The Heavener Roadcut: Deltaic Environment or Flood Deposit?

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Abstract

The Hartshorne Formation in Oklahoma has been interpreted as being deposited in various delta-type environments. A better explanation would be that the strata were deposited in a catastrophic environment as illustrated by cross-bedded sand units and a significant amount of plant material. The plant material likely was derived from a floating forest, and its fossil remnants are now found as upright tree casts and molds, along with carbonaceous layers of plant debris and coal.

Introduction and Site Location

The Heavener roadcut exposes two formations: the Atoka Formation and the overlying Hartshorne Formation. This exposure of the Hartshorne Formation probably has been visited by more geologists than all other Hartshorne Formation outcrops in Oklahoma combined. The accepted uniformitarian interpretation (Suneson and Hemish, 1994) is that the exposed strata in the roadcut were deposited in interdistributary marshes and swamps in a delta-plain environment. Over the years, this exposure has been interpreted in many ways (see below), ranging from fluvial-deltaic to marine settings. A better explanation is that the strata were deposited by flood processes.

The roadcut is located along U.S. Highway 59/270, approximately two miles south of Heavener, Le Flore County, Oklahoma (Figure 1). Structurally, this outcrop is in the southern part of the Arkoma basin in eastern Oklahoma. Situated on the south flank of the Pine Mountain syncline, the roadcut is approximately one mile north of the trace of the Choctaw thrust fault, which is the leading imbricate fault of the Ouachita Mountains. Beds in the exposure dip approximately 30 degrees to the north but are otherwise undisturbed.

The Hartshorne Formation is the basal Desmoinesian (Middle Pennsylvanian) unit in the Arkoma Basin of Oklahoma and Arkansas. The Hartshorne Formation conformably to disconformably overlies the Atoka Formation and is generally conformable to the overlying McAlester Formation, which is missing at the study site. The Atoka Formation is visible on the southern end of the roadcut and consists mostly of black to gray shale. The Hartshorne Formation consists of sandstone, siltstone, shale, coal, and rare conglomerates (Suneson, 1998). In general, the formation forms a ridge bordered on both sides by valleys underlain by the shale-dominated Atoka and McAlester Formations.

Uniformitarian Interpretations of the Hartshorne Formation

Many geologists have interpreted the depositional environment of the Hartshorne Formation.

- Suneson and Hemish (1994) state that the strata were deposited in interdistributary marshes and swamps in a delta-plain environment. Coal beds represent periods of peat accumulation with little or no sediment influx; shale intervals represent periods of slightly greater clastic sedimentation; and the sandstones are overbank and/or crevasse-splay deposits that probably represent periods of flooding.
- Suneson (1996) indicates that the *Calamites* casts at this locality are comparable to modern

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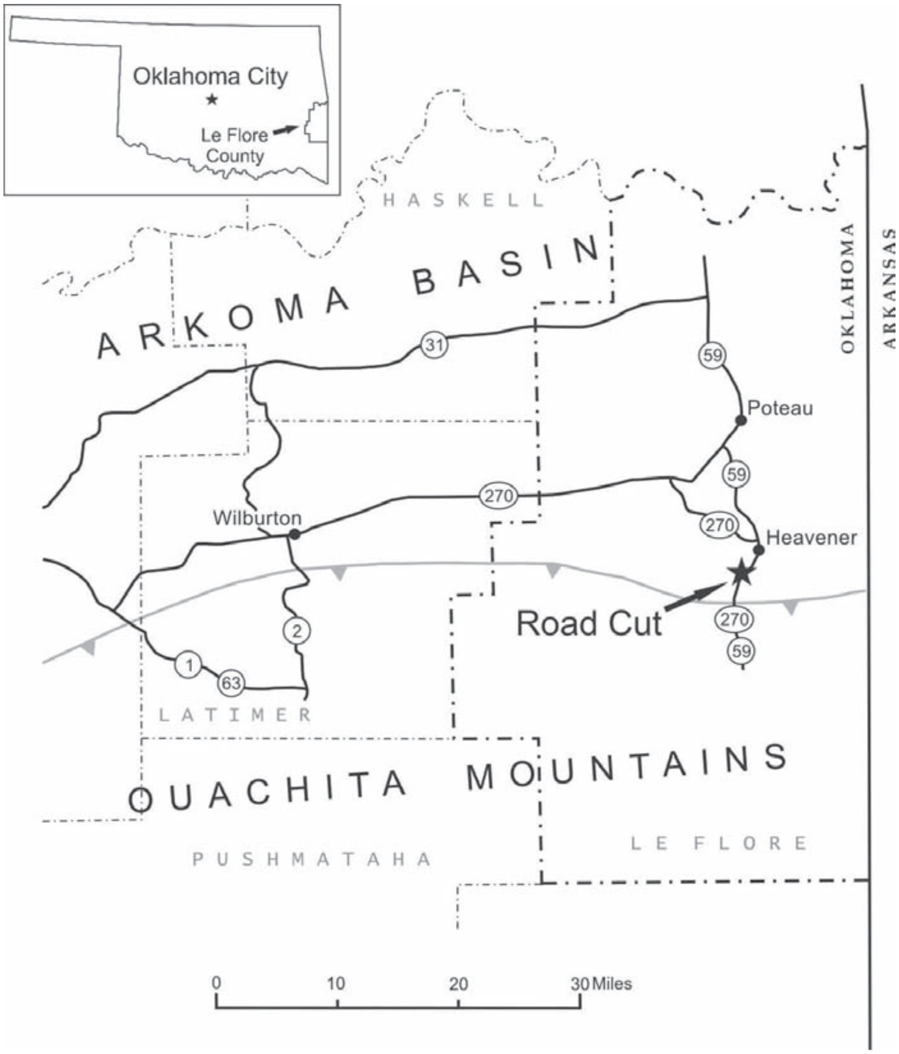

