VI. *On the Structure of certain Limestone Nodules enclosed in seams of Bituminous Coal, with a Description of some Trigonocarpons contained in them.*

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THE specimens of plants which we are about to describe were found imbedded in nodules of limestone, enclosed in a thin seam of bituminous coal not above 6 inches thick, in the lower part of the Lancashire coal-field. Their relative position is best understood from the following section (in a descending order).

1. Black shales containing *Avicula papyracea*, *Goniatites Listeri*, *Orthoceras attenuatum* and other Mollusca, apparently of marine origin.
2. Bituminous coal enclosing a horizontal layer of limestone nodules containing fossil vegetable remains.
3. Fire-clay full of *Stigmaria ficoides*.

The roof of the seam is also full of fossil shells, and those in the shales lie in immediate contact with the bituminous coal.

The nodules of limestone occur at short irregular distances, and their size varies from that of a walnut to lumps weighing half a hundred weight. The smaller nodules are spherical, the larger are vertically compressed, being oval, compressed oval, cylindrical or flattened cylinders. The presence of the small nodules may be readily detected by the weight of the coal containing them, whilst the larger ones cause the coal to bulge out, both in the roof and floor of the mine. The surfaces of the nodules are extremely hard, but frequently present faint traces of lamination, or more rarely of concentric foliation.

An examination of the surface offers very little indication of the fossil contents of these nodules, except that iron pyrites is more abundant in those containing *Halonia*, *Lepidodendron* and *Stigmaria*, causing in some instances a partial decomposition of the fossils.

The origin of these nodules may probably be ascribed to the presence of mineral matter, held in solution in water and precipitated upon, or aggregated around certain centres, in the mass of vegetable matter now for the most part turned into coal. The effect of this has been to preserve certain portions of the mass from becoming bituminous and to produce their calcification. We however offer this explanation with considerable diffidence, being aware that the whole subject of the formation of nodules of one mineral in a matrix of another, is one that involves many considerations, and shall therefore confine ourselves to remarking, that the appearances are of these nodules being sealed masses of fossil vegetable remains, and as such are probably fair samples of the vegetation that has produced the surrounding coal. The immediate cause of the calcification was no doubt due to the abundance of fossil shells in the shales immediately overlying the coal and nodules.

The remains of fossil plants hitherto met with comprise the following genera, which are given in the order of relative abundance in which they occurred, viz. *Calamodendron*, *Halonia*, *Sigillaria*, *Lepidodendron*, *Stigmaria*, *Trigonocarpon*, *Anabathra*, *Lycopodites*, *Lepidostrobus*, *Medullosa*, and others that are indeterminable. An analysis of a piece of fossil-wood (*Calamodendron*) taken out of the centre of a nodule, has been made for us by Mr. HERMANN.

Carbonate of lime	76·66
Carbonate of magnesia . .	12·87
Sesquioxide of iron	4·95
Sulphate of iron	0·73
Carbonaceous matter . . .	4·95

From the above observations, it would appear, that the fossils in question are possessed of a double interest; the geologist recognises in them an association of vegetables that certainly prevailed throughout the epoch of the Coal formation, and in all probability contributed largely, if not almost exclusively, to the formation of that mineral; whilst the botanist detects in them characters of the greatest value as throwing light upon the affinities of the Flora of the period.

A section of any of these nodules shows a confused mass of decayed and apparently decaying vegetable remains; they present no appearance of these remains having been brought together by any mechanical agency; they appear to be associated together just as they fell from the plants that produced them, and to be the rotting remains of a redundant and luxuriant vegetation. Fruits of *Trigonocarpon*, entire or more or less decayed, occur abundantly, in the masses, along with the stems and roots of ferns and other cryptogamic plants and isolated masses of wood of unknown affinity. *Lepidostrobi* of various sizes, and apparently in all states of growth, are intermingled with these; but we have found no traces of coniferous wood, nor of the fronds of ferns; the absence of the latter may readily be accounted for from the fact of the nodules never cleaving so as to expose flat surfaces of any of the vegetables, and it is difficult to conceive the delicate fronds of ferns so preserved, that their structure should be recognized on a transverse section of them in a fossil state. The absence of coniferous wood is not so easily accounted for; and coupled with it we may remark, that we have not hitherto found any tissue at all resembling that which occurs occasionally abundantly in bituminous coal, and is known as mineral charcoal and mother-coal.

