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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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FOSSILS OF THE CARBONIFEROUS COAL OF THE GLACIAL DRIFT AT ANN ARBOR*

HARRIS BARTLETT

THE campus of the University of Michigan is situated on an outwash apron that borders the outer ridge of the Defiance moraine of the Erie-Huron ice lobe. According to Leverett[1] this apron was probably laid down in a lake that bordered the ice lobe from the site of Ann Arbor southwestward to Raisin River in Bridgewater Township. The elevation of the surface of the lake may have been a little below 875 feet. It was determined by the altitude of the nearest available outlet, near Tecumseh. Back of the outwash basin is a depression or fosse containing several basins, one of which is the “cat hole” just north of the College of Dentistry. This fosse marks the position of the ice border while the lake at the front of the ice was being filled in to a depth of about forty feet to form the outwash plain. The campus is near the edge of the outwash, Angell Hall and the new Physical Laboratory being less than a quarter of a mile from the “cat hole.”

The structure of the outwash plain was well shown in the excavations for the two new buildings just mentioned. The coarsest and least assorted bed, containing all grades of material from large boulders to clay, was at the top. It was about six feet deep. Underneath it were cross-bedded deposits of fine, washed gravels and sands, in which the material was well sorted, and varied from the finest whitish sand to gravel in which the larger pebbles of crystalline rocks might average half a centimeter to several centimeters in diameter. The lower beds, of washed and sorted material, were sharply set off from the brownish or yellow mixed stratum above them. (See Plate III.)

In the lower beds, conspicuous because of both their size and color, were the coal pebbles which form the subject of this paper. They were first found in the excavation for Angell Hall, and were then looked for and found in abundance at the site of the new Physical Laboratory and in a deep excavation for a heat conduit east of the College of Dentistry.

They were so soft that they were at first thought to be lignite or compact peat, quite like the Lignit-Gerölle of the German Diluvium, figured by Potonié.[2] Some of the first ones collected could readily be moulded into a plastic mass between the fingers, and the writer's first supposition that they were peat, consolidated by pressure and then water worn, was picked up by reporters and published in the daily press. Mr. Leverett's uncanny sagacity in all matters pertaining to .the glacial deposits led him to view them as Carboniferous coal from the start, and his diagnosis was shortly confirmed by botanical study, with the use of the maceration method.

The writer has lately had occasion to search through the old accession books of the Museum of the University of Michigan, and was interested to find that coal pebbles from the drift at Ann Arbor were known to Professor Winchell over fifty years ago. Among others were "four specimens of coal obtained from a cistern dug at the corner of the University Campus, and presented by Dr. E. W. Hilgard," May 16, 1874 (accession 579), and "a specimen of coal pebbles obtained from a cistern dug at northwest corner of the University Campus, and presented by Eugene G. M. Hilgard" (accession 581).

That the coal pebbles are more widely distributed has been shown by Professor W. H. Hobbs, who has recently found them in a gravel pit near Huron Hills, two miles west of Ann Arbor. Material from this locality has not yet been examined, but is doubtless similar to that from the University Campus.

Since the ice planed off the exposed deposits of the Carboniferous throughout the entire Michigan coal field it is of course not at all surprising that coal fragments are found in the drift. It has seemed difficult of explanation to the writer, however, that so much coal should occur east of the supposed easternmost limit of the coal basin, in view of the fact that the material of the drift is considered to have come from the eastward. The literature seems to throw no light upon the precise origin of any of the coal of the drift. Without citing localities, Lane[3] says (p. 8): “The fragments of coal often found in the gravel and till . . . are especially common in Michigan, in the sands and gravels. . . .” Botanical analysis of the coal pebbles of the drift, and a systematic examination of the various beds of Michigan coal to determine the origin of the pebbles, might give data of value in the interpretation of glacial features.

The coal pebbles examined varied in size from a pea to a hen’s egg, and were generally flattened, since erosion had taken place much more rapidly in the plane of the bedding than across the bedding. Their occurrence with much finer materials is explained by their low specific gravity, which enabled them to be carried by weak currents into deep water, where they were deposited with the sands and fine gravels. In appearance (see Plate VI) they closely resembled the Lignit-Gerölle figured by Potonié[2] from the German Diluvium. Some were so soft that they could be crushed into a peat-like mass between the fingers. Others were firmer, but could be cut with a knife like fresh lignite. They split readily into thin flat layers in the bedding planes, especially when beginning to dry. Shrinkage was great during drying, and the material fell into small fragments, which broke across with the lustrous fracture of jet. The color of a cut surface of the fresh material was dull brown or black, not lustrous. The pebbles could be preserved only in a moist condition. They appear to keep indefinitely if immersed in water. If buried in moist sand and allowed to dry very slowly, they undergo a disintegration resembling the air-slaking of lime, and are reduced to an impalpable black powder.

The moisture content of the pebbles was determined in four small pebbles, and in one composite sample consisting of pieces of five pebbles. The results showed 48.5 per cent water in a soft pebble; 36.1 per cent, 36.6 per cent, and 37.9 per cent water in three firm pebbles; 37.6 per cent water in the composite sample. Moore[4] gives the water content of lignite from various parts of the world as 0.75 to 43.0 per cent, (average 14.4 per cent); of sub-bituminous coals from the United States as 1.9 to 40.6 per cent; of bituminous coals from various countries as 0.04 to 34.3 per cent (average 2.5 per cent); of bituminous coals from the United States as 2.0 to 10.0 per cent. It is obvious from these figures that the drift coal contains too much water to be classified as typical bituminous coal. It seems to conform better with the lignites, but even in this category it would be looked upon as a relatively unconsolidated member of the group. One must of course take into consideration the possibility that the long weathering to which the drift lignites have been subjected may have altered them. Centuries of soaking under relatively slight pressure might possibly produce in a soft coal the same degree of softening and swelling that may be attained in a few days by appropriate treatment with alkaline solutions, as, for example, in the procedure used by Jeffrey[5] in the preparation of coals for microtome sectioning. It seems most likely, however, that the coal of the drift is a true lignite from some of the soft, upper strata of the Carboniferous.

Moore[6] states that there are many examples on record of seams of Carboniferous coal that are still in the lignitic condition. He cites particularly the occurrence in Western Australia of a small area in the Permo-Carboniferous coal measures which was preserved from intense pressure by faulting, and has remained brown coal, although all other Australian coal of the same age is bituminous or anthracite. With regard to the Michigan coals, which are all Carboniferous, Smith[7] says: "According to analyses, the Verne coals appear to be related to the lignite coals. Probably they were never subjected to deep burial, so still resemble the woody end of the coal family." The full series of coal seams in the Michigan field, as recognized by Smith, following Lane,[8] is as follows in order from below upward: Bangor Coal, Bangor Rider, Lower Coal, Lower Rider, Saginaw Coal, Middle Rider, Lower Verne Coal, Lower Verne Rider, Upper Verne Coal, Upper Rider, Salzburg Coal, Salzburg (?) Rider, Unionville Coal (?), Reese Coal (?). Of the higher coals he says: “The Salzburg Coal and its rider are very often removed by erosion. It is only locally that the bed-rock surface is high enough to contain these horizons. . . . The Reese and Unionville coal seams are little represented in drillings. Lying so high in the coal measures, erosion would have removed them in large part if they really ever existed.”

No precise correlation of the Michigan coals with those of other regions has been made. David White (quoted by Lane[8]) examined the scanty available plant fossils from the Michigan coal measures and reported that they indicated a very low place in the coal measures. He wrote: "From the characters of the little flora I conclude that it can hardly be later than the Lower Kanawha in West Virginia, of the Brookville coal in Ohio and Pennsylvania. In fact, notwithstanding the small number of species, I am disposed to regard the plants from the Standard Mine (Saginaw) as Pre-Allegheny, or at least older than the Brookville coal. On the other hand, they are not older than the Sharon coal. . . . Although the material is very fragmentary and the species are few, they indicate for the coals, at whose horizons they occur, a very low place in the coal measures; probably in the Sharon or Mercer groups for the nodules, while the Standard fossils seem to belong below the Homewood sandstone."

The precise origin of the coal pebbles of the drift at Ann Arbor must remain for the present an unsolved problem. The present edge of the Michigan coal basin is roughly fifteen or twenty miles to the westward of Ann Arbor, and the material composing the drift supposedly came from the eastward. If the coal pebbles were derived not from consolidated bituminous coal, but from the upper, lignitic deposits of the Carboniferous, it is unlikely that the material could have been transported far. It may have come, prior to the last glaciation, from west of Ann Arbor, in which case it is present in the deposits of the last glacial period as reworked material, or it may have been derived from an outlying lobe or isolated basin of superficial Carboniferous strata nearer Ann Arbor, perhaps entirely demolished by glacial erosion, and now represented only by pebbles in the drift.

