DOUGHERTY GAP: EVIDENCE FOR A TURBIDITY CURRENT PALEOENVIRONMENT

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Abstract

A trace fossil exposure located at Dougherty Gap, Walker County, Georgia, provides an excellent opportunity to evaluate existing physical information, and compare a uniformitarian interpretation and a young-earth Flood interpretation for that site. This examination reveals that a turbidity current depositional environment better explains the stratigraphic record found at this site than does the proposed uniformitarian prograding delta model. Additionally, a turbidity current depositional environment fits within both the expected depositional environment and the timeframes of the young earth Flood model.

Introduction

Any attempt to reconstruct paleoenvironmental settings will reflect the model (i.e., uniformitarian or young-earth Flood) on which it is based. Because significant dissimilarities exist between these two models, most of the paradigms used to construct and interpret them will be different (e.g., concept of time, depositional rates, water depth, energy levels, etc.). So while creation scientists have access to much uniformitarian geological information, we must sift through it to determine its relevancy to our own model (i.e., "science" versus "interpretation"). In many cases this may leave us with only the physical information for the site under investigation. Such is the case for this paper. A glossary is included at the end of this article to aid the reader in understanding some of the geologic terminology.

This article addresses what we view as evidence for turbidity current emplacement of alternating sandstones and shales found at an outcrop located at Dougherty Gap in Walker County in northwest Georgia (Figure 1). Additionally, the authors believe that the stratigraphic record presented at this outcrop supports the deposition and bioturbation of these sediments within a much shorter timeframe than is currently recognized by Uniformitarians. This paper will only attempt to present evidence in support of a turbidity current depositional environment specifically for this exposure. Readers who wish to review the uniformitarian prograding delta model for this outcrop are referred to Sheehan (1988).

The turbidity current depositional environment suggested by the writers for this site is presently not recognized by uniformitarian geologists because their current model requires a coastal swamp paleoenvironment to explain the occurrence of coal layers found in adjacent overlying strata. However, as young-earth catastrophists we are required to interpret and defend the sedimentary and stratigraphic record within the framework of the young-earth Flood model. This interpretation is best explained by using changing energy levels, evidenced through physical and biogenic features found in sediments, which were deposited over what we interpret as short periods of time (i.e., the Lower to Middle Flood Event Timeframe—see Froede 1995a).

