# An Investigation into an In Situ Lycopod Forest Site and Structural Anatomy Invalidates the Floating-Forest Hypothesis

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## Abstract

The hypothesis of an extinct pre-Flood floating-forest ecosystem has been promoted in the creationist literature for several decades and used as an explanation for the massive Carboniferous coal beds. However, it was recently shown that the idea sharply conflicts with both the available geological data and timing of global coal deposits and with the necessary hydrological criteria to sustain a freshwater lens. In this report, we present additional evidence negating the floating-forest hypothesis based on a well-preserved in situ lycopod biome known as the "Fossil Grove" in Glasgow, Scotland. This site reveals relatively equidistant-spaced trees at the same stratigraphic level that would typically occur in a forest ecosystem. The fossilized trees have downward penetrating roots within a lithified clay-rich soil in the same ecological schema as modern-day lowland/swamp trees. In addition, we present evidence that conflicts with the speculation by some creationists that both the aerial trunks and stigmarian roots of lycopods were hollow, a feature required to reduce weight and make the floating forest tenable. Based on data presented in this paper, combined with that given in a previous report, we strongly recommend that the floating-forest hypothesis be abandoned by the creationist community.

## Introduction

The idea of a floating forest has its original ideological roots in the ideas of nineteenth-century writings of Kuntze, a German author who could not envision a land-based source of origin for the transportation of plant debris to form the vast global coal deposits (Kuntze, 1895). This led Kuntze to the hypothesis that these plants must have been aquatic floaters. The work of Kuntze was published in German and not readily accessible to English-speaking researchers. Woolley (2010) recently published an account of Kuntze's ideas and the development of his silvomarine floating-forest idea.

Within the creationist community, Scheven (1981, 1996), was the first major proponent of the floating-forest

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hypothesis, which relied upon the early work of Kuntze. Building upon Scheven's reworking of the Kuntze hypothesis, other creationist authors such as Wise (2003, 2008), Woolley (2010, 2011a, 2011b), and Wieland (1995) have further elaborated upon the floating-forest idea and promoted the hypothesis within the creationist community.

The floating-forest hypothesis in its current form, postulates that an arboreal lycopod-dominated biome with trees up to 100 feet or more (30.5 m) in height existed on floating forests of continent-scale extent. In this scenario, the supposed hollow nature of lycopod trunks and stigmarian roots are thought to have made the floating forest possible. These floating forests were believed to have become so structurally and ecologically advanced that even freshwater pools and springs capable of supporting animal life were possible (Wise 2003, 2008).

The floating-forest hypothesis was developed by some creationists to explain extensive coal beds found in Carboniferous rocks. However, this paleontology-based hypothesis was never adequately tested against geological data. Clarey (2015) recently published a paper that presented three geological challenges to the floating-forest hypothesis. First, floating forests are incapable of maintaining a freshwater lens sufficient to support plant life, pools, and springs as suggested. Second, tsunami-like waves triggered by plate movements (Baumgardner, 2016) and other causes would have broken up the floating-forest biome earlier in the Flood than suggested, depositing coal beds throughout much of the stratigraphic column, contradicting the rock record. Third, relatively few coal beds developed as a result of the closure of the Iapetus Ocean ("proto-Atlantic") early in the Flood as Rodinia began to fragment. It is not until after this pre-Flood ocean was completely consumed that extensive coal beds deposited on the adjacent continents are found. When examined against available geological data, the floating-forest hypothesis lacks explanatory ability.

In addition to the coal-deposition argument, creationists have also used the claim that the dominant plant species of the carboniferous coals, arborescent lycopods, which can achieve heights of 111 feet (34 m) (Thomas and Watson, 2007), were the dominant plants of floating forests. It is believed that they formed floating mats with their stigmarian root systems, growing more densely than do trees in modern forests. But most importantly, it is believed that they contained hollow trunks and stigmarian roots that provided sufficient buoyancy to enable floating. These claims of alleged hollow trunk and roots lack significant support from available paleontological and geological data.

## Allochthonous vs. Autochthonous Upright Fossil Trees

One of the issues creationists must deal with is the claim by secular science that many upright fossil trees are found in growth position, commonly referred to as in situ trees. Secular paleontologists have used this claim as evidence against the Flood, even arguing that fossil-erect, in situ trees demonstrate an autochthonous origin for coal (Gastaldo, 1984, 1999). Creation scientists have countered this argument with evidence supporting the allochthonous origin of coal, showing many claimed in situ trees are better explained by active transport of trees and other vegetation during the global Flood.

The beginning of the allochthonous interpretation for coal goes back to the work of Kuntze (1895), Lemiére (1905), Nelson (1927), Price (1943), and Whitcomb and Morris (1961). These authors argued that pre-Flood trees were swept from the land during the Flood event, transported and subsequently buried as coal deposits. Upright trees or stumps were explained as trees that sank upright and were buried erect by additional Flood sediment (Nelson, 1927), resulting in polystrate fossils.

More recently, Austin (1979) and Scheven (1981, 1996) and Wise (2003, 2008) have concluded, albeit somewhat differently, that vast mats of floating vegetation existed in the pre-Flood world, either along the continental margins and/or across the open ocean. These proposed massive mats are envisioned to have later broken up during the Flood event, becoming deposited as represented by the globally extensive Carboniferous coal beds.

Though Clarey (2015) presented three geologic arguments against any pre-Flood floating-forest biome, he supports an allochthonous origin of coal. Clarey envisioned forests of lycopod trees fringing coastal and lowland areas of the pre-Flood continents that were similar to the cedar swamps and mangrove forests today. He postulated that as the height of the Flood waters increased, tsunami-like waves tore the lycopod forests free and deposited them *en masse* as coal seams within the sedimentary strata.

Over the course of this debate, many sites containing upright trees and stumps have been identified. There is no disagreement that upright trees and stumps exist in the rock record, but a central question remains: are these upright trees allochthonous or autochthonous? The answer to this question has tremendous implications for the extent of the Flood and the development of any global Flood model.

Empirical support for the allochthonous origin for upright fossil trees was found soon after the 1980 eruption of Mt. St. Helens. Austin (1986) estimated that more than 19,000 upright and randomly spaced trees had accumulated in the sediment beneath Spirit Lake in just a few years. These trees became waterlogged and sank upright because of their heavier bases and roots. Austin postulated that if these trees were buried by additional sediment, they would give the appearance of an in situ forest.