In none of the extensive series of sections that we have made and examined is there any appearance of that longitudinal arrangement of the mineral matter traversed by parallel canals of amber-coloured deposit that is so conspicuous in many good bituminous coals, and which has been considered by some eminent microscopical observers to be positive evidence of such coal being compressed vegetable tissue: on the contrary, the cellular and vascular tissues of our specimens, wherever they have decayed, present a homogeneous black or brown mass; and where no such decomposition has supervened, the vegetable tissues are so preserved that their real nature is evident. We are not, however, prepared to lay any particular stress upon this point, because, even if it be allowed that these nodules present a fair sample of the vegetable constituents of the coal surrounding them, it does not follow that the same assemblage of species has formed other coals; we may however remark, that with regard to some bituminous coals at any rate, we are inclined to regard the appearance of fibrous tissues as due to a molecular arrangement of the particles of that mineral, which no doubt had its origin in vegetable matter, but in which every trace of structure has been destroyed previous to, or during its mineralization.

The absence of *Calamites* (one of the most typical and universal of coal plants) is another curious fact connected with these fossils; the explanation is however very simple, for it has long been known to one of us, that some species of this genus represent the casts of the hollow or cellular axis of *Sigillaria* and *Calamodendron*, and perhaps of many other genera, as *Sternbergia* does of *Dadoxylon*; this is a subject however to which we shall recur at another time, when, having completed the analysis of the specimens of *Calamodendron* contained in these nodules, we shall hope to lay the results before the Royal Society. In the mean time we shall proceed to describe the structure of *Trigonocarpon*, the most interesting of the genera which we have named.

The usual form in which *Trigonocarpon* occurs is well known, and has been repeatedly figured. That this, however, was that of an incomplete organ has long been considered probable, and almost confirmed by the discovery of such specimens as those of *T. ovatum*, figured in LINDLEY and HUTTON's 'Fossil Flora' (tab. 142 A), and in the 'Records of the Geological Survey of the United Kingdom' (vol. i. p. 430). There have also been found in the coal shales compressed *Trigonocarpons* surrounded by a disc, as if lying in the concavity of a scale, and suggesting the possibility of these fruits having been detached from a cone similar to that of a pine. In none of the specimens preserved in the limestone nodules are any such appearances presented; and it may be assumed that the appearance in question is due to the compression of the fleshy coat of the *Trigonocarpon*. The presence of this integument and of various others was stated in a notice printed in the 'Proceedings of the Royal Society' for March 30, 1854, and was one of the first results of our examination of these fossils: the more detailed analysis and figures were, as was then stated, reserved for an after communication.

Plate IV. fig. 1 represents a very beautiful specimen of *Trigonocarpon*, exposed by breaking a nodule of limestone. It is crossed by a fissure, dividing it into portions A. and B., and to understand its structure it is necessary to refer to fig. 2, which represents the same fossil, with the portion A. removed; fig. 3 represents the under surface of A; figs. 4 and 5 are of thin slices taken off fig. 2; and finally, figs. 11 to 17 represent highly magnified figures of the minute anatomy of the organs represented above, but taken from a large selection of specimens, some of which are represented at figs. 6 to 10.

The outermost integument (Plate IV. fig. 1*a*) is entirely cellular; it encloses the whole seed, except at the perforated apex; it presents neither cuticle nor epidermis, having apparently undergone partial decomposition; and in many specimens its tissue is entirely confounded with that of the surrounding vegetable remains, so that its limits cannot be defined. At fig. 12*b* it is seen almost in contact with a fragment of *Anabathra* (fig. 12*a*). This integument is composed of large utricles, that appear hexagonal when cut across (*b* of figs. 11 to 14); the individual cells do not retain any traces of having been nucleated, nor do they present any markings on their walls; they become smaller and closer in approaching the next integument, into which this outer one seems to pass insensibly, without any interruption of continuity.

The second integument (Plate IV. fig. 1*b*) consists of a much denser tissue than the former, and forms the body of the fruit; it is frequently preserved in a fossil state, but more often the cast of its cavity alone remains: it varies from one line to a quarter of an inch in thickness, and at the rounder end of the fruit it presents an annular ridge, surrounding a cuspidate point. This ridge, it may be assumed, surrounds the base of the seed; on a vertical section it presents the appearance of shoulders on each side (Plate IV. fig. 7 & 9*a*), the intervening space being probably the surface of attachment. At the opposite or narrow end of the fruit these integuments are prolonged as a conical cylindrical or trigonous beak, traversed by a narrow canal leading to the cavity of the second coat. The termination of this beak is always decomposed, but its base appears in some cases to be surrounded by an annular ridge, seen in a longitudinal section at Plate IV. figs. 5, 9 & 10*b*: it is remarkable, however, that though this ridge is evident on the slice fig. 5, which was taken from specimen fig. 1 at a considerable distance from the axis of the fruit, no traces of it are seen at figs. 1, 2 & 4, which are from nearer the axis of the same specimen.