The fossils recovered from the pebbles threw no light upon the matter of origin, for our knowledge of the characteristic floras of different coals is still too slight to enable a coal to be identified by the plant remains in it. As a result of the admirable researches of Jeffrey,[9] White and Thiessen,[10] Thiessen,[11] and Thiessen and Voorhees,[12] progress has recently been made in the study of coal which may result, before many years, in paleobotanical criteria for determining the age of such samples as these drift pebbles. Until the plant constituents of the various Michigan coal seams are examined, further speculation as to the origin of the drift coal can hardly prove profitable.

THE MACERATION OF COAL

A scientifically conducted coal maceration is entirely comparable in principle with the determination of humus in soil. That portion of humus which is combined with calcium, magnesium, and similar elements is not directly soluble in sodium or ammonium hydroxide. The complex organic acids must first be liberated by treating the soil with acid. Then a dilute alkaline hydroxide will dissolve out the humus, leaving in the soil undecomposed fragments of plants that are quite comparable with the structural fragments left after a coal maceration.

On account of the remarkable softness of the drift coal, it was readily disintegrated, by the maceration method, for botanical examination. Some of the pebbles consisted practically entirely of cuticles of leaves. Such pebbles yielded relatively little soluble material when macerated, but preserved their shape and became flexible so that they could be bent double. After becoming flexible they could be shaken with water and a vast number of cuticles isolated. The cuticles from such pebbles, however, were far less well preserved than occasional cuticles of similar nature found in pebbles of more mixed composition. The pure leaf coals were apparently laid down under such conditions that decomposition had left little of the leaf but the cuticle by the time that deep enough burial took place to halt decay. The pure leaf coal appears to have been laid down on the very surface of the swamp where aërobic decomposition was active. Subsequently burial took place and decomposition was retarded. Finely laminated leaf coals are of course well known, and are referred to in the standard works on coal. (From a botanical standpoint they were studied by Reinsch, who did much of his work on the Blätterkohle of Central Russia.)

Other pebbles contained more structureless matrix derived from wood, leaf parenchyma, etc., and these gave better fossils. Successive treatment with dilute acid and alkali resulted in the complete solution and removal of the structureless material, leaving a residue of spores, cuticles, a few carbonized particles showing woody structure, and vestiges of siliceous structures interpreted as of Calamite origin. The spores included both microspores and megaspores of Pteridophyta and less distinctive types that might pass for pollen grains. The cuticles were in part of Lepidodendron, and in part unidentified as to origin. The aspect of the material was typically Carboniferous.

Actual charcoal, the so-called mother of coal, hardly occurred at all in most of the pebbles. A few fragments were found which give very strongly the appearance of having been charred before deposition in the swamp floor where the original Carboniferous peat was deposited. It is the writer's very decided opinion that all true charcoal which can be isolated from bituminous coal resulted from forest fires contemporary with the deposition of the beds. Some of the pebbles contained material that was obviously derived from wood, but it dissolved out completely during the maceration of the material. Portions of the coal derived from wood had undergone very great compression. Fragments of charcoal, on the contrary, were of course totally insoluble, and relatively little compressed or distorted by pressure in comparison with the coal derived from wood. Some coals, as, for example, the coal mined at Midland, Michigan, contain a very large component of actual charcoal, almost pure carbon, which can be isolated in fragments and fairly large chunks by dissolving away the other constituents of the coal. Except for charcoal from fires, peat contains no elemental carbon in any form, but only organic compounds that can be dissolved without very drastic chemical treatment. Exactly the same is true of the lignitic coal composing these pebbles in the drift. They consisted almost entirely of material that was soluble in alkali after removal of the ash constituents by acid. The more highly decomposed and structureless portion of soft coal is a mixture of calcium, magnesium, and iron salts of organic acids. These salts are not soluble in water. If they are decomposed by leaching with dilute acid, the acids alone are left, themselves insoluble in water and therefore retaining the structure of untreated coal. The salts of sodium, potassium, and ammonium are soluble in water, and the acid-treated coal therefore dissolves readily in a weak alkaline solution. The portion not dissolved consists (1) of mineral inclusions, such as sand, (2) charcoal, and (3) organic structures which have not been greatly modified, chemically, during the process of coal formation, such as certain spore exines and cuticles.

If we find fragments of charcoal in soil we may be very sure that charring took place by fire or heat, and not by any slow process of decomposition in the soil. We may be equally sure that fragments of charcoal, little consolidated and with well-preserved structure, if found in coal, were likewise originally deposited as charcoal, and not as wood. In holding this view the writer is heartily in accord with Jeffrey, who, commenting upon a Cretaceous coal with wood structure preserved, says: "In all such cases the wood was partially or completely transformed into charcoal before it was incorporated into the accumulation, later transformed into coal. Carbonized wood is in fact the only material derived from the grosser parts of plant bodies which retains its structure in coal. It is generally designated mineral charcoal or mother of coal, and may be present in all categories of coal, from cannels to anthracites." Thiessen has been broader in his definition of mother of coal, including material derived from highly resinous woods which have disintegrated completely, as far as the carbohydrate constituents are concerned, but have left a vestige of structure represented in the undecomposed resin content of the wood.

THE MEGASPORES REFERRED TO TRILETES

Without including dubious specimens which might have been too badly decomposed before burial to display true specific distinctions, the material included three elaborately appendaged types of megaspores which are here described under the convenient inclusive name Triletes. (See the following article, entitled "The Genus Triletes, Reinsch.") These spores probably belong to Lepidodendreae.

Triletes superbus, sp. nov. Body of exine rounded-subtri-angular, 1.7 to 2.3 mm. in diameter, the mean being near 2.25 mm.; triradiate clefts extending over half the distance to the periphery; body invested with an indument of cylindriform processes 0.04 to 0.07 mm. long and roughly 0.015 mm. in diameter, blunt or rounded at the apex; equatorial wing often more than 0.8 mm. broad on the radii of the triradiate fissures, and about 0.6 mm. in between, making the total diameter of the spore 3.1 to 3.7 mm.; inner portion or sometimes the whole width of the wing radiately convolute, or the outer portion consisting of more or less completely anastomosed rami extending outward from the convolutions; periphery of wing discontinuous or continuous by the anastomosis of terminal ramuli.—Ann Arbor, Michigan; drift coal. Plates VII and VIII. This spore type was recovered more frequently than any other. When in the finest state of preservation it is indeed a remarkable structure to isolate from coal. Some of the specimens suffered from decay before they were deeply enough buried for perfect preservation, and it is therefore necessary to have considerable material in order to find the short club-like processes with which the body of the spore is invested, and which are quite as interesting and characteristic as the more conspicuous broad equatorial flange. As the specimens are isolated from the coal there is so great a contrast between the very dark mass of the central body and the thin appendage that it was difficult to get photographs showing proper detail in both parts. In Plate VII, Figure 1, the appendage is brought out at the expense of the central body. In Plate VIII, Figure 1, the short cylindriform processes of the body may be made out, but the negative is greatly overexposed for the wing-like appendage, which is nearly lost in the print. The wing was probably an organ which insured the dispersal of the megaspores by wind, doubtless after the triradiate fissures had opened and fertilization had taken place. The Ann Arbor drift coal contains a microspore of similar structure which one is to associate with *Triletes superbus*. The latter is so it is unsurpassed in size and beauty of form among all the that have been described from coal.

Triletes rotatus, sp. nov. Body of exine practically round, from 0.70 to 0.75 mm. in diameter; triradiate clefts reaching two thirds of the distance to the equatorial appendage; appendage consisting of about fifty long slender sinuate widely branched toward the apex and fusing into a marginal rim, the whole spore with the equatorial appendage resembling a wheel with hub, spokes and rim; or processes of the appendage cfenate at apex, either anastomosing or not; average greatest diameter of spore with equatorial appendage 1.7 mm. — Ann Arbor, Michigan; drift coal. Plates IX-XII. A rare and very beautiful type, perhaps actually not as rare as seldom isolated in good condition. A considerable number of spore bodies were recovered which were of the right size to be *T. rotatus*, but lacked the equatorial appendage.

Triletes mamillarius, sp. nov. Roughly globose, with a tendency to be irregular, but not angular; greatest dimension varying from 1.4 to 2.1 mm., mean about 1.5 mm.; equatorial appendage none; triradiate clefts with somewhat thickened margins, short, extending a third to a half of the distance to the periphery; exine covered with mamilliform papillae, the latter hemispheric or taller than broad with the narrowed apical portion generally laterally deflected. — Ann Arbor, Michigan; drift coal. Plates XIII-XVI. Intermediate in abundance between the frequent *T. superbus* and the rare *T. rotatus*. *T. mamillarius* is an extremely characteristic type, and one that would appear from Reinsch's figures to have close relatives in European coals. The supposed genus of parasites named Rhizostaemis by Reinsch (*Micropaleophytologia*, Vol. 2, p. 15) seems to have been based upon just such tubercles as those which invest the exine of *Triletes mamillarius*.