But does this explain all claims of in situ trees by secular science? In other words, are there any claimed in situ sites where the trees are in original growth position, or are they all products of transport during the Flood? The answer to this question also tests the validity of the floating-forest hypothesis. If a true in situ site is identified, showing no evidence of transport and with complete root systems embedded in a pre-Flood soil horizon (as opposed to having the roots torn off close to the trunk), it would strike a major blow to the floating-forest model. More importantly, it would demonstrate that lycopod forests existed rooted in soil, not floating as mats in water as proposed. However, the identification of an in situ site would not necessarily invalidate the allochthonous origin of coal beds. An in situ site could merely represent a location where the tops of the trees were sheared off, leaving the trunks and stumps buried in place.

This paper presents geologic criteria to assess whether or not an upright tree (or trees) is (are) in situ or not. And it identifies a site near Glasgow, Scotland, that appears to meet the vast majority of these proposed criteria and is possibly the first identified truly in situ lycopod forest.

## Geologic Criteria to Determine In Situ Trees

There are many claims of in situ tree sites in the secular literature, sometimes preserved as either Lagerstätten, or mass burials of entire ecological communities (Locatelli, 2014), or upright trees in claimed growth position, called $T^0$ assemblages (DiMichele and Falcon-Lang, 2011). Proposed in situ trees are most commonly found in Pennsylvanian system rocks (DiMichele and Falcon-Lang, 2011), the upper part of the Carboniferous. And all claimed Carboniferous in situ trees are from the Lower-Middle Pennsylvanian only (DiMichele and Falcon-Lang, 2011), corresponding to the onset of the Absaroka megasequence, the fourth of six recognized marine transgressions of the continents (Blakey, 2010; Morris, 2012).

Finally, the majority of the fossil Pennsylvanian system upright trees are arborescent lycopsids, or the rush, *Calamites*, preserved as mud- or sandcast plant stems, with only the basal 1–2 m of the fossil foliage commonly preserved in the rock record (DiMichele and Falcon-Lang, 2011). Secular paleontologists also believe that Pennsylvanian lycopsid forests were most likely preserved in wetlands, or wetter parts of dry environments that were buried and preserved due to a rapid rise in sea level (DiMichele and Falcon-Lang, 2011), coinciding with the advance of the Absaroka megasequence.

Interestingly, DiMichele et al. (2009) found that most of the stumps within claimed in situ assemblages, even as many as 800 trees at a single site, are randomly distributed spatially, not equidistantly spaced, and not interacting with one another in terms of the expected biological spacing for trees. The trees at these sites were undoubtedly transported and deposited by Flood waters and were not buried in their actual growth position. Tree spacing in such cases of transport would be expected to be random, showing no semblance of nearly equidistant spacing as observed in extant forests, as DiMichele et al. (2009) observed. Sites with claimed in situ and upright solitary trees also seem to be placed haphazardly and randomly and are often found above extensive deposits of coal and other sediments (DiMichele and Falcon-Lang, 2011). These individual stumps must also have dropped in place after a significant amount of Flood sediment was already deposited.

As creationists, how do we ascertain which trees are truly in situ, if any, and which ones are not? Criteria need to be developed in order to discern which fossil assemblages were buried in growth position and which were transported. The following are suggested criteria for the determination of an in situ assemblage. Some of these are from the secular literature, and others are tied directly to a global Flood perspective. Fossil trees that fulfill all, or at least most, of these criteria likely represent in situ assemblages.

1. Finding multiple, single-species trees spaced in growth position in the same horizontal plane, nearly equidistantly spaced in all directions from the trunks, tree to tree, and not merely randomly spaced (DiMichele and Falcon-Lang, 2011; DiMichele et al., 2009; DiMichele and DeMaris, 1982; Gastaldo, 1984).
2. Finding multiple trees in the same rock layer or along a common surface and/or stigmarian (root) axes interlacing with other trees over a common, three-dimensional, single rock layer (Gastaldo, 1984).
3. Finding trees with root systems (stigmarian axes) that crosscut bedding layers up to and even exceeding 30 degrees and possessing perpendicularly inserted radiating appendages (rootlets) (Gastaldo, 1984).
4. Evidence of rapid burial by thick sediment and water, which is common for most standing lycopsids (DiMichele and Falcon-Lang, 2011; DiMichele et al., 2009), and multiple trees at a single site that were distorted by water flow in the same direction during burial (Gastaldo, 1986).
5. Finding a lack of sedimentary rock layers underneath the trees. The presence of Flood-related layers underneath the trees would eliminate the possibility of in situ growth. In contrast, a lack of sedimentary layers under the trees, other than the fossil soil (paleosol) layer that contains the trees, would support the interpretation of an original pre-Flood setting.

In other words, in situ trees should have no substantial sedimentary layers beneath or fossils beneath or coal layers beneath.

6. Likewise, finding no bowing or distortion of any sedimentary layers beneath the tree stumps, which would indicate the tree was transported and emplaced from above during burial, distorting the underlying sediments (Oard and Giesecke, 2007).
7. Finding accompanying vegetation like *Calamites*, although rare, that crosscut the same layers as the lycopod tree stumps (Gastaldo, 1984).

## Geologic Setting of the Glasgow "Fossil Grove" Site

We have identified one particular site, in Glasgow, Scotland, that seems to meet nearly all these criteria. It is our contention that this site represents the remnants of a pre-Flood forest, with the fossil trees still rooted in a pre-Flood soil horizon (paleosol), now lithified to rock. If so, it is possibly the best preserved example of an in situ lycopod forest in the world (Gastaldo, 1986), and possibly the first identified in a Flood context. "Fossil Grove," as it is called, is located in Victoria Park in Glasgow, Scotland (Figure 1).

The Victoria Park "Fossil Grove" was discovered in 1887 as a path was being cut across an abandoned quarry outside of Glasgow (Owen et al., 2007). After excavation down to the common "soil" horizon containing the tree stumps and roots, a building was constructed to protect the site and allow public viewing. The site (Figure 2) consists of a monotypic assemblage of eleven lycopod tree stump casts with attached axial root systems (Gastaldo, 1986). However, only ten stumps are presently preserved and on view; one stump was significantly damaged in World War II (Owen, et al., 2007). The lycopod tree fossils at Victoria Park are found in rocks of the Clackmannan Group (Mississippian-Pennsylvanian systems), in a rock unit called the Limestone Coal Formation (Figure 3).