Figure 1. Location of the Heavener roadcut, Le Flore County, Oklahoma (Section 36 of Township 5N and Range 25E, NW, SE, NW) just north of the Choctaw thrust fault, separating the Ouachita Mountains and the Arkoma Basin.

plants found in swamps and along streams.

- Slatt et al. (2005) state that the Atoka Formation at this locality consists of bay-fill shale and marsh (coal) deposits. The overlying, lowermost sandstone of the Hartshorne Formation varies from marine bar to incised-valley fill to delta-plain crevasse-splay and bay-fill deposits.
- Roberts (1987) interprets this section to represent various delta-plain facies.
- Suneson (1998) summarizes previous interpretations based on the different lithofacies associated with the Hartshorne Formation. He states that most studies have focused on its depositional environment within a delta system. Workers recognized the many abrupt lateral facies changes within the Hartshorne Formation and related the different lithofacies to sedimentation on different parts of a delta. The different lithofacies include
  - o Prodelta facies
  - o Distal-bar subfacies of the delta-front facies
  - o Distributary-mouth-bar subfacies of the delta-front facies
  - o Frontal-splay subfacies of the delta-front facies
  - o Interdistributary-bay/tidal-flat facies
  - o Crevasse-splay facies
  - o Marsh-swamp facies
  - o Fluvial facies
- Suneson (1998) also summarizes other workers' interpretations from an overall basin perspective. These workers concluded that in eastern Oklahoma, the Lower Hartshorne Member consists of a delta-front facies overlain by two west-to-southwest-trending, relatively narrow distributary channels, separated by widespread interdistributary-bay deposits. In the western part of the Arkoma Basin, strata of the distributary-channel facies are relatively thin and narrower to the east and show repeated bifurcations. The interdistributary facies is widespread, and the delta-front facies is absent. The Upper Hartshorne Member is generally similar to the Lower Member, except that a delta-front facies has not been recognized. In Oklahoma, the prodelta shale of the Atoka Formation is widespread, as is the marsh-swamp facies (Hartshorne coals).
- Suneson (1998), when again describing the Hartshorne Formation, makes two comments about the depositional environment. First, he states that the Hartshorne in the southern part of the Arkoma basin of Oklahoma is fluvial-deltaic in origin. Then,

in the next paragraph it is noted that despite the near absence of marine fauna, most of the exposed part of the Hartshorne Formation is marine, except in the eastern part of the Arkoma basin of Oklahoma, where parts of the upper Atoka contain coal. His statement then follows that it is possible some of the Hartshorne in the southern part of the Arkoma basin is not associated with deltaic processes, in which case it would be preferable to use marine-coast terminology.

- Finally, Suneson (1998) again states that nearly all workers have accepted the delta model, but in the next paragraph he makes the statement that most outcrops of the Hartshorne Formation in the southern part of the Arkoma basin in Oklahoma were deposited in a marine environment. However, as noted above, he states that the Hartshorne Formation in the southern part of the Arkoma basin is fluvial-deltaic.

