

The origin of the Carboniferous coal measures—part 3: a mathematical test of lycopod root structure

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The notion of the compatibility of form and function in plant organisms is used as a guide to mathematically predict the geometrical shape of Carboniferous *Stigmaria* (i.e. lycopod roots). It is assumed that *Stigmaria* were created to be in an abundant fluid environment. The analytical predictions resulting from this assumption are compared to the Paleozoic fossil evidence. This mathematical model is part of a complete lycopod model that is outlined in enough detail to be reproduced. Finally a rationale for the discrepancies in the depiction of *Stigmaria* in popular and scientific venues versus what has been used in this model developed is given. Agreement between predicted stigmarian structure and the fossil evidence strongly supports an abundantly fluid environment for them. It favors the floating forest, catastrophic paradigm of Paleozoic coal formation.

Part 1 of this paper¹ noted how uniformitarians thought the Paleozoic coal deposits of the northern hemisphere formed in swamps. This was despite the plethora of evidence they uncovered which presented problems for their paradigm. Particularly troublesome were the difficulties surrounding the incredible biodensity of fossils in the coal measures coupled with a lack of biodiversity; the disarticulation of the fossils coupled with their excellent preservation; and the separation of different fossilized parts of the same object, such as roots and trunks, into different stratigraphic layers. Other anomalies included the lateral geographical extent of the coal seams, the high purity of the coal seams with minimal contamination from mud and sand, and the inability to find an analogous modern environment.

The first part of this paper further noted the existence of an alternate paradigm, that of the floating forest or silvomarine origin of the Paleozoic coal deposits. This hypothesis by biologists is supported by their paleontological and chemical evidence that the dominant Paleozoic fern tree plants were structured for a water environment. In line with this, the second part of this paper² concentrated on presenting new fossil and field evidence directly bearing on the elastic and vacuous nature of those fern trees. The author's calculations concerning their root structures, their unusual ontogeny and radiating rootlets and other evidence were found to strongly support the floating forest hypothesis.

The silvomarine hypothesis for the formation of Paleozoic coal beds was first put forth in the latter part of the nineteenth century by the German biologist Dr Otto Kuntze. His concept was that the Paleozoic coal beds formed from dense vegetative mats or forests which had floated on the oceans' surfaces. His two books on the subject were filled with numerous observations of the fossil evidence in addition to a phenomenal breath of quantitative analyses (e.g. on coal bed chemistry).

However, he failed to address some major questions which arise concerning the viability of his floating forest

hypothesis. Where did the intervening limestone, shale, sandstone, and clay layers come from? Why are the fern tree roots that form the base of this forest almost always separated from their trunks? How do you account for the large number of coal layers in cyclothem? Why is the biodiversity so low? And so forth.

As a first step in quantitatively examining some of these questions, a mathematical model of the dominant vegetation in the Paleozoic coal beds should be made. This is of much greater significance because of the extraordinarily low biodiversity seen in the coal beds. This paper presents a mathematical model of a lycopod or fern tree, concentrating on the significance of its root structure.

A mathematical test

A reasonable assumption for the spread of a lateral Paleozoic lycopod root system in an aqueous environment would be that at its termini for the mature *Stigmaria*, and perhaps in its intermediate stages at the points where its roots bifurcate, its roots should be equidistant from each other. That is, they would be distributed equally around a circle centered at their genesis point. This is certainly the case for the start of all lycopod root systems: the four roots are spaced at 90° from each other to begin with (figure 1).³

Now consider the next stage of growth: from the first root bifurcation to where the root is ready to bifurcate again. If we had the lengths of the first two stages of these *Stigmaria*, then there would be a uniquely determined angle between them if the roots are equidistant from each other at the termini of both stages. If 'a' is the common length of the first four branches, and 'b' the common length of the next eight, with 'α' being the bifurcation angle, then 'a' and 'b' are related explicitly through the following equation:

$$a = b ([1 + \sqrt{2}] \sin [\alpha/2] - \cos [\alpha/2]).$$

Therefore any previously published example of such a root system could have both the lengths of its first two stages

measured and that of the bifurcation angle between them. The lengths could then be put into the equation that calculated the ideal bifurcation angle under the given assumptions. The calculated and measured angles could then be compared to see how valid the assumption is in practice.