The 10 remaining stumps vary in height from 15–68 cm, and the tree spacing suggests a density of 4,500 trees per square kilometer (Owen et al., 2007). Each tree has preserved branching roots anchoring them in an irregularly laminated silty or sandy mudstone with

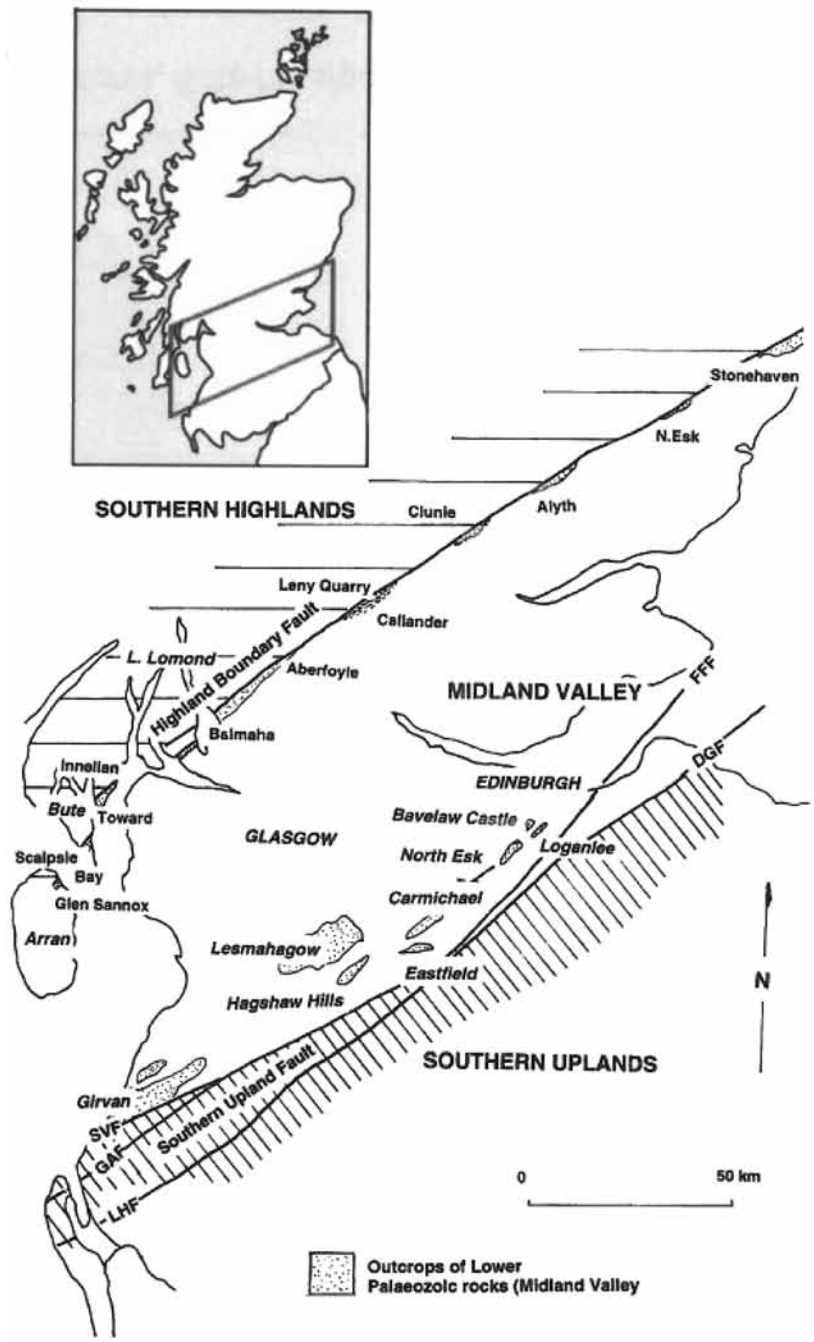



**Figure 1. Location map for Fossil Grove, Victoria Park, Glasgow, Scotland. Map shows the Midland Valley terrane bounded to the north and south by major fault systems. Map also shows the Lower Paleozoic outcrops clustered along the southern and northern boundaries of the terrane (modified from Bluck, 2002).**

**Figure 2. Late 1880s photograph of the lycopod tree stumps at Victoria Park, Fossil Grove. Note the intact roots penetrating the common subsurface horizon and the nonrandom (growth position), equidistant-spaced trees. Reproduced courtesy of Glasgow Museums and the Glasgow City Council.**

stigmarian (subterranean stem) "rootlets" penetrating the "paleosol" horizon (Gastaldo, 1986). This layer may have been a clay loam or a silty clay soil, according to the USDA classification system, and prior to burial, compaction, and lithification. The top of the mudstone is exposed as the surface layer of the exhibit (Figure 2).

Criteria to conclusively determine a preserved paleosol often involves a three-dimensional exposure and can be ambiguous (Klevberg et al., 2009). Unfortunately, the Fossil Grove site is exposed only down to the silty mudstone surface containing the tree stumps, making identification of soil structure impossible. Any sort of true, organic-rich A or O horizon may have been removed during deposition of the high-energy, overlying sandstone (see below). However, assuming the trees grew in a swampy, wetland-type environment; it is likely the trees would have been rooted in a clay-rich soil as observed (Mitsch and Gosselink, 1993).

The sandstone that had previously encased the stumps (before removal during excavation of the site) is a fine- to medium-grained, massively bedded sandstone (beds thicker than 20 cm) with asymmetrical ripples (Gastaldo, 1986). All of the tree stumps terminated upwards into this encasing sandstone layer. The sandstone also contains fossil casts of sand-filled *Stigmaria* and compressed *Cyperites* and prostrate broken trunk fragments, oriented in a dominant NE-SW direction (Gastaldo, 1986). Ripples in the encasing sandstone indicate water flow to the southwest during deposition, matching the long-axis orientation of the trunk fragments. The ten upright tree stumps also show marked distortion in the NE-SW direction, matching the flow orientation.

