IX—On a Flora, including Vascular Land Plants, associated with *Monograptus*, in Rocks of Silurian age, from Victoria, Australia

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(Received July 13, 1934)

[Plates 29–32]

Introduction

The earliest vascular or land-plants yet known with certainty from the northern hemisphere are those met with in the Lower Devonian or Lower Old Red Sandstone. The few records from earlier rocks have all been open to doubt, either because the age of the beds was not proved or because the plant-remains were obscure. The object of this paper is to describe some well-preserved plants of Silurian age from Victoria, Australia. Since certainty as to the geological age is essential, the present account is limited to the plants collected in four localities, in all of which they were associated with specimens of *Monograptus*, the graptolites being found in the same beds and often on the same slabs of rock as the plants, figs. 51-53, Plate 32.

The four localities will be referred to under the following names: (1) Yarra Track.—A quarry for road material on the Yarra track between Wood's Point and Warburton, about 17 miles from the former place. (2) Alexandra.—Two exposures in mudstone (Geol. Survey, loc. 5 and loc. 9), both by the side of the railway line, near the town of Alexandra. (3) Killingworth Road.—Two exposures (Geol. Survey, loc. 14 and loc. 20) at Yea. (4) Thomson River.—This includes a number of exposures along the valley of the Thomson River, where black beds containing *Monograptus* have long been known in the Jordan River beds (Baragwanath, 1925). This is the locality in which the stratigraphical succession is described (Skeats, 1928).

Since we had numerous specimens of the graptolites associated with the plants from two of the localities (Yarra Track, Alexandra) we submitted them to Professor W. J. Pugh, and through him to Dr. G. L. Elles. We are greatly indebted to them for the trouble they have taken to obtain a critical determination that would indicate the age to be assigned to the plants. Dr. ELLES reports that the graptolites submitted to her place the age beyond doubt as Lower Ludlow. From Yarra Track she identified *Monograptus uncinatus*, var. *orbatus*, and from a slab from Alexandra (loc. 9) *M. chimaera*, *M. uncinatus*, var. *orbatus* and *M. uncinatus*, var. *microspora*, which she speaks of as an assemblage typical of a Lower Ludlow horizon.

On this unequivocal statement as to the age indicated by the graptolites we feel justified, without entering into a full discussion of other opinions that have been previously expressed on palæontological and stratigraphical grounds, in regarding this flora as of Silurian age and not younger than the Lower Ludlow. The plants to be described are thus the most ancient vascular plants yet known from any part of the world, and it is fortunate that their preservation is sufficiently good to afford a considerable amount of accurate information as to their form and structure.

Although it is beyond our scope and competence to enter into the geological problems, it is, nevertheless, desirable to indicate briefly previous opinions as to the age of the flora with which we are concerned. The *Monograptus* Beds, as shown in the critical section at Thomson River, have been long regarded by the Geological Survey as in the Jordan River Beds, and some 600 feet below the conglomerate and limestone at the base of the Walhalla Beds (BARAGWANATH, 1925 ; SKEATS, 1928). This basal conglomerate has been regarded as of the age of the Wenlock Limestone and the underlying beds with the plants have been correlated with the Wenlock Shale (DAVID, 1932). Recently the graptolites associated with the plants at the Yarra Track locality were identified by Mr. R. A. KEBLE as *M. riccartonensis* " which places the beds in the Yeringian of the Victorian Silurian or its equivalent the Wenlock of the British Silurian succession " (KEBLE, 1933). A different view is expressed by Mr. D. THOMAS of the Geological Survey, who, in a statement which he kindly sent to us, regards the graptolites (apparently from all the four localities) as *M. galaensis*, and therefore places the beds somewhat lower, either at the top of the Keilorian (Llandoverian) or in the Yeringian ; he suggests in a stratigraphical table that they may be correlated with the Tarannon of the British succession. On the other hand, Mr. F. CHAPMAN a number of years ago suggested, on palæontological grounds, that the beds containing the plants were " later than the divisions of the Melbournian and Yeringian," and " may have to be classed as Lower Devonian " (CHAPMAN, 1926). On re-examining the stratigraphy, however, this view was not accepted (SKEATS, 1928).

From what has been said in the last paragraph it will be clear that the general opinion of Australian geologists has been in favour of regarding these plant-containing beds as of Middle Silurian (Wenlock) age. The determination of their age in two localities as shown by the graptolites to be Lower Ludlow is thus of evident geological interest. We are only concerned with it as establishing the age of the plants to be described in this paper.

In 1930, when describing a flora from the Centennial Beds, which are near the top of the Walhalla Series, 7–10,000 feet above the basal conglomerate, we mentioned that plant-remains were known from the Jordan River Beds, and that they were associated with graptolites. We explicitly deferred any consideration of the flora of these *Monograptus* beds until adequate material of recognizable plants should be available for investigation. This material has now been obtained by one of us (C) from Yarra Track, Alexandra and Killingworth Road. It has been impossible to visit the Thomson River locality to collect additional material, but we have had for examination the few specimens of plants collected by the Geological Survey. The most abundant plant, the stout stem of which was clothed with long simple leaves, will be named *Baragwanathia longifolia*. Along with it occur slender branched axes of the general type often placed under the form-name *Hostimella* sp. These two occur in all four localities and in addition at Yarra Track, a peculiar fructification, to which the generic name *Yarravia* will be given, was found.

The plant-remains, as exposed on the bedding planes of the fine-grained mudstone, occur as isolated specimens. In some cases they are remarkably complete, having evidently been enclosed in the sediment without previous mutilation. There is a striking absence of fragmentary remains along with the definite pieces. Though originally of considerable size and thickness, the plants now exist as very thin, flat incrustations. The carbonaceous material composing these is not even continuous, but is represented by minute angular black fragments. Such specimens give a very clear and complete picture of the form, but it is useless to try to ascertain details of structure from them. This was the condition of the specimens from Yarra Track and Alexandra (*cf.* figs. 1, 6, Plate 29, and figs. 37, 40, Plate 32). In most of the specimens from Killingworth Road (*cf.* figs. 3, 5, Plate 29, and figs. 25, 27, Plate 31) the organic remains had been replaced by a granular, brownish-orange material, presumably oxide of iron. This also, as a rule, preserves no trace of the structure, but in a few specimens of *Baragwanathia* the vascular system has persisted as a semi-petrifaction in oxide of iron. The structure of this can be studied by appropriate methods, but in no case have the superficial tissues been preserved.

Before entering on the description of the plants the few earlier references to this flora must be summarized. There is little to be said as to the discovery of the plants, since the early specimens were collected with other fossils by members of the Geological Survey, and are not described in the Memoirs on the various districts; specimens can, however, be traced to their localities by their numbers. The first definite reference to them appears to be in a paper by CHAPMAN (1908), where, after mentioning the occurrence of plants in the uppermost beds of the Walhalla Series, it is remarked, "There is another series known as the *Monograptus dubius* beds, said to be below the Yeringian coral limestone, which also contains the remains of *Haliserites*, and this is of undoubted Silurian age." In this paper and in a later one (CHAPMAN, 1912) there are figures of slender branched axes from Thomson River. In 1926 CHAPMAN, besides recording this type of plant under the name *Haliserites*, states that "other plants of the *Psilophyton* flora" occur in the beds. He refers to a specimen which came from the Thomson River. This specimen was shortly afterwards described and figured as *Arthrostigma gracile* (COOKSON, 1926).

It will be referred to below as an imperfect example of *Baragwanathia*. CHAPMAN (1926) also refers to what now prove to be good examples of the leafy shoots of this plant, collected by WHITELAW in the Jamieson district, and points out that they resemble specimens collected previously by BARAGWANATH at Thomson River. It is, indeed, largely due to Mr. CHAPMAN that attention has been directed to the interest and significance of the early fossil plants of Victoria. Examples of these various types of plant-remains were among a small set of specimens brought to England for examination, and described by us in a preliminary paper (LANG and COOKSON, 1927). It was pointed out that some of the remains described as *Haliserites* were indeterminable, and that the application of this name to the Australian specimens should be discontinued. Specimens of the large leafy shoots from the Jamieson district were figured (*loc. cit.*, figs. 12–15), and described, but no name or systematic position was suggested for them ; these figures may now be referred to as illustrations of *Baragwanathia longifolia*. Since the plants in that locality are not known to be in association with graptolites, they are not included in the material dealt with here. The most recent paper dealing with this flora is that by KEBLE (1933), already mentioned. This paper contains the first demonstration, by photographic illustration, of the occurrence of graptolites along with plant-remains on the same pieces of rock.

This last point is so important that it is desirable to extend the evidence of the immediate association of graptolites with the plants afforded by KEBLE's paper. We therefore include three photographs, figs. 51–53, Plate 32. Fig. 51 shows a typical leafy shoot of *Baragwanathia* and a graptolite on the same piece of mudstone from the Yarra Track locality. Fig. 52 shows a stem of this plant and a number of specimens of *Monograptus* on a piece of stone from Alexandra. The hand-specimen from the same locality in fig. 53 bears a large stem of *Baragwanathia*, and also a slender indeterminable axis, along with numerous graptolites. We have seen graptolites and plants together on hand-specimens from Killingworth Road, and the same is stated to hold for the beds at Thomson River (SKEATS, 1928).

Acknowledgments.—We have already expressed our indebtedness to Professor PUGH and to Dr. ELLES for examining the graptolites associated with the plants, and thus critically determining the age of the beds. We have to thank the Directors of the National Museum and of the Geological Survey Museum, Melbourne, for the loan of specimens in the collections under their charge. We owe sincere thanks to Mr. R. A. KEBLE and Mr. D. THOMAS for information from their field-notes, which guided one of us to the localities at Alexandra and Killingworth Road in order to collect the plants. To Mr. THOMAS we are further indebted for a considered statement of his views, in relation to those of other geologists, as to the stratigraphical position of the plant-containing beds. We have to thank Mr. F. SINGLETON and Mr. W. ABRAHAMS for useful information regarding the Yarra Track locality. Lastly we wish to acknowledge the invaluable assistance of Mr. E. ASHBY in the photographic illustration of the specimens.

Description of Plants

I. *Baragwanathia longifolia.* n.g. and n.sp.

For reasons that will be discussed later the most distinctive and fully known plant of this small flora is placed in a new genus to which we give the name *Baragwanathia* in recognition of the collection of the first specimens from Thomson River by Mr. W. Baragwanath, now Secretary of Mines for Victoria. All the remains of this type can at present be included in one species, *B. longifolia,* and can be conveniently grouped for description under the following headings :—

(*a*) Leafy shoots, in some cases bearing sporangia;
(*b*) stems with incomplete leaf-bases, leaf-scars or without remains of leaves;
(*c*) stems with laterally placed branches, that were possibly rhizomatous;
(*d*) specimens showing the structure of the vascular system.

(*a*) *Leafy shoots in some cases bearing sporangia*

Numerous examples of leafy shoots, that must have been practically complete and uninjured when embedded in the sediment, have been found. The longest piece we have seen measured 28 cm. In the case of many of the shoots the stems were between 1 and 2 cm wide, but both narrower and wider examples occur. The leaves are 1–0·5 mm in width, and attain a length of 4 cm. It is difficult to find places where the tips of the leaves are clearly shown, but the leaf appears to maintain a uniform width for the greater part of its length, and then to taper gradually to a rounded or moderately acute point; it is certainly never spine-like.

The fine specimen of a leafy shoot, about 10 cm long, represented of natural size in fig. 1, Plate 29, exists as a very distinct, thin, carbonaceous incrustation on a piece of cream-coloured mudstone from Yarra Track. There are graptolites on the back of this hand-specimen, and a less perfect shoot from the same block (fig. 51) has already been referred to as showing *Monograptus* in its immediate neighbourhood. The shoot in fig. 1 consists of a stout stem, 1·5 cm across, covered with the simple leaves. These are seen flattened against the surface of the stem, and appear more distinctly where they project at acute angles from both sides. The distal portions of the long, linear leaves, which are most complete on the left-hand side, bend into a more horizontal position, suggesting that, though firm, they were not stiff or rigid. They often overlap, cross and diverge, but all the indications from this and other specimens show that they were simple unbranched structures of uniform width.

Fig. 2, Plate 29, represents, at a reduction to two-thirds natural size, a shoot from the same locality which is of special interest in being the terminal portion of a branch-system showing the shoot divided into two equal branches. The occurrence of dichotomous branching is thus established. The considerable width of the shoot as a whole, some 6 or 7 cm, is due to the long leaves; the stem appears to have been relatively slender, probably under 1 cm.

The leafy shoot from the Killingworth Road locality, a portion of which is photographed of natural size in fig. 3, Plate 29, was over 15 cm long. In total breadth and in width of stem it agrees with that just described, but the mode of preservation is different. It is completely flattened on, or in, a thin layer of the matrix that is darker in colour than the rest of the rock. The remains of the plant are replaced by a brownish-orange granular material. The individual leaves thus stand out clearly against the dark matrix, and some of them show the tapering terminal region.

The interest of the specimen in fig. 4, Plate 29, lies in the fact that it was collected from the *Monograptus* Beds at one of the Thomson River exposures. Its registration number is 1144, and it therefore comes in the list of fossils that include graptolites, from Locality E (Baragwanath, 1925). The appressed leaves in the upper part give the impression of having been rather erect and slender. This is, however, probably due to imperfect preservation, for the remains of leaves lower down appear similar to those of the examples described above, *i.e.*, nearly 1 mm wide, over 2 cm long and lax.

The leafy shoots in figs. 1–4 come from three of the localities in which *Monograptus* is known to occur in close association with the plants. Similar shoots, in which a fairly stout stem bears closely and equally placed leaves, were collected from the exposures at Alexandra, but since they add nothing to our knowledge of the plant need not be described or figured. The shoot from Alexandra shown in fig. 10, Plate 29, will be dealt with later.