Take the example from the literature shown at the top of figure 1. However, note that there is considerable variation in the lengths of the root sections (the averaged values were used), apparently because some suffered from adverse growing conditions. The first bifurcation angle was calculated to be 79° , and the averaged measured angle between them turned out to be 75° . Hence, we have reasonable agreement, though it is not perfect. However, the final stage of root growth in this specimen is far more interesting.

Given the lengths and the analytically determined angle from the example under discussion, an iterative mathematical procedure can be used to calculate the angles between the final branchings of the roots and their lengths if they must be equidistant from each other.

The calculations showed that every second pair of terminal roots *has* to cross each other. That the terminal roots have to cross each other can also be shown geometrically. Up to the first bifurcation, the stigmarian branches make an equal angle of 90° with any circle centered at the start of the root system. At the first bifurcation point, the new outwardly progressing branches then make the same angle in absolute magnitude (but not 90°) with any circle of expansion. However, these angles have opposite signs at alternate positions around the periphery of any of these circles. When the branches have grown to where they are equidistant from each other, the second point of bifurcation has been reached, by definition. The angles made by the two new branches in the next bifurcation then have to be radically different: one of them approaches any circle of expansion at a more tangential aspect, while the other one approaches at more of a normal aspect. Therefore, the adjacent branches that approach from a skimming tangent must necessarily cross each other eventually, because they are rapidly approaching each other while the other pair is on a more nearly parallel course. Thus the distance between them closes as they grow outward before they cross. They have to cross in order to put distance between themselves equal to that of the more nearly parallel branches. This is a most unnatural circumstance if the roots are embedded in soil and not a fluid, at least from the perspective of efficient use of resources.

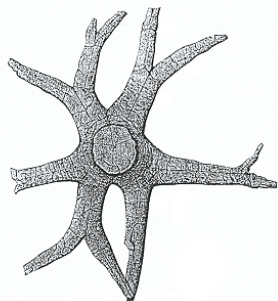
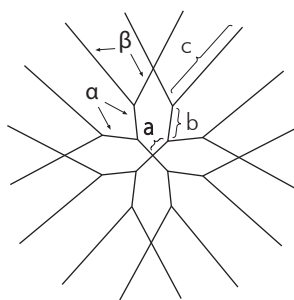


Figure 1. [Above] A *Stigmaria ficoides* Brongniart from the Middle Pennsylvanian of the Piesberg near Osnabruck, Germany; [Below] a schematic configuration (top view).



Alpha = 78.86 degrees, **beta** = 69.2 degrees;; for a 9-meter diameter: **a** = 0.716829006 m, **b** = 0.942453873 m, **c** = 2.98482897578 m; for a 6.7-meter diameter: **a** = 0.533639371 meters, **b** = 0.7016045499 meters, and **c** = 2.22203934863.

One example from the scientific literature had an angle of 57° .⁴ This was consistent with the calculated angle for the crossing of the stigmarian roots of 58.06° . The author also collected one sample of fossil stigmarian roots preserving this junction; the angle measured at it was 53° . Another sample, from southeastern Kentucky's Bryson Formation, was also located. It again had an angle that measured 53° . These three examples give some added confidence in the mathematical model, though the agreement could be better.

Other assumptions on the root lengths and bifurcation angles were considered, but found wanting. For instance, retaining the assumption of the equal separation distance at the termini of the roots (just before they bifurcate or at their maximum extent), but adding the requirement that the bifurcation angles between all the sets of roots for all bifurcations be equal, will not allow the branches to cross each other and remain equidistant. That is, such a solution is impossible: it is mathematically excluded when the angles are required to be equal. Furthermore, for the case where the terminal branches are not allowed to cross but the equal bifurcation angles requirement is retained, the solution space is from just above 30° to 60° , which is below the value of any bifurcation angle seen in fossil evidence the author is aware of. Finally, the ratios of lengths which meet both the equal-

spacing-only-at-the-final-terminal and equal-bifurcation-angles-for-all-of-them without crossing requirements are far from those observed in real fossil remains.