However, the tree roots (stigmarian axes) of the stumps imbedded in the mudstone paleosol below the encasing sandstone are not distorted in a NE-SW direction, and only show distortion vertically from burial (Gastaldo, 1986). This indicates that the tree roots were embedded in the underlying soil layer prior to burial by the encasing sandstone, strongly supporting an in situ interpretation. This sandstone also served as the casting lithology for the lycopod stumps and axial root systems (Gastaldo, 1986). Gastaldo (1986) also suggested that the "streamlining" of the stumps and loose trunk fossils in a NE-SW direction, the asymmetrical ripples, and the massively bedded character of the sandstone, indicate a high (mid-upper) flow regime during burial of the stumps.

Above the encasing sandstone is another thinly laminated, rippled, and cross-bedded coarse siltstone and interbedded sandstone. A disordered and transported coalified megaflora is found in this rock layer (Gastaldo, 1986). Both the encasing sandstone and the sandstone layer above indicate rapid deposition, contributing to the burial and preservation of the tree stumps.

In summary, the Glasgow site fulfills geologic criteria #1, #2, #3, and #4 for an in situ assemblage. The 11 single-species stumps were found in growth-position spacing as opposed to random spacing (Figure 2). The trees are all found in one common rock layer, likely representing a pre-Flood soil horizon. The root systems penetrate the paleosol horizon, similar to modern root systems. The encasing sandstone layer contains ripples and oriented, broken trunk fragments indicative of a high-energy flow system directed toward the southwest. The ten tree stumps are also consistently distorted in a southwesterly direction, matching the paleo-flow direction. This indicates all of the trees were likely in place prior to burial by the encasing sand.

Likewise, it is significant that the roots of the tree stumps are not distorted in a southwesterly direction like the tree stumps. If the tree stumps, roots and all,

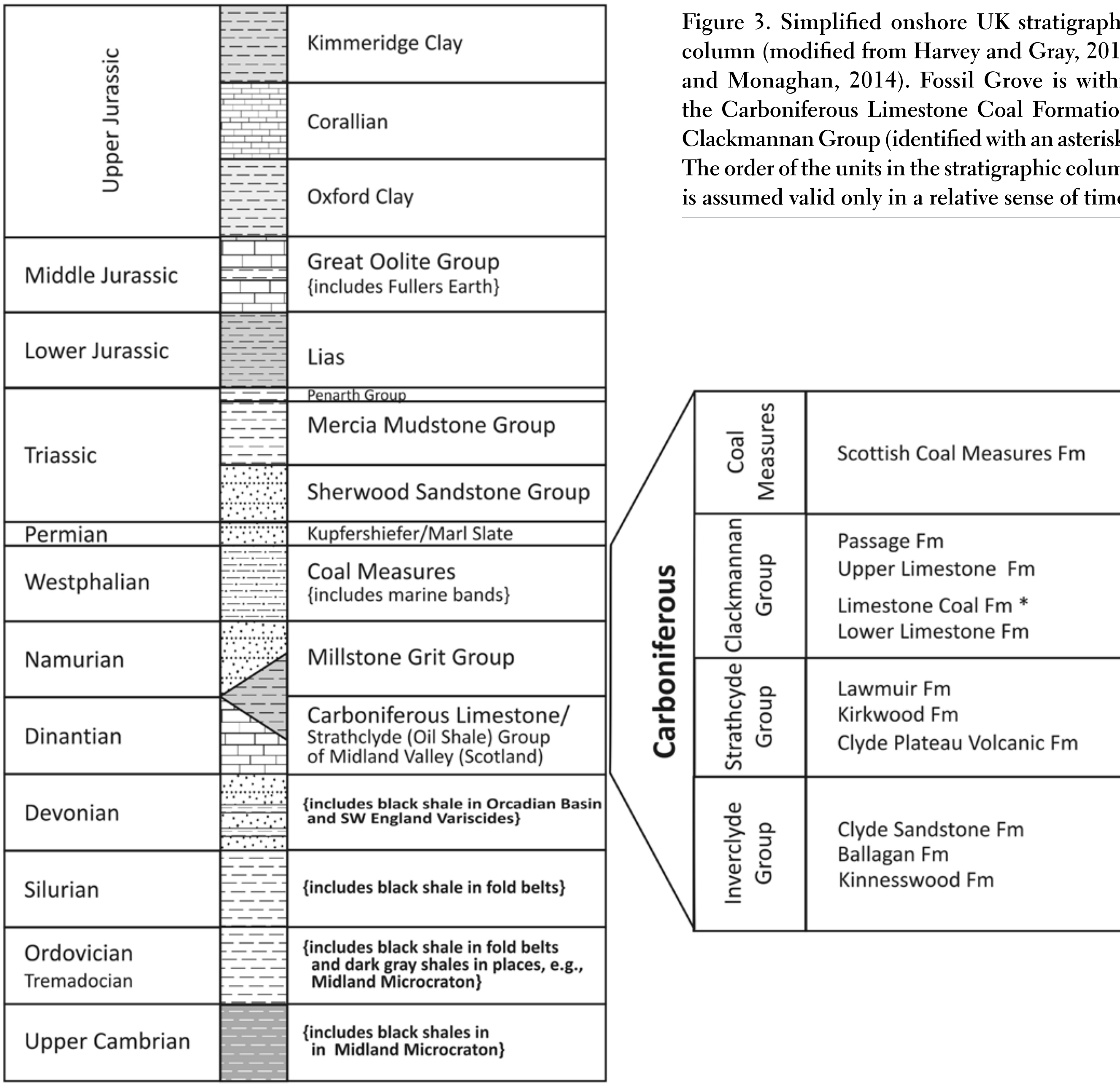



**Figure 3. Simplified onshore UK stratigraphic column (modified from Harvey and Gray, 2013, and Monaghan, 2014). Fossil Grove is within the Carboniferous Limestone Coal Formation, Clackmannan Group (identified with an asterisk). The order of the units in the stratigraphic column is assumed valid only in a relative sense of time.**

were transported in and deposited, there should be a consistent southwest distortion to the trunks and also to the roots. However, the lack of directional distortion in the roots (Gastaldo, 1986) suggests that the trees were rooted in the substrate prior to burial by the encasing sandstone. The only distortion of the roots is in a vertical direction, likely from compaction.