The majority of the leafy shoots of *Baragwanathia* have been of the size of the examples so far described, the stems being 1–2 cm wide. A few specimens have been found showing that the stem attained a much greater thickness. The short piece of shoot represented of natural size in fig. 5, Plate 29, is the broadest that has been seen with the leaves preserved, though a still wider stem that had lost its leaves will be described below. There is nothing special to say of the specimen in fig. 5, except that the stem, the exact limits of which are obscured by the covering of leaves, must have been between 4 and 5 cm wide. In contrast to this the stem of the shoot represented in fig. 13, Plate 30, is only 4 mm wide. It bears numerous leaves, 2 cm long by about 0·5 mm wide. Though somewhat different in general appearance owing to the stem being less obscured by the leaves, this slender leafy shoot is most naturally kept, for the present at least, along with the more usual stouter examples, but proof of their connection in one branch-system is wanting.

The two specimens now to be described are of special importance since they demonstrate the sporangia of *Baragwanathia*. That shown of natural size in fig. 6 was a piece of shoot including the terminal bud. Its relation to an adjacent less perfect tip on the stone indicates that it was one of the divisions of a dichotomy. In a region or zone some 5 cm below the tip a number of bodies among leaves of ordinary type were conspicuous, by reason of their shape and the greater amount of persisting carbonaceous material. There seemed little doubt that these were the sporangia, and, as will be shown below, this has been conclusively proved. The zone in which they occur extends for about 2 cm, and both below and above it are regions where only leaves are evident. The appearance is thus not that of a cone, but of a fertile zone of the ordinary leafy shoot. The sporangia are arranged in obliquely ascending series across the stem. This arrangement corresponds on the whole to the spiral of the leaf-insertions, but is somewhat confused by both sides of the stem being practically in the same plane owing to the shoot being, as usual, a very thin incrustation. The correspondence between the arrangement of the sporangia and of the leaves is suggestive of the former having been borne on the adaxial surface of the leaf-bases. There are appearances that support this view, both in this specimen and that to be next described, but, owing to the nature of the preservation, it cannot be established. It remains possible that the sporangia were sessile on the stem itself between the leaf-insertions, but they were evidently related in position to the latter. The sporangia on the surface of the shoot are compressed so as to show their outline as if in tangential section. In this view they are large reniform bodies, measuring 2 mm across and slightly less in height. Towards the sides of the stem other sporangia are seen more radially and here measure slightly over 1 mm in this direction. A few of the sporangia are enlarged two and a half diameters in fig. 7, Plate 29. This figure also shows the greater thickness of carbonaceous material in the sporangia as contrasted with that forming the incrustation of the stem and leaves.

When the sporangia were examined by reflected light under a low power of the microscope the dark material, though fragmentary, gave the appearance of being made up of small circular areas, sometimes convex but mostly concave. This was sufficiently suggestive of its representing a mass of spores, but a further demonstration was afforded by making a cellulose film-pull from part of the specimen, including a number of sporangia. Nothing could be ascertained as to the structure of the sporangial wall, but at places this was traceable as a carbonaceous outline. None of the spores had their walls preserved as a continuous translucent layer, but the carbonaceous fragments of the spore-walls were held together on the cellulose film and showed the outlines of the spores and their sizes. A number of spores thus preserved are seen enlarged 200 diameters in fig. 8, Plate 29, and an especially well-preserved spore, isolated at the margin of the spore-mass, in fig. 9, Plate 29. The spores are slightly oval and measure about 50μ (45–55μ).

While the specimen just described, which demonstrates the sporangia with certainty, came from Yarra Track, the other shoot bearing sporangia was obtained from one of the exposures at Alexandra. It is rather peculiar in general appearance, as will be seen from fig. 10, Plate 29, which is of natural size. As regards the preservation, the width of the stem and the size of the leaves it agrees with the other thin incrustations of *Baragwanathia*. It differs from them, however, in the leaves, or those that persist, appearing to be associated in groups separated by portions of the stem without leaves. This feature is shown in the figure, but it is difficult to decide from this single specimen what degree of significance, if any, to attach to it. It can further be seen that a number of bodies which we have no doubt are sporangia are present, sessile on the stem, and in some cases in an axillary position in relation to leaves. They are about 2 mm in diameter and characterized by the greater thickness of amorphous carbonaceous material as compared with the stem and leaves. Some seven of these bodies could be distinguished, five marginally placed, and two at least on the surface. They are distributed over a length of some 4·5 cm of the shoot. It was found impossible to demonstrate spores, even from film-transfers made from portions of the counterpart. It seems clear, however, that we are dealing with a second, though less perfectly preserved, example of a fertile shoot. When it is compared with the fertile shoot of more normal appearance seen in fig. 6 it is further clear that the peculiar grouping of the leaves shown in fig. 10 is not to be related to the presence of sporangia.

In connection with the grouping of the leaves on the stem of the specimen in fig. 10 reference may be made to an interesting fragment from Yarra Track in the Geological Survey collection. This specimen probably belongs to *Baragwanathia*, although this cannot be taken as established with certainty. It is enlarged 2 diameters in fig. 50, Plate 32, and shows three bud-like structures, standing one above the other in a way that suggests that they were borne laterally on a stem to the right; their bases are just connected, but the stone beyond this is broken away. The middle one of the structures is the clearest. There is little doubt that it corresponds to a group of leaves about 1 cm long, apparently borne on a short stem. One leaf below the main portion of the bud is of larger size, measuring over 1 cm by 0·5 mm in width, and approximates in appearance to the leaves of *Baragwanathia*. The whole question as to the occasional groupings of leaves in more or less distinct bud-like groups must, however, be left to be cleared up by the discovery of further specimens.

(*b*) *Stems with incomplete leaves, leaf-scars or without remains of leaves*

The portions of two shoots from Yarra Track shown of natural size in fig. 11, Plate 30, present a different appearance from the specimens of *Baragwanathia* described in the preceding section, owing to the leaves having been partially lost before or during fossilization. Though their relative position at first sight suggests a branching there is no evidence of continuity. The shoot on the right, which measured 10 cm in length, is 18 mm wide; it has a distinct central strand 4 mm wide. That on the left must, when complete, have been wider, but only the central strand and one-half of the stem is present on this surface of stone. A number of incomplete leaves are represented by their lower portions attached to the surface or, more clearly, to the margins of the stems. The places of insertion of others is indicated by roughly circular areas where the carbonaceous material is more abundant.

All intermediate conditions have been seen between shoots with complete leaves and those on which the remains of leaves are even less clearly shown than on the stems in fig. 11 or are wholly absent. The short piece of stem from Thomson River which was previously described by one of us (Cookson, 1926) as *Arthrostigma gracile*, and is refigured here (fig. 49, Plate 32), is evidently a poorly preserved specimen of *Baragwanathia*, only a few leaves represented by their basal portions persisting on the stem.

In the large thin incrustation shown in fig. 12, Plate 30, occasional leaves of the usual width can be detected, though most of the leaves from partial decay appear as slender linear marks. The position of the leaf-insertions is indicated by the dark spots regularly distributed on the surface. In addition to demonstrating the spiral arrangement of the leaves the specimen is of importance as being the widest stem that has been met with. The portion preserved is at least 6·5 cm wide, and the stem may not be shown in its whole width. It proves that some stems of this plant attained a considerably greater thickness than that of the majority of the specimens.

A portion of a piece of stem 17 cm long and 2 cm wide is represented in fig, 14, Plate 30. No leaves remained, but the surface was marked by numerous, spirally arranged scars, some appearing as depressions and others as elevations. Though it looked like a black incrustation of some thickness, film-transfers showed that the organic remains of the plant formed an extremely thin film, and that the black material was altered mudstone in contact with the stem. A different indication of the leaf-position is shown by the thin brown incrustation, a short length of which is represented in fig. 15, Plate 30. There are no projecting leaves and no leaf-scars, but the arrangement of the leaves is recorded by slender vertical lines in the material of the incrustation ; these represent the distal portions of the leaf-traces in the cortex of the stem. The traces are not displaced and are thus spirally arranged, like the leaves which they supplied.

Stems of this plant were also met with that had lost all indication of the places of insertion of the leaves. The two stems lying across one another, portions of which are shown in fig. 16, Plate 30, are in this condition. The organic material has been replaced by granular oxide of iron and a more definite strip of this marks the position of the central strand. Such specimens, were we not fortunately provided with better, would be important from these ancient rocks. As it is they enable us to appreciate the record of the form of complete leafy shoots in the examples described in the preceding section and also the clear records of internal structure to be described below. It is not worth while multiplying examples of the numerous poorly preserved pieces of stem, which are of diverse widths. There is no evidence that they belong to other types of plant, though some of them may. In any event they add nothing to our knowledge of the flora.

(*c*) *Stems with laterally placed branches that were possibly rhizomatous*

A few rather poorly preserved incrustations from the Killingworth Road locality bore the bases of branches. These were not only lateral in position, but were much more slender than the relatively thick main axis which bore them. Their interest was increased when the question was raised whether the branches were directed upwards, as was naturally assumed at first, or whether the main axis ought to be placed so that the lateral branches were directed obliquely downwards. As will be shown the evidence is in favour of the latter interpretation.

This evidence is afforded by the specimen represented of natural size in fig. 17, Plate 30. It is an incrustation in brownish-orange of a straight piece of stem 10 cm long and slightly under 1 cm wide. On the left-hand side its margin passes into the stone so that lateral structures, if present, would be hidden. On the right-hand side there are the bases of two branches, one about 2 cm from the upper end, and the other about 1 cm from the lower end. The portion of the upper branch that remains is only 5 mm long and slightly over 2 mm wide. The lower branch is slightly wider (3 mm) and 1·5 cm of it persists. When the right-hand margin of the main axis was carefully examined a few rather obscure projections, that were most naturally interpreted as remains of leaves, were found. The most definite of these is below the lower branch, and this region of the specimen is enlarged 2 diameters in fig. 18, Plate 30. The attached basal portion of a leaf measuring 3 mm by 0·5 mm, could be clearly seen, though it is difficult to bring out in a photograph. Since this incomplete leaf was directed upwards at an acute angle, it indicates the position in which the stem should be placed and the lateral branches are then directed obliquely downwards.

In the light of the specimen just described that shown in fig. 20 is similarly placed, although there are here no leaf-bases to provide direct evidence. The small piece of rock is crossed by a stem 4 cm long and about 9 mm wide, but, since it is broken across at both ends, it is only a portion of a longer structure. From its left-hand side two branches depart laterally, both of which are much more slender than the main axis. The upper branch, which was exposed by removing the matrix, is 5 mm long by about 1·5 mm wide. The lower branch is 2 mm in width. At its departure it stands almost at right angles to the main axis, but it gradually curves downwards in the course of the 2·5 cm of its length. The curvature seems suggestive of the position of the specimen on the plate being the natural one. This specimen will be further described as regards its structure in the next section.

A third specimen shown in fig. 19, Plate 30, may be associated with the others. A piece of axis 5 cm long and 5 mm wide bears a number of lateral branches about 1 mm wide. A considerable length of two of these is preserved, while only the bases of others persist.

The most natural interpretation of these specimens would seem to be that they are remains of portions of the shoot-system, bearing slender branches that were rhizomatous or root-like in function. The available evidence justifies this suggestion, but does not suffice to establish it. Tangled masses of slender branch-systems showing at places remains of the central strand may be of this nature, but are too obscure for detailed description, though they appear to belong to the plant under consideration.

(*d*) *Specimens showing vascular structure*

Some of the shoots or stems described above have shown the size and position of a central strand or stele, but this was either quite structureless, fig. 11, or exhibited obscure traces of the tracheidal structure under reflected light, fig. 10.

Had no better material been available as much as possible would have been ascertained from such poor specimens. Fortunately a few specimens from Killingworth Road afforded clear and detailed information as to the vascular system of *Baragwanathia*. In these the vascular system was semi-petrified, and its structure could be studied in various ways. The general features of the three important specimens may be first described and the histological details then considered.

Fig. 25, Plate 31, represents, at slightly less than natural size, a piece of rock the surface of which includes two planes. The greater part of the surface is covered by a brown incrustation of two leafy shoots. The dark grey stone is exposed at a slightly lower level in the left-hand lower part of the figure. On this is a piece of a leafless stem which has no trace of a central strand and no structure, and will not be mentioned further. At the higher plane a slightly curved shoot can be traced from the lower right-hand corner of the figure for 13 cm by the help of its central strand, and for the remaining 4 cm of its length by the ill-defined leaves. The width of this stem is about 2 cm, and that of its central strand about 4 mm. For part of its length the semi-petrified strand is preserved in the solid. At other parts it is represented by the concave impression left by the strand which has been removed on the counterpart, fig. 26, Plate 31. Another shoot about 7 cm long lies to the right, parallel to the longer specimen. It has a similar solid central strand in its lower portion, but this is wanting above. Lying obliquely between these two shoots in the upper part of the figure is a piece of central cylinder, measuring 3·5 cm by 3–4 mm. This might indicate the presence of a third stem, but it seems more probable that it is the missing portion of the stele from the shoot on the right, displaced during fossilization. Between the first and second stems and to the right of the latter there are numerous leaves, individually obscure and forming a tangled mass. Leaves were also evident in the upper regions of both shoots where the stele is wanting. The breadth of these is slightly less than 1 mm; the length could not be ascertained, but was evidently of the order known for other shoots of *Baragwanathia*. In some of these leaves a slender vascular strand could be recognized (fig. 23, Plate 30).

The second specimen of importance for the investigation of the stelar structure was a slightly curved piece of stem which had completely lost its leaves. It was 28 cm long and 2 cm wide, and is represented, reduced to one-half natural size, in fig. 27, Plate 31. The cortical region is a brown structureless incrustation. The central cylinder on the other hand, though somewhat flattened, is semi-petrified. It is 8 mm wide and thus much stouter, relatively to the width of the stem, than in the specimen previously described. This can be seen by comparing fig. 28, Plate 31, of a portion of this stem with fig. 26, which is a piece of the first specimen; both are photographed of natural size. The stele has undergone obliquely transverse cracking at intervals of its length after petrifaction. The surface appears longitudinally striated, the expression, as will be seen below, of the vascular structure.