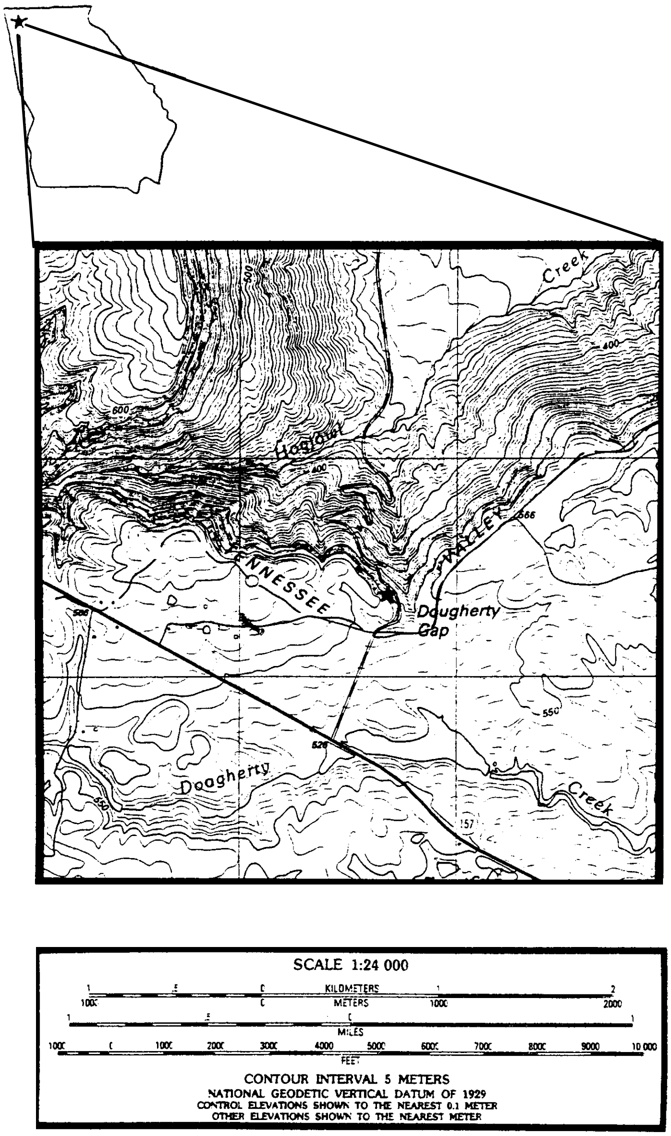

Figure 1. State of Georgia with U.S. Geological Survey (1983) topographic map showing elevation and features of the Dougherty Gap location. The site is located on the west side of West Cove Road, north of Georgia State Highway 157.

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Appalachian Depositional Environments

While turbidity current generated strata are recognized within the Appalachian stratigraphic section, these deposits are believed by Uniformitarians to only occur in the lower sections of the Paleozoic (McIver, 1970, pp. 69-81). This is due to the paleoenvironmental restrictions of Walther's law of facies succession and the restrictions imposed by the Carboniferous System on the interpretation of the southern Appalachians stratigraphic sequence.

Current uniformitarian interpretation for most, if not all, of the Appalachian upper Paleozoic stratigraphic sequence is based on a prograding delta model originally proposed by Joseph Barrel in 1908 (McBride 1973). The prograding delta model was proposed due to the presence of coal deposits interbedded in what Uniformitarians postulated as cyclical marine assemblages. This model proposes the autochthonous (i.e., in situ) formation of coal from peat swamps. These swamps are postulated as having been located along epeiric seaways, which with changing sea-levels due to glacial activity, resulted in the cyclical drowning of the swamps and the concomitant deposition of clays, silts, and sands (see Froede 1995b, 1995c). This limited framework for the Carboniferous paleoenvironment resulted in the recognition of many anomalous sites which required explanation not always directly supported with the physical data. We suggest that the current depositional model paradigm for the Carboniferous System should be reexamined to determine if it still "fits" with new data generated as a consequence of sequence, event, and/or dynamic stratigraphy. This examination could result in the formulation of new models which could lead to the eventual change in the depositional model paradigm for the Carboniferous System. However, we acknowledge that this is a complicated task, in terms of removing an old paradigm even with direct evidence to the contrary, and will probably take years to perform (see Lightman and Gingerich, 1991; Kuhn, 1970).

The uniformitarian acceptance of the Appalachian prograding delta model is based on a general concept in geology called Walther's law of facies succession, which states that a vertical sequence of facies will be the product of a series of depositional environments which lay laterally adjacent to each other (Allaby and Allaby, 1009, p. 398; Boggs, 1987, pp. 532-533). Walther's law forces a shallow marine to coastal deltaic plain environment for much of the Appalachian upper Paleozoic geologic vertical section. This is due to the facies succession required when coal deposits are present, because coal is viewed by Uniformitarians as occurring in a coastal setting, while the surrounding clays, shales, and sands are viewed as occurring in a nearshore marine setting. Work performed by Austin (1979, 1991) on coal formation; and Julien, Lan, and Berthault (1993) using sand tank experimentation, now seriously question the validity of Walther's law. Additionally, we suggest that their work seriously challenges the current uniformitarian environmental interpretation for the Appalachian vertical stratigraphic column.

Today any attempt to identify the original depositional environmental setting for the Appalachian upper Paleozoic sequence is confined to locating where, within the prograding delta model, the sediments were deposited (e.g., channels, levees, overflow areas, etc.) [Walls, 1975; Humphreys and Friedman, 1975; Horowitz, 1966; Friedman and Johnson, 1966; Bergenback, Wilson, and Rich, 1980; Woodrow and Sevon, 1985; Greb and Chesnut, 1994]. Trace fossils are viewed as providing supporting evidence to the prograding delta model (Gibson and Gastaldo, 1989; Miller and Knox, 1985; Knox and Miller, 1985; Rindsberg, 1991). However, serious questions remain regarding the original location of the prograding delta and its source area (Allen and Friend, 1968; McBride, 1973, p. 113; Miller and Knox, 1985, pp. 77-79; Mack, 1982).