The consistent distortion of the trunks, the lack of similar distortion of the roots, and the nearly equidistant spacing of the tree trunks within a single horizon, collectively provide strong support for an in situ interpretation.

## Regional Geology of the Fossil Grove Site

The Fossil Grove site is in the center of the Midland Valley terrane of southern Scotland (Figure 1). This terrane is bounded to the north by the Highland Boundary Fault and to the south by the Southern Upland Fault. These two steeply dipping fault systems divide the Midland Valley terrane from the Southern Highlands to the north and from the Southern Uplands to the south (Figure 1). Lower Paleozoic sediment outcrops are found along and near both boundaries. Any potential Lower Paleozoic exposures between the two fault systems, including near Glasgow, are covered by Upper Paleozoic strata (Bluck, 2002). The lack of observed Lower Paleozoic rock exposures across the Midland Valley has left room for much speculation about its stratigraphic history (Bluck, 2002). As Bluck cautioned, “Flanking rocks may record a history that is not directly related to the Midland Valley itself but possibly to some extension of it along strike” (Bluck, 2002, p. 149). In other words, Lower Paleozoic sediments may not exist beneath Glasgow at all.

If the Glasgow fossil forest is truly an in situ site, Lower Paleozoic sediments within the Midland Valley terrane should gradually thin and become nonexistent in the Glasgow area. There should not be Flood-derived sediment underneath the fossil forest, according to criteria #5 and #6 above. The Glasgow area would have been high ground in the pre-Flood world so that the earliest Flood sediments (assumed to be Lower Paleozoic) failed to cover it until the water level became high enough to inundate the forest itself, encasing the tree trunks in sediment.

## The Case for a Pre-Flood High at Victoria Park, Glasgow

The oldest likely Flood-related rocks in the Midland Valley are Cambrian system limestones found along the northern edge of the terrane (near the Highland Boundary fault) (Bluck, 2002). Although creationists do not universally agree (Snelling, 2014), it is assumed that the Lower Paleozoic layers represent the earliest, globally extensive Flood deposits. Below these rocks lies a metamorphic complex composed primarily of amphibolite (Bluck, 2002). The Cambrian system rocks are overlain stratigraphically by limited amounts of Ordovician system black shale and more limestone on the southern margin of the terrane (Bluck, 2002) (Figure 3). Silurian system deposition was a bit more extensive in the Midland Valley; these black shales blanket the Ordovician system rocks along the southern margin of Midland Valley, just north of the Southern Uplands fault (Figure 1). Some of these Silurian system rocks may even be part of the lowermost Old Red Sandstone sequence (Bluck, 2002).

However, throughout this Early Paleozoic depositional cycle, the Glasgow area seems to have been a topographic high, receiving little, if any deposition. Bluck (2002) showed a topographic high, termed the Midland Valley Arc, likely existed during deposition of the Ordovician and Silurian system sediments in the center of the Midland Valley terrane, including the Glasgow area, sloping downward on both the north and south flanks. The Midland Valley in general is not a simple graben, or downthrown block, between major fault systems (Figure 1); “it is composed of a series of inter-related depocentres and intra-basinal highs” (Monaghan, 2014, p. 26).

The lack of sediment accumulation in the Glasgow area apparently continued during deposition of the Lower Old Red Sandstone (Silurian?), where outcrops are visible only along the northern and southern margins of the Midland Valley terrane and seem to match the extent of other Lower Paleozoic sediments (Trewin and Thirlwall, 2002). The Middle and Upper Old Red Sandstone (Devonian) sequence also thickens on the margins of the Midland Valley terrane with some deposits of over 1,000 meters along the northern margin and several hundred meters along the southern margin (Trewin and Thirlwall, 2002). Neither of these rock units can be observed in the vicinity of Glasgow, which may indicate that a sizable pre-Flood high prevailed in the Glasgow area with deposition only on the adjacent flanks (Figure 4). Bluck (2002, p. 166) said, “The difficulty [of these geologic interpretations] lies not only in the paucity of evidence but also in the ambivalence of the evidence available.”

Analysis of the Lower Carboniferous strata (below the level of the Fossil Grove strata) (Figure 3) also indicates thinning near Glasgow (Read et al., 2002), indicative of a paleo-high. Rocks of the Mississippian system Inverclyde and Strathclyde Groups are either nonexistent or are observed to thin dramatically near Glasgow (Read et al., 2002) (Figure 5). Although Read et al. (2002) interpreted some deposition of

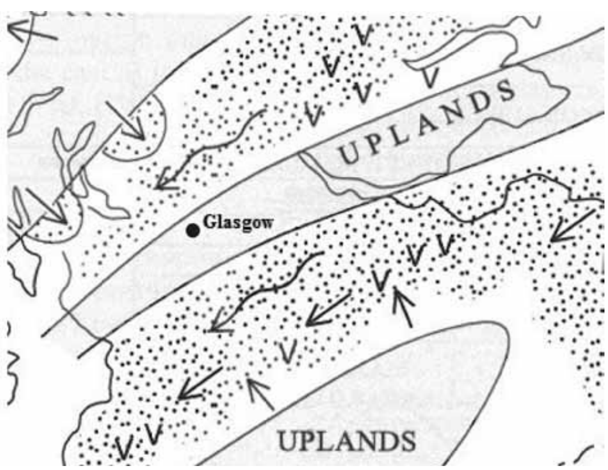



**Figure 4. Paleogeographic map of the Lower Old Red Sandstone (Silurian system?) (modified from Trewin and Thirlwall, 2002). Note the interpreted uplands across the Glasgow area where no deposition is observed.**

the Strathclyde Group near Glasgow, the thickness is only postulated and not based on empirical borehole data.

One oil well was drilled about 10 km east of Glasgow in 1989, the Marinex Bargeddie 1, that encountered rocks of the Strathclyde Group (West Lothian Oil-Shale Formation), finding some minor natural gas (Monaghan, 2014). However, there are no available deep well data beneath the city of Glasgow and Victoria Park. Monaghan (2014) reported that 98 oil wells were drilled in the Midland Valley between 1919 and 2008, and only 15 of these wells went deep enough to penetrate the Mississippian (Lower Carboniferous) Strathclyde Group. This lack of empirical information has added to the difficulty in the subsurface interpretation. All existing data indicate that a high existed during the deposition of the Mississippian system (Lower Carboniferous) units near Glasgow.