While the specimens described above show the central cylinder of the stem and the presence of a bundle in some of the linear leaves, there was only one doubtful leaf-trace in the cortex. The third specimen to be considered had the leaf-traces preserved. It is the small piece of stem shown in fig. 20, Plate 30, the branching of which was considered above. Only obscure remains of the central cylinder of stem and branch persisted. In the cortical region of the stem, however, though as usual the soft tissues had disappeared, the leaf-trace bundles have persisted as slender cord-like strands, and are semi-petrified like the steles in the other stems. A number of them are shown enlarged 10 diameters in fig. 21, Plate 30 ; their irregular course is doubtless due to displacement in the course of the decay that preceded petrifaction.

These three specimens thus afford a demonstration of all the regions of the vascular system of the shoot of *Baragwanathia* ; the central cylinder of the stem, the leaf-traces in the cortex and the foliar bundle. The following account of histological details is based on their study. A few other specimens which showed corresponding features less clearly need not be described or figured.

A good deal has been learnt as to the structure of the vascular tissue by examining the specimens on the rock by reflected light. The coarser striation apparent with a pocket lens depends on the xylem being exposed on the surface in parallel strands, separated by strips of amorphous material ; the appearance was consistent with a view from the side of a stellate xylem, an inference that will be shown below to be correct. The finer striation is due to the tracheides and becomes more evident under low powers of the microscope. While ordinary illumination is sufficient, the structure of the xylem was particularly well seen when the Leitz Ultropak was used with polarized light, the Nicol prisms being crossed. Fig. 29, Plate 31, is a photograph obtained in this way of a portion of the stele of the specimen in fig. 26 magnified 75 diameters. It includes two of the strands of xylem, separated by amorphous material. In this figure and in figs. 30, 31, Plate 31, which are at twice this magnification, the tracheides are seen to be long tubular elements with a system of alternating light and dark transverse lines, indicating the thickening of the wall. With this method of illumination the dark bands appear considerably wider than the light bands separating them.

Another method adopted for the study of the tracheides was to make cellulose film-pulls from the central cylinder. These removed some of the superficial tracheides and, when the thickness of the small portions of xylem thus pulled off was not too great, the structure could be seen by transmitted light after the film had been mounted in Canada Balsam. These film-pulls could be made, not only from the outer surface of the stele but, when this was split open, at deeper levels. The tracheides were always of the same type, indicating their uniformity throughout the xylem. The tracheides in figs. 32, 33, Plate 31, are from film-pulls. As photographed by transmitted light they show the thickening clearly, and it is evident that this consists of narrow rings separated by relatively wide unthickened portions of the wall. This view gives a truer picture of the thickening than the view given by reflected light. The latter can, however, be readily interpreted by what is shown by the tracheides on the film-pulls. The true thickening rings are the narrow black lines crossing the tracheides in figs. 32, 33. Thus as seen by reflected light in figs. 29–31 it is the narrow light lines and not, as one could readily be misled into thinking, the broad dark bands that represent the thickening.

Since most of the material of the semi-petrified xylem consists of an oxide of iron, the film-pull has to be mounted without the preliminary treatment with hydrofluoric acid usually employed in making such preparations If it is so treated almost all the material on the film disappears, leaving only faint, granular, dark lines representing the very small amount of carbonaceous matter present in the xylem ; this, however, just indicates the outlines and the thickening of the tracheides.

A third method of studying the elements of the xylem in longitudinal view was to impregnate a piece of the central cylinder with synthetic resin and then to grind a very thin section, using fine emery papers. Only one such section was made, and a portion of it is photographed by transmitted light in fig. 34, Plate 31. It shows the longitudinal walls of the tracheides and the narrow thickening rings black in the yellow granular material.

Combining the information obtained in these various ways it is clear that the xylem of the central cylinder consisted throughout of tubular elements with narrow annular thickening bands. These elements were evidently long and only a few doubtful examples of their tapering ends have been met with. The area of suitable xylem available for search has, however, been small, and there seems no reason to doubt that the elements were tracheides. They show a considerable range in width, tracheides from 12·5 μ to 42·5 μ having been measured ; many of them were 30–33 μ wide. There is no reason to regard the narrower tracheides that occur mixed with the broader ones as protoxylem. The thickening of the tracheides is of the same type throughout the xylem, so that no distinction of protoxylem and metaxylem is possible on this ground. The question whether the thickening is to be correctly described as annular has been looked into carefully. Not only do the thickening bands always appear to extend across complete tracheides, but they often do not come opposite one another on the two sides of a longitudinal wall. No tracheide that was clearly to be interpreted as showing scalariform thickening has been found. There is a considerable range in the width of the intervals between the thickening rings, even in portions of the same tracheide. The rings are always about the same thickness, slightly under 2 μ, the interspaces range from 4·5 μ to 7·5 μ.

It has also been found possible to study the structure of the stele and of the xylem of *Baragwanathia* as shown in the transverse plane. For this purpose pieces of the large central cylinder of the specimen in figs. 27, 28, Plate 31, were used. These cannot be ground down uniformly without preliminary treatment, as the hardness is unequal ; the xylem is very soft and granular, while the mineral matrix between and around the strips of xylem is very hard. It was necessary, therefore, to impregnate the piece of the central cylinder thoroughly with synthetic resin, and so render it uniformly hard and resistant. Even when this had been done it was found impracticable to grind a transverse section that would show the structure in the usual way by transmitted light. A good picture of the complete stele was, however, obtained by grinding a smooth transverse surface with fine emery papers and polishing it as perfectly as possible with dry plate-powder. The polished surface was examined with reflected light and to get a good view it was found essential to use polarized light with the Nicol prisms crossed. The walls of the tracheides then appear brownish-yellow on a black ground, the material in the lumina of the tracheides and between and around the strands of xylem being dark, figs. 35, 36, Plate 31.

A complete transverse section from such a polished surface is photographed at a magnification of 12·5 diameters in fig. 35. The stele, which was doubtless originally circular, is considerably compressed, but not so flattened as to destroy the plan of arrangement of the tissues. The xylem was stellate in cross-section, the interspaces or bays between the rays of the star extending almost to the centre, and the rays of xylem widening out and subdividing as they extend to the periphery. There appear to have been some 12 or more rays of xylem in this large stele. The whole construction is primary; there is no trace of secondary xylem or of radially seriated wood. The soft tissues of the stele are not preserved; their position is represented by the dark mineral matter between the rays and forming a thin peripheral zone outside the ends of the rays and around the whole stele.

A region of the transverse section, including the widened end of a ray of the xylem and portions of two others, is shown at a higher magnification in fig. 36. The tracheides exhibit a range in size, as was found in longitudinal view, but no localized protoxylem could be distinguished nor could the departure or structure of a leaf-trace be demonstrated in the few polished surfaces available for study.

Examination by reflected light of the semi-petrified leaf-traces in the cortical region of the specimen shown in figs. 20, 21, Plate 30, demonstrated their tracheidal structure. A portion of one of the traces, photographed at a magnification of 95 diameters, in fig. 22 shows the annular thickening. In the same way it was possible to observe under reflected light the tracheidal structure of the bundle present in the leaf, fig. 23. It was, however, difficult to obtain a photograph demonstrating the thickening as clearly as it could be seen. The piece of a foliar bundle in fig. 24, Plate 30, shows the close general resemblance to the leaf-trace bundle in fig. 22 and also indications of the transverse markings on the tracheides. Confirmatory evidence was obtained by removing tracheides on a film-pull.

It is rather surprising, considering the good preservation of the vascular system, that nothing has been ascertained as to the structure of the outer tissues of the shoot. As is often the case with incrustations, the soft tissues of the cortex have disappeared. What is more remarkable is that no indication of the epidermal structure has been found. All possible specimens were carefully scrutinized for this and film-pulls made from possible, though unpromising, specimens, but without result. Knowledge of the epidermis and stomata of this plant, which would have been valuable for comparison, is thus completely lacking.

Discussion

If the main features of the plant described in the preceding pages are summarized, it will be clear that a good deal is already known about it. It had leafy shoots, sometimes dichotomously branched, but, although large specimens of these are known, they do not give a picture of the habit of the whole plant. The stem was often 1–2 cm wide, and there is evidence that it attained a much greater thickness. The simple linear leaves, which were fairly closely placed and spirally arranged, attained a length of 4 cm and a width of 1 mm. They were not spine-like or even rigid. Some pieces of stem, which may have belonged to the lower region of the plant, bore relatively slender lateral branches that apparently bent downwards, and are *suggestive* of having been rhizomatous organs. The vascular system is fairly well known, leaf-traces extending from the central cylinder of the stem to supply the single vascular bundles that traversed the leaves. The stele, which was some 3–8 mm in diameter, had the xylem exhibiting in cross-section the form of a many-rayed star, the rays widening towards the periphery. There was no secondary thickening, at least in the stems of 2 cm diameter which showed the stele. The primary xylem was composed of similar tracheides which had an annular thickening. The leaf-traces and foliar bundles had tracheides of the same type. Nothing is known of the structure of the cortex or epidermis. The sporangia were borne in fertile zones on the shoot and not in cones. They were reniform, about 2 mm in breadth and height, and sessile among the leaf-insertions to which they correspond in arrangement. The indications are that they were situated adaxially in relation to the leaf-bases, though this is not proved. The spores measured about 50 μ. While the leaves in numerous specimens are equally spaced in the stem, there is a suggestion from two specimens that they may sometimes have been grouped together ; this feature, however, is still obscure.

The plant has been placed in a new genus on account of the striking and distinctive appearance of its shoots, with the stout stems clothed with long leaves, that were apparently lax rather than in any way spine-like and of uniform width throughout their length. It is clear, however, from our considerable though incomplete knowledge of both types that *Baragwanathia* comes very close in its main morphological features to the plant-remains from the Lower Devonian that have been long known under the names *Drepanophycus*, Goeppert and *Arthrostigma*, Dawson, the former name having priority. It is only after prolonged consideration that we have thought it wiser not to place the Australian plant of Silurian age in this genus, but to regard it as a closely related form.

The new plant must therefore in the first place be compared with the remains described as *Drepanophycus spinæformis* from Germany (Goeppert, 1852 ; Weiss, 1889 ; Kräusel and Weyland, 1930), and those described under the name *Arthrostigma gracile* from Canada (Dawson, 1871), Scotland (Jack and Etheridge, 1877 ; Kidston, 1893 ; Lang, 1932), Norway (Nathorst, 1913 ; Halle, 1916), and China (Halle, 1927). These are all from the Lower Devonian, but recently specimens from the Middle Devonian of Bohemia have been placed in this genus (Kräusel and Weyland, 1933).

The remains of *Baragwanathia* indicate a plant of larger size than those of *Drepanophycus*, the shoots most commonly met with being of a width only attained by the largest recorded specimens of the latter plant, while others were much stouter. Similarly as regards length of leaf the closest comparison is with some shoots of *D. spinæformis* from Goeppert's original locality at Hachenberg. For these, stems 2·5 cm wide and leaves 2·3 cm in length are mentioned by Kräusel and Weyland (1930). The majority of the specimens were, however, evidently smaller and the leaves most clearly shown in a photograph of natural size are slightly over 1 cm in length. They also show a characteristic narrowing from a vertically extended basal region to a pointed tip, and give the impression, as do those of *Drepanophycus* (*Arthrostigma*) from other localities, of having been rigid and spine-like. The broad stems from Norway and all those from Scotland bear short, stout spines with slightly rounded tips ; the evidence is against their being the incomplete bases of longer leaves. The long leaves of *Baragwanathia* contrast with the various types of spiny leaf found in *Drepanophycus*. The vascular system of the shoot is more fully known for *Baragwanathia*, but the various pieces of evidence for *Drepanophycus* indicate that the two plants agree in possessing leaf-traces and a vascular strand in the leaf. The type of tracheide forming the xylem is apparently the same, but is widespread among plants belonging to the Psilophytales.

In *Baragwanathia* the reniform sporangia among the leaf-bases have been shown to contain spores ; the plant was doubtless homosporous. It is of interest for comparison that specimens of *Drepanophycus* are described by Kräusel and Weyland as having large sporangium-like bodies in relation to some of the leaves. The position of the sporangia and their apparent relation to the bases of leaves are features that suggest comparison with the Lycopodiales rather than with typical Psilophytales. This position is also known even more clearly for the sporangia of *Protolepidodendron* (Kräusel and Weyland, 1932). A minor point of comparison concerns the slender rhizomatous branches ; in calling attention to a small lateral branch on a stem of *Arthrostigma* from Scotland, Kidston (1893) speaks of it as a "small root-like branch."

All additions to our detailed knowledge of *Drepanophycus* have tended to emphasize the differences between it and *Psilophyton princeps*, which it was once thought to resemble so closely that the question whether we might not be dealing with the stouter and finer branches of the same plant was raised by several investigators. The contrast between *Baragwanathia* and *Psilophyton* is still more marked. There are, however, features of general agreement with *Psilophyton* and the Psilophytales that must be kept in mind ; the tracheidal structure is important among these. The stellate arrangement of the stelar xylem now known for *Baragwanathia* can be closely compared with that found in *Asteroxylon*, and was probably a widespread type of construction among early plants. It contrasts with the stellate xylem of *Schizopodium* from the Middle Devonian of Australia (Harris, 1929) in the latter having secondary thickening and its wood being composed of pitted tracheides.