CUTICLES OF LEPIDODENDRON

Hardly less interesting than the spores are the cuticles found in the drift coal, since they give an opportunity to study some details of the superficial anatomy of Lepidodendron that appear not to have been described. The material doubtless includes a number of species. About the coarser kinds, which could not, of course, be adequately represented in a small pebble, it is impossible to say much until additional supplies of coal come to hand. Several smaller sorts, however, are fairly well represented by specimens from the pebbles.

When broken-off branches of Lepidodendron were buried in swamp deposits, the entire structure was transformed into humus except the interareolar cuticle, often very narrow. The stems were pressed practically flat, consequently when a perfect cuticle is recovered from coal by maceration it may be opened out into a tubular net. The open center of the areoles represents the absciss layer of the leaf scar, and the net-work the original cuticle of the stem. Nothing whatever remains of the fibrovascular tissues or the cortex. The interesting specimens represent the few, relatively speaking, which were buried before the stems were subjected to subaerial decay.

Such cuticles are thickest at the center of the ridge between areoles, and are there generally very dark and well preserved. Toward the leaf scar (represented by the opening of the areole) they become thinner, and if well preserved show clearly that the areolar region contained many specialized inflated cells which stood like little domes above the general surface. The function of these, apparently, was to rupture and produce openings into the subepidermal intercellular spaces. The specialized cells frequently had one or more peculiar cuticular outgrowths (of a dark brown color in the recovered cuticles), which for want of a better name may be called cuticular crests. Such a crest may be likened in shape and attachment to a low dorsal fin of a fish, or the keel of a boat. It is an erect plate, not always straight, several times longer than high, adnate by one of its edges, often longitudinally fimbriate or ctenate at the ends, but showing no cellular structure, however large it may be, and therefore apparently a purely cuticular structure. In size it may be so small that several crests occur on a single cell as in the case of the areolar dome cells, or thirty times as long as a single cell. The small ones are so low and rigid that they are seldom seen forced over onto their sides, and without comparison with larger ones would not be recognized for what they are, since they appear on cursory examination as thickenings or wrinkles of cuticle. In general the largest crests, those which are large enough to have been pushed over onto their sides, are found on the thickest cuticle, near the ridge between areoles.

The plates of Lepidodendron cuticles are chosen to illustrate the structural details mentioned, without, for the present, attempting to differentiate the several species, of which there appear to be at least five in the material.

MICROSPORANGIA OF PROBABLE AFFINITY TO LEPIDODENDRON

Many macerations yield very delicate cuticles representing the remains of branches about a millimeter or two in diameter with regularly arranged areoles which resemble those of Lepidodendron, but are more frequently heart-shaped and more distant from one another than in vegetative Lepidodendron.

They do not show any trace of silicification of the cuticle and are, therefore, more like Lepidodendron than Calamites. The state of preservation of the specimens in hand is not altogether satisfactory, but there is no remaining evidence that the areoles represent leaf scars. On the contrary, every specimen contains, tightly adhering to the inner surface of the cuticle, numerous microspores, varying from rounded to subtriangular in outline, with a hyaline margin and darker center. The spores cannot be made out with certainty to have triradiate dehiscence. Similar spores in lenticular masses are found in the coal, each mass representing the content of a whole microsporangium, but too large to belong to the very delicate sporangial branches under consideration, and not yet found associated with any remains of the sporangia by which they were produced. They may represent micro-sporangia of coarser species than those yielding the delicate fossils under consideration. Although the heart-shaped or oval areolar openings of the slender branches are probably the same as the areoles of the stem of Lepidodendron, namely, leaf scars, the invariable occurrence of microspores in the structure leads to the belief that they also represent openings into cavities in which microsporangia were produced. The areole of Lepidodendron represents more than a leaf scar, of course. The writer suggests that at fertile tips of branches the ligular cavity may in some types of Lepidodendron contain the microsporangium. Although the fossils are distinctly problematic, it seems not unlikely that some of the delicate species of Lepidodendron bore microsporangial branches on which the foliar structures were either much reduced or else quickly caducous, and in which the ligular cavities contained microsporangia. The fact that other types of micro-sporangia are known for Lepidodendron probably merely demonstrates the heterogeneity of the group. It is greatly hoped that more and better material of these problematic structures may come to light. The writer's suggestion, of course, emphasizes the affinity of Lepidodendron with Isoetes.

MISCELLANEOUS FOSSILS

Numerous fairly well-preserved cuticles have been isolated which are too miscellaneous and uncertain in affinity to make it worth while to discuss them yet. Numerous microscopic pellicles of silica, in shapes suggesting rhizopod shells, are now considered to be the siliceous remains of specialized epidermal cells of Calamites. There are likewise structures with most interesting perforations which are possibly of animal origin. The consideration of much material which now seems hopelessly miscellaneous must be deferred until further accumulations shall have thrown more light upon it.

SUMMARY

The water-worn coal pebbles from the glacial deposits at Ann Arbor, although resembling lignite in softness and high water content, are actually Carboniferous. The coal is almost certainly of local origin. Too soft to have been transported far, it is nevertheless found to the eastward of the supposed edge of the Michigan coal basin.

On account of its extremely soft lignitic nature the drift coal was easily macerated, and yielded three characteristic and beautifully preserved megaspore exines (probably belonging to Lepidodentron), which are described as *Triletes superbus*, *T. rotatus*, and *T. mamillarius*.

Other fossils include perhaps five species of Lepidodendron, represented by cuticles. These have the surface features in excellent preservation, and show that the epidermis of Lepidodendron had curious cuticular crests which are characteristic and will furnish diagnostic points in discriminating the species. The areolar cuticle shows that there were in this region specialized cells which probably broke down and made openings from the outside to the cortical intercellular air spaces.

Delicate cuticles of branches with areoles arranged as in Lepidodendron may represent fertile microsporangial branch tips of Lepidodendron. They contain numerous microspores, which could not easily have got within the cuticle unless the microsporangia were produced in ligular cavities.

Other fossils of obscure affinity include numerous miscellaneous objects, such as siliceous structures that may represent specialized epidermal cells of Calamites.

UNIVERSITY OF MICHIGAN

* Paper from the Department of Botany of the University of Michigan, No. 252. (Read at the 28th Annual Meeting of the Academy, in 1923.)

[1] Russell, I. C., and Leverett, Frank. *Description of the Ann Arbor Quadrangle.* Geol. Atlas U. S., Folio (reprint) No. 155. 1915. (Glacial geology by Leverett.)

[2] Potonié, Henry, *Die Entstehung der Steinkohle und der Kaustobiolithe überhaupt*. 6 Aufl., Berlin, 1920. (See Fig. 49, p. 141.)

[3] Lane, A. C., *Coal of Michigan, Its Mode of Occurrence and Quality*. Geol. Surv. Mich., Vol. VIII, Part II. Lansing, 1902.

[4] Moore, Elwood S., *Coal, Its Properties, Analysis, Classification, Geology, Extraction, Uses, and Distribution*. New York, 1922. (See pp. 84-89.)

[5] Jeffrey, E. C., "The Nature of Some Supposed Algal Coals." *Proc. Amer. Acad. Arts and Sci*., 46 :273-290. 1910.

[6] Moore, Elwood S., *op. cit*., p. 163.

[7] Smith, R. A., "Michigan Coal." Mich. Geol. and Biol. Survey, Publication 8 ; 257-303. Lansing, 1912. (See pp. 264-266 and 278.)

[8] Lane, A. C., *op. cit*.

[9] Jeffrey, Edward C., "On the Composition and Qualities of Coal." *Economic Geology*, 9 :730-742. 1914.

[10] White, David, and Thiessen, Reinhardt, *The Origin of Coal*. U. S. Bureau of Mines, Bull. 38. Washington, 1913.

[11] Thiessen, Reinhardt, *Structure in Paleozoic Bituminous Coals*. U. S. Bureau of Mines, Bull. 117. Washington, 1920.

[12] Thiessen, R., and Voorhees, Anson W., *A Microscopic Study of the Freeport Coal Bed, Pennsylvania*, Carnegie Institute of Technology, Bull. 2. Pittsburgh, 1922.

DESCRIPTION OF PLATES

PLATE III

FIG. 1. Vertical section at northeast corner of excavation for Angell Hall, looking east. (The northwest comer of the old building, Mason Hall, shows at the upper right.) Above, coarse, loamy, almost unstratified, brown till containing almost no coal pebbles. Below, more uniform-textured, light-colored washed sands and gravels, variously stratified and cross-bedded, containing numerous coal pebbles. Fig. 2. A few feet from the locality shown in Fig. 1, where a relatively coarse layer, indicated by arrows, consists largely of coal pebbles and smaller fragments of coal.

PLATE IV

Masses of gravel (natural size) from the black stratum shown in Plate III, Fig. 2. FIG. 1 shows six coal pebbles of considerable size. FIG. 2 shows numerous very small pebbles and broken fragments of coal, making up about 25 per cent of the sample, by volume.