The structure of this part of the fruit is curious; it appears to consist of parenchyma, the cells of which radiate upwards and outwards from the inner walls of the integument: the outer layer of cells (figs. 13 & 14*c*) is much transversely elongated; in passing inwards they become shorter, irregular, tortuous and confused (fig. 13*d*); towards the inner wall (figs. 13 & 15*e*) they are very small and short, and suddenly become longer (figs. 13 & 15*f*); they form a lining of long slender tubes to the whole cavity of the fruit. Amongst these last-mentioned cells some may be found marked with annular or spiral bands. All the cellular tissue of this integument is almost filled with dark golden-brown or blackish contents, and it is the presence of these contents that defines this integument from that surrounding it. The real nature of these cell-contents can only be conjectured; they may be the coloured inner walls of the cells, or a deposit of chlorophyle or resin in a peculiar condition: the appearance is exactly that presented by the cellular tissue of *Salisburia* and *Phyllocladus* fruits, where the rich brown colour is probably due to a deposit of resin.

Within these integuments is a large oval cavity, full of carbonate of lime and magnesia, of a yellowish white colour, and very compact. When the fossil is fractured, this mineral presents a cast of the surface of the cavity (as represented at Plate IV. fig. 1), and, when sliced, exposes a delicate membrane or sometimes two concentric ones, as represented in most of the specimens figured. These membranes have always more or less collapsed, and apparently are broken up into layers (Plate IV. figs. 7 & 8). These appearances of a double or treble membrane are probably due to the breaking up of one, or to the decomposition of the walls of the cavity; for all are uniform in structure, and shreds of cellular tissue and scalariform vessels are often found uniting them, and they are further identical in structure with the walls of the cavity. A very highly magnified view of a portion, taken from the section figured fig. 7*e*, is given at fig. 15, where the arrow indicates the position of the vascular bundles, which are more highly magnified at fig. 16. At fig. 15 the section of this membrane is seen bent at an angle on the right-hand side, and traversing the transparent carbonate of lime; to the left of it is a broad fissure in the mineral, and to the extreme left of the circle at *f* are the tissues of the inner wall of the second integument of the fruit. At fig. 17 is seen another section of the same membrane, formed of cylindrical utricles, with no traces of vascular tissue.

We have been thus particular in describing these structures, because we find them to be uniform throughout the very numerous suites of sliced specimens which we have examined: it is scarcely necessary to add, that though they exhaust our materials, they leave much to be desired in our knowledge of the fossil to which they belong. Nothing, however, has occurred during our study of them, to warrant our expecting to find any further structure in the cavity of the seeds taken from the limestone nodules.

Although no positive proof of the real nature and affinities of *Trigonocarpon* can be offered until the discovery of embryos or spores within the cavity of the fruit, there are so many important points now shown to exist in their structure, as to warrant more exact comparisons than have ever yet been instituted. We have already mentioned *Salisburia* as the nearest existing analogue known to us, and shall accordingly proceed to discuss it.

Salisburia is a drupe-bearing coniferous tree, a native of China and Japan, long cultivated in Europe, but only producing fruit in the middle and southern regions of this continent; these are oblong, about the size and colour of a damson plum, and are produced on the terminal branches of the tree, from which they are easily detached when ripe. The drupe consists of three integuments, which are the metamorphosed coverings of a naked ovule. The external integument is thick and fleshy as in *Trigonocarpon*, is covered with a delicate cuticle (Plate V. fig. 6), and is formed of membranous utricles; the outer layers of these cells are empty, but the inner, which gradually become longer, are filled with a viscid resinous fluid. Towards the inner surface of this integument the cells are much elongated, and become mixed with scalariform and annulate and subspiral vessels and long empty cells (fig. 8 *a* and fig. 9); within this is a thin crustaceous integument, formed of densely packed, vertically elongated sclerogen cells (figs. 10, 11), and this again is lined by a delicate coat of annulated cells similar to those outside it (fig. 15): all these integuments are perforated in a young state for the impregnation of the ovule, and this is the only explanation or analogue which we can offer of the canal leading down to the cavity of the *Trigonocarpon.* An extremely delicate membrane (fig. 16) surrounds the albumen of *Salisburia*, and the latter is formed of a densely packed mass of cells (fig. 17) enclosing minute starch granules* (fig. 18).