II. *Yarravia.* n.g.

The very definite and characteristic type of plant-fossil placed in a new genus, to which we give the name *Yarravia*, may be interpreted and concisely described as an unbranched axis or stalk terminated by a large synangial fructification. This appears to have included a small number of large linear-oval sporangia. The terms " fructification " and " sporangium " will be employed for clearness and with little or no doubt as to their correctness, but, as will be evident from the descriptions, this interpretation of the morphology is based on the indications afforded by flattened structureless incrustations, and not on conclusive demonstration. The organic remains in all the specimens consist of carbonaceous particles, and it has proved impossible to demonstrate spores in the bodies regarded as sporangia. The specimens have all come from the Yarra Track locality. Most of them were in one block of the mudstone sent to the Geological Survey of Victoria and broken up by Mr. ABRAHAM. These specimens, numbered 35001–35007, are the types on which the species *Yarravia oblonga* is established. Another solitary but instructive specimen (No. 34562) occurred on a piece of stone sent separately from the same locality; it is of the same general type, but differs in size and proportions and must be described as a distinct species, *Y. subsphærica*.

The general appearance and mode of occurrence of *Yarravia oblonga* is shown by the two surfaces of stone photographed of natural size in figs. 37, 38, Plate 32. In fig. 37 a number of pieces of the linear axis, several more or less incomplete fructifications, and one good complete example of the latter are to be seen. Fig. 38 shows pieces of the axis, one of which terminates in a good specimen of the fructification. The axes have a width of 2 mm, and the longest pieces seen measured between 4 and 5 cm. Though pieces of the axis often lie across one another, and may thus appear to diverge, no instance of branching has been found. The axis or stalk widens gradually at the base of the terminal fructification, which is about 9 mm long by 4–5 mm wide. The fructification shown in fig. 38 is enlarged 3 diameters in fig. 39, and the complete example from fig. 37 is enlarged 4 diameters in fig. 40. These two figures give a good idea of the details shown by the best fructifications from the block. The whole fructification, though now flattened, was probably originally cylindrical and radially symmetrical. The constituent structures shown in these good specimens are, however, all in one plane representing the object as seen from the side.

The axes or stalks are represented by a very thin incrustation, but are clearly defined as a faint brownish stain with scattered carbonaceous particles. The same applies to parts of the fructification, but a considerable thickness of carbonaceous material remains, localized in certain regions. It is these black masses that appear to be derived from, and indicate the shape and size of, the sporangia. These are evidently included in a region representing a mass of tissue continuous with the stalk and resembling the latter in preservation. There is a narrow strip of this running up either side of the fructification as seen in figs. 39, 40, Plate 32. Within this comes the region that is dark, owing to the abundance of the powdery carbonaceous material. In some lights this may appear as if confluent, but in other views it is seen to be localized in a small number of linear-oval areas, three of which are visible on the surface in each of these figures. They can sometimes be seen to be clearly delimited and separated by narrow intervals or strips, similar in preservation to the outer layer. The linear areas, which are most naturally regarded as sporangia, continue as short free tips, a feature which affords additional justification for recognizing their individuality lower down where they are enclosed and coherent. They exhibit some variation in size, but are about 7 mm long by over 1 mm broad.

A peculiar feature, the explanation of which is obscure, is that the free tip of the sporangium is not filled with the black amorphous mass so prominent a little further back. This stops about 1 mm below the upper end of the sporangium; the terminal portion being represented by a discoloured film with angular particles of carbon. That this is not an accidental appearance, due to the loss of the black mass, was shown by its being revealed as the fructification in fig. 40, was exposed by careful removal of an overlaying layer of matrix. The three sporangial tips in this specimen all show this feature, which is also seen, though less clearly, in fig. 39. The tip of a sporangium from another specimen is represented under a higher magnification in fig. 41, Plate 32. The suggestion is that the tip was composed of sterile tissue.

The appearance of the rather thick masses of black material in the bodies that have been spoken of as sporangia, is highly suggestive of being derived from the broken down walls of masses of spores. In the light of what was learnt from the similarly preserved sporangia of *Baragwanathia* (p. 427), we have little doubt that this is the correct interpretation of the amorphous black mass here also. In the case of *Yarravia*, however, neither examination by reflected light nor film-pulls provided a demonstration of spores.

The general appearance of these fructifications is strongly suggestive of their being flattened incrustations of radially symmetrical structures. But in the condition of the specimens so far obtained it is impossible to demonstrate more numerous sporangia in a fructification than those shown on the exposed plane. There are some indications of other sporangia being present in the suggestion of additional free tips in some specimens and also by the rock in one imperfect example having split so as to show layers of the carbonaceous material at two distinct levels. If the assumption that we are dealing with a radially arranged set of coherent sporangia is correct there cannot have been more than five or six sporangia in the fructification.

The specimen which will be distinguished as *Yarravia subsphærica* is represented of natural size in fig. 42, Plate 32, and enlarged 3 diameters in fig. 43, Plate 32. Comparison with figs. 38 and 39 of *Y. oblonga* will at once indicate the similarity in general morphology and the differences in size and shape between the two forms. The specimen to be described affords somewhat better evidence of the radial construction of the fructification.

As fig. 42 shows, the surface of a piece of mudstone bears an incrustation of an unbranched axis, 7·5 cm long and 2·5 mm wide. Diverging at an acute angle from this, but without proof of connection, was a short length of axis or stalk about 1 cm long by 2 mm wide, ending in a compressed fructification. The fructification measured about 1 cm, both in length and breadth. As the enlarged figure shows, it is possible to distinguish a narrow band on either side continuous with the stalk and within this a small number of sporangia. The sporangia are large elongated-oval structures which measured at least 9 mm by 2 mm. The upper portion of one of these and its projecting rounded tip is seen on the right in fig. 43. Centrally is a broad abraded sporangium on the side towards the observer; the tip of this is imperfect. On the left-hand side and appearing somewhat in profile, is a third sporangium. Owing to the incompleteness of the median sporangium a view is obtained into the centre of the flattened structure, and on the far side two projections are evident, which appear to be the free tips of two other sporangia. This direct evidence, combined with a consideration of the width of the sporangia, makes it probable that five of the latter were present ; there might have been six, but could not be more. There are indications of strips of tissue intervening between and connecting the sporangia.

In the preservation of this specimen very little carbonaceous material remains. The distinctness of the sporangia, and especially of the terminal regions of some of them is due to their having been replaced by a mineral material different from the general matrix. This gives an appearance of the sporangia being filled with rather large oval or rounded bodies. But neither from direct observation nor from a film-pull could any evidence that this indicated the original presence of spores be obtained. A feature of difference from *Y. oblonga* is that there is no trace of the differently organized tip to the sporangium. The difference in the method of preservation makes it difficult to decide how much reliance to place on this distinction, but it appears to be real and may be important.

Discussion

The examination of these specimens had led us to interpret them as exhibiting a small number of large sporangia grouped on the end of a stalk, and to regard it as highly probable that these sporangia were radially arranged and coherent to form a peculiar fructification. The presence of the outer zone continuous with the margin of the stalk, and the fact that in none of the specimens was there any sign of the individual sporangia being displaced or diverging from one another were in favour of some type of firm coherence among them. Though incompletely known, it appeared to be a peculiar type of fructification suggestive of derivation from a terminal group of large sporangia of the kind known among the Psilophytales. Comparisons with *Telangium* and *Xenotheca* (Arber and Goode, 1915) suggested themselves as possible, though not close. The description would have been left with this interpretation in the hope of more light being shed on the question by the discovery of better preserved specimens.

At this stage in our work we received the important paper by Dr. T. G. HALLE (1933), on "The Structure of Certain Fossil Spore-bearing Organs believed to belong to the Pteridosperms." It was at once evident that there was agreement between his demonstration of the structure of these better preserved Carboniferous fossils and our tentative interpretation. The results obtained by Dr. HALLE's skilful investigations thus helped to elucidate the less perfectly preserved Silurian specimens with which we were concerned.

It is not necessary to enter into the variety of types of fructification dealt with by HALLE. It is sufficient to point out the resemblance which exists between *Yarravia* and such a form as *Aulacotheca*, in which a small number of large sporangia are situated at the end of a stalk and laterally coherent around a small central cavity. In *Aulacotheca* the sporangia are united to their tips and the upper region is incurved, giving the whole fructification an oval, seed-like appearance. The spores were demonstrated in the sporangia and transverse sections of the whole compressed fructifications were obtained on which a reconstruction could be based. In *Yarravia* there is no proof of the presence of a central space, though on comparative grounds this might be regarded as probable. The sporangia are not incurved, so that the whole fructification is more oblong. A more important difference is that the sporangia are free in the terminal region. The resemblance is, however, so close in essentials that we feel justified in regarding *Yarravia* as similar in morphological construction to such a form as *Aulacotheca*.

III. *Cf. Hostimella*, sp.

In addition to the large and characteristic plant, *Baragwanathia*, including more obscure remains that are probably referable to it, and the peculiar fructification, *Yarravia*, there is evidence of the presence of slender leafless axes in this flora. The specimens as yet found are few and poor, but they come from all the four localities in which plants and graptolites are associated. All that will be done here is to describe and figure some of the more distinct examples.

Remains of this type have long been known from the *Monograptus* Beds at Thomson River, and were described by CHAPMAN under the name *Haliserites dechenianus*. Some of them are rather obscure. One specimen is, however, quite definite, and has been available for re-examination. The drawing by CHAPMAN (1912), shows its general appearance well, though it is doubtful whether the axes were all connected in one branch-system. A natural size photograph of the specimen is given in fig. 44, Plate 32. The various pieces of axis are between 1·5 and 2·5 mm wide, and were evidently firm and rigid. They are now mostly represented by concave moulds in the black stone, though there are remains in some of these of the mineral casts with which they were filled. There is no indication that the casts have retained any trace of the structure, such as was represented in a detached cast by CHAPMAN.

A small specimen from Killingworth Road though poorly preserved as a thin incrustation of iron oxide, shows the morphology of a connected branch-system.

It is represented of natural size in fig. 45, Plate 32. To the left is the piece of the relatively main axis, about 12 mm long ; it is 1·5 mm wide, increasing to 2 mm below the departure of the branch on the right. The lateral branch-system extends for about 2·5 cm, and exhibits three successive dichotomies, with progressive diminution of width from over 1 mm at the base to 0·25 mm or less in the ultimate ramifications. The main axis is sharply defined by a narrow linear region on each side ; the central region, which is of some thickness, has a shallow median depression separating two convex ridges.

The example from Yarra Track, enlarged 2 diameters, in fig. 46, Plate 32, may have been of the same rigid nature as the two preceding specimens, though the preservation as a thin incrustation does not show this. A piece of axis 2·5 cm long and 3 mm broad bears a lateral branch 1·5 mm wide that almost immediately gives off a slender branch. Of quite different type is the portion of a dichotomous axis, 8 mm broad, represented in fig. 47, Plate 32. This is from Killingworth Road, but a piece of similar size and form has been figured from Yarra Track (Keble, 1933). Some other branch-systems from the latter locality were suggestive of having been portions of a lax, rather than of a rigid, plant, fig. 48, Plate 32, but nothing can be said with certainty regarding them. Poor specimens of slender branched axes are also found at the Alexandra locality. One is seen in association with graptolites in fig. 53, Plate 32.

Discussion

While it is desirable to record fragmentary remains of the kind described above from this flora there is little need to discuss them at length. It is rather remarkable in the light of their abundance in other deposits, how scarce they are in these mudstones. Some of them, such as the first two specimens, figs. 44, 45, were doubtless vascular plants, though there is no direct evidence of this. These are similar to fragmentary remains of smooth branched axes commonly met with in Early Devonian rocks, and often placed under the form-name *Hostimella* sp. None have detailed features of agreement such as justified the unqualified use of this name for examples previously described from the Centennial Beds (Lang and Cookson, 1930), though some of them exhibit a sufficiently close general resemblance. The proportions and appearance of others indicate derivation from different kinds of plants. In the circumstances it seems best to avoid not only naming, but too definite comparisons of these unsatisfactory remains, and to await discoveries of better material.

Conclusion

The importance of the highly organized land-plants described in this paper lies in the fact that their Silurian age is established by the occurrence along with them of *Monograptus*. The graptolites from two localities have been determined by Dr. Elles, and shown to indicate conclusively that the plant-containing beds are there Lower Ludlow. It might perhaps be reasonably assumed that this will apply to the other localities, but, since so far geologists have regarded these as at a still earlier Silurian horizon, the question is left open by taking the age of this flora as Silurian and not younger than the Lower Ludlow. The three types of plant-remains have been discussed severally, and only brief reference to some general bearings of them is necessary here.

The slender branched axes of the general type, often referred to as *cf. Hostimella* sp., are fragmentary remains of a kind that is common in Early Devonian rocks. Their presence serves in a general way to connect this flora with others of early age, but is not of stratigraphical significance.

Baragwanathia, with its characteristic large leafy shoots, is not only an addition to well-known early vascular plants, but may prove of local stratigraphical value. It occurs in the two deposits definitely dated as Lower Ludlow, in the two other localities where the plants occur along with *Monograptus* and also in a number of other localities. The natural presumption might be that it indicates a corresponding horizon where met with. But its vertical distribution has still to be determined, so that we do not place too much weight on its occurrence as by itself exactly dating the beds. As is well known, fossil plants have often a considerable vertical range as compared with animals of stratigraphical value.

In size, organization, and vascular structure *Baragwanathia* has been shown to be most closely comparable with *Drepanophycus* (*Arthrostigma*), a fairly well-known type of plant characteristic of the Lower Devonian flora. It is, however, as strikingly a plant with long lax leaves as the forms referable to *Drepanophycus* are in various degrees spiny leaved. The sporangia and spores of *Baragwanathia* are recognized with certainty. What is known of them supports the interpretation of the sporangium-like bodies in a specimen of *Drepanophycus* as of this nature also ; the resemblance to the Lycopodiales was pointed out by KRÄUSEL and WEYLAND (1930).