PLATE V

At the west side of the same excavation; the coal pebbles here indicated (by arrows) are some of those shown natural size in Plate VI.

PLATE VI

Coal pebbles, from the locality shown in Plate V, natural size. They are all greatly flattened in the plane of the bedding.

PLATE VII

Triletes superbus, sp. nov. Fig. 1, a large specimen with equatorial wing and cylindriform indument in perfect preservation. FIG. 2, a portion of the margin of the wing showing fenestration due to anastomosis of complicated convolutions and branches.

PLATE VIII

Triletes superbus, sp. nov. Fig. 1, a perfect specimen, especially as regards the indument of the central body. FIG. 2, a specimen with narrower and more fenestrated wing.

PLATE IX

Triletes rotatus, sp. nov. Six spores at the same magnification, exposed particularly for the rotate appendage, with loss of detail in the central body.

PLATE X

Triletes rotatus, sp. nov. FIG. 1 shows the usual condition in which the rami of the appendage all fuse into a continuous margin. FIG. 2 shows rami with ctenate ramuli at the apex, in part not anastomosed into a continuous rim. Both figures show the triradiate clefts perfectly.

PLATE XI

Triletes rotatus, sp. nov. Detail of the margin of the appendage of the spore shown in Plate X, Fig. 1.

PLATE XII

Triletes rotatus, sp. nov. Detail of the branches of the equatorial appendage of the spore shown in Plate X, Fig. 2.

PLATE XIII

Triletes mamillarius, sp. nov. Two of the most perfect megaspores, showing investiture with mamilliform tubercles, and the short triradial clefts.

PLATE XIV

Triletes mamillarius, sp. nov. Four spores showing the range of variation in shape and size. The ones in upper left-hand corner and lower right show particularly well the thickened rim of the triradiate clefts. (Both are imperfect specimens viewed from inside the exine.)

PLATE XV

Triletes mamillarius, sp. nov. Tubercles in surface and lateral view, showing the deflection of apical portion,

PLATE XVI

Lepidodendron cuticle. In this species the stem is about 2 cm. in diameter and the areoles are 4 mm. long. It is photographed as the cuticles are usually found, i.e., double, — a cylindrical net pressed flat.

PLATE XVII

Lepidodendron cuticle. A part of the net shown in Plate XVI unfolded (along the line running obliquely through the photograph).

PLATE XVIII

Lepidodendron cuticle. An entire stem width of a species smaller than that shown in Plate XVI, showing the complete loss of everything but the cuticle, which may be opened out as a cylinder over a narrow glass rod. The length of the specimen is 12 mm.

PLATE XIX

Lepidodendron cuticle. The figures both show examples of large and small cuticular crests, the latter appearing as black lines.

PLATE XX

Lepidodendron cuticle. Fragment of a large species, of which Plate XXI is a detail. X ca. 11 diam.

PLATE XXI

Lepidodendron cuticle. Detail of areolar region showing the specialized dome-like cells, with cuticular crests, which appear to have burst and thus to have provided air passages through the epidermis.

PLATE XXII

Supposed mierosporangial branches of Lepidodendron. Length of specimens about 10 and 8 mm., respectively.

PLATE XXIII

Supposed microsporangial branch of Lepidodendron. A detail of a similar specimen to that shown in Plate XXII, Fig. 2.

PLATE XXIV

Supposed microsporangial branch of Lepidodendron. High power view of microspores seen through the cuticle.

PLATE XXV

Supposed microsporangial branch of Lepidodendron, a larger species than that shown in Plates XXII-XXIV. Note the distant heart-shaped areoles.

PLATE III

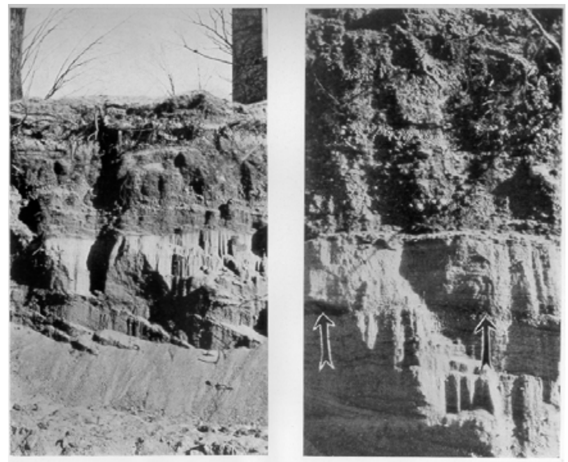


Fig. 1 Fig. 2

Structure of glacial outwash plain at Ann Arbor

PLATE IV

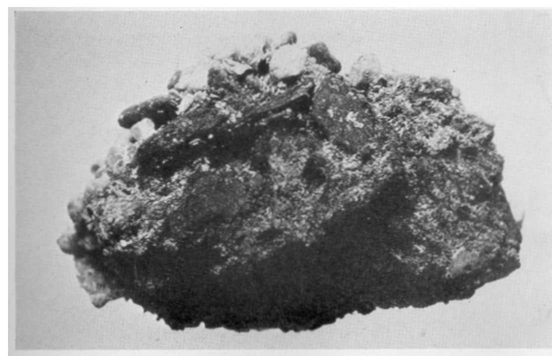


Fig. 1

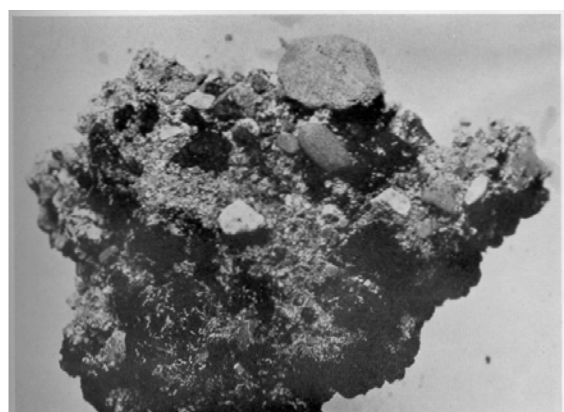
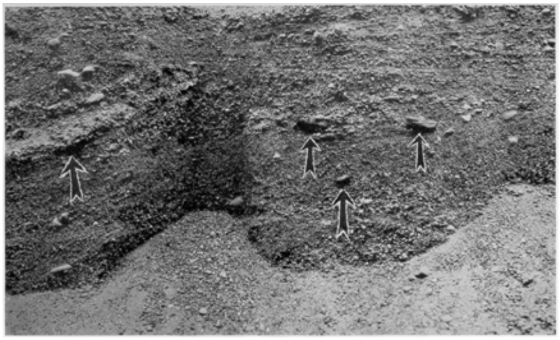


Fig. 2

Glacial outwash containing coal

PLATE V



Glacial outwash containing coal pebbles

PLATE VI

Coal pebbles from glacial outwash deposits

PLATE VII

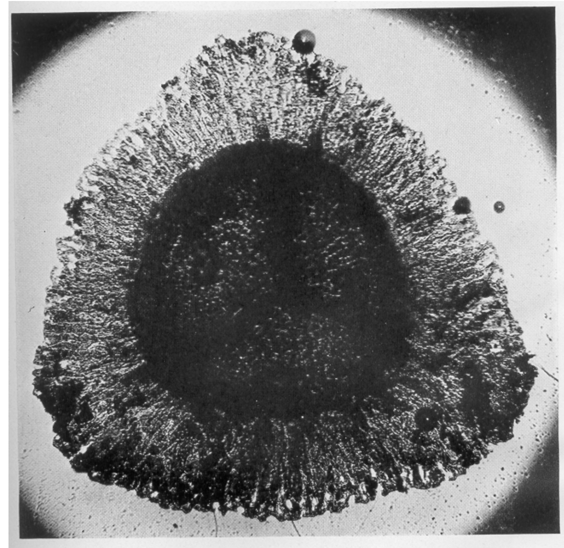


Fig 1

Fig. 2

Triletes superbus, sp. nov.

