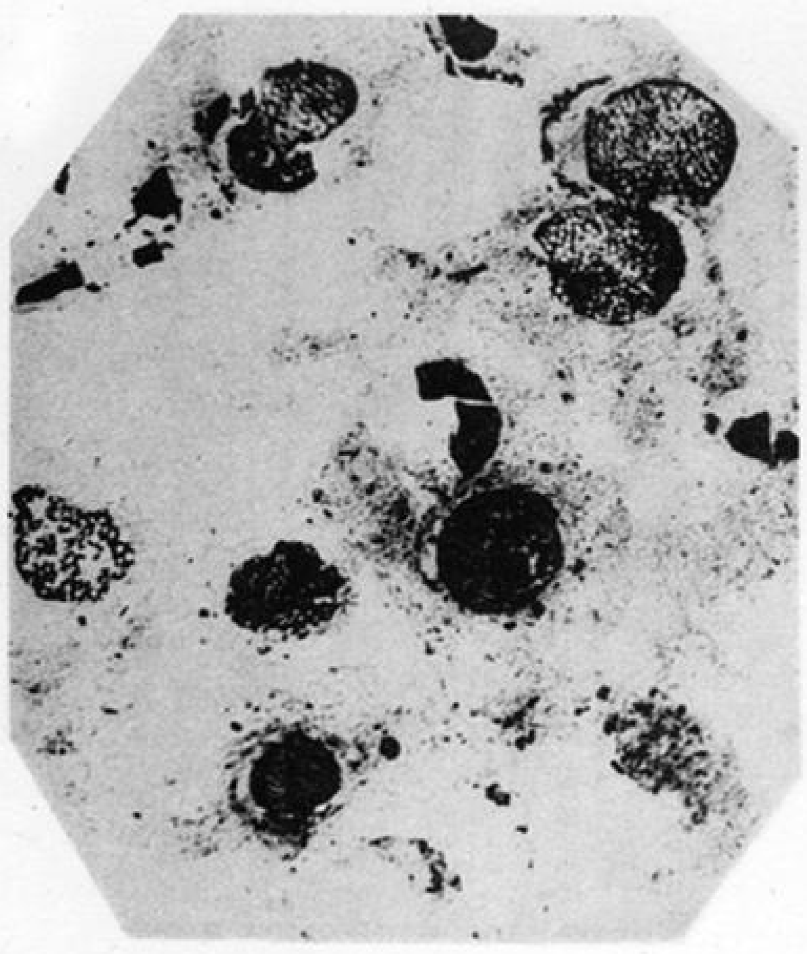

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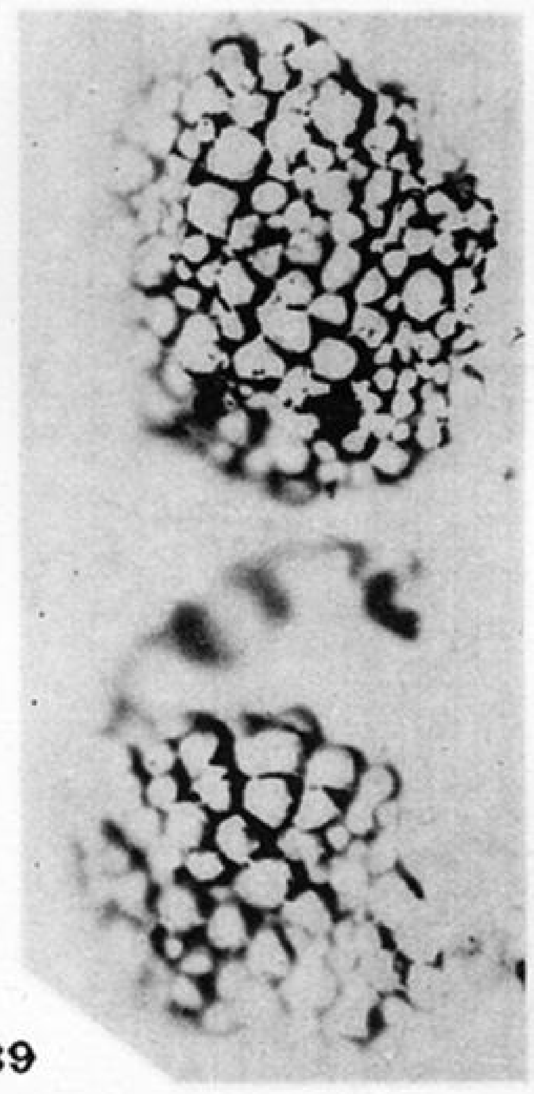