The shape and position of the sporangia of *Baragwanathia* suggest strongly a comparison with Lycopodiales. It is of great interest to find a Silurian plant that resembles in these respects *Lycopodium*, clues to the fossil history of which have so far been slight. The distribution of the sporangia in fertile zones of a leafy shoot affords an early example of what has been known as the *Selago*-condition. The position of the sporangia in relation to the leaves appears to be an approach to the Lycopodiales, and would formally separate the plant from the Psilophytales as originally defined. While full weight must be given to these characters, the details of the vascular system provide evidence of close connection with the Psilophytales. In its stelar arrangement and especially in its tracheidal structure *Baragwanathia* exhibits agreement with a number of early plants that are clearly and typically Psilophytales and as definitely contrasts with the Lycopodiales.

As knowledge of the early Palæozoic plants gradually increases it is thus becoming evident that there were forms occupying a doubtful, or rather an intermediate, position between Psilophytales and Lycopodiales. This has already been shown to be the case when other definite groups of the Pteridophyta (Sphenophyllales, Equisetales, Filicales) are considered in relation to the Psilophytales. Many of the early plants have been leafless, or, if they had small leaves these have been spines or suggested comparison with emergences. *Baragwanathia*, with its long simple leaves, provided with a vascular supply, does not throw any light on the problem of the phylogenetic origin of the microphyllous shoot, but it gives no support to the derivation of simple leaves from emergences. It is remarkable to find a large vascular plant with a well organized leafy shoot, and exhibiting relatively advanced features not only in these respects but in sporangial position, in the Silurian flora.

The fructification to which the name *Yarravia* has been given is not only an addition to the morphological types known for Early Palæozoic floras, but is remarkable on account of its resemblance to complex structures from the Carboniferous only recently elucidated by HALLE. The closeness of the morphological comparison in essential features between *Yarravia* and such an example of the Whittleseyinæ as *Aulacotheca* has been pointed out in the special discussion. In both there is a synangial union of a small number of large elongated sporangia to form a terminal fructification. The only indication of what may be regarded as more primitive construction in *Yarravia* is afforded by the freely projecting tips of the sporangia. In the case of the Carboniferous fructifications the presumption is that they are the microspore-producing organs of certain Pteridosperms. It is in the highest degree unlikely that the morphological similarity of the fructification of *Yarravia* indicates systematic relationship in the sense of belonging to that group. The Silurian plant, of which only the stalked fructifications are known, was probably one of the Psilophytales, although it provides no evidence directly bearing on this point. Its occurrence in these early rocks gives strong support to HALLE's clear and interesting speculations as to the way in which the fructifications he is describing might have been derived from the Psilophytales. While reference must be made to his complete discussion, a quotation will bring out the main point. " Broadly speaking, the terminal sporangia of the *Psilophytales* and of some primitive Ferns without laminæ may be regarded as derived from spore-producing tips of ordinary ultimate thallus- or rachis-branches. In the case of a terminal tuft of sessile sporangia, as in some forms of *Psilophyton*, each sporangium would then represent an entire ultimate rachis-branch (telome) producing spores. Just as sterile rachis-branches (telomes) are generally supposed to have given rise to the lamina of a pinnule through lateral fusion in one plane (webbing), so a group of terminal sporangia in cyclic arrangement may produce through tangential fusion a spore-bearing cupule-like structure." (HALLE, 1933.)

It is somewhat surprising that the fructification of *Yarravia* appears to be almost as completely synangial as the Carboniferous forms. It might have been anticipated that less integrated structures, illustrating some of the earlier steps indicated by HALLE, would have been met with in these early rocks. Specimens that appear to be of this nature from another deposit in Victoria are at present under investigation.

It is clear that any consideration of the character of this flora would not by itself have led to the right conclusion as to the age of the beds in which it is found. Comparison with fossil plants from other parts of the world would, on our present knowledge, have suggestd an age not older than the Lower Devonian. The proved Silurian age of these recognizable land-plants gives a new starting point for the study of pre-Devonian floras, and raises anew the question of records of vascular plants from these strata. Unsatisfactory as these records have mostly been, they must be summarized here.

In Britain there are indications that vascular plants were present in rocks of Downtonian age before the typical Lower Old Red Sandstone in which *Drepanophycus* (*Arthrostigma*), *Psilophyton princeps* and *Zosterophyllum myretonianum* are known. A specimen showing the type of branching of *Zosterophyllum* was found on Caldy Island in what are now regarded as upper beds of the Downtonian (LANG, 1927), and narrow branched axes with a central strand occur throughout the series. Proof of the vascular structure has not, so far, been obtained. There are no vascular plants known from the Silurian or earlier rocks. The nature of the large graphitic incrustations (*Berwynnia Carruthersi*) associated with graptolites from the Pen-y-glog beds of Wenlock age (HICKS, 1881, 1882; DAWSON, 1882) is undetermined. The same applies to a record of large carbonized stems from the Silurian of Ireland (BAILY, 1866). The strata in Cornwall from which fragments of a highly organized wood (*Dadoxylon hendriksi*) were obtained (LANG, 1929) were formerly regarded as (?) Ordovician, but are now referred to as possibly Middle Devonian (FLETT, 1933).

For Europe generally the position appears to be similar. There are undoubted vascular plants in Lower Devonian rocks (*Psilophyton*, *Drepanophycus* (*Arthrostigma*), *Protolepidodendron*, *Zosteropnyllum*, *Tæniocrada*, *Hostimella* sp.), but none have been proved to be present in Silurian strata. There is no evidence that the axis with leaf-like appendages which HALLE (1920) described as *Psilophyton* (?) *Hedei* was a vascular plant. His specimens came from the Lower Ludlow of Gothland, and were associated with graptolites. What appears to be the same plant from England was described by KIDSTON (1886) as "Algoidal (?) Impression." Mention must be made of the "wood" described by KRÄUSEL (1924) as *Archæoxylon Krasseri* from pre-Cambrian rocks of Bohemia; it is doubtful whether either the age or the exact nature of this fossil are sufficiently certain to establish the existence of vascular plants in the pre-Cambrian.

When the more numerous records of pre-Devonian plants from America are critically considered, they also are found to provide no clear and reliable evidence. There are figures of two branched specimens under the name *Hostimella silurica*, GOLDRING, which may well be portions of vascular plants, though there is no evidence of this. They are from the Bertie Waterlime (RÜDEMAN, 1928). DAWSON (1871) figured and described fragmentary plants, in some cases showing vascular structure, from the Helderberg Limestone immediately underlying the Gaspé sandstone. This limestone was then regarded as Silurian, but the strata are now included in the Lower Devonian. This applies also to some doubtful plants (? *Calamophycus*, *Annularia Roemingeri*, *Psilophyton cornutum*) from the Lower Helderberg, Michigan, described by LESQUEREUX (1877). There is a record of a single specimen from the Clinton Limestone as being part of the surface of a Lepidodendroid plant which was named *Glyptodendron eatonense*. Nothing further appears to have become known of this, nor have additional remains been found since the original description by CLAYPOLE (1878). Critical confirmation would be needed before this evidence could be accepted, but the account of this one fragment is definite so far as it goes, and must be mentioned. The paper by CLAYPOLE is highly critical of remains shortly before described as land-plants from a still lower horizon in the Silurian by LESQUEREUX (1877); these have not been regarded as affording any reliable evidence.

It is clear from the above survey and from all recent works on palæobotany that there is no accepted evidence for the existence of vascular plants in the Silurian, although investigators have had an open mind on the possibility of their having existed.

The absence of any real knowledge of Silurian land-plants in any part of the world brings out the interest of the abundant plant-remains in rocks which have for long been regarded as of this age in Victoria. The small flora described in this paper has the special importance of being assigned to a definite horizon in the Silurian by the graptolites associated with the plants, and the latter are not merely fragments but are adequately known to be of complex organization. The demonstration of plants of this nature, of established Silurian age, has general bearings on the way in which early plant-bearing deposits in Australia or elsewhere are to be regarded. The occurrence of vascular land-plants can no longer be taken by itself as indicating a later geological age. Critical evidence of the age of such beds, from stratigraphy or palæontology or both, becomes not only desirable but necessary in dealing with early palæozoic floras.

These considerations will apply to collections of plants from Victoria that may be at the same horizon as the flora here described. They also lead to modification of the views expressed as to the probable age of the Centennial Beds (LANG and COOKSON, 1930). These beds, from which a flora, including vascular plants (*Hostimella* sp., *Zosterophyllum australianum*), has been described as of an Early Devonian type, have no animal fossils to indicate their age. They have been regarded by the Geological Survey as much younger stratigraphically than the *Monograptus* Beds. Partly for this reason, but influenced by the type of the flora, geologists have suggested that sedimentation here might have continued into Lower Devonian times, and Sir EDGEWORTH DAVID correlates the beds as (?) Gedinnian. But in the light of the complex plant *Baragwanathia*, now known to have been already present in the Silurian, the weight naturally attached to the presence of *Zosterophyllum*, etc., in the Centennial Beds disappears. The question as to the age of these beds becomes a completely open one to be decided by other evidence. The same caution will have to be exercised with regard to early beds containing vascular plants in other regions.

It is premature to discuss fully the general questions raised by the demonstration of a flora of vascular land-plants in the Silurian. One question of general interest is whether there is any special significance in the occurrence of land-plants of a type only known from the Lower Devonian of the Northern Hemisphere in the Silurian of the Southern Hemisphere. This may be merely due to the conditions for the preservation of a record of the flora having been favourable in this region of Victoria. On the other hand it may indicate an earlier development of land-plants in this region. Another point of importance in considering the evolutionary history of plants concerns the size and structural complexity of these Silurian plants. They are by no means very primitive land-plants. Their existence implies a preceding period of evolution, of what length there is as yet no evidence.

It is evident that further discoveries may be anticipated in the Silurian rocks of Australia and perhaps in more ancient rocks. The beds dealt with here have yielded the most ancient land-plants as yet clearly known and of definitely determined age. What is wanted is an extension of the body of accurate fact regarding the pre-Devonian land-flora. Without neglecting other regions of the world, the early rocks of Victoria appear at present to be the most promising field for this work.

Diagnosis of New Genera and Species

Baragwanathia, n. gen.

Stems of considerable size clothed with spirally arranged, long, simple leaves. Leaves maintaining a uniform width, not contracted from a markedly expanded base and not spine-like. Sporangia, among the leaf-insertions in certain zones of the ordinary shoots; possibly adaxially, near the bases of leaves. Large cylindrical central cylinder with primary xylem, which is stellate in cross-section and composed of uniform tracheides with narrow annular thickening.

Baragwanathia longifolia, n. sp.

Characters of Genus—Leafy shoots with dichotomous branching. Stems from 4 mm–6·5 cm broad; mostly 1–2 cm. Leaves up to 4 cm long and 1 mm wide; appearing rather lax. Sporangia reniform, 2 mm tangentially and 2 mm high. Spores 50 μ. Suggestive indications of downwardly directed, (?) rhizomatous, slender, lateral branches, and of bud-like grouping of leaves laterally on the main stem.

Horizon—Jordan River Beds.

Locality—Yarra Track; Alexandra; Killingworth Road, Yea; Thomson River; Jamieson district, and other places in the Walhalla geo-syncline and neighbourhood. Victoria, Australia.

Age—Silurian; in the first two localities determined as Lower Ludlow.

Yarravia, n. gen.

Synangial fructification, terminal on axis, consisting of a small number of large, linear-oval sporangia, apparently radially arranged around a central space. Sporangia with freely projecting tips, not convergent above.

Yarravia oblonga, n. sp.

Stalk 2 mm wide ; fructification about 9 mm long by 5 mm wide ; Sporangia, probably 5 or 6, usually three visible; about 7 mm long by 1·25 mm broad; with (?) sterile tips.

Locality—Yarra Track, Victoria, Austrălia.

Age—Silurian, determined as Lower Ludlow.

Yarravia subsphærica, n. sp.

Stalk 2 mm wide ; fructification 1 cm long by 1 cm broad; sporangia, about 5 or 6; about 9 mm long by 2 mm broad.

Locality—Yarra Track, Victoria, Australia.

Age—Silurian, determined as Lower Ludlow.

Summary

1—A small flora is described from four localities in the region of the Walhalla geo-syncline, Victoria, Australia, where the plants occur in immediate association with graptolites. For two of the localities the age has been determined as Lower Ludlow. The plants are thus undoubtedly Silurian and not younger than the Lower Ludlow. They are the oldest clearly known vascular land-plants.

2—In addition to fragmentary branch-systems, *cf. Hostimella*, sp., the flora includes two new types, *Baragwanathia* and *Yarravia*.

3—*Baragwanathia longifolia* has stout stems, clothed with long simple lax leaves. The large reniform sporangia are borne in zones of the shoot, among and in relation to the bases of foliage leaves ; they contained spores of one kind, measuring 50 μ. There are indications of downwardly directed rhizomatous branches. The central vascular cylinder, the leaf-traces and the foliar bundles are known. The stele had a primary xylem, stellate in transverse section and composed of similar tracheides with annular thickening. The tracheides of the leaf-trace and foliar bundle are of this type also.

4—*Yarravia* was a synangial fructification borne terminally on a smooth axis or stalk. It was apparently radially symmetrical, consisting of a small number of large linear-oval sporangia, united laterally and possibly surrounding a central space. The tips of the sporangia are free. Two species are distinguished by the proportions of the fructification ; *Y. oblonga* and *Y. subsphærica*.

5—*Baragwanathia* is most closely comparable with *Drepanophycus* (*Arthrostigma*) from the Lower Devonian of the northern hemisphere. *Yarravia*, which is a type new from early palæozoic rocks, appears to have a similar morphological construction to some Carboniferous fructifications belonging to the Pteridosperms, recently described by HALLE. This morphological agreement is confirmatory of that investigators' phylogenetic speculations but does not indicate systematic affinity.

6—In the light of the demonstration of highly organized plants in the Silurian it can no longer be inferred from the occurrence of such plants that the beds containing them must be as young as the Lower Devonian. It follows from this that the age of the Centennial Beds, Victoria, which contain a flora of Early Devonian type, is an open question to be determined by evidence other than that of the fossil plants.