PLATE VIII

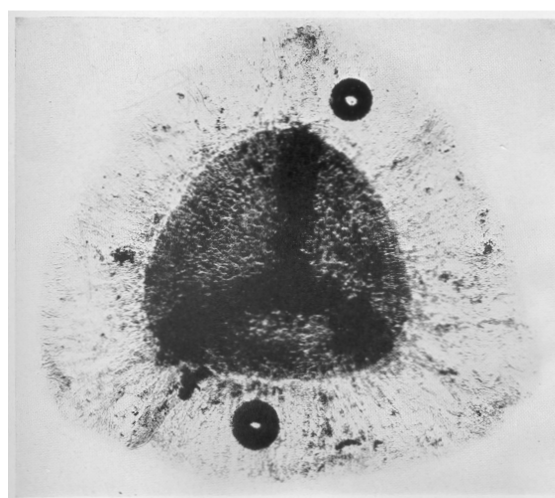


Fig. 1

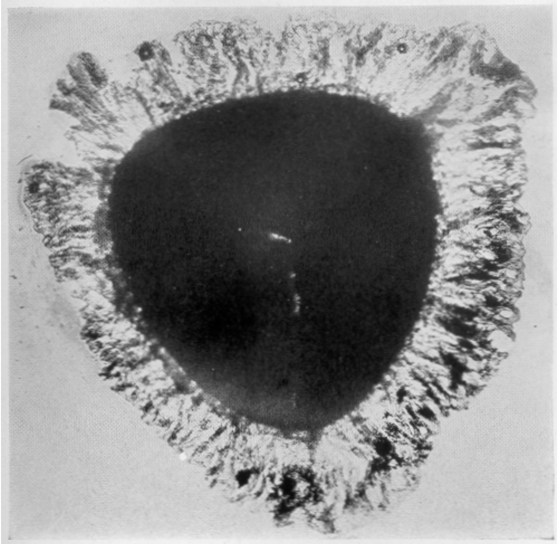
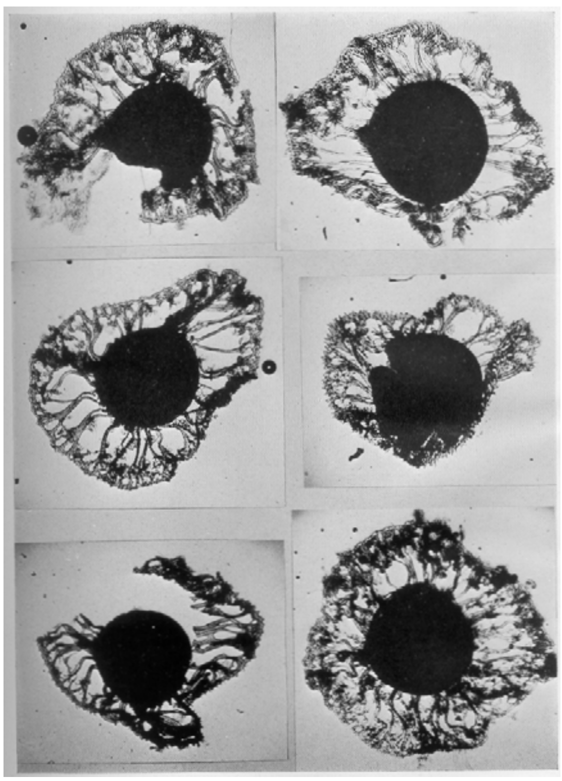


Fig. 2

Triletes superbus, sp. nov.

PLATE IX



Triletes rotatus, sp. nov.

PLATE X

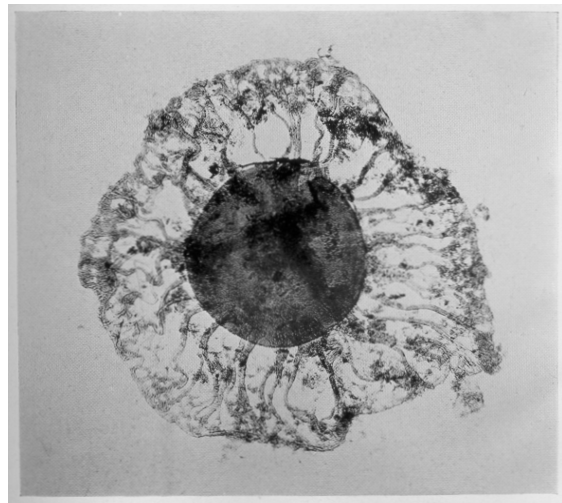


Fig. 1

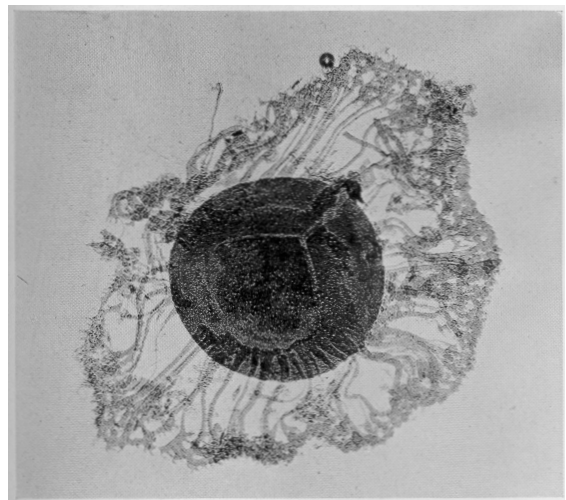


Fig. 2

Triletes rotatus, sp. nov.

PLATE XI

Triletes rotatus, sp. nov.

PLATE XII

Triletes rotatus, sp. nov.

PLATE XIII

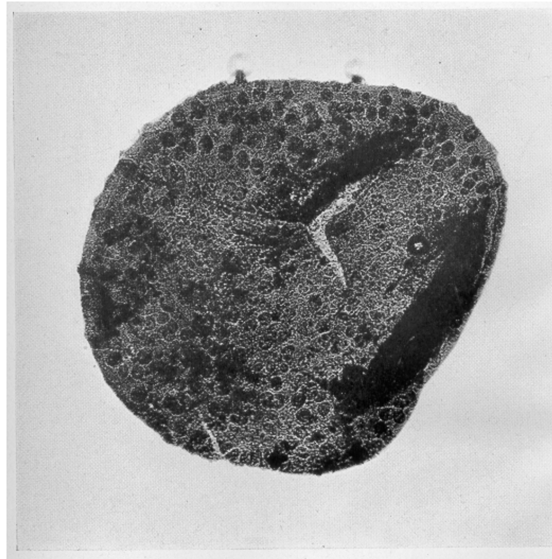


FIG. 1

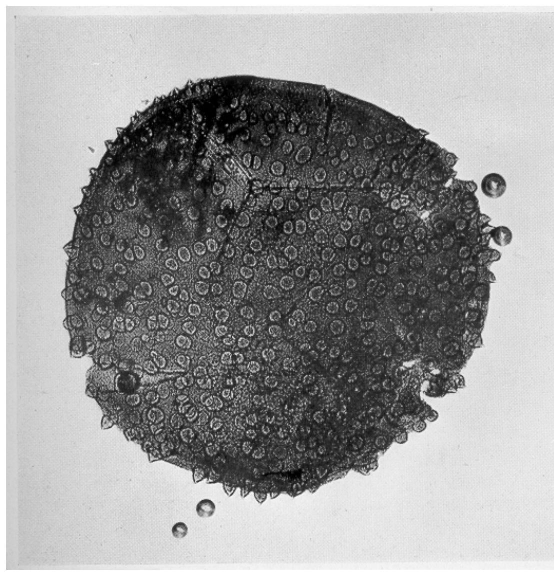
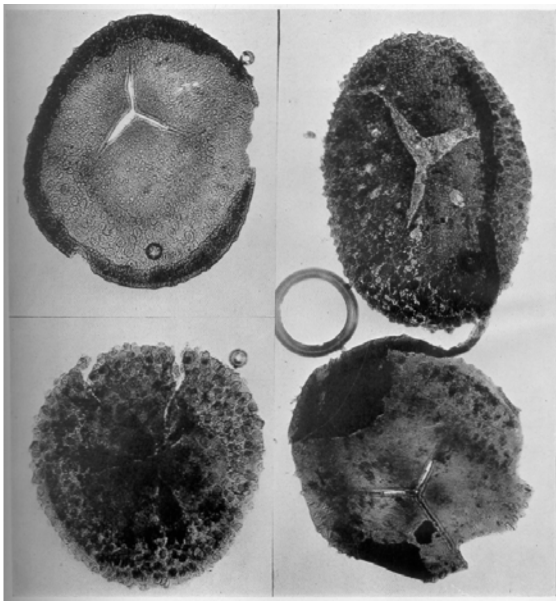


PLATE XIV



Triletes mamillarius, sp. nov.