Which one is it, fluvial-deltaic or marine? The general consensus from all previous workers is that the Hartshorne Formation is part of a vast delta system that existed in the Pennsylvanian. The issue is confused by stating that the Hartshorne in the study area is: (1) fluvial-deltaic; (2) marine, except in the study area where the underlying Atoka contains coal; and (3) may not be deltaic in the southern Arkoma basin but rather a marine-coast environment. The depositional environment varies even in the same publication by the same author. The delta model is entrenched in the literature, and because few think outside the model, these obvious contradictions throw doubt on the interpretation. A close study of the rocks indicates that the strata were laid down in swiftly flowing water and upright tree casts found there are not relicts from trees that grew there.

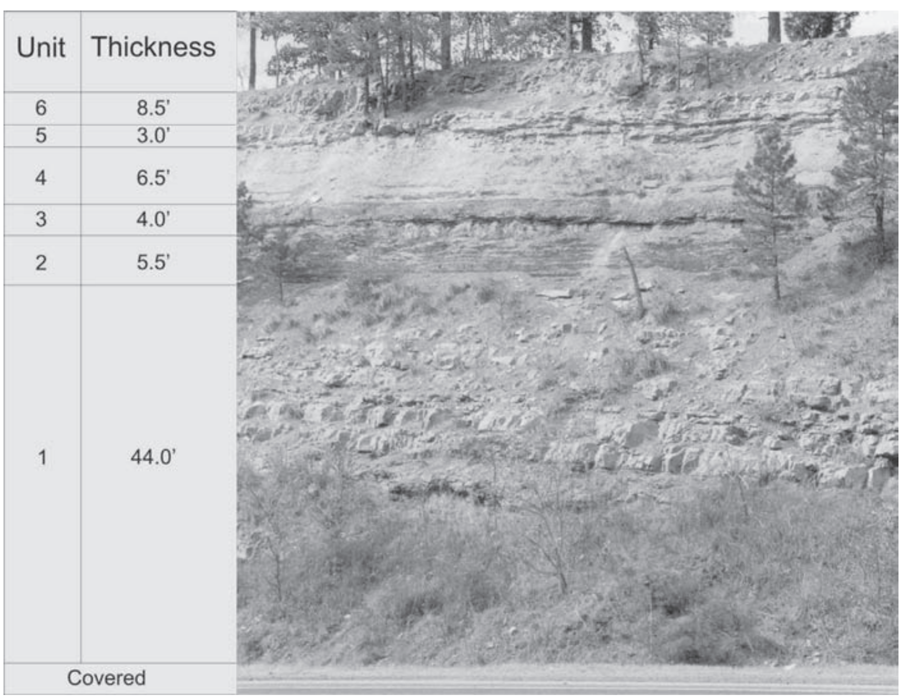

Figure 2. The Heavener roadcut showing the six-part division of the Hartshorne Formation based on rock type.

Evidences Favoring Catastrophic Flood Deposition

Commenting on the Hartshorne Formation, Suneson and Hemish (1994, p. 100, emphasis added) state that "the sandstones are overbank and/or crevasse-splay deposits that probably *represent periods of flooding*." Evidence for this interpretation is not listed by those authors, but their interpretation may be derived from the abundant cross-bedding in the Hartshorne sand units, along with the paleocurrent direction exhibited by *Calamites* molds. These indicators will be discussed below.

Rock Units

Donica (1978) divides up the Hartshorne at this location into 20 different zones. Most of these come from subdividing the interbedded sands and shale units in the lower Hartshorne. For the current study, the exposure has been divided into six intervals based on rock type (Figure 2). From the base upward, we find:

- Unit 1: Interbedded light brown massive sand and shale.
- Unit 2: Black, jumbled, carbonaceous plant material.
- Unit 3: Black coal (Lower Hartshorne coal seam) with underlying gray clay (underclay).
- Unit 4: Black shale, grading upward to gray
- Unit 5: Sand, mostly tan with some gray and poorly cemented. Minor coal seams.
- Unit 6: Sand, light brown and massive.

Flow Indicators

Two primary flow indicators can be found in the strata. Units 1, 5, and 6 all exhibit extensive cross-bedding (Figure 3). The orientation of the cross-beds indicates that water flow depositing the sand was from south to north. Also seen in Unit 1 are *Calamites* molds, which can be seen in various orientations from vertical to horizontal (Figures 4 and 5).