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EXPLANATION OF PLATES

(All the figures are from untouched negatives. C before a specimen number refers to the Cookson Collection.)

PLATE 29

Baragwanathia longifolia

FIG. 1—Portion of a leafy shoot, preserved as a thin incrustation composed of minute fragments of carbonaceous material, showing the stem clothed with long simple leaves. Yarra Track. Nat. size. (C 115.)

FIG. 2—Terminal part of a branch-system, showing dichotomy of the leafy shoot. Yarra Track. 2/3 nat. size. (C 9.)

FIG. 3—Upper portion of a leafy shoot preserved as a thin orange incrustation on a black layer of the mudstone; some of the leaves are complete and show their tips. Killingworth Road. Nat. size. (C 56.)

FIG. 4—Leafy shoot on black shale. Thomson River. Nat. size. (Geol. Survey Victoria, No. 1144.)

FIG. 5—Short piece of broad-stemmed leafy shoot. Killingworth Road. Nat. size. (C 118.)

FIG. 6—Shoot, with terminal bud, and a fertile zone with large reniform sporangia. Yarra Track. Nat. size. (C 119.)

FIG. 7—Region including a number of sporangia from specimen in fig. 6. $\times 2\frac{1}{2}$.

FIG. 8—Spores on film-pull from sporangium of specimen in fig. 6. $\times$ 200.

FIG. 9—Isolated spore at edge of a spore-mass from film-pull from specimen in fig. 6. $\times$ 200.

FIG. 10—Another shoot bearing a number of sporangia; the specimen is peculiar in having the leaves associated in groups on the stem. Alexandra. Nat. size. (C 176).

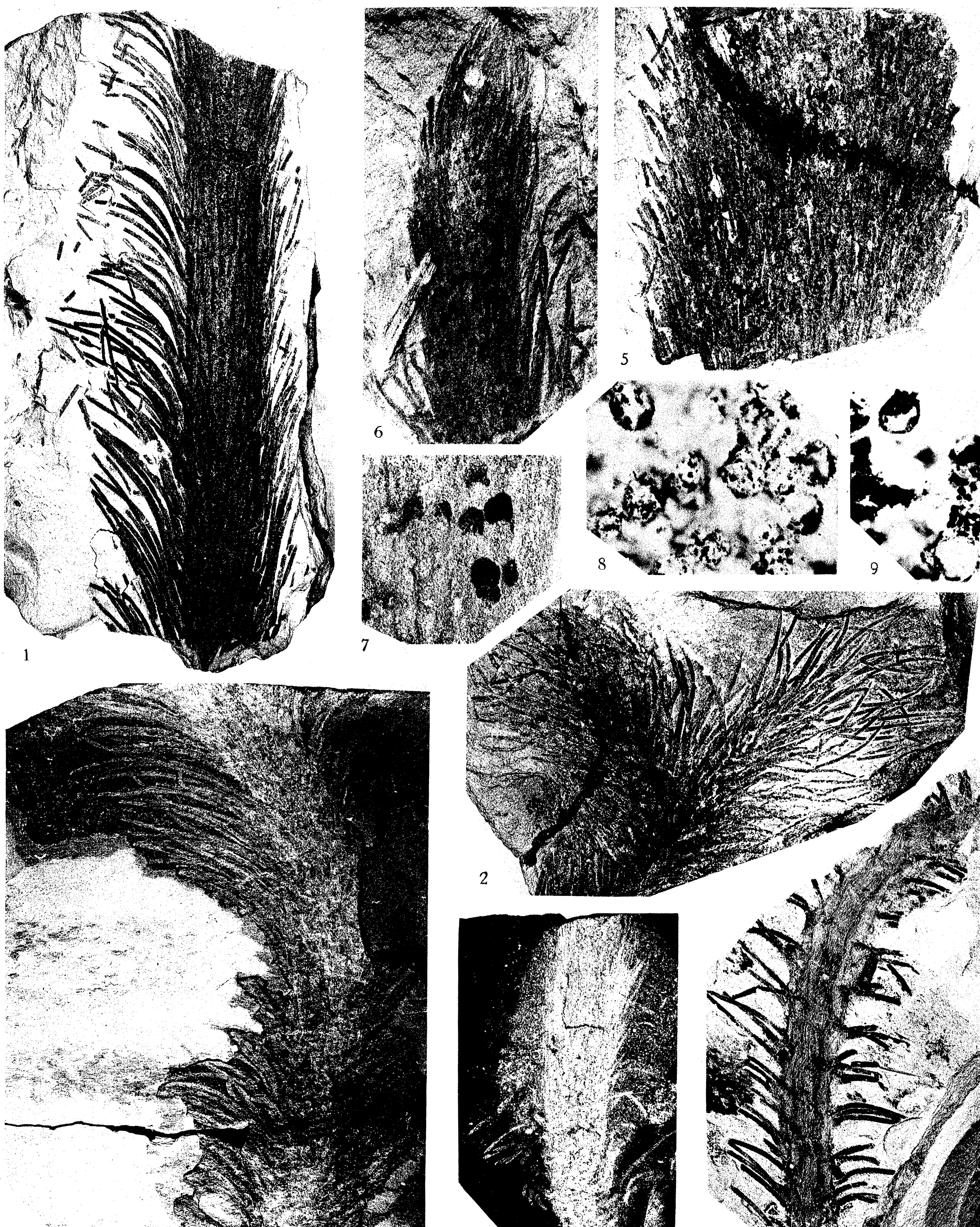
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PLATE 30

Baragwanathia longifolia

FIG. 11—Portions of two shoots with incomplete leaves, only the basal parts persisting. Yarra Track. Nat. size. (C 170.)

FIG. 12—The broadest stem seen ; the leaf-insertions are represented by dark areas with occasional remains of the basal part of the leaf. Yarra Track. Nat. size. (C 116.)

FIG. 13—The most slender shoot seen. Yarra Track. Nat. size. (Geol. Survey Vict., No. 34980.)

FIG. 14—Thin impression of a leafless stem on blackened surface of mudstone, the leaf-insertions being represented by elevations and depressions, spirally arranged. Killingworth Road. Nat. size. (C 143.)

FIG. 15—Thin incrustation of leafless stem, the position of the leaves being indicated by the leaf-traces. Killingworth Road. Nat. size. (C 139.)

FIG. 16—Two leafless stems, the central strand indicated by a strip of the orange material. Killingworth Road. Nat. size. (C 147.)

FIG. 17—Leafless stem, with bases of two (?) rhizomatous branches and remains of leaf-bases. Killingworth Road. Nat. size. (C 62.)

FIG. 18—Lower region of the preceding specimen, including the lower, (?) rhizomatous branch and the upwardly directed leaf-base. $\times$ 2.

FIG. 19—Leafless stem with slender lateral (?) rhizomatous branches. Nat. size. (Geol. Survey Vict., No. 32658.)

FIG. 20—Leafless stem bearing two slender lateral branches ; the branches here and in the two preceding figures were possibly rhizomatous and directed as shown. Killingworth Road. Nat. size. (C 64.)

FIG. 21—Portion of the cortical region of the stem in the preceding figure, showing the persistent, semi-petrified leaf-traces. $\times$ 10.

FIG. 22—Part of one of the leaf-traces in the preceding figure, showing the tracheides with annular thickening. $\times$ 95.

FIG. 23—Portion of the surface shown in fig. 25, including a leaf, the vascular bundle of which is visible. Killingworth Road. $\times$ 10. (C 60.)

FIG. 24—Portion of the vascular strand of a leaf, showing indications of the tracheidal structure. Killingworth Road. $\times$ 78. (C 60.)

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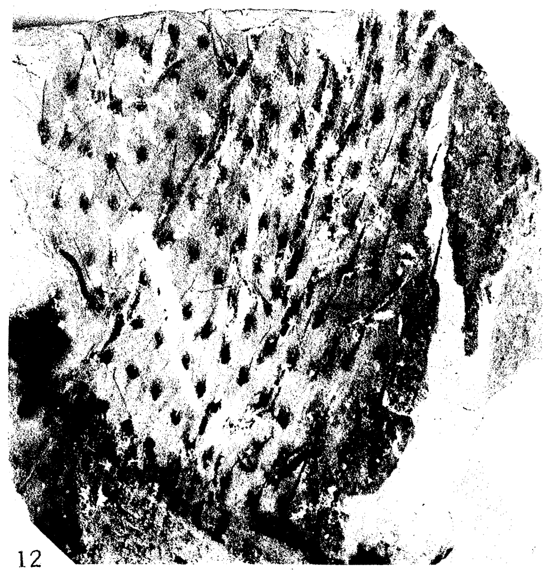

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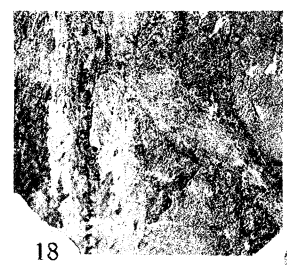

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Plate 31

Baragwanathia longifolia

Fig. 25—Surface of rock with remains of two leafy shoots, in which the stele is semi-petrified. Killingworth Road. Slightly reduced. (C 60.)

Fig. 26—Piece of stem with semi-petrified central cylinder from the counterpart of the preceding specimen. Nat. size. (C 60a.)

Fig. 27—Leafless stem with a stout semi-petrified central cylinder. Killingworth Road. $\times \frac{1}{2}$. (C 132.)

Fig. 28—Portion of preceding specimen, showing the central cylinder. Nat. size.

Fig. 29—Surface view, by reflected polarized light of part of the stele of the specimen in fig. 26, showing the longitudinal strands of xylem and the tracheidal structure. $\times$ 75.

Fig. 30—Part of same region showing one of the tracheides. $\times$ 150.

Fig. 31—Another region of the same stele. In this and the two preceding figures the light lines represent the thickening rings. $\times$ 150.

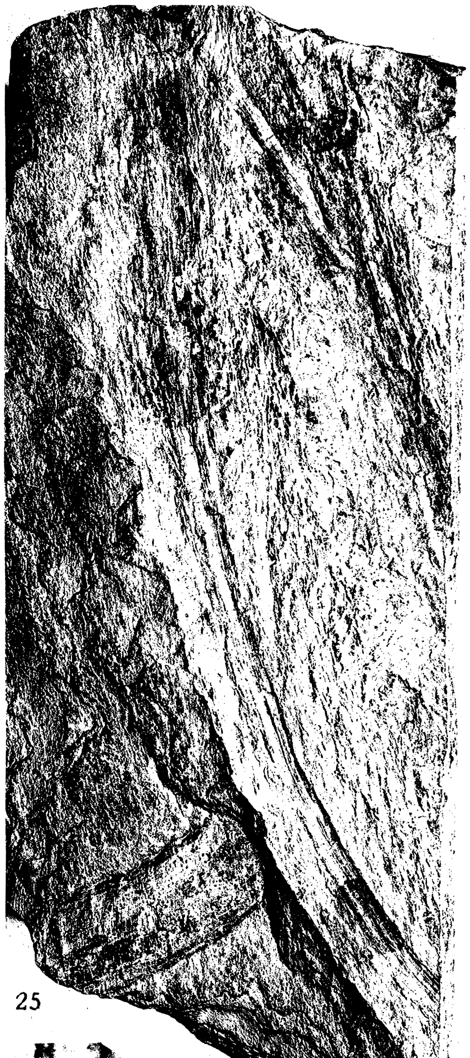
Fig. 32—Portion of xylem, including one of the transverse cracks in the stele, as shown on a film-pull viewed by transmitted light. $\times$ 150.

Fig. 33—Tracheides from another film-pull. $\times$ 250.

Fig. 34—Portion of a ground section showing the tracheides in longitudinal section. $\times$ 250.

Fig. 35—Transverse surface from the large stele from the specimen in figs. 27, 28, impregnated with synthetic resin, polished and viewed by reflected polarized light. It shows the stellate outline of the xylem as in a transverse section. $\times$ 12·5.

Fig. 36—Portion of a similar polished surface to that in the preceding figure. It includes the widened outer regions of three of the rays of xylem. The walls of the tracheides, seen as in a transverse section, appear light and the lumina dark. $\times$ 63.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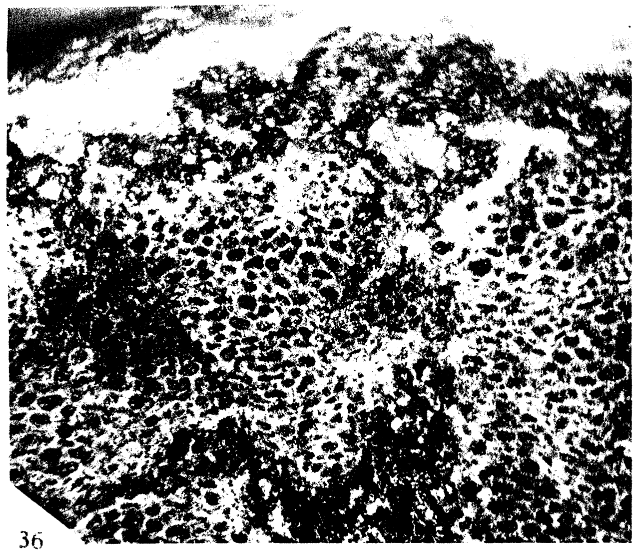
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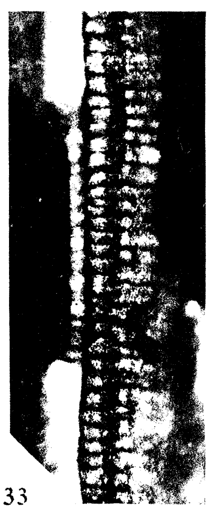
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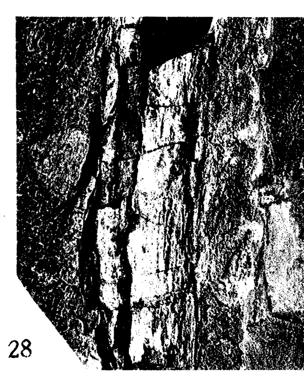
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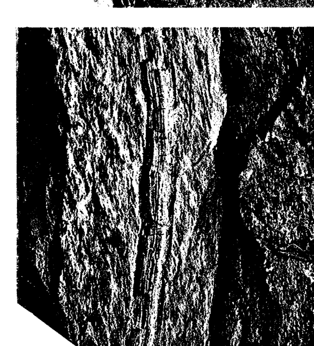
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Plate 32

Fig. 37—*Yarravia oblonga.*—Piece of mudstone from Yarra Track, showing a group of axes, several imperfect fructifications and one complete fructification. Nat. size. (Geol. Survey Vict., No. 35001.)