This all strongly suggests that such a root system was indeed designed for a watery environment. If it were not, then the plant would have, at one point in the terminal stage of its roots' growth, a situation where every second pair of root tips of the plant would be nearly coincident. This is definitely not a strategy that one would imagine a plant would pursue to maximize its nutrient intake in a water-limited environment. When this prediction is compared to the photographs of the few existing extant stigmarian root systems available to the author, good agreement is found.

The mathematical model of a *Stigmaria* is just one part of a complete lycopod mathematical model outlined here.⁵ It was developed to quantitatively answer the many tough questions about the Paleozoic floating forest, e.g. those concerning the large number of layers in Paleozoic cyclothem; the biodiversity and particular spacing of lycopods; and the origin of the limestone, shale, sandstone, and clay layers in cyclothem. These questions and others, like why *Stigmaria* are nearly always found separated from

their lycopod trunks, will be answered in forthcoming articles. The answers are both intriguing and surprising, providing good reasons to believe the superior merit of the silvomarine hypothesis.

Typical misleading representations of *stigmaria* and lycopods

Despite the long-term existence of unequivocally clear evidence to use in reconstructing lycopod root systems, especially the crossing of their roots, accurate portrayals of them are exceedingly rare.⁶ What reconstructions are attempted usually mimic the roots of contemporary trees with shallow roots splayed out radially from the base, with a notable absence of any root crossings. A few typical examples of this tendency follow.

The University of California at Berkeley paleontology department's web site reproduces a representation of *Stigmaria* (see figure 2) which ignores the symmetry and consistent root crossings of *Stigmaria*.⁷ In addition, the height of the *Lepidodendron* lycopod is distorted by a factor of nearly five (despite referencing work by Eggert where this is not the case). All these gross distortions help hide the true nature of the floating forest. The particular height distortion is ubiquitous in the scientific literature⁸ as are similar misrepresentations of the *Stigmaria*.

Pennsylvania contains some of the world's best examples of Upper Carboniferous strata. Accordingly, the Pennsylvania State Museum in Harrisburg has exhibits highlighting coal-producing Carboniferous vegetation. This vegetation is dominated by the lycopod fern trees, shown uprooted in the three accompanying photographs of paintings and models from the museum (figures 3,4 and 5). However, even though the exterior dimensions and morphology of the lycopods are well known, they are grossly misrepresented in the museum. For example, the roots are only one fourth the size they should be, the rootlets are one twelfth the size they should be (the equivalent of pretending a six foot man is only six inches high!), and they are missing on the top of the roots (except at the tips of them) and shown bending downward rather than radiating straight out from the root. All of these disingenuous representations are necessary, along with other ones concerning the biodiversity and biochemistry of the Pennsylvanian, to maintain the fiction that Pennsylvanian coal was produced in swamps rather than from a flood-beached floating forest.

Some may suggest that governments cannot be expected to get things of a technical nature correct. However, the Pennsylvania State exhibit was

dedicated on June 18, 1976, and had paleontologist Donald Baird as a consultant.⁹ Although his expertise centers on tetrapods (i.e. amphibians and lepospondyli), it would be logical to assume that he was aware and approved the presentation of lycopods at the museum.

There were several species of *Stigmaria* named before 1820. However, these names are not given scientific credence because they occur before the date an international commission on botanical names was established.¹⁰ After that date various researchers began to produce descriptions of new species and otherwise add to our knowledge of *Stigmaria*. Because this data was scattered throughout various scientific publications in multiple languages, it became evident that an encyclopedic review of the subject would be most beneficial. Such a review was undertaken in French under the editorship of Edouard Boureau, with William G. Chaloner writing it.¹¹

Chaloner is noted for his work on fossil spores, not on lycopods. Perhaps because of this his review was all the more candid than it would have been otherwise. He noted that it was difficult to affirm the validity of the different species of *Stigmaria* that had been described. This was because some of them had been established only after a few transverse cuts had been made on fossil specimens and it was not certain these were not just displaying different stages of stigmarian ontogeny. In fact, it is likely the three groups that species were placed into were simply reflections of taphonomic disturbances rather than speciation. More on this topic will be given after the following discussion.