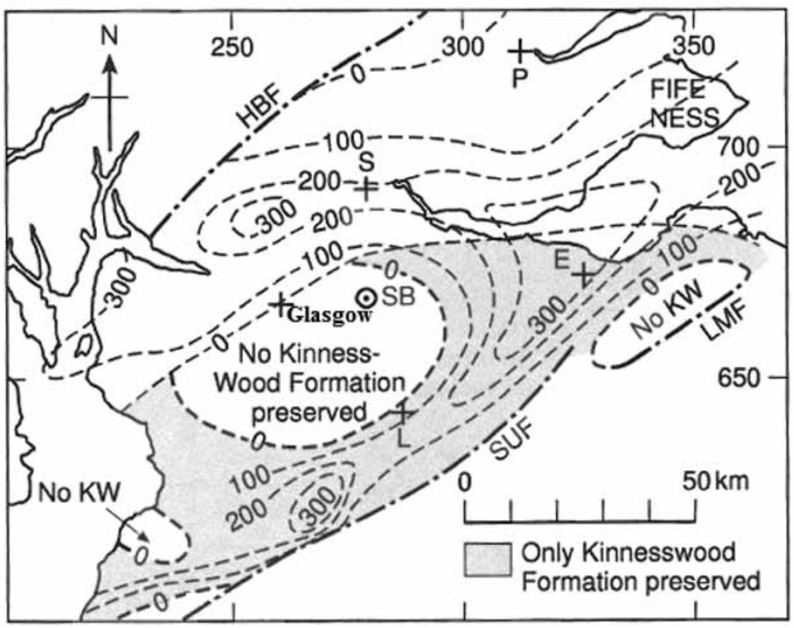
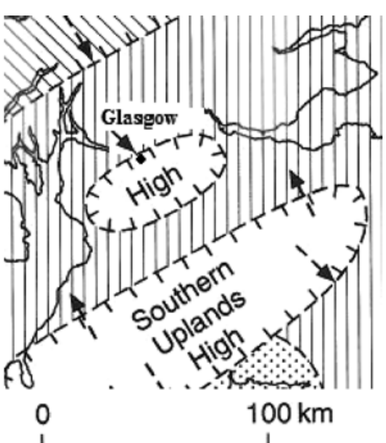



**Figure 5. (5A, above) Isopach map (m) of the Kinnesswood Formation, Inverclyde Group in central Scotland, showing little to no deposition near the city of Glasgow. The Inverclyde is the unit below the formation containing Fossil Grove (Figure 3). SB = Salsburgh Borehole; HBF = Highlands Boundary Fault; SUF = Southern Upland Fault (modified from Read et al., 2002).**




**(5B, left) Paleogeographic map of the Ballagan Formation, Inverclyde Group, showing a well-developed high interpreted across the Glasgow area during deposition of this unit (Figure 3), resulting in no deposition. Vertical lines = marine sediments, Dotted areas = siliciclastics (Modified from Read et al., 2002).**

The next unit deposited in the Midland Valley was the Clackmannan Group (Mississippian-Pennsylvanian). The lowermost unit in the group is called the Lower Limestone Formation (Figure 3). The next younger unit above is the Limestone Coal Formation, which contains the lycopod tree fossils at Victoria Park. The Lower Limestone Formation, the unit just below the fossil forest layer, has been interpreted to have attained a thickness of about 150 meters near Victoria Park, Glasgow (Read et al., 2002). However, Read et al. (2002, p. 276) pointed out:

> Because the Lower Limestone Formation lies below most of the economically workable Carboniferous coals, borehole information is sparse and our knowledge is more dependent on scattered outcrops. Thus the isopach map [showing 150 m of sediment] and the map summarizing palaeogeography, active structures and volcanicity are more conjectural than the corresponding maps for higher formations [including the layer containing the lycopod trees].

As for the layer that contains the fossil forest, Read et al. (2002) mapped a thickness of about 300 m for the Limestone Coal Formation across the Glasgow area. It is well exposed over a large portion of the central Midland Valley and has been extensively studied from outcrop and shallow borehole data in the search for coal (Read et al., 2002).

Possibly the strongest argument for a pre-Flood high persisting until the Carboniferous at Fossil Grove, Glasgow, comes from a recent three-dimensional seismic model done by the British Geological Survey (Monaghan, 2014). The model utilized 1,325 km of onshore seismic data, 478 km of offshore seismic data, 37 of the deepest oil wells from the 98 total boreholes, and all available coal mine data in the Midland Valley. Unfortunately, the seismic data did not extend across the city of Glasgow but was limited to about 3 km to the east, and the nearest oil well was also about 6 km east of the city of Glasgow (Monaghan, 2014). Results of the three-dimensional study showed a dramatic thinning of all Carboniferous units from the east, near Edinburgh, to the west, near the city of Glasgow (Monaghan, 2014, Section B-B' their Figure 66). Their model confirms the interpretation of a preexisting high found early in the Flood, preserving the Fossil Grove in Victoria Park from flooding until encased by the sandstone of the Limestone Coal Formation.

## Were the Trunks and Roots of Arborescent Lycopods Hollow?

Another line of reasoning put forth in support of the floating-forest hypothesis is that the arborescent lycopod trees were allegedly hollow in both their main aerial trunks and in their stigmarian roots—a contention based primarily on superficial speculation and not soundly supported by the scientific literature. The postulated hollowness of these large trees by floating-forest proponents would be required to reduce weight, provide buoyancy, and keep the whole floating forest from sinking into the primeval ocean.

The idea that the stems and roots were actually hollow rather than filled with easily degraded parenchymous tissues seems to be the track favored and promulgated among creationists, first by Scheven (1981, 1996) and then later by Wise and Woolley (Wise 2003, 2008; Woolley 1999, 2010, 2011a, 2011b). Unfortunately, the majority of these studies do not take into account a number of key reports describing the non-hollow internal structure of lycopods that will be briefly recounted here. For all practical purposes, creationist authors such as J. F. Woolley and Wise have taken Scheven's assertions regarding the alleged hollow nature of lycopods without serious critical analysis of the existing literature on the topic.