Fig. 38—Another surface with axes and one good terminal fructification. Nat. size. (Geol. Survey Vict., No. 35003.)

Fig. 39—The fructification in fig. 38. × 3.

Fig. 40—The complete fructification in fig. 37. × 4.

Fig. 41—Upper part of a sporangium of *Yarravia oblonga*, showing the dark mass of carbonaceous material and the terminal region in which it is not present. × 24.

Fig. 42—*Yarravia subsphærica.* The specimen on the piece of mudstone. Yarra Track. Nat. size. (Geol. Survey Vict., No. 34563.)

Fig. 43—The fructification in fig. 42. × 3.

Fig. 44—Slender branched axis, *cf. Hostimella*, sp. Thomson River. Nat. size. (Nat. Museum Melbourne, No. 12881.)

Fig. 45—Slender axis with lateral branch-system. Killingworth Road. Nat. size. (C 149.)

Fig. 46—Axis with laterally placed branch that again divides. Yarra Track. × 2. (C 138.)

Fig. 47—Dichotomous axis. Killingworth Road. Nat. size. (C 130.)

Fig. 48—Dichotomous branch-system of slender axes. Yarra Track. Nat. size. (Geol. Survey Vict., No. 28968.)

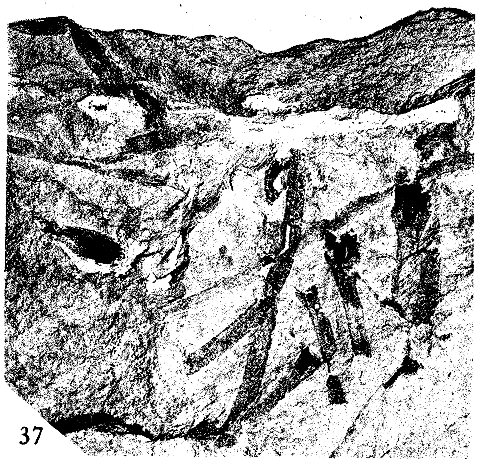
Fig. 49—*Baragwanathia longifolia.*—Piece of stem with the persistent bases of a few leaves. Thomson River. Nat. size. (Geol. Survey Vict., No. 22059.)

Fig. 50—(?) *Baragwanathia longifolia.*—Three bud-like structures, that appear to have been borne by a stem to the right. Yarra Track. × 2. (Geol. Survey Vict., No. 35009.)

Fig. 51—*Monograptus* on same piece of stone as a shoot of *Baragwanathia longifolia.* Yarra Track. Nat. size. (C 115b.)

Fig. 52—Specimens of *Monograptus* on same stone as a leafless stem of *Baragwanathia.* Alexandra, *loc.* 9. Nat. size. (C 112.)

Fig. 53—Specimens of *Monograptus*, along with a slender branched axis and a stem of *Baragwanathia* with a few remains of leaf-bases. Alexandra, *loc.* 9. Nat. size. (C 113.)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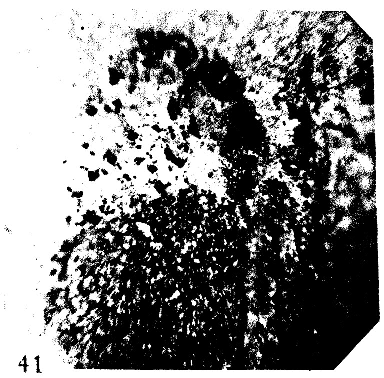
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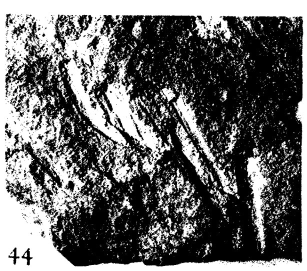
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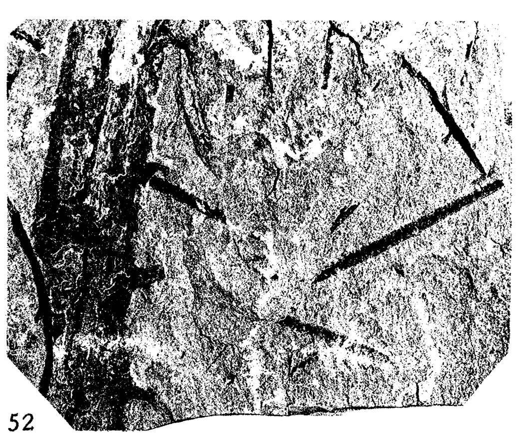
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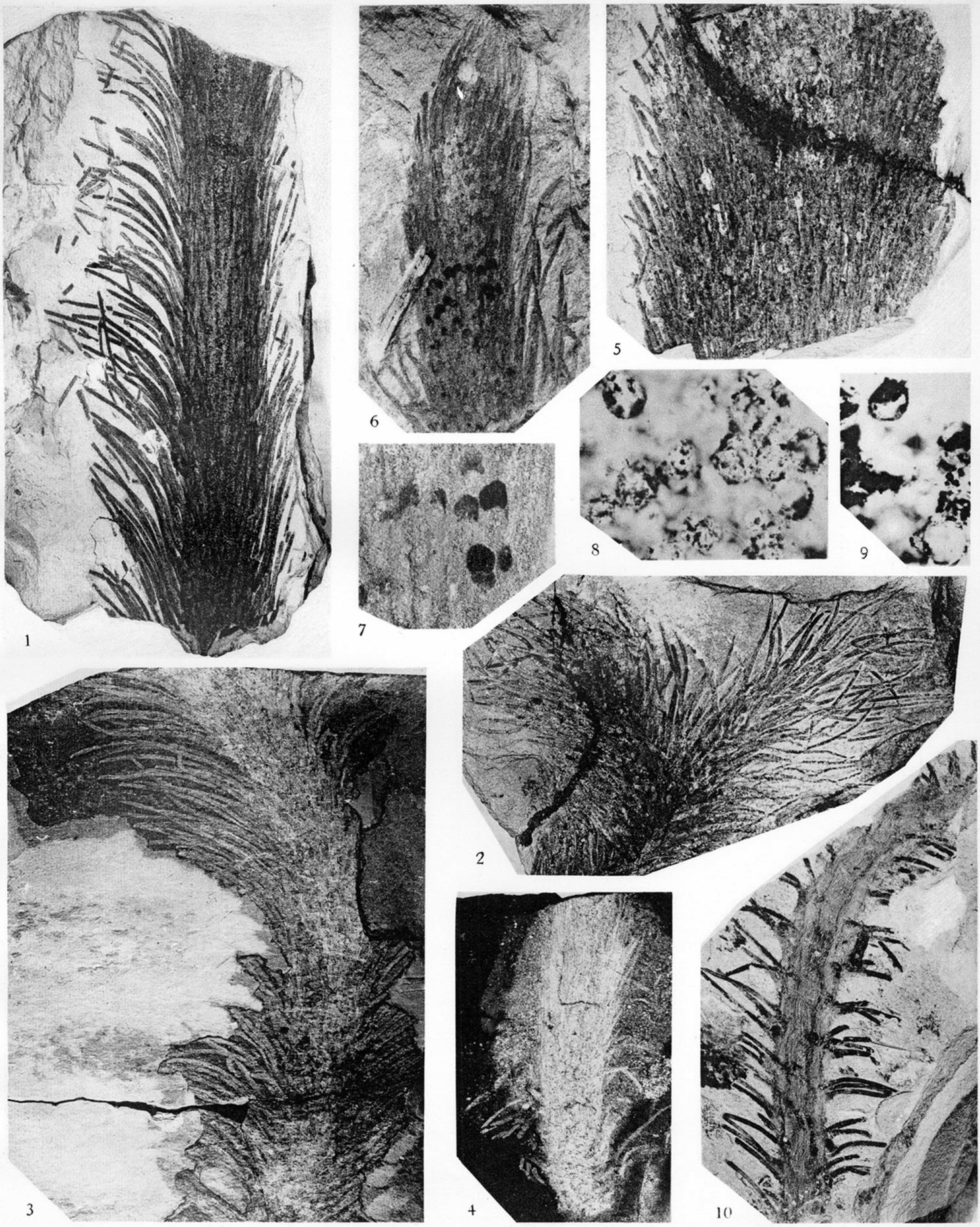

PLATE 29

Baragwanathia longifolia

FIG. 1—Portion of a leafy shoot, preserved as a thin incrustation composed of minute fragments of carbonaceous material, showing the stem clothed with long simple leaves. Yarra Track. Nat. size. (C 115.)

FIG. 2—Terminal part of a branch-system, showing dichotomy of the leafy shoot. Yarra Track. 2/3 nat. size. (C 9.)

FIG. 3—Upper portion of a leafy shoot preserved as a thin orange incrustation on a black layer of the mudstone; some of the leaves are complete and show their tips. Killingworth Road. Nat. size. (C 56.)

FIG. 4—Leafy shoot on black shale. Thomson River. Nat. size. (Geol. Survey Victoria, No. 1144.)

FIG. 5—Short piece of broad-stemmed leafy shoot. Killingworth Road. Nat. size. (C 118.)

FIG. 6—Shoot, with terminal bud, and a fertile zone with large reniform sporangia. Yarra Track. Nat. size. (C 119.)

FIG. 7—Region including a number of sporangia from specimen in fig. 6. × 2½.

FIG. 8—Spores on film-pull from sporangium of specimen in fig. 6. × 200.

FIG. 9—Isolated spore at edge of a spore-mass from film-pull from specimen in fig. 6. × 200.

FIG. 10—Another shoot bearing a number of sporangia; the specimen is peculiar in having the leaves associated in groups on the stem. Alexandra. Nat. size. (C 176).

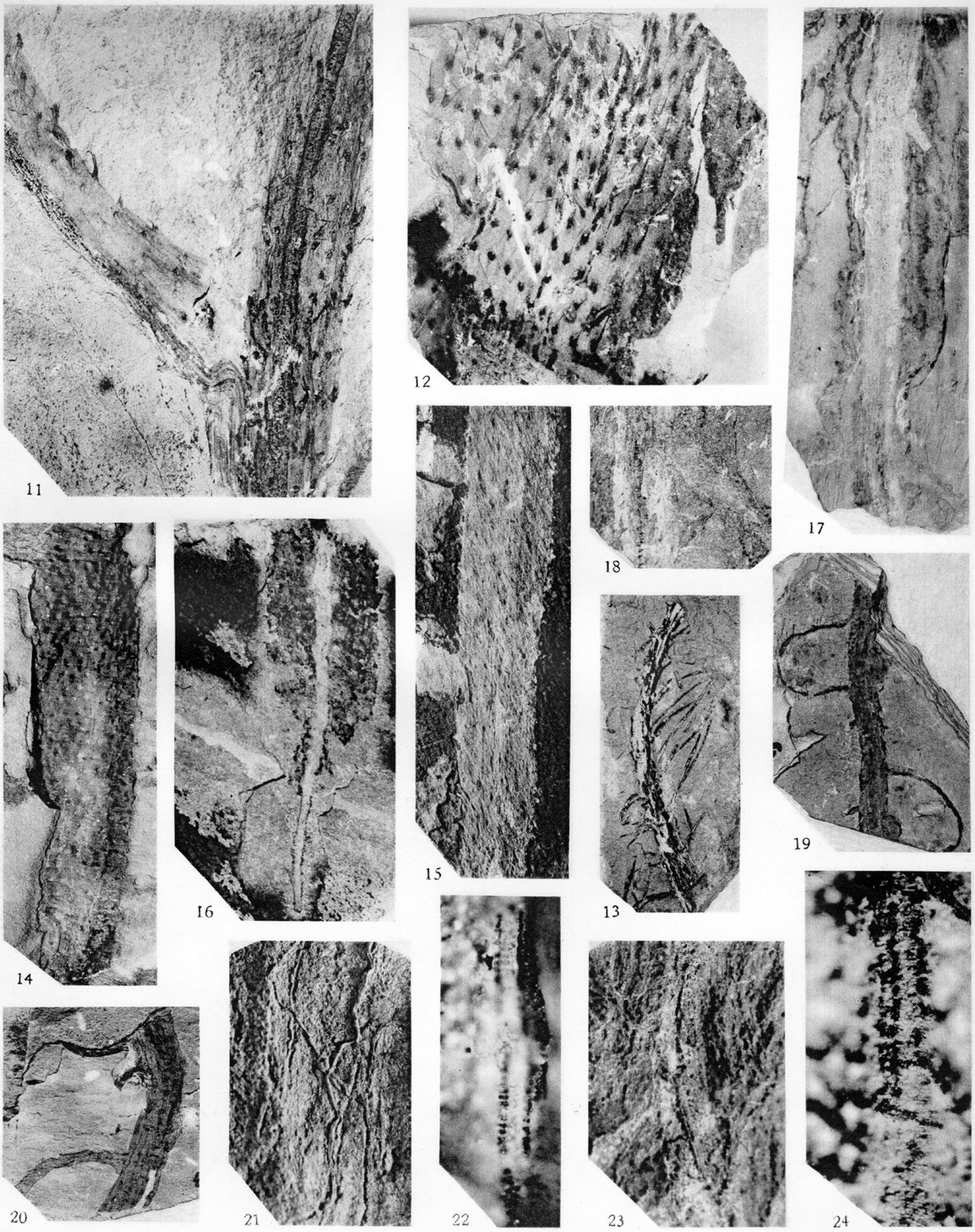

PLATE 30

Baragwanathia longifolia

FIG. 11—Portions of two shoots with incomplete leaves, only the basal parts persisting. Yarra Track. Nat. size. (C 170.)