Similarly, the author has seen a complete gradation between smooth and grooved stigmarian steles, so this may also be a taphonomic development that is not related to differences in *Stigmaria* species. Note that Chaloner fails to even mention the two books written by the botanist

Dr Otto Kuntze. Yet Kuntze's work is far broader in scope of specimens considered and had far more empirical rigour than any reference Chaloner chose to cite.

Figure 6 is from Chaloner's review.¹² The upper part of it gives a typically disingenuous, asymmetrical view of generally non-crossing *Stigmaria*. The distortions of the fossil evidence all tend to support the swamp-generation hypothesis at the expense of the silvomarine one. The lower part of the diagram is much worse. The rootlets are shown visibly tapering with one of them bifurcating. They are noted as being 40 cm long, one fifth of the length reported elsewhere. They are shown bending downward. Out of the estimated 100,000 rootlets seen by the author, none have been visibly tapered,

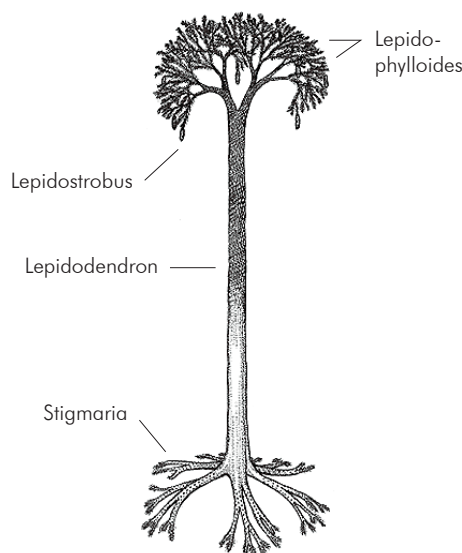


Figure 2. Reproduction of an unrealistically distorted depiction of a *Lepidodendron* and its roots, abstracted from the University of California at Berkeley's department of paleontology website.



Figure 3. A questionable reproduction of the Upper Carboniferous forest, as displayed at the Pennsylvania State Museum in Harrisburg, Pennsylvania.



Figure 4. A questionable reproduction of an uprooted *Stigmaria* with rootlets, as displayed at the Pennsylvania State Museum in Harrisburg, Pennsylvania.



Figure 5. A questionable reproduction of an uprooted *Stigmaria* with rootlets (note absence of rootlets on most of the top [left] side) as displayed at the Pennsylvania State Museum in Harrisburg, Pennsylvania.

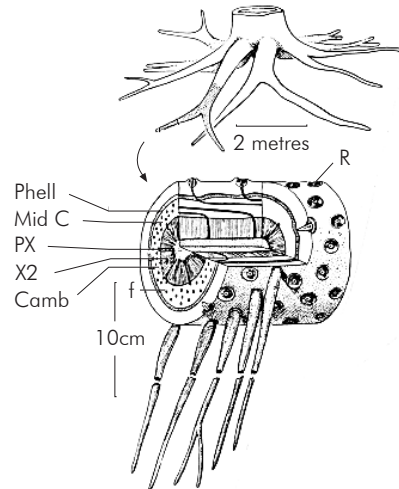


Figure 6. The details, as well as the overall picture, of *Stigmaria* are misrepresented in the above diagrams abstracted from an encyclopedic review of lycopods.

bent downward instead of radiating out perpendicularly to the surface of the *Stigmaria*, bifurcated, or been as short as represented here when their lengths could possibly be traced that far.¹³

The lower part of figure 6 does present the hollow space in the interior of the *Stigmaria*. However, the rootlets are shown as traversing parallel to the stele in this space before they enter it. This has never been observed by the author. Numerous examples of the rootlets entering the stele perpendicularly—without undergoing any bends in the interior of the *Stigmaria* have been seen. The case of usually broken rootlets being swept in one direction along the axes of the stele has also been observed. Could it be that the few cuts examined by other researchers on a simple *Stigmaria* are running into this phenomenon without correctly interpreting it? Are *Stigmaria* species being defined on the basis of structural disturbances having nothing to do with evolutionary differentiation and everything to do with a violent placement of a floating forest? Is it possible investigators haven't seen the superiority of the floating forest hypothesis because they have been too preoccupied with the quest to prove an untenable guess to have noticed the true macroscopic nature of lycopod fern trees?