PLATE XV

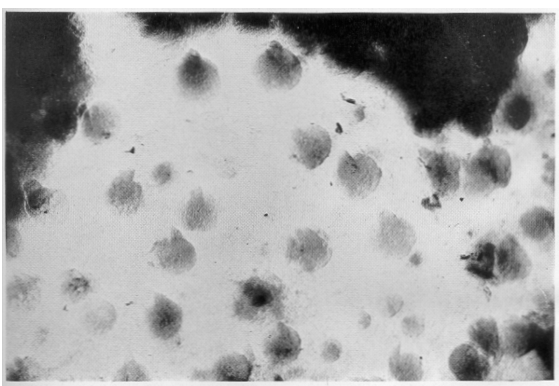


Fig. 1

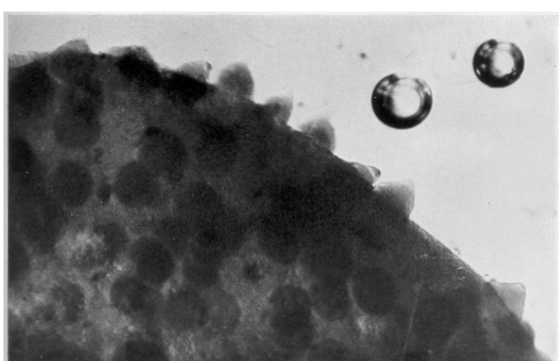
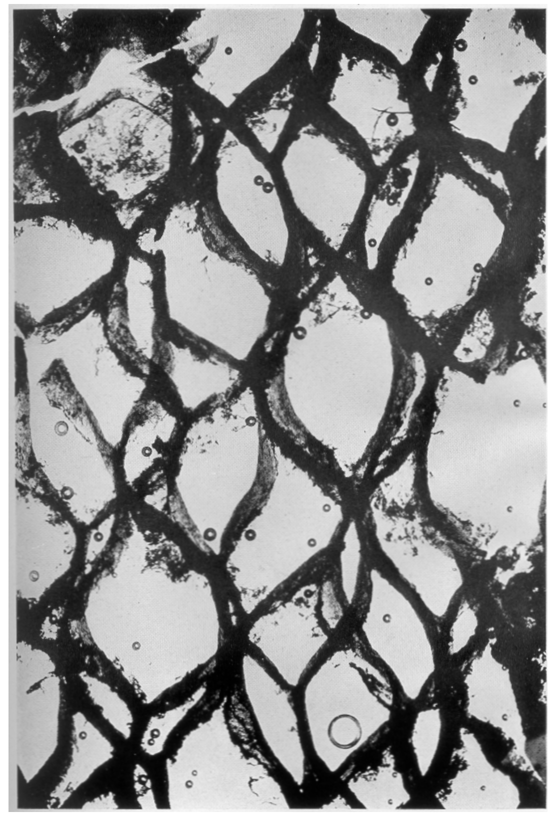


Fig. 2

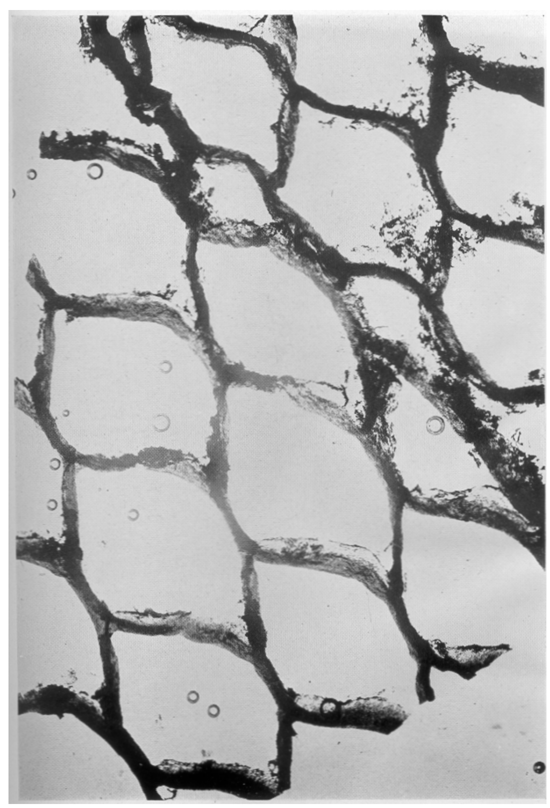
Triletes mamillarius, sp. nov.

PLATE XVI



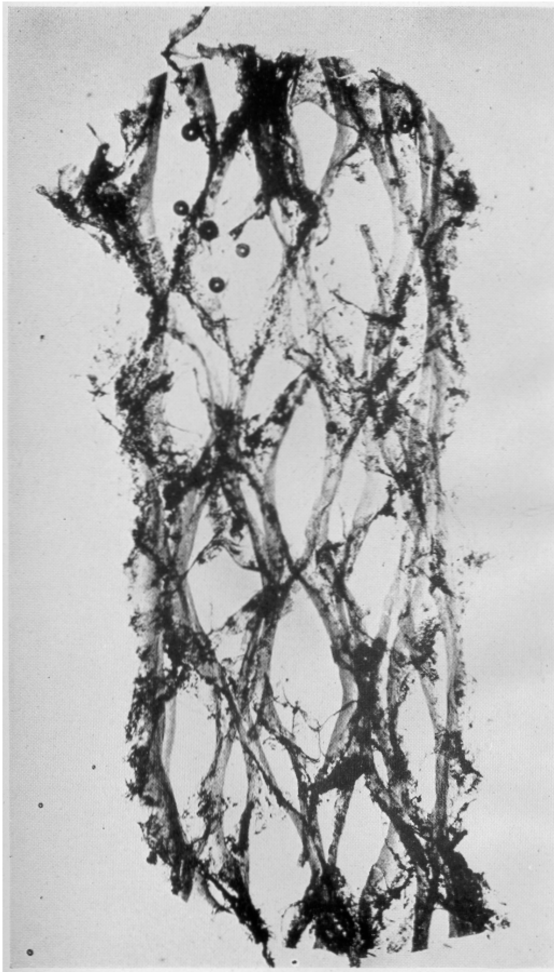
Cuticle of Lepidodendron

PLATE XVII



Cuticle of Lepidodendron

PLATE XVIII



Cuticle of Lepidodendron

PLATE XIX

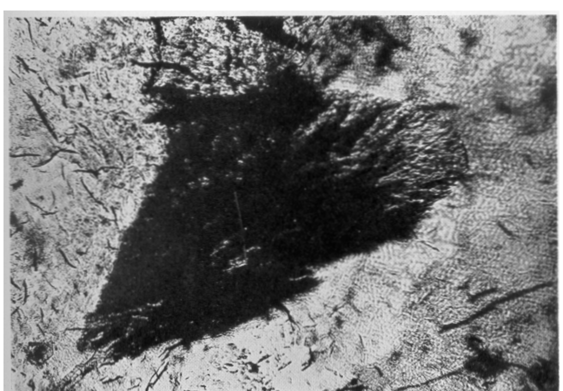


Fig. 1

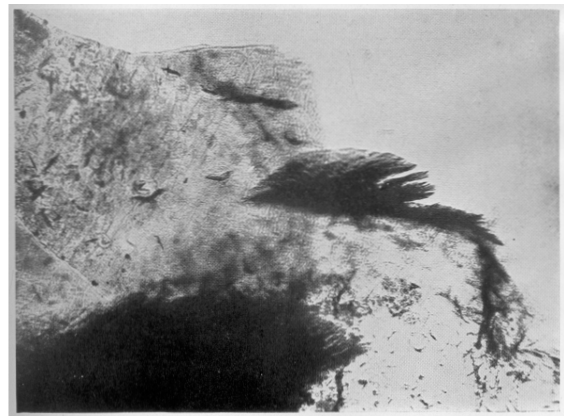


Fig. 2

Cuticular crests of Lepidodendron

PLATE XX

Cuticle of Lepidodendron

PLATE XXI

Dome cells and cuticular crests of Lepidodendron

PLATE XXII

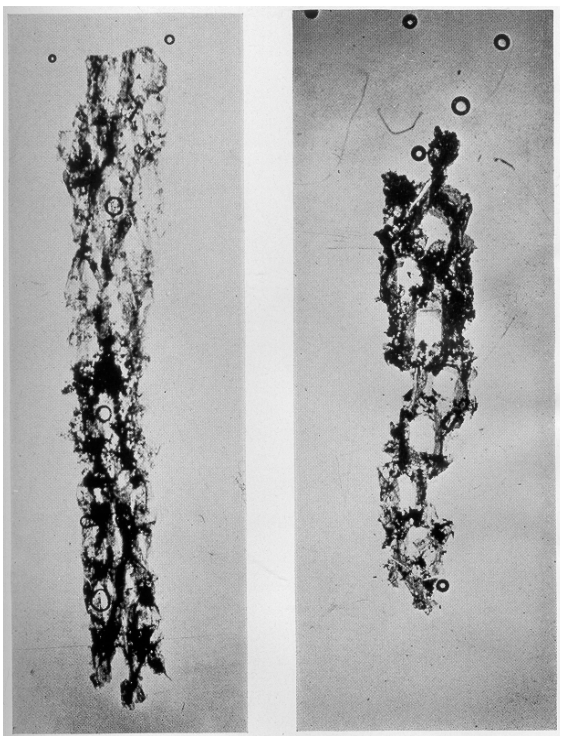


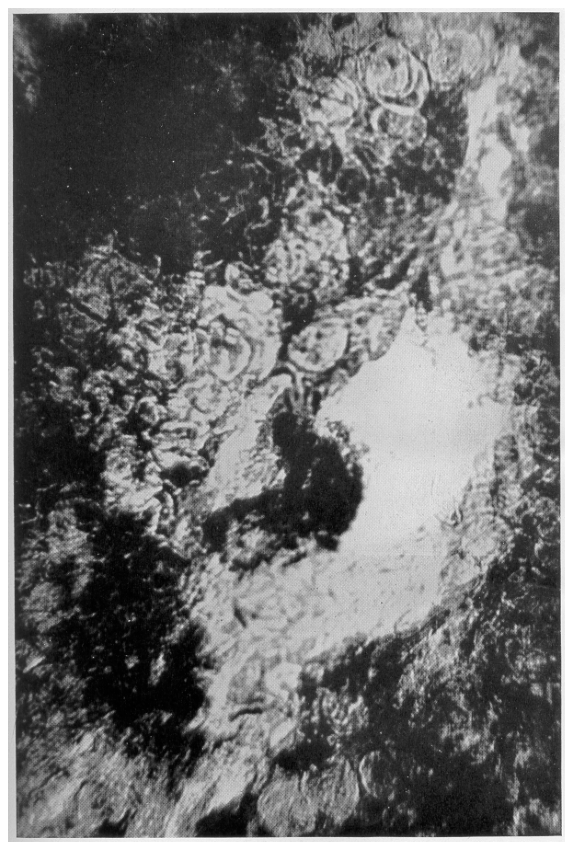
Fig. 1 Fig. 2

Microsporangial branches (of Lepidodendron?)