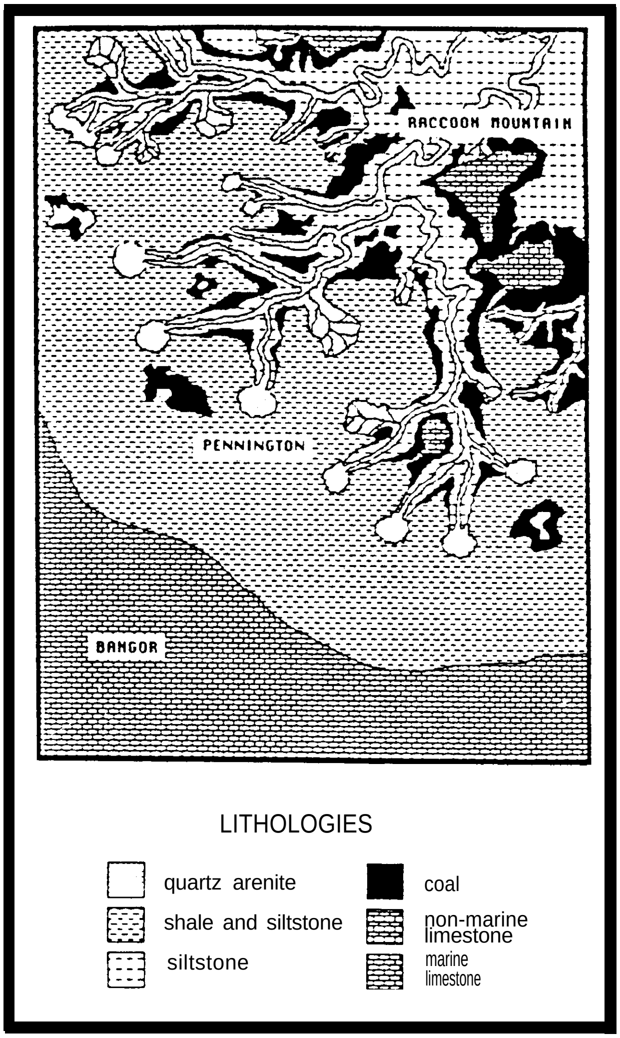

Figure 2a. Prograding delta model used to explain the Southern Appalachian stratigraphic section—Figure 39 (Sheehan, 1988, p. 144). This model is proposed based on the uniformitarian model for coal formation.

Past Investigations at the Dougherty Gap Exposure

The most intensive study performed at this locale was a Masters thesis investigation conducted by M. A. Sheehan (1988). His investigation focused primarily on the trace fossils preserved in the sediments and what they imply about the original depositional environment. [Background information about trace fossils, i.e., ichnology, within the framework of the young-earth Flood