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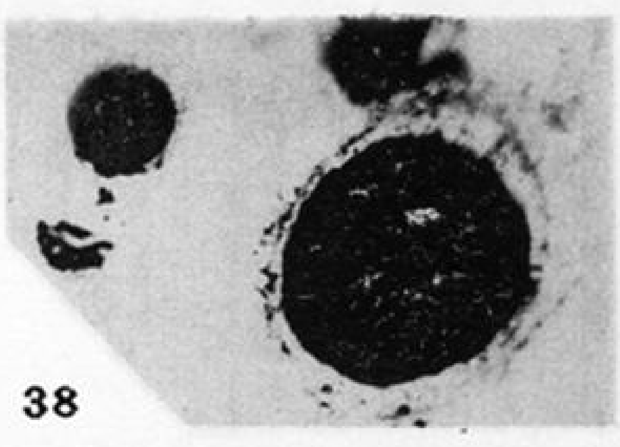

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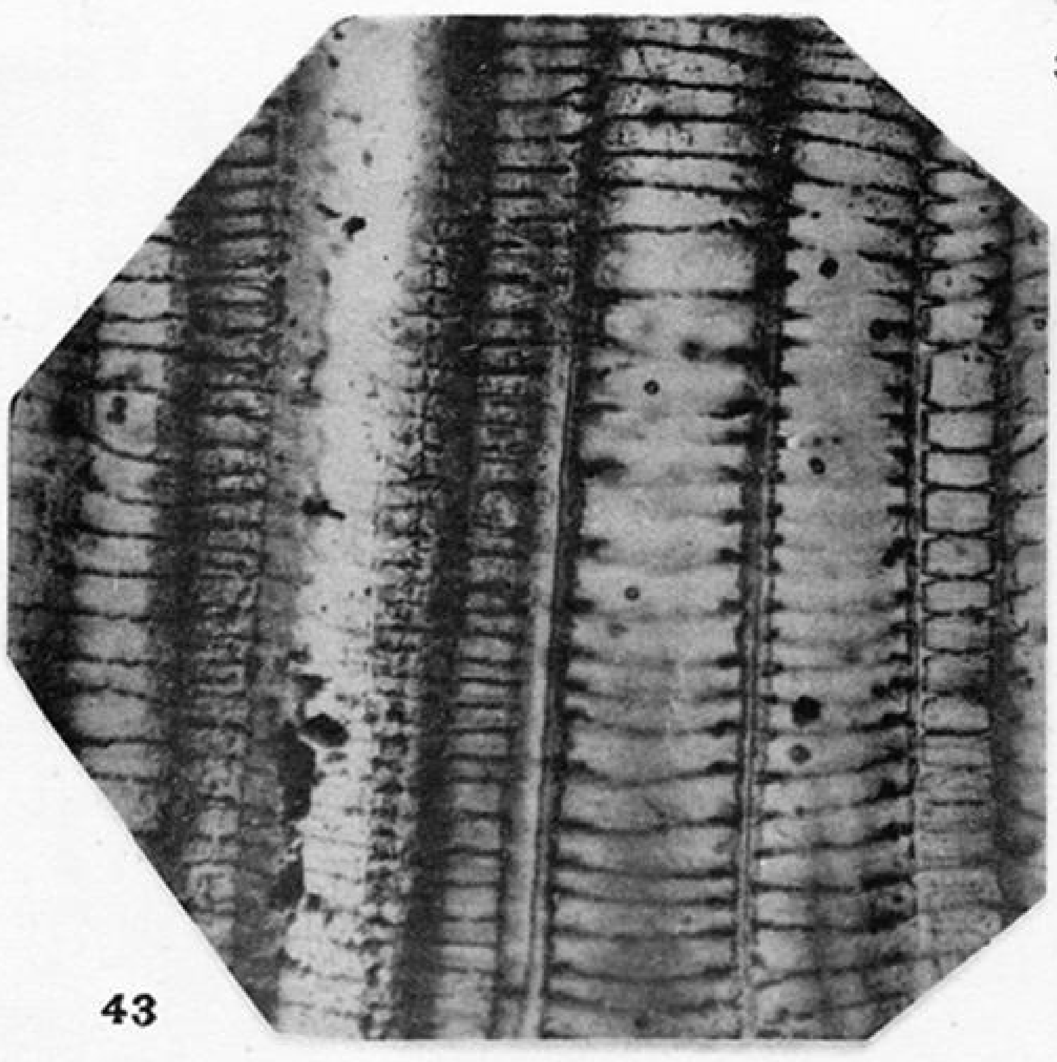