The absence of any crustaceous integument exactly similar to *Salisburia* is to be remarked in *Trigonocarpon*; but these organs are so extensively modified in the allies of *Salisburia,* that the suppression of one in *Trigonocarpon,* or its representation by the middle coat (which certainly appears to have been much indurated), is a consideration of comparatively little moment, whilst the resemblance between the structures which we have described in the two genera is very remarkable.

The supposed alliance of *Trigonocarpon* with *Coniferæ* does not, however, rest on the above comparison alone, but to a certain extent upon collateral evidence: thus, the presence of wood, closely resembling what is supposed to be typical of *Coniferæ*, is abundant in the carboniferous formation; while the absence of cones and of foliage similar to that of those *Coniferæ* of the present day, whose seeds are similarly arranged, renders it probable that the drupe-bearing division of the Order, which is now chiefly prevalent in the Southern hemisphere, predominated in the carboniferous æra. The remarkable fact too, of the resemblance of *Noggerathia* leaves (a carboniferous genus) to that of *Salisburia,* was long ago indicated by Lindley and Hutton; and though adduced by Brongniart in favour of *Trigonocarpon* (which is sometimes found associated with these leaves) being allied to *Cycadeæ*, accords better with the assumption of both being coniferous.

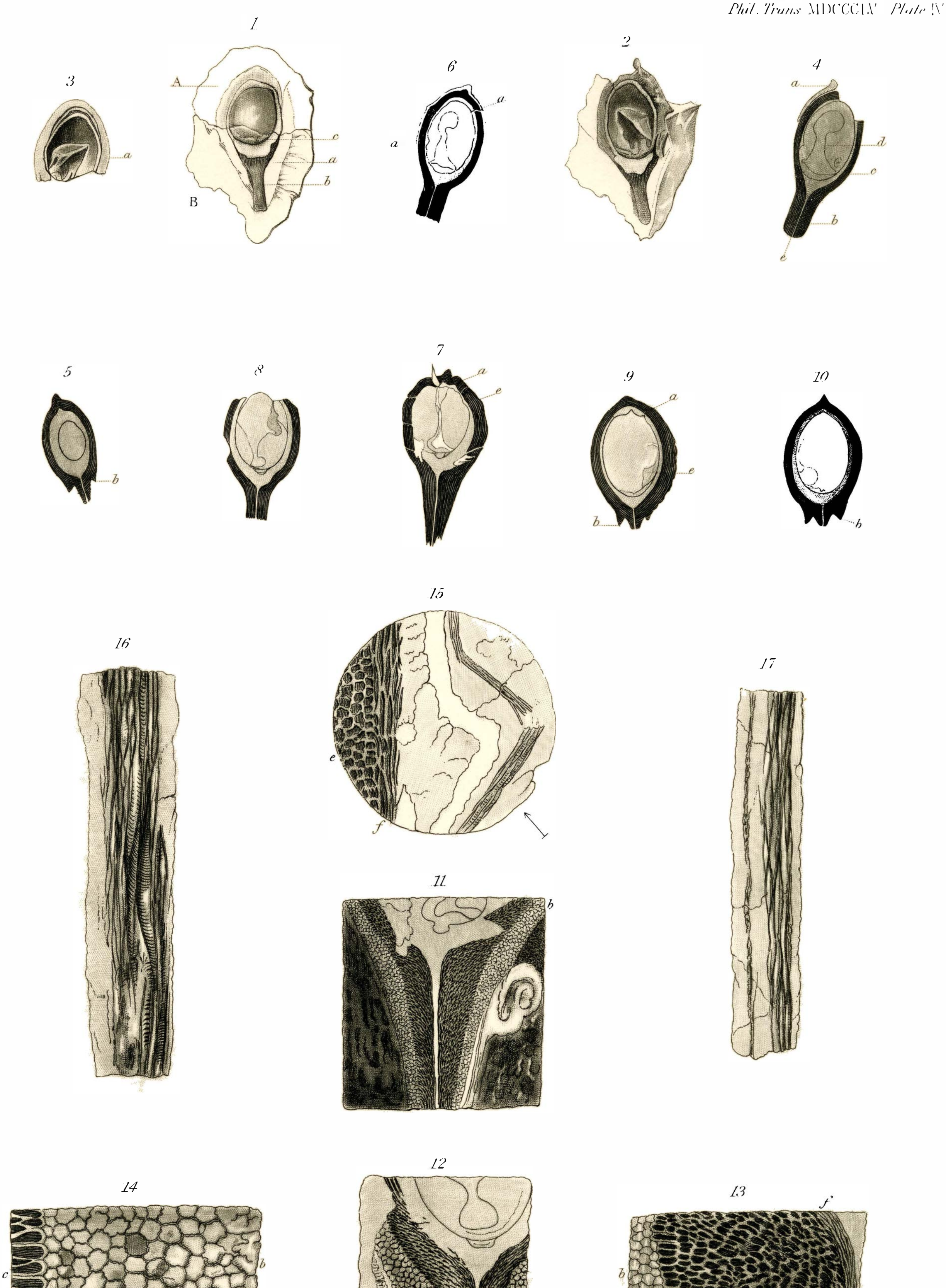
The association of *Trigonocarpon*, in the nodules we have examined, unfortunately offers no clue to their affinities, as we find neither cycadeous nor coniferous wood along with them; while of plants belonging to or allied to Filices and Lycopodiaceæ we find abundant remains in close proximity with the *Trigonocarpons,* but in the latter there are no traces of the tissues so prevalent in these plants. It is further to be remarked, in connection with these plants, that *Salisburia* fruit not only presents no trace of coniferous tissues, but abounds in scalariform annular and subspiral vessels, which are supposed to be very rare in the order to which it belongs.