Conclusions

The Paleozoic fern tree root model is an integral part of a more extensive model of the entire lycopod. Such a model is necessary to quantitatively examine the various aspects of the hypothesis that the Carboniferous coal measures were emplaced by the beaching of floating forests. The input to the Paleozoic fern tree model is contrasted to the input that would have been derived if the contemporary consensus depiction of lycopods by uniformitarians were used. It is conjectured that arguments about homologous structures and evolutionary adaptive reduction, the dwelling on evolutionary expectations rather than on observations, has steered researchers away

from a more realistic appreciation of Paleozoic lycopod structure and the floating forest hypothesis. Contemporary examples of dubious depictions of lycopod structures, ones showing gross distortions from the fossil evidence, are given. The work presented herein favors the silvomarine or floating forest hypothesis of Kuntze at the expense of the swamp hypothesis for the genesis of Paleozoic coal beds.

Acknowledgments

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References

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 2. Woolley, J.F., The origin of the Carboniferous coal measures—part 2: The logic of lycopod root structure, *J. Creation* **25**(1):69–76, 2011.
 3. The measurements of a Piesberg, Germany, *Stigmara* were taken from a figure in Hirmer, M., *Handbuch der Paleobotanik, Band 1: Thallophyta, Bryophyta, Pteridophyta*, R. Oldenbourg, Berlin, p. 294, 1927.
 4. Gillespie, W.H., Latimer Jr, I.S. and Clendening, J.A., *Plant Fossils of West Virginia*, West Virginia Geological and Economic Survey, Morgantown, WV, p. 55 (plate 7), January 1966.
 5. The modeling assumptions for the *Stigmara* were as follows: all rootlets were considered as being neutrally buoyant in water (based on the author's observations of the fossil evidence of their ease of pliability relative to their encasing medium and their radial symmetry). This fixed the density of the assumed rootlet solid structure to be 2.62 g/cm³ (using a cross-section for the rootlets of *Stigmara ficoides* Brongniart from Westfalen, Germany (Middle Pennsylvanian) as presented in Hirmer, ref. 3, p. 294, bottom right example, assuming their cores to be air-filled). As an aside, the density of silica and calcite are, respectively, 2.6 and 2.7 g/cm³. The roots were taken as being configured precisely as calculated in this section (calculated using averaged dimensions from a *Stigmara ficoides* Brongniart from Piesberg, Germany (Middle Pennsylvanian), Hirmer, ref. 3, p. 286; after: Potonié, H., Lichthof der Königlichen geologischen Landesanstalt und Bergakademie aufgestellte Baumstumpf mit Wurzeln aus dem Carbon des Piesberges, *Jahrbuch d. k. Preuß. Geol. Landesanst. für das Jahr*, 1889, Berlin, 1892. The lengths of the roots from their genesis point were normalized to be 4.5 m (9 m in diameter) for a mature specimen, as reported in Williamson, W.C., *A Monograph on the Morphology and Histology of Stigmara ficoides*, Palaeontological Society of London, London, 1887.
- It was assumed that the root development paralleled the development of the trunk, including that of its pith. Therefore, the trunk development will now be discussed. The height of a modeled *Sigillaria* was taken to be 30 m, a generally accepted maximum value (although higher estimated and actual values have been reported). The pith of the trunk was taken to follow a third order equation fixed to points along the figure presented below (from the literature) and allowed to asymptotically converge to its genesis point on the origin. This equation (in meters with y being the vertical distance) is
- $$y = 150.31 x^3 - 191.38 x^2 + 94.61 x$$
- for a *Lepidodendron* branching at 17.5 m. This and its vertical extension are taken as also representing a non-branching *Sigillaria* up to its maximum height. The conical exterior was also taken from this hand-drawn figure from the literature after obvious necessary smoothing adjustments were made. This same third-order equation that represented the trunk interior was taken as representing the mature interior development of the roots up to their first bifurcation. Thereafter up to (but excluding) the growth tip, the interior narrowing was taken as being linear. The spacing density of rootlets on the roots was taken as uniform but rootlets were assumed not to remain on the mature *Stigmara* before its branches became horizontal. A better,