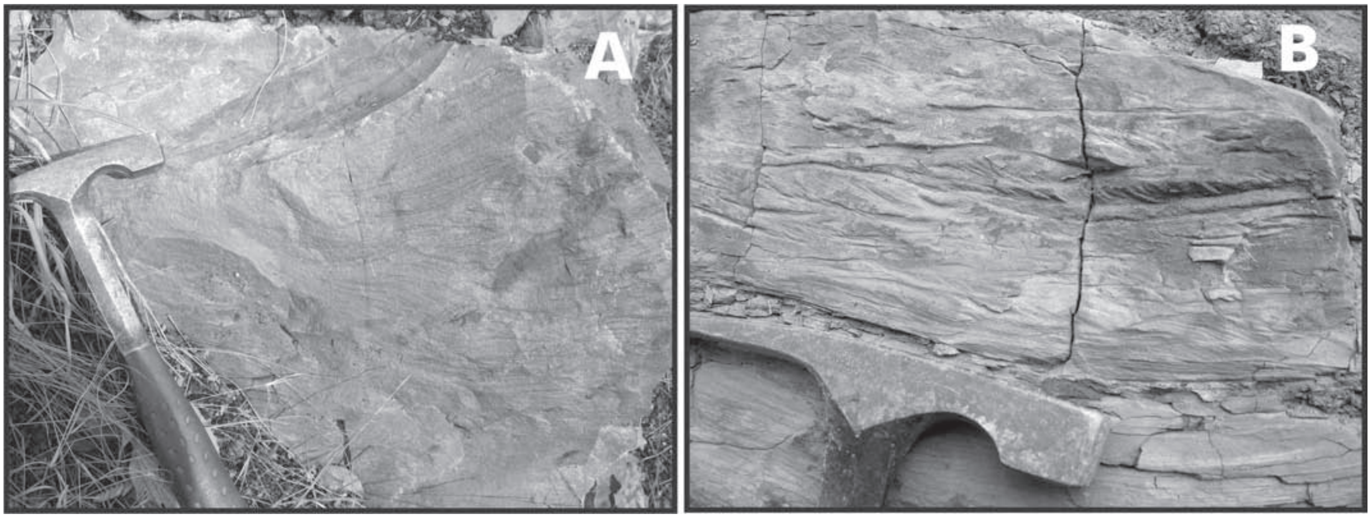

Figure 3. (A) Cross-bedded sandstone of Unit 1. Note the *Calamites* mold in a near-horizontal position. North is to the right. (B) Cross-bedded sandstone of Unit 5 showing flow direction from left to right (north). Rock hammer for scale.

These molds do not represent in situ plants. They were transported there from somewhere else by floodwater and then buried in sand that was also deposited by flowing water as illustrated by the cross-bedding. In addition, the lack of roots on all *Calamites* molds found in Units 1, 4, 5, and 6, along with the appearance of some molds being "dropped" into place (Unit 4, discussed below), support the idea that the plant material was not in situ.

Figure 4. Calamites **molds in various orientations in Unit 1. Mold orientation and cross-bedding indicate water flow was to the north (right).**

Stigmaria Root

A *Stigmaria* root was identified in Unit 1, approximately three feet below the Lower Hartshorne coal seam. The exposed portion of the root is approximately 11 feet long, and the sand unit immediately above the root contains rootlets that extend upward from the *Stigmaria* root (Figure 6). *Stigmaria* is the generic name given to fossil root casts of various tree species of the Pennsylvanian Period, regardless of the form, genera, and species (Heib, 2006). The type of root found is mostly associated with *Lepidodendron*.

Stewart (1983) describes *Stigmaria* as being frequently found in the unstratified shale that represents the underclay of the original swamp. A seam of coal representing the decayed and compressed vegetation on the floor of the swamp usually lies on top of the stigmarian underclay. Wieland (1995) agrees that *Stigmaria* are generally underneath coal seams. Stewart (1983) suggests that they are in situ and were produced by the lycopods that grew in the ancient swamp that are now part of the coal seam.