* These analyses are added in the hope that they may aid others in the investigation of this interesting subject, should any one be so fortunate as to detect any contents within the cavity of *Trigonocarpon.* We have also at fig. 12 figured some loose sclerogen cells that are found occasionally on the inner wall of the crustaceous integument, and at figs. 13 and 14 some modifications of the cellular tissue in the inner coat.

The abundance of these *Trigonocarpons* in the nodules, and the fact of their lying at all angles and in all positions, suggests the probability of their having fallen from a height into a soft or spongy mass of decaying vegetable matter; and it may be noticed, that the very similar fruits of *Podocarpus ferruginea*, a New Zealand drupe-bearing Conifer, are in like manner shed in profusion from the lofty trees that produce them, and become imbedded in the swamps out of which the trees grow; and that the latter are often covered with Ferns and Lycopodia in great profusion, the decay of all which produces a spongy bog, in consistence not unlike that of the mass in which the *Trigonocarpons* are imbedded. Such comparisons cannot, however, be carried far; for whereas these New Zealand bogs, and the clay upon which they almost invariably rest, are everywhere traversed by woody roots of coniferous trees, we find in the substance of the limestone nodules and in the underclay of the coal no trace of these, but in the latter *Sigillaria* roots abundantly (viz. *Stigmaria ficoides*). In our present state of knowledge (or rather ignorance) of the physiognomy, as well as of the botanical characters of the vegetation of the coal epoch, all references of detached organs are extremely rash, and in the present case we cannot venture beyond alluding to the facts, that the flower and fruit of *Sigillaria* are totally unknown, and that these and *Trigonocarpon* fruit and *Noggerathia* leaves are very abundant throughout the coal formation. There is another curious point, to which also we can only incidentally allude, which is, that *Salisburia* has several embryos in each seed, which in germinating become as many young plants: these often coalesce at a very early period, and the result is a compound tree, with one main axis, but as many primary roots as there were embryos: though offering no explanation of the phenomenon, it may be mentioned as a curious circumstance, that the base of every *Sigillaria* trunk is marked by a cruciform ridge, separating the four primary divisions of the root, of which ridge no explanation has ever been offered.

With regard to the evidence of *Coniferæ* having existed during the carboniferous period, we are far from considering that afforded by the wood abounding in discs as conclusive, however much these resemble the discs of *Araucaria*: it is now well known that very similar discs abound in the wood of many Natural Orders that have no alliance with *Coniferæ*; but it is not hitherto known that there is a coniferous tree, in which the discs are not present in all parts of the wood, but are totally absent from one-half of each annual wood deposit. This tree, probably a drifted one, was discovered on the shores of Wellington Channel by Sir Edward Belcher, and it renders it not impossible that coniferous wood may be found in which these discs are totally absent. It is now, however, universally admitted by those botanists who have made both the anatomical structure and affinities of plants their study, that the structure of the axis of Exogens affords no guide to their affinity; *Coniferæ* have been supposed to form the best marked exception to this rule, and there is no doubt that they do so; but the coniferous woods of the coal epoch present so many remarkable deviations from those existing at the present time, that it becomes dangerous to speculate upon them.