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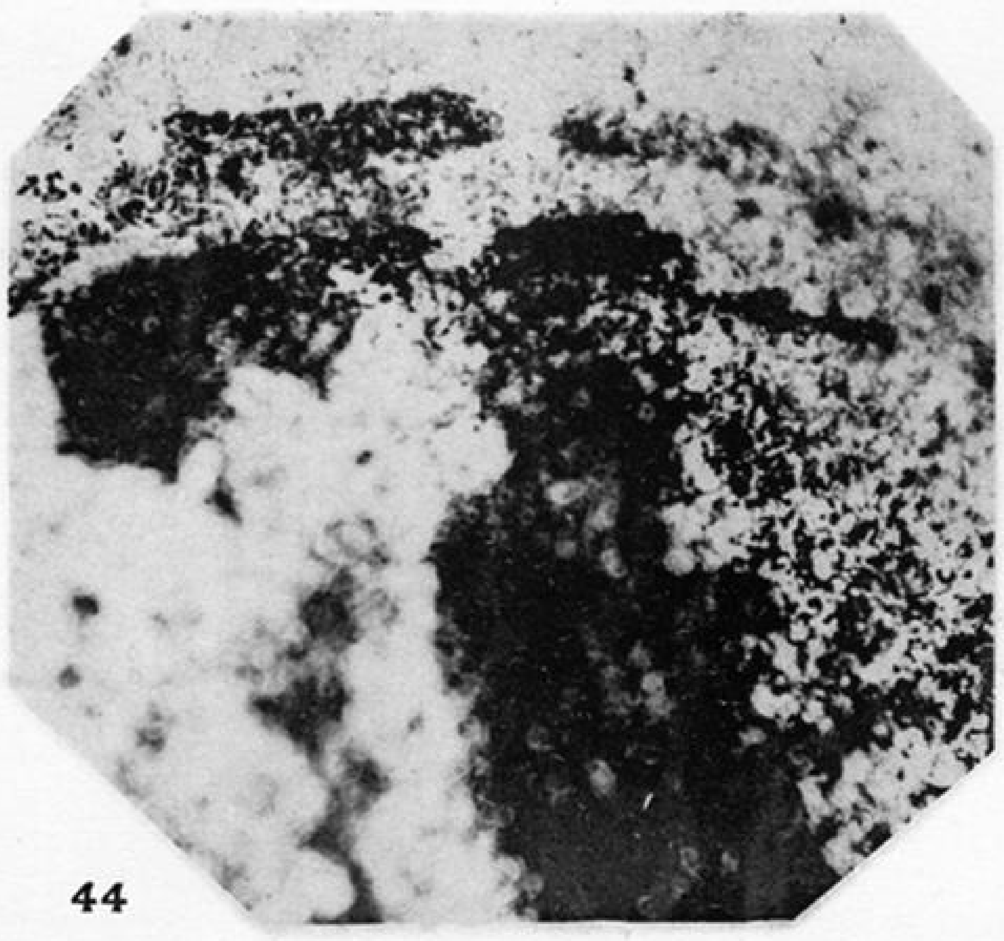