Schonknecht and Scherer (1997) state the following about Carbonifer-

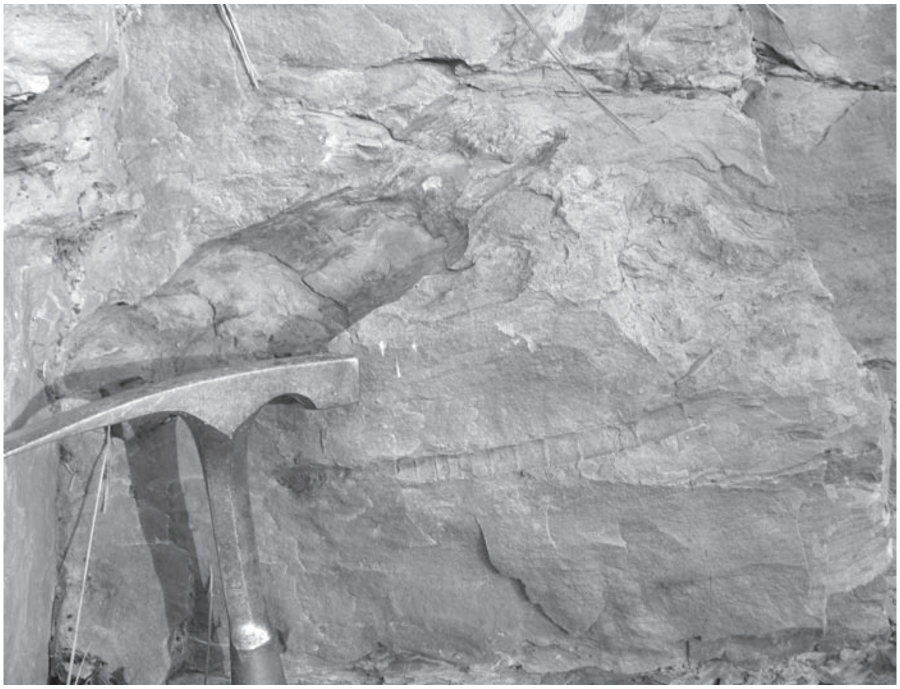

Figure 5. More *Calamites* molds from Unit 1. Note that the lower one is horizontal. Mold orientation and cross-bedding indicate water flow was to the north (right).

ous vegetation: (1) the anatomy of the vegetation (i.e., *Lepidodendron*) indicates floating plants, and (2) the vegetation had the characteristics of a floating forest, an alternative to swamp forests. The round nodes on the surface of *Stigmaria* are scars where ribbon-like rootlets were once attached and arranged radially about *Stigmaria* like the bristles of a bottlebrush. A radial root pattern is found only in water plants (Sarfati, 2004; Wieland, 1995). Water in soil moves downward under the influence of gravity, so roots growing in soil are designed to send their secondary rootlets in that direction, away from the soil surface. By contrast, the rootlets of plants floating in water grow straight out from the main root in all directions, just like the *Stigmaria* appendices (Wieland, 1995).

Discussion

Unit 1 is a 44-foot sequence of interbedded sand and shale that was deposited by moving water, as indicated by extensive cross-bedding, with the flow direction to the north. Donica (1978) divided this unit into 11 separate units based on interbedded sand/shale sequences. Unit 1 contains abundant plant material in the form of *Calamites* molds. The *Calamites* molds, which are mostly horizontal to subhorizontal, were transported into the area as illustrated by the lack of roots and the molds are completely encased in cross-bedded sand. Unit 1 grades vertically