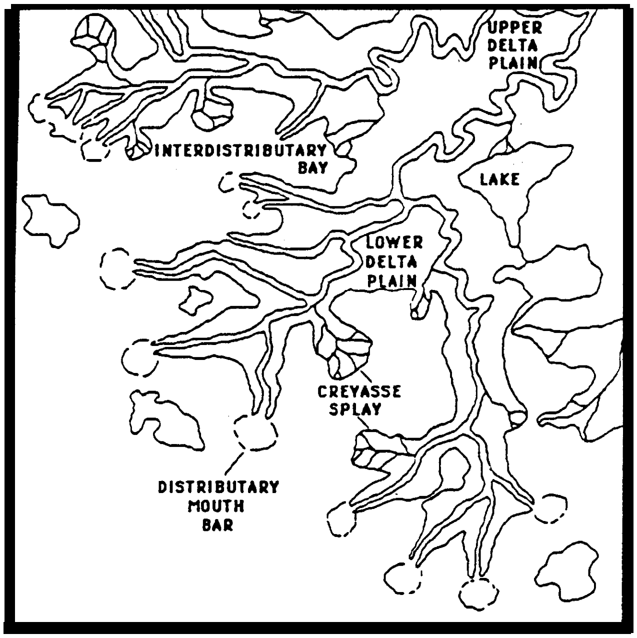

Figure 2b. The proposed location and conditions under which Sheehan (1988) views this specific outcrop-Figure 40 (Sheehan, 1988, p. 148). Sheehan proposed the crevasse splay as providing the original environment for that seen today in outcrop.

model, can be found in Cowart and Froede, 1994]. Sheehan (1988, p. 143) viewed the depositional setting as having been originally a deltaic environment (Figures 2a, and 2b). He envisioned that crevasse splays formed as river channels breached their levees and spilled over into the interdistributary bays, depositing their sedimentary load of sands, silts, and clays (Sheehan, 1988, pp. 152-153) [Figure 2c]. The original source of sediments and the location of the prograding delta were not addressed in Sheehan's investigation.

Interdistributary Bay Depositional Environment

In order to determine if Sheehan's postulated interdistributary bay depositional environment with multiple crevasse splay "events" is correct, we must briefly examine this type of depositional environment.

Coleman and Gagliano (1965, p. 146) describe the modern interdistributary bay environment of the Mississippi River as:

> . . . areas of open water within the active delta which may be completely surrounded by marsh or distributary levees, but which more often are partially open to the sea or connected to it by tidal channels. Bays with some coarse detritus contain a very distinctive group of minor structures. The most abundant single structure is the lenticular lamination, a product of reworking and concentration of the coarse fraction by waves. The horizontal extent of each lens varies, but is generally less than 3 cm (1.18 inches). The lateral continuity of the parallel laminations was not ascertained, but it is believed that they are persistent and probably originated during times of high flooding of the Mississippi. Current ripple marks and scour and fill structures are present in some cores and indicate that currents were occasionally active during deposition. These structures are formed by tidal currents and overflow during floods. Burrows and shell remains attest to the profusion of brackish and marine molluscan fauna. Bays generally enlarge by wave action at the expense of adjacent marsh areas, hence reworked plant remains are often incorporated in bay sediments. [Parentheses ours]

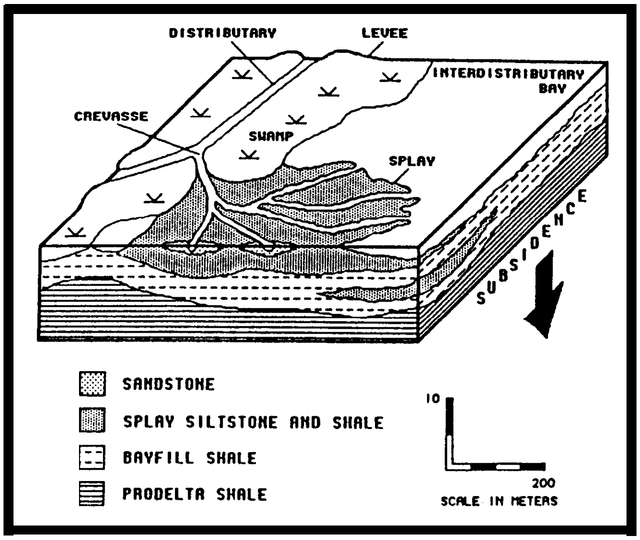

Figure 2c. This is a more detailed figure of the proposed depositional environment-Sheehan's Figure 41 (Sheehan, 1988, p. 153). This environment is required using the uniformitarian model due to the near-by coal deposits found in overlying rocks. This is the depositional environment suggested as being reflected by trace fossils and sediments.