- consistent estimate of the spacing density as a function of root diameter is possible only if the effects of elastic distortion due to the crushing of the roots can be adequately taken into account—something the author has yet to accomplish. The spongy material in the roots was taken to cover 30% of the remaining interior space, with the low density of 0.1 g/cm³. This estimate is predicated upon measurements taken on a *Stigmara* from the Scrubgrass coal layer of western Pennsylvania collected by the author. The *Stigmara* sample underwent an unusual electrochemical taphonomy, preserving the interior of the *Stigmara*. Rootlets are taken to be uniformly 2 meters long (with the density as noted above), a calculational consideration only when they are exposed out of the water. The exterior of the tip of the *Stigmara* was taken to be a right circular cone tapering from a radius of 2.60238226322 cm to a radius of zero in the last 10.16 cm of its length, following the formula
- $$y = -41.6000200119 r^2 + 32.7052618017 r + 10.16$$
- implicitly giving the radius of the circular cross section r as a function of y , the start of the last 10.16 cm of the root ($y = 0$) to its termination ($y = 10.16$), as averaged from measurements on specimens collected by the author [not believed by the author to have undergone much, if any, crushing].
6. However, note that root crossings were obviously known to leading researchers Kuntze, Brongniart and Williamson over a century ago. The early and ubiquitously copied misrepresentation of the appendices or rootlets on the *Stigmara* is noted by Dr Otto Kuntze in an extensive footnote on page 50 of his booklet *Geogenetische Beiträge*, Gressner and Schramm, Leipzig, 1895. They were once thought to be, and illustrated as, leaves.
 7. www.ucomp.berkeley.edu/IB181/VPL/Lyco/Lyco2.html. See figure 5.7 where the break in the lower, mature lycopod has been omitted, making it appear nearly five times smaller than it is known to be. The site was last visited by the author in January 2010.
 8. See e.g. Taylor, T.N., Taylor, E.L. and Krings, M., *Paleobotany: the Biology and Evolution of Fossil Plants* Elsevier, Burlington, MA, p. 251, 2009.
 9. Smith, E.L., *The State Museum of Pennsylvania: A Centennial History, 1905–2005*, Pennsylvania Historical and Museum Commission Harrisburg, PA, p. 26, 2005, as seen at www.portal.state.pa.us/portal/server.pt/document/1009151/100years_pdf, accessed 1 May 2011.
 10. McNeill, J., Barrie, F.R. and Burdet, H.M. et al. (Eds.), *International code of botanical nomenclature (Vienna Code) adopted by the seventeenth International Botanical Congress, Vienna, Austria, July 2005* (electronic edn), International Association for Plant Taxonomy, Vienna, Article 13, 2006; ibot.sav.sk/icbn/main.htm.
 11. Chaloner, W.G., Lycophyta; in: Boureau, E. (Ed.), *Traite de Paleobotanique, volume II: Bryophyta, Psilophyta, Lycophyta*, Masson, Paris, 1967.
 12. This figure is a copy of a diagram found on p. 316 of Stewart, W.N., A Comparative Study of Stigmarian Appendages and Isoetes Roots, *American J. Botany* **34**(6):315–324, June 1947. While this excellent coalball study takes great pains to argue along the lines of homologous development and adaptive reduction, using detailed microscopic evidence to argue its case, its phenomenal distortion of the macroscopic physiology of lycopods typically mirrors its evolutionary myoptism.
 13. The author has observed considerable taphonomic variation in rootlet diameter and great variation—including wrapping around the root—in rootlet direction. The rootlets are usually observed as being stiff, but they can also be undulating. The author does not discount the possibility of rootlet bifurcation.

Joanna F. Woolley is a store manager for a national jewelry store chain. She has an avid interest in gemstones, minerals, and fossils. This article is an outgrowth of a home school science project by Joanna F. Woolley. In addition to an avid interest in fossils, minerals, and gemstones, she is active in church work.