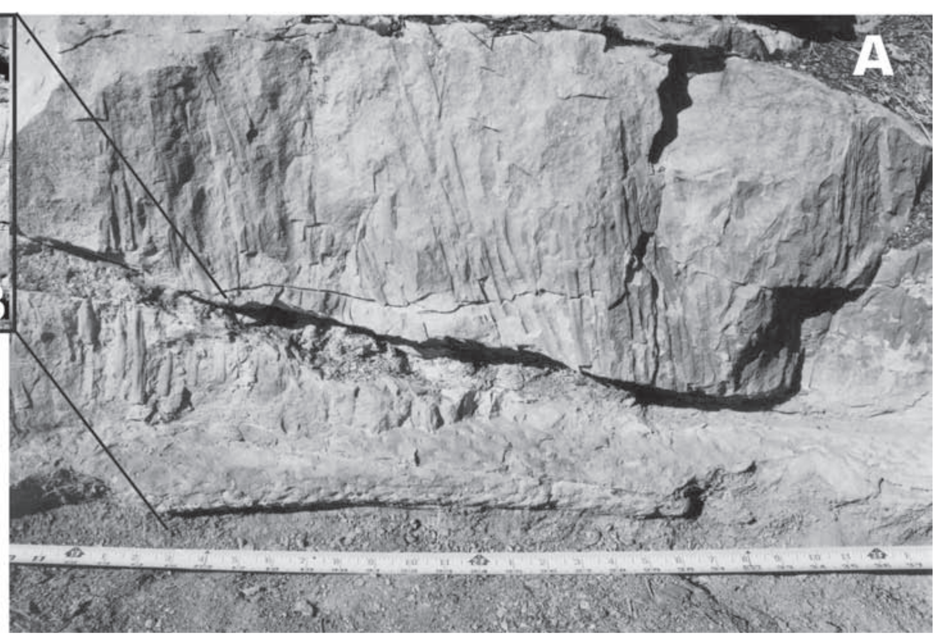

Figure 6. (A) *Stigmaria* root in the upper part of Unit 1. Many rootlets are visible in the cross-bedded sandstone above the root. Tape measure for scale. (B) Close up of (A).

Figure 7. Two *Calamites* casts in cross-bedded sandstone from Unit 5. Rock hammer for scale.

from massive sand into thinly bedded, shaley sand.

Unit 2 is a 5.5-foot sequence of carbonaceous, black plant material, composed mostly of leaf remnants. The nature of this material suggests an abundant plant source that was catastrophically stripped of the foliage, jumbled together, and then buried. The carbonaceous plant material contains several thin coal stringers and infrequent nodules containing more plant material. Interestingly, Donica (1978) classified this layer as shale.

Unit 3 comprises the 4-foot-thick Lower Hartshorne coal seam that, like Unit 2, indicates a tremendous amount of plant material that was buried and transformed into coal. The coal appears to grade vertically into the overlying shale layer. Unit 4 is a 6.5-foot-thick shale sequence that was divided into three separate shale intervals by Donica (1978). The distinguishing feature of this shale is that it contains a three-foot-diameter *Calamites* cast that shows indications of being "dropped" into place. The large tree cast exhibits no roots, and the shale under it actually bends around the cast.

Unit 5 is 3-foot-thick sandstone with abundant cross-bedding and many upright *Calamites* casts (Figure 7). These casts also have no roots and apparently were transported to this location because they are encased in cross-bedded sandstone. Unit 6 is a sandstone layer approximately 8.5 feet thick with well-defined cross-bedding and few plant casts. Units 5 and 6 are very similar and almost indistinguishable from one another. The boundary was placed at a slight color change, a textural change from poorly cemented to massive, and a decrease in plant material.

All the evidence, which includes (1) the extensive cross-bedded sandstone, (2) the *Calamites* molds oriented from horizontal to subhorizontal, (3) the carbonaceous plant interval, (4) the coal seam, (5) the abundant *Calamites* casts, and (6) plant remnants having no signs of roots (with the exception of the *Stigmaria* root) and are therefore not in situ, points to a catastrophic depositional event and not processes associated with a delta environment. The *Calamites* molds in the sandstones of Unit 1 probably originated from a floating forest, being swept away and then buried by sand-laden floodwater. The presence of the *Stigmaria* root underneath the Lower Hartshorne coal seam fits into the floating forest model as described by Schonknecht and Scherer (1997). The fact that the rootlets are encased in cross-bedded sandstone suggests that they did not grow into the sand but were buried by the sand. As the floating forest was battered by the dynamic flood environment, the foliage would be stripped off, torn apart, and then buried, creating the carbonaceous layer (Unit 2) with abundant leaf impressions. The bulk of the floating forest eventually would become buried and converted into coal (Unit 3). A layer of clay (Unit 4) was then deposited over the coal, followed by more sand units (Units 5 and 6). Remnants of the floating forest that were not initially buried may have floated in the water for a time before they themselves became trapped and buried in sand (Units 5 and 6) and preserved as casts.

Conclusions

The various uniformitarian interpretations of the Hartshorne Formation clearly indicate uncertainty as to its depositional environment. This article provides evidence that the delta-type environment should be discarded in favor of a flood interpretation. Evidence points to a floating forest that was disrupted by water action and then quickly buried by sand in a catastrophic environment. Cross-bedded sandstones, in conjunction with significant plant debris (including coal seams), clearly illustrate that the Hartshorne Formation was not deposited in a delta-type environment. Various indicators point to swiftly moving water and rapid deposition. The location of the *Stigmaria* root supports the floating forest interpretation and contradicts the in situ explanation offered by Stewart (1983). The root and rootlets were not in situ, and the sand that encases the rootlets was deposited on top of the root and rootlets, burying them. This adds further support to the interpretation that the coal seam represents the remains of a buried, floating forest. *Calamites* casts and molds above and below the coal seam reflect remnants of the forest that were swept away and buried by sand.

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