Prior to the creationist promotion of the hollow-lycopod hypothesis, the idea that they were hollow or contained possible air cavities within the parenchymatous tissue (known as *aerenchyma*) was first promoted by Kuntze (1895). However, there is a significant difference between empty space inside the trunks and roots of a large tree-like plant as opposed to the presence of supporting structural tissue. The concept that the internal cortex tissue may have in fact been parenchymatous with small air spaces is a viable idea since the woody stele containing the central vascular system of the stem and roots would have required an extensive network of support tissue to keep it situated in place in addition to the lateral vascular rays emanating from the stele and connecting with the outer periderm. This is even more true regarding the large stigmarian roots that are horizontal to the gravitational field of the earth. To assume that there was not parenchymatous cortex support tissue inside them to keep the central woody stele and vascular rays in place defies the laws of physics and common sense.

In fact, this basic non-hollow anatomy is well established in arboreal lycopod stem tissue, which is typically well preserved (DiMichele 1981). The problem lies in the fact that very little of this internal cortex tissue is well preserved in the large trunks and stigmarian roots. Based on evidence of the preserved trunks at the Fossil Grove site mentioned above, which contains much better-preserved specimens than are typically found, Gastaldo (1986) was able to re-create the internal anatomy of lycopod trunks as shown in Figure 6. From these fossilized tree tissues, Gastaldo was able to show that three layers of internal parenchymatous cortex tissue existed that became preferentially degraded over the other intervening layers and central vascular stele.

The idea that easily degraded aerenchymatous tissue is the best explanation for the apparent hollowness of lycopod casts contains significant support from porous parenchyma found in the root cortices of many wetland plants alive today (Green 2010). In addition, in many other non-wetland plants, aerenchymatous tissue can develop in response to oxygen-depleted soils in a process called "induced" or "facultative" aerenchyma, while in other species it is formed irregardless of the growth conditions (Green 2010). In fact, the spongy mesophyll tissue in dicot plant leaves is also known as aerenchyma. Given that it is widely acknowledged that arboreal lycopods inhabited tropical lowland and/or wetland areas based on the types of sediments in which they are found (DiMichele and Philips 1994), it is not surprising that they would exhibit a tissue structure similar to modern plants inhabiting the same environs.

It is believed that root respiration in lycopods would not have been possible without the ability of the aerenchyma system to facilitate the supply of oxygen downward to the stigmarian roots (Green 2010). Based on the apparent rapid accumulation of biomass in lycopod forests, the amount of carbon acquired from leaf stomata would have been limiting. Therefore, it is highly probable that carbon was obtained from the clay-rich soils in which they grew. This rapid biomass accumulation scenario further limits the viability of a floating mat but is best explained by a lowland clay-rich soil.

Our knowledge of the stigmarian root structure of arborescent lycopods is chiefly based on the tree-sized lycopod species *Stigmaria ficoides*. The three most complete studies of this structure come from Williamson (1887), Frankenberg and Eggert (1969), and Eg-

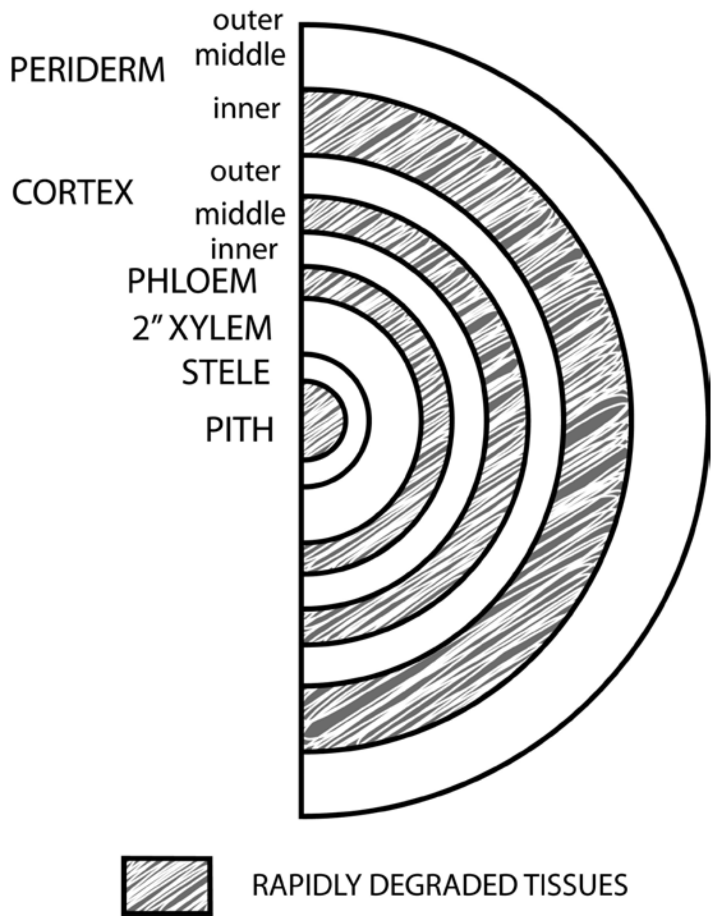



**Figure 6. Diagram of the anatomy of lycopod trunks at the Fossil Grove site in Glasgow, Scotland, showing tissues predisposed to early degradation prior to being encased in sediments. This feature provided the mechanism for introducing sediments into the trunk for casting. Figure adapted from Gastaldo (1986).**

gert (1972). The stigmarian roots are composed of a central woody stele that contains the vascular tissue surrounded by pithy tissue. Then surrounding the central stele is a three-zoned cortex similar to that of trunks but on a smaller scale. The inner cortex composed of parenchyma surrounding the stele is typically poorly preserved. However, a specimen in the curation of the Institute for Creation Research (ICR) clearly shows a contiguous region of well-preserved aerenchymatous tissue between the central stele and outer periderm (Figure 7). This specimen has yet to be sectioned for further study but adds additional strong evidence of internal supporting tissue, negating the alleged hollowness of stigmarian roots.

## Discussion and Conclusions

Local geologic studies, based on extensive seismic, well, and outcrop data, support the interpretation that early Flood sedimentation did not occur at the Fossil Grove site in Glasgow. In addition, the site satisfies six of the seven proposed criteria for an in situ site. The only criterion it does not meet is the expectation of accompanying vegetation crosscutting the same horizon as the trunks (#7), likely because the evidence for other plant fossils was destroyed during the removal of the encasing sandstone to expose the trees. Nonetheless, because this site meets the vast majority of the criteria, the Fossil Grove site is interpreted as a true remnant of a pre-Flood forest that was not inundated and buried until deposition of the latest Mississippian/earliest Pennsylvanian (Carboniferous) system rocks, approximately midway through the rising portion of the Flood. Allochthonous layers of coal were further deposited on top of the trees as part of the Scottish Coal Measure Group (Figure 3).