On Plate V. are four highly magnified views of the tissues in the limestone matrix surrounding the *Trigonocarpons*: these appear to belong to very different groups of vegetables, and being a very small proportion of the variety that does exist, lead to the conclusion that the flora of the period was a varied and profuse one. We have few remarks to offer upon them. Fig. 1 represents a tissue resembling that of *Dadoxylon*. Fig. 2 probably belongs to a plant allied to the Ferns. Fig. 3, apparently an exogenous wood, crossed by medullary rays. Fig. 4 is also a Fern.



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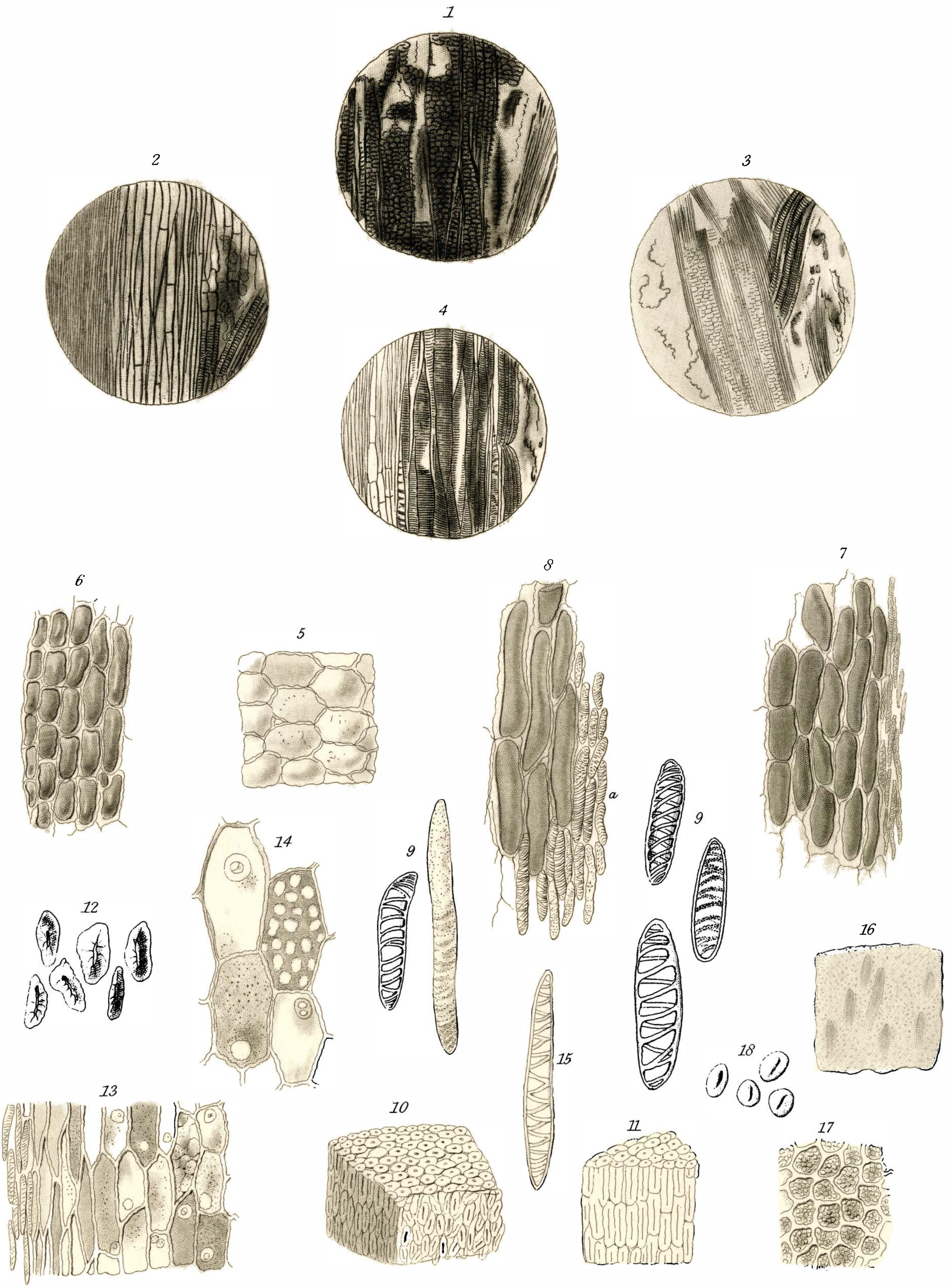
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