PLATE XXIII

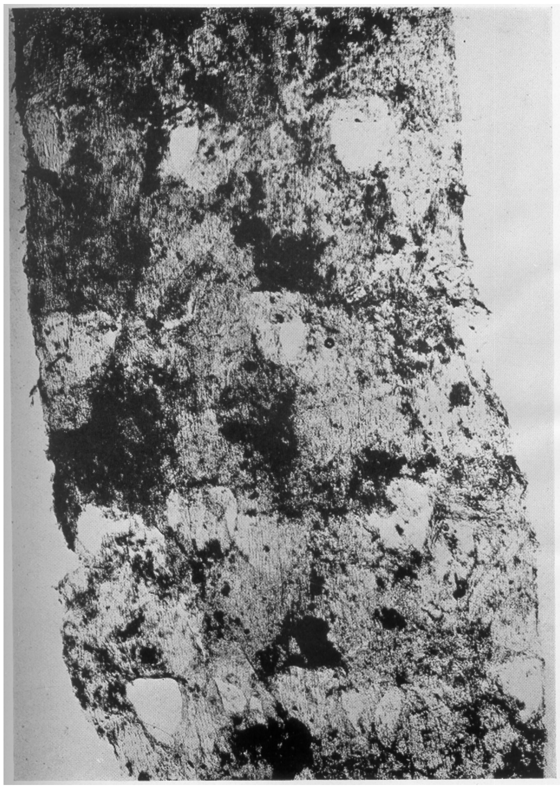
Microsporangial branch (of Lepidodendron?)

PLATE XXIV



Microspores (of Lepidodendron?)

PLATE XXV



Microsporangial branch (of Lepidodendron?)

THE GENUS TRILETES, REINSCH*

HARLEY HARRIS BARTLETT

INTRODUCTION

THE paleobotanical publications of Paul F. Reinsch[1-7] have suffered general and not altogether deserved neglect. It may seem paradoxical to speak of his work as neglected when as a matter of fact it is not infrequently cited as the basis of the theory of the algal origin of coal — a theory which has had adherents until quite recently. Careful scrutiny of the references to Reinsch by later authors seems to show that most of them are at second or third hand. The overturning of his fantastic interpretation of the plant remains in coal as of algal affinity led to the disregard of a vast amount of painstakingly and accurately recorded data, most of which is contained in his latest and least frequently cited work on the coal flora.

It was Reinsch's misfortune to be led astray by erroneous ideas regarding the nature of the plant fossils in coal. It is clear from the introduction to the *Micropalaeophytologia*[7] that Reinsch had never seen a megaspore of Selaginella. He discovered in the coals of Russia and Saxony a beautiful series of micro-spores and megaspores, many of them elaborately sculptured or provided with ornate appendages of various forms which may have been important in dispersal by wind. He considered the entire series as Algae because of the great range in size, pointing out in his argument that the spores of all groups of living Pteridophyta, however diverse, are of nearly the same size. His measurements, however, in the case of Selaginella, are for microspores only, although he knew of the existence of two types of spores, and possibly thought that the range of size he quoted included both microspores and megaspores. He was equally unfortunate in his ideas of the spore appendages, since he came to the conclusion that they were parasitic organisms growing upon larger plants, the central bodies of the spores. Consequently he frequently figures the appendages with meticulous care, but not the rest of the spore, which he viewed as merely the substratum of the parasites.

Perhaps seldom in the history of science has so much excellent observation and painstaking technique been nullified by bad judgment and prepossession with erroneous hypotheses.

The immediate rejection of Reinserts ideas by his contemporaries threw discredit upon his entire accomplishment, which stands even today without an equal in the field of coal botany. So completely was Reinsch's work neglected that within a few years even his erroneous theory of the origin of coal from Algae or alga-like plants could be revived by Bertrand and Renault[8-9] without anyone attempting a new appraisal of his contributions. Bertrand and Renault clearly enough acknowledged their indebtedness to Reinsch for the germ of the algal theory of the origin of coal by giving the name Reinschia to one of the two chief types of supposed Algae, the other being Pila.

Thiessen[10] is inclined to attribute the germ of the algal hypothesis to Von Gümbel,[11] from whom he thinks Bertrand and Renault got it. After a commendatory account of Von Gümbel's work he says: "But Von Gümbel made the seemingly harmless statement that certain bodies looked like certain algae. He was very careful to say that he would not venture the assertion that they actually were such, but, as he was not a botanist, would leave this matter to those who were more familiar with plants. . . . Seemingly acting on the suggestion of Von Gümbel Bertrand interpreted these as gelosic algae, similar to the Volvocineae." The name Reinschia, dating from one of the first papers of Bertrand and Renault (1893)[9] would seem to show that they followed the lead of Reinsch rather than Von Gümbel.

Recent authors, among them Potonié[12] and Thiessen[10] refer to the earlier one of Reinsch's monographs, but strangely enough, not to his final and most significant one, the *Micropalaeophytologia*.[7] Thiessen says (p. 195):[10] "Reinsch developed a technique of his own . . . and prepared numerous samples of coal. He thought the yellowish red and brown, somewhat translucent or transparent figures a very peculiar plant form that he called 'Protophytae of which he believed he had recognized seven fossil types not comparable with recent plant forms. Many of his figures show excellent representations of Pteridophytic spore exines; in other cases he allowed his imagination to carry him into the representation of grotesque and odd plant forms." Thiessen goes on to mention the severe criticisms of Reinsen's work that followed the publication, in 1881, of the *Neuere Untersuchungen über die Mikrostruktur der Steinkohle*. Petzholdt[13] in 1882 identified the hypothetical Protophytae with inorganic bodies, fragments of coal, and decomposition products termed bitumen. In 1883 Fischer and Rüst14 reviewed Reinserts material. Although they were unable to interpret all the structures figured by Reinsch, they concluded that most of them were amber-like resins, and others leaf cuticles, spores, and wood fibers. They rejected Reinsch's ideas entirely.

It is probable that the unfavorable reception of the *Neuere Untersuchungen* explains the neglect of the *Micropalaeophytologia*,[7] sumptuously published in 1884. In spite of all its defects of interpretation, the latter is a mine of accurate figures of plant structures (mostly spores) recovered from coal in almost incredible perfection.

In addition to other structures, over five hundred spores (referred to as Triletеae) are figured. Although Reinsch interprets them as Algae or algoid plants, his terminology seems to indicate that he may have had some misgivings, since he uses the term exosporium for the sculptured or appendaged outer portion of the structures, stating that he does so for convenience and not because he doubts his own conclusions. The accuracy of the figures as representations of spores affords the strongest possible internal evidence of the accuracy of the figures, since they have not been distorted or modified to bring them more in accord with their supposed algal affinity. One supposed case of cell-division shows patently two similar spores slightly overlying each other.

Even though they may not be associable with impressions of the vegetative parts of the plants to which they belong, or with structural material, Reinsch's Trileteae are significant both botanically and geologically — botanically because they will give us an idea of the extent of specific diversity in the Carboniferous flora, and geologically because, as Thiessen[15] has discovered, and as Reinsch vaguely appears to have recognized, the different types are characteristic of particular beds, and are sure to come into importance in stratigraphic correlation.

REVIEW OF REINSCH'S "MICROPALAEOPHYTOLOGIA"

The first volume of the *Micropalaeophytologia*[7] is devoted to the Trileteae, of which a single genus, Triletes, is characterized, and to the Stelideae, with the genera Trichostelium and Stichostelium, each comprising a "subtribe." According to present conceptions, the Trileteae are the spores of the Lepidodendraceae and allied plants. Seward[16] retains the name Triletes as a convenient designation for such fossils, with the following comment (p. 192): "The general generic name Triletes, originally used by Reinsch, is a convenient term by which to designate Pteridophytic spores which cannot be referred to definite types." Elsewhere (p. 215) he says: "The designation Triletes is applied to isolated spores of Sigillaria or to those of Lepidodendron."