It has been shown that the interdistributary bay depositional environment has physical evidence which reflects its specific type of environmental setting (Archer and Maples, 1984; Coleman and Prior, 1980; Elliot, 1974; Coleman, Gagliano, and Webb, 1964; Prothero, 1990). Some of the physical evidence includes nodular siderite in the shale layers, which reflect the brackish water or fluctuating salinity in sediments of moderately low pH and oxygen content, and a coarsening-upward thickening upward sandstone sequence (Archer and Maples, 1984, pp. 458-459: Coleman and Prior, 1980, p. 58).

According to Coleman and Prior (1980, p. 53), the crevasse splay sequence of sediments can form, adjacent to the river channel, in 100 to 150 years. Regarding the crevasse-splay facies, Osborne, Leverett, and Thomas (1991, p. 60) state:

> Crevasse-splay facies are characterized by a coarsening upward sequence of very fine- to medium-grained sandstone, siltstone, and mudstone. The top of the sequence locally shows root penetrations and contains abundant fossil plant debris, suggesting marsh development on the splay.

Some features found at the Dougherty Gap exposure have similarities to those of the modern interdistributary bay environment and crevasse splay facies (e.g., current ripples, scour and fill structures, and burrows). However, many more differences exist (e.g., lack of lenticular lamination, graded bedding, brackish and marine molluscan fauna, root traces, or the reworked plant remains preserved as siderite, pyrite, carbon

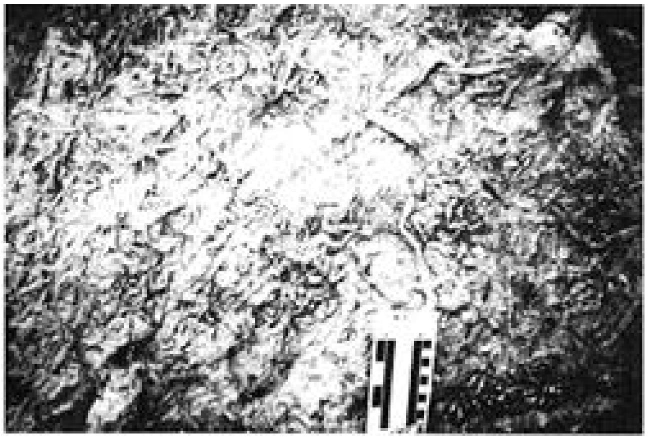

Figure 3. Photograph showing trace makers sole markings cast in sandstone (i.e., convex hypichnia) which we suggest reflect a *pre-event trace fossil association* (see text). Top layers of the semi-lithified clays were eroded away as the turbidity current passed across it. Sands subsequently filled the traces, resulting in sole casts along the bottom of each sandstone layer.

films, or coal lenses). Now we must ask the question. how much evidence is necessary to support a specific depositional setting and could another depositional setting better explain the physical evidences present at this site?

The Dougherty Gap outcrop will be examined to determine what depositional environment best correlates with the physical evidence of the outcrop, and compare our suggested depositional environment with what is currently proposed.

Trace Fossil Interpretation At Dougherty Gap

Sheehan (1988) suggests that following a crevasse splay event, trace makers would bioturbate those newly deposited sandy sediments in search of organic matter. Primary trace maker activity, which is believed to account for the traces found at this site, is believed to be the result of the search for food **(fodinichnia)** [Sheehan, 1988, p. 166]. However, the traces used by Sheehan (1988, pp. 38-142) to support the deltaic environmental setting are ambiguous in that they do not reflect any specific environment; rather, they only reflect a specific behavior (i.e., feeding). Goldring (1993, p. 403) has accurately stated that deltaic, estuarine, and lagoonal paleoenvironments have not been defined into any particular ichnofacies scheme.

Trace fossils at the Dougherty Gap site consist of sandstone casts primarily of convex hypichnia with less common convex epichnia (Sheehan, 1988, p. 31; see Cowart and Froede 1994, for a discussion of these terms) [Figures 3, 4, and 5]. These same trace fossils are also recognized in turbidity current depositional environments (see Seilacher, 1962, 1978, 1984; Kern, 1980; Wetzel and Aigner, 1986; Bromley, 1990; Einsele, 1991, pp. 322-326; 1992, pp. 214-231).

The trace fossils exposed at the Dougherty Gap site occur in several