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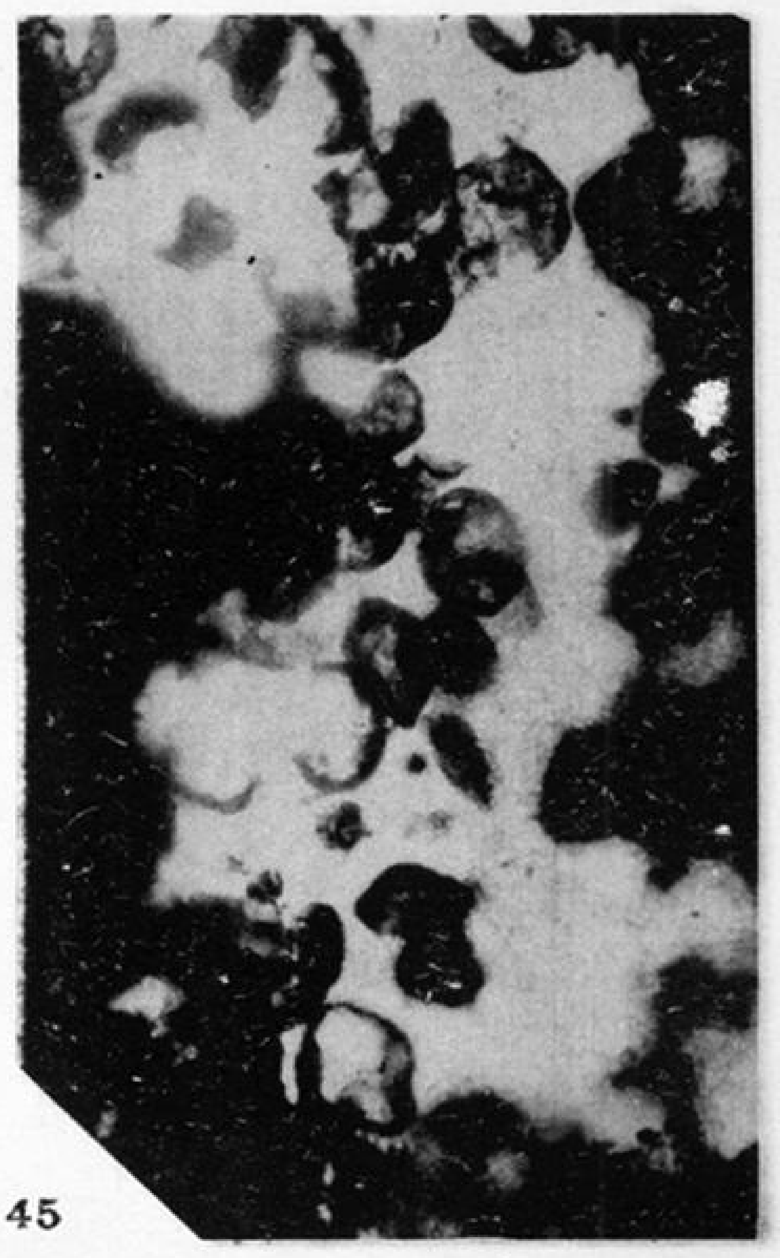

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PLATE 13.

FIG. 30.—Strand of tracheides, flattened on a smooth surface of the rock and removed by a cellulose film-transfer. × 100.

FIG. 31.—Portion of the strand of tracheides in fig. 30 to show the thickening more clearly. × 250.

FIG. 32.—Isolated tracheide of exceptional width, removed from the rock on a film-transfer. × 250.

FIG. 33.—Another isolated tracheide from a similar preparation. × 250.

FIG. 34.—Cast of a tracheide isolated from the rock by solution of the matrix in hydrofluoric acid; the dark bands represent the interspaces between the rings of thickening. × 250.

FIG. 35.—Portion of macerated wood from a similar preparation to that which provided fig. 30, to show the further breaking down of the organic material and the pattern produced as the result. × 250.

FIG. 36.—Slender tracheides with a somewhat different type of thickening from a cellulose film-pull of a small fragment in the rock. × 400.

FIG. 37.—Group of spore-like bodies removed from a smooth surface of the rock on a film-transfer. × 75.

FIG. 38.—Two spore-like bodies to show the condition with a thick black wall, and the range in size. × 75.

FIG. 39.—Two small specimens of the spore-like bodies in the condition with reticulate walls. × 250.

FIG. 40.—Reticulate incrustation. Nat. size. (C 92.)

FIG. 41.—Another portion of the reticulate incrustation. × 2.

FIG. 42.—Portion of specimen from Wood's Point showing smooth axes and an axis with markings suggestive of the presence of small leaves. × 3. (C 21.)

FIG. 43.—*Asteroxylon Mackiei*, from a section of Rhynie Chert; showing very perfectly preserved tracheides in longitudinal section. × 250. (L 1001.)

FIG. 44.—*Zosterophyllum myretonianum*, from Carmyllie beds of the Lower Old Red Sandstone of Scotland. Edge of a flattened sporangium, showing the line of dehiscence and portions of both valves of the wall. × 50. (L 704.)

FIG. 45.—*Zosterophyllum myretonianum*, from the Carmyllie beds. Spores from a film-transfer of a flattened sporangium. × 250. (L 704.)