Recent writers do not appear to have commented upon Trichostelium and Stichostelium. Reinsch himself looked upon them as plants of parasitic nature, and called attention to the fact that they frequently parasitized the larger forms of Triletes. It appears obvious that the majority of them are merely fragments of the elaborately sculptured, complicated zonal appendages of the megaspores included under Triletes. References are made elsewhere (see the foregoing paper) to similarities between some of Reinserts figures and certain spores described by the present writer from the Ann Arbor drift coal. Reinsch's two names will doubtless fall into the synonymy of Triletes, although not all of his figures conform to appendages of known spore types. The coals containing these peculiar structures should by all means be reëxamined in order to bring to light whole spores bearing the elaborate appendages figured by Reinsch as Trichostelium and Stichostelium.

The second volume of the *Micropalaeophytologia* contains descriptions and figures of a congeries of structures — spores, spore appendages, cuticles, etc., from various formations all the way from the Devonian to the Tertiary. Reinsch, of course, considered most of them as autonomous organisms. Some, such as his Discieae, including Sporangites Dawson and Chroococcites Reinsch *ex parte*, seem to fall for the most part under Triletes. Probably the name Sporangites should be reserved for fossil sporangia of dubious association rather than for spores. It was established by Dawson for Devonian shale fossils. The type species of Chroococcites, as indicated by Reinsch (p. 9),[7] is a Triletes of which the exine bears a ramentum designated by Reinsch as an independent parasitic organism, belonging to his group Leptoideae. As to the true nature of Leptoideae there can be no doubt. Reinsch states his unfortunate misconception as follows: "Corpus filiforme, procumbens, substrate viventi (Trileteae, Stelideae et Discieae et a.) dense adpresum et in interna substantia plantularum affectarum expansum; et erectum, substrate parte inferiore affixo."

Another group, the Rhizostaemideae, including only the genus Rhizostaemis, is based upon tubercles of a Triletes not very dissimilar to the *Triletes mamillarius* described by the writer from coal in the glacial deposits at Ann Arbor. The Rhizostaemideae are described (p. 15)[7] as "Plantulae parasitice radicantes et nidulantes in Triletum majorum et aliorum corporum organicorum superficiec . . ."

Most of Reinsch's Sphaerocladiteae (another group containing a single genus — Sphaerocladites) must remain dubious pending the reinvestigation of his materials. One, however, is of extraordinary interest because of its striking correspondence to Bertrand and Renault's Reinschia. It is figured from the English torbanite (Torbane Hill) and the Scotch boghead cannel coal, constituting, according to Reinsch, as high as 92-98 per cent of the coal in some sections. It is a megaspore type, a Triletes.

As to Reinsch's remaining groups little need be said. Our author's prevailing error of regarding the appendages of spores as distinct parasitic organisms accounts for some, at least, of the Dictyophiteae, as would be clear from the text even if the plates did not indicate it. He says: "Corpuscula vegetabilica incertae sedis in Systemate, tantummodo reperta parasitica superficiemque aliorum Corpusculorum vegetabilicorum majorum (Trileteae, Discieae, etc.) obducentia. Corpus Plantulae sicut in Stelideis ex Thallo subhomogeneo . . . formatum . . . Dictyophiteas esse corpora propria, nec ad substantiam substrati exhibentia, elucit, 1, ex connexione Dictyophitearum cum substrato, 2, ex facto ut haec corpuscula infecta (Trileteae, etc.) reperiantur partim corpusculis alienis obtectis, partim liberis." His argument that the spore appendages are independent organisms because one kind of spore is found both with and without appendages, and because a simple spore may be partly with and partly without an investiture, is very weak. Prior to burial many spores became more or less completely disintegrated, and in any coal sample containing many spores of a single type, all stages of preservation may be found. Nor can the accidents during isolation by the maceration process be left out of account. The Stolidermieae (type genus Stolidermium) include a variety of cuticles, some of very characteristic aspect. It may be advisable to retain the name Stolidermium for certain Carboniferous cuticles not yet associated with definite genera, just as it will certainly be convenient to retain Triletes for spores.

UTILITY OF THE NAME TRILETES

As already noted, Seward[12] proposes to retain the name Triletes as a convenient designation for fossil spores presumably belonging to Lepidodendraceae and allied families, but not definitely associated as yet with fossils of the vegetative phase of the life-history. Used in this manner, as the writer proposes to do, the name will probably actually cover many genera, belonging to several families.

Thiessen is firmly opposed to the use of names for isolated spores, cuticles, etc., but it seems to the writer that such an attitude cannot fairly be maintained in view of his own conclusion that such fossils are the stratigraphically significant components of the coal. He says (p. 71):[15] "No thorough classification of the spore-exines found in the coals has been made. . . . To try to give a definite name to them, without knowing their affinities and relationships, as has been done by some in the past, would be a waste of time and space. No benefit is gained by naming the exine predominant in and characteristic of the Pittsburgh seam 'Sporangites' Pittsburghensis, as does Dawson, or 'Trilet' Pittsburghensis, as do Bennie and Kidston, or giving some such meaningless name. When their relationships are known proper names will be given them."

Thiessen[15] shows convincingly that coals may be identified as to origin and that correlations may be established through comparison of the characteristic spore exines. How such work is to proceed, easily without having a convenient nomenclature for the spores is not evident. Form genera of Fungi Imperfecti with countless named species are maintained in mycology, for present convenience. In the cases of many economically important fungi the perfect forms, which make possible a precise placing in the scheme of classification, may never have been discovered, but who, for that reason, would be willing to get along without names for them? Moreover, it is quite possible that the study of spores, whether or not they are ever connected with vegetative structures, may give us a better idea of the diversification and geographical distribution of the Lepidodendron allies than any other type of fossil. Quite conceivably Lepidodendron stems from America and Europe might appear identical, whereas spores, if known, would demonstrate specific or generic differentiation. To take a concrete case, let us suppose that our knowledge of the species of Selaginella in the group of *S. rupestris* were based only upon vegetative stems, poorly preserved. We could then probably distinguish only one species. If the spores were preserved, however, the existence of several species would become obvious. If the spores only existed, their study would give phytogeographic and floristic information even though we had no information about the kinds of plants that bore them.

The writer is quite convinced of the value of names for the characteristic spore types. If Reinsch had not been content to characterize his coal species under numbers, the inclusion of the specific names in indexes would repeatedly have called attention to his monumental *Micropalaeophytologia* and would have led sooner to a recognition of the importance of his discoveries. Reinsch examined not only Carboniferous coal, but also Devonian material (shale and coal) and coal of later formations. His material came mainly from various localities in Central Russia and from Zwickau in Saxony. The fact that he gives localities for most of the types described would justify the procedure of giving names to the outstanding ones since new specimens may doubtless be isolated as desired from coal from the type localities. If naming a few of his species were to lead interested botanists and geologists to consult his monograph, the writer would gladly be responsible for the iniquity of basing a few names upon his plates and descriptions instead of upon type specimens. Although Reinsch was led astray by consistent adherence to false theories regarding the nature of the structures found in the coal, his work was too good in detail and too extensive to be neglected as it has been. His collections are presumably still preserved and would repay careful examination. It will be obvious to anyone experienced in the study of such material that Reinsch described an excessive number of types. Many of his figures represent the same species over and over again. It is much to be hoped that someone favorably situated to do so will study his type specimens in the light of new isolations from the coals that he investigated, and that the interesting line of investigation opened by Reinsch may lead to many more studies such as those of Jeffrey[17-18] and Thiessen.[10,15]

UNIVERSITY OF MICHIGAN

* Paper from the Department of Botany of the University of Michigan, No. 253. (Read at the 28th Annual Meeting of the Academy, in 1923.)

[1] Reinsch, P. F., *Neue Untersuchungen über die Mikrostruktur der Steinkohle des Carbon, der Dyas und Trias*. Leipzig, 1881.

[2] Reinsch, P. F., "Über Algen-ähnliche und eigenthümliche einzellige Körper in der Karbonkohle Central Russlands" (mit Tafeln III und IV), *Flora*, 4 :113-120. 1883.

[3] Reinsch, P. F., "Weitere Beobachtungen über die eigenthümlichen einzelligen Korper in der. Carbonkohle," *Flora*, 41 :187-189. 1883.

[4] Reinsch, P. F., "Über parasitische Algen-ähnliche Pflanzen in der Russischen Blätterkohle und über die Natur der Pflanzen, welche diese Kohle zusammensetzen" (mit Tafeln X, XI und XII), *Flora*, 41 :323-330, 839-344. 1883.

[5] Reinsch, P. F., "Ein neuer algoider Typus in der Stigmarienkohle von Kurakino (Russland)" (mit Tafel XIII), *Flora*, 41:335-360. 1883.

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