This interpretation supports the suggestion by Clarey (2015) that as the Flood waters increased, tsunami-like waves tore the bulk of the lycopod forests free and deposited them elsewhere as coal beds (allochthonously). As is the case with the Fossil Grove, the lycopod trees were likely already dead and their trunks already broken off, allowing substantial decay of the stumps to have occurred prior to burial in the encasing sand (Gastaldo, 1986).

If this interpretation is correct, Fossil Grove would be the first documented in situ preservation of antediluvian soil and plants. However, it does not support the floating-forest hypothesis as the tree roots of the eleven stumps are found embedded throughout a common paleosol horizon. All geological findings indicate that these tree stumps are in growth position and were inundated, buried, and fossilized in situ by rising Floodwaters. The trees are nearly equidistantly spaced, their roots penetrate downward into the soil horizon, and there is no indication of earlier Flood sedimentation beneath the soil layer. Even if the argument is made that the Glasgow site represents a landslide that transported the eleven intact tree stumps during the Flood, along with the surrounding soil, it still demonstrates that the trees were rooted

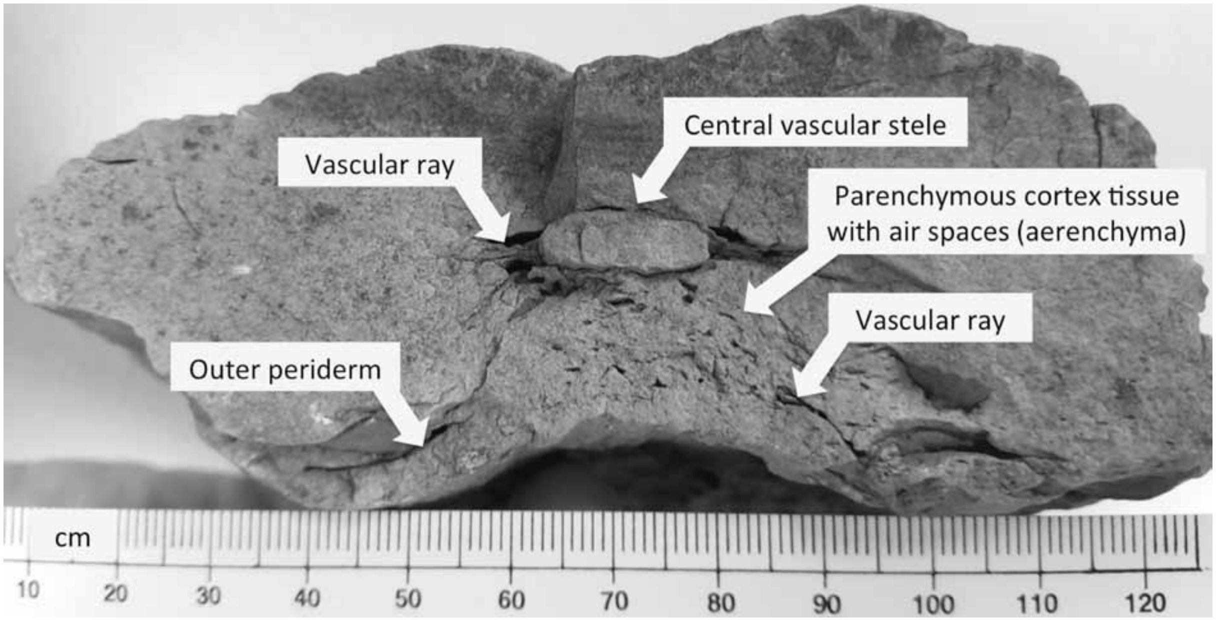



**Figure 7. Cross section of a stigmarian lycopod root recovered in northeast Texas near the Oklahoma border.**

and not part of a floating-forest biome. The floating-forest hypothesis clearly fails the test based on this site.

The aerial parts of arborescent lycopods were structurally composed of a limited amount of secondary xylem tissue in proportion to a large quantity of periderm (DiMichele, 1981). Figure 6 depicts the anatomy of lycopod trunks as determined by a study done at the fossil grove in Scotland discussed above. The trees in the fossil grove had achieved significant levels of decay prior to being buried in sediments, given that they were easily sheared off at different heights (Gastaldo, 1986). Because the outer bark is quite woody and durable, this clearly shows that a significant level of tissue decay had taken place before the trees were sheared and inundated with sediments.

In fact, it is now becoming apparent that the global Flood occurred in successive waves of inundation (Snelling, 2014) and that initial stages would have caused a great deal of plant death followed by decomposition of easily destroyed parenchyma tissue in the internal cortex region of lycopod trunks and roots. The aerial structures and stigmarian root systems would have undergone selective decay of tissues in the central cortex while retaining overall morphological shape during the hollowing process in which sediments were introduced into the cavity, creating casts. In addition, intact non-decayed aerial stems of arborescent lycopods clearly indicate a contiguous tissue structure across the breadth of the stem with the same general schema found in trunks and roots, although the trunks tend to rarely have the inner cortex tissues preserved.

The idea that the more resilient central stele tissues inside the stems and particularly within roots somehow stayed situated in the center of these structures in defiance of gravity during normal growth, and without the aid of any supportive tissue besides the vascular rays, is patently absurd and not observed in any known plant species today. Furthermore, a well-preserved stigmarian root in the curation of ICR clearly shows that the parenchymatous cortex forms a contiguous progression from the stele to the outer periderm (Figure 7), adding further fossil evidence negating the alleged hollowness of these structures required for reducing weight in a floating mat.

All available geologic and fossilized anatomical data support the existence of pre-Flood lycopod forests rooted in soil. These forests were likely located in wetlands and/or coastal lowland areas as suggested by Clarey (2015). Detailed analysis further demonstrates the trunks and the roots were not hollow as previously claimed. Based on these data, and that of Clarey (2015), we strongly recommend abandoning the floating-forest model.

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