FIG. 12—The broadest stem seen; the leaf-insertions are represented by dark areas with occasional remains of the basal part of the leaf. Yarra Track. Nat. size. (C 116.)

FIG. 13—The most slender shoot seen. Yarra Track. Nat. size. (Geol. Survey Vict., No. 34980.)

FIG. 14—Thin impression of a leafless stem on blackened surface of mudstone, the leaf-insertions being represented by elevations and depressions, spirally arranged. Killingworth Road. Nat. size. (C 143.)

FIG. 15—Thin incrustation of leafless stem, the position of the leaves being indicated by the leaf-traces. Killingworth Road. Nat. size. (C 139.)

FIG. 16—Two leafless stems, the central strand indicated by a strip of the orange material. Killingworth Road. Nat. size. (C 147.)

FIG. 17—Leafless stem, with bases of two (?) rhizomatous branches and remains of leaf-bases. Killingworth Road. Nat. size. (C 62.)

FIG. 18—Lower region of the preceding specimen, including the lower, (?) rhizomatous branch and the upwardly directed leaf-base. $\times$ 2.

FIG. 19—Leafless stem with slender lateral (?) rhizomatous branches. Nat. size. (Geol. Survey Vict., No. 32658.)

FIG. 20—Leafless stem bearing two slender lateral branches; the branches here and in the two preceding figures were possibly rhizomatous and directed as shown. Killingworth Road. Nat. size. (C 64.)

FIG. 21—Portion of the cortical region of the stem in the preceding figure, showing the persistent, semi-petrified leaf-traces. $\times$ 10.

FIG. 22—Part of one of the leaf-traces in the preceding figure, showing the tracheides with annular thickening. $\times$ 95.

FIG. 23—Portion of the surface shown in fig. 25, including a leaf, the vascular bundle of which is visible. Killingworth Road. $\times$ 10. (C 60.)

FIG. 24—Portion of the vascular strand of a leaf, showing indications of the tracheidal structure. Killingworth Road. $\times$ 78. (C 60.)

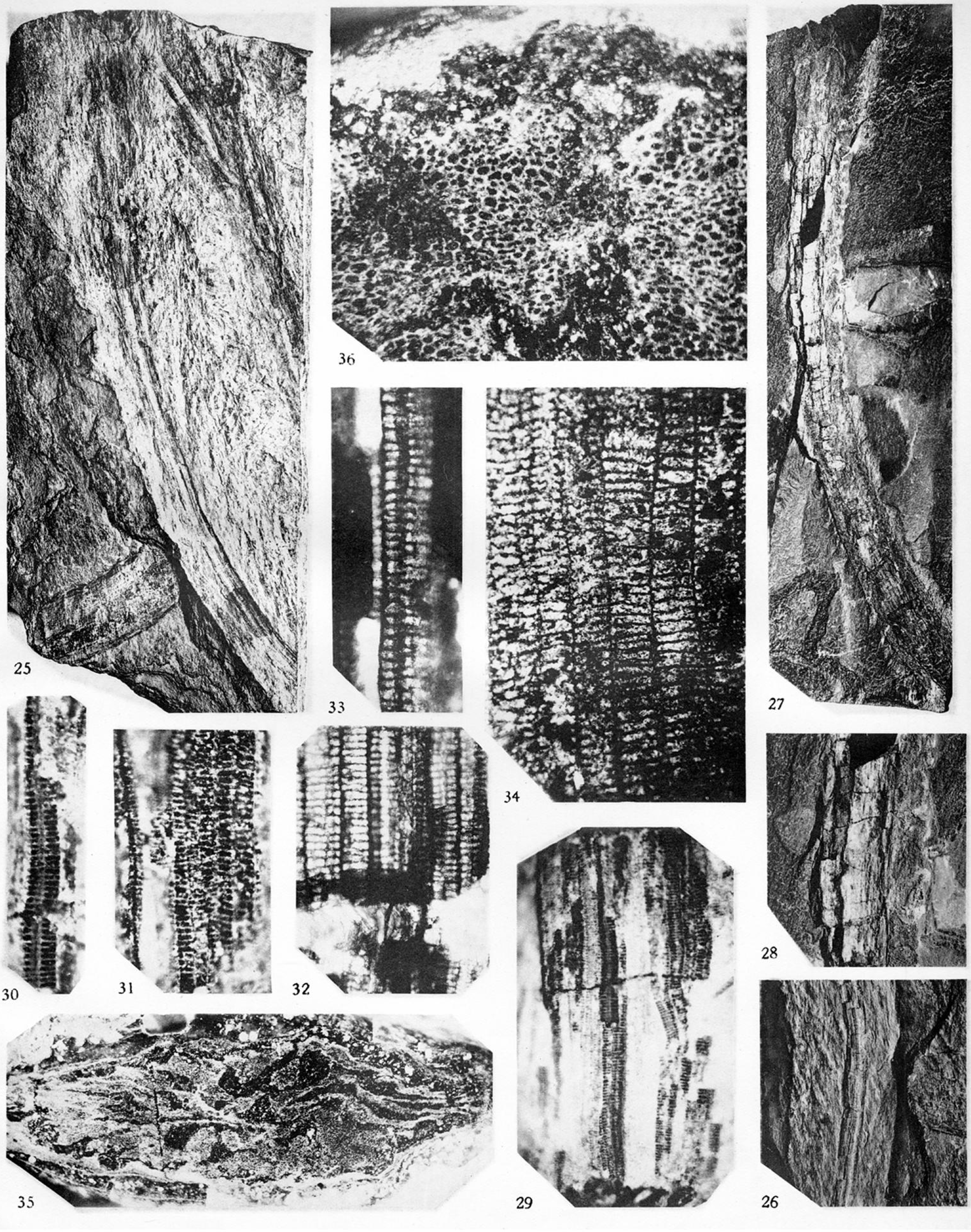

PLATE 31

Baragwanathia longifolia

FIG. 25—Surface of rock with remains of two leafy shoots, in which the stele is semi-petrified. Killingworth Road. Slightly reduced. (C 60.)

FIG. 26—Piece of stem with semi-petrified central cylinder from the counterpart of the preceding specimen. Nat. size. (C 60a.)

FIG. 27—Leafless stem with a stout semi-petrified central cylinder. Killingworth Road. $\times \frac{1}{2}$. (C 132.)

FIG. 28—Portion of preceding specimen, showing the central cylinder. Nat. size.

FIG. 29—Surface view, by reflected polarized light of part of the stele of the specimen in fig. 26, showing the longitudinal strands of xylem and the tracheidal structure. $\times$ 75.

FIG. 30—Part of same region showing one of the tracheides. $\times$ 150.

FIG. 31—Another region of the same stele. In this and the two preceding figures the light lines represent the thickening rings. $\times$ 150.

FIG. 32—Portion of xylem, including one of the transverse cracks in the stele, as shown on a film-pull viewed by transmitted light. $\times$ 150.

FIG. 33—Tracheides from another film-pull. $\times$ 250.

FIG. 34—Portion of a ground section showing the tracheides in longitudinal section. $\times$ 250.

FIG. 35—Transverse surface from the large stele from the specimen in figs. 27, 28, impregnated with synthetic resin, polished and viewed by reflected polarized light. It shows the stellate outline of the xylem as in a transverse section. $\times$ 12·5.

FIG. 36—Portion of a similar polished surface to that in the preceding figure. It includes the widened outer regions of three of the rays of xylem. The walls of the tracheides, seen as in a transverse section, appear light and the lumina dark. $\times$ 63.

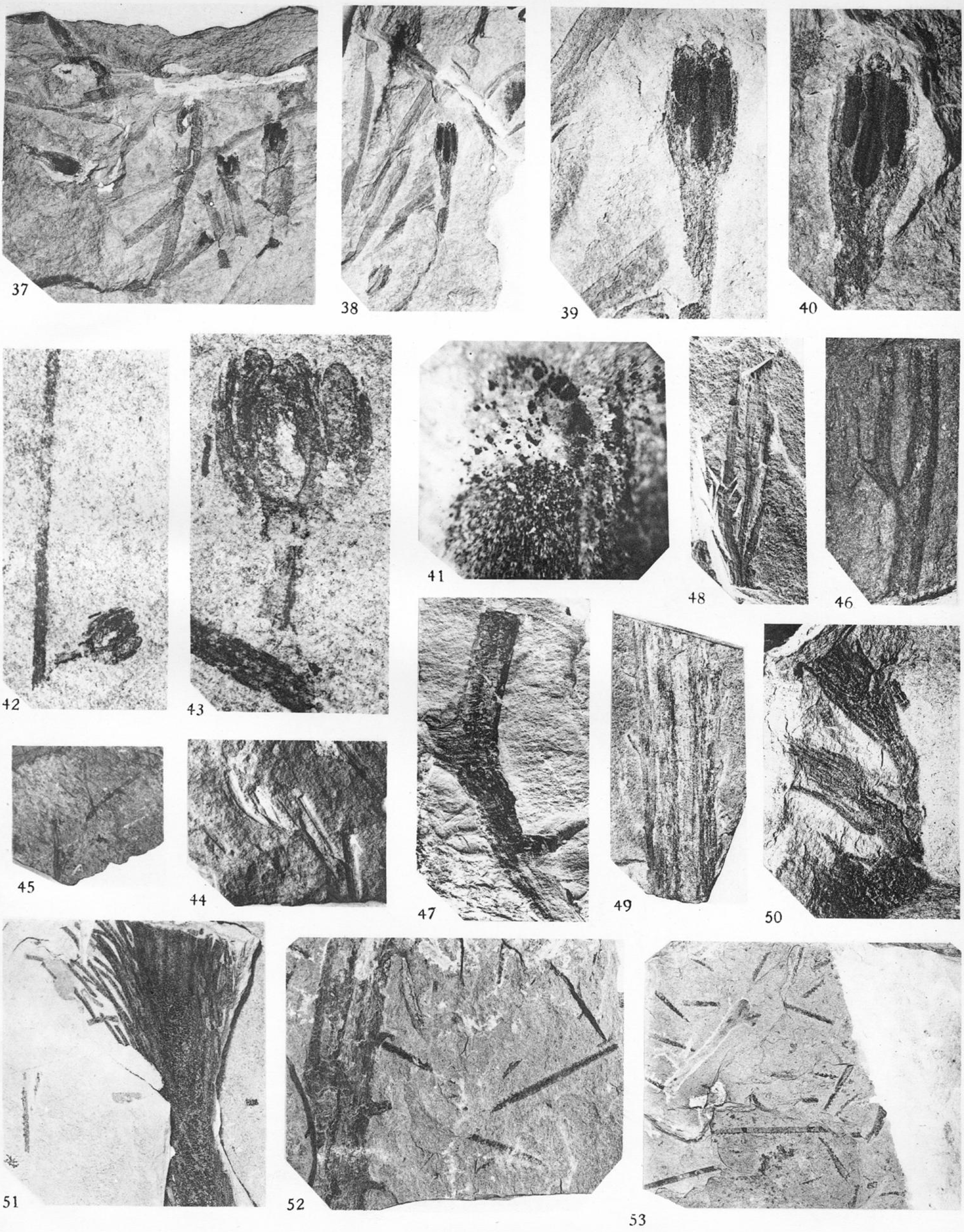

PLATE 32

FIG. 37—*Yarravia oblonga.*—Piece of mudstone from Yarra Track, showing a group of axes, several imperfect fructifications and one complete fructification. Nat. size. (Geol. Survey Vict., No. 35001.)

FIG. 38—Another surface with axes and one good terminal fructification. Nat. size. (Geol. Survey Vict., No. 35003.)

FIG. 39—The fructification in fig. 38. × 3.

FIG. 40—The complete fructification in fig. 37. × 4.

FIG. 41—Upper part of a sporangium of *Yarravia oblonga*, showing the dark mass of carbonaceous material and the terminal region in which it is not present. × 24.

FIG. 42—*Yarravia subsphærica.* The specimen on the piece of mudstone. Yarra Track. Nat. size. (Geol. Survey Vict., No. 34563.)

FIG. 43—The fructification in fig. 42. × 3.

FIG. 44—Slender branched axis, *cf. Hostimella*, sp. Thomson River. Nat. size. (Nat. Museum Melbourne, No. 12881.)

FIG. 45—Slender axis with lateral branch-system. Killingworth Road. Nat. size. (C 149.)

FIG. 46—Axis with laterally placed branch that again divides. Yarra Track. × 2. (C 138.)

FIG. 47—Dichotomous axis. Killingworth Road. Nat. size. (C 130.)

FIG. 48—Dichotomous branch-system of slender axes. Yarra Track. Nat. size. (Geol. Survey Vict., No. 28968.)

FIG. 49—*Baragwanathia longifolia.*—Piece of stem with the persistent bases of a few leaves. Thomson River. Nat. size. (Geol. Survey Vict., No. 22059.)

FIG. 50—(?) *Baragwanathia longifolia.*—Three bud-like structures, that appear to have been borne by a stem to the right. Yarra Track. × 2. (Geol. Survey Vict., No. 35009.)

FIG. 51—*Monograptus* on same piece of stone as a shoot of *Baragwanathia longifolia.* Yarra Track. Nat. size. (C 115b.)

FIG. 52—Specimens of *Monograptus* on same stone as a leafless stem of *Baragwanathia.* Alexandra, *loc.* 9. Nat. size. (C 112.)

FIG. 53—Specimens of *Monograptus*, along with a slender branched axis and a stem of *Baragwanathia* with a few remains of leaf-bases. Alexandra, *loc.* 9. Nat. size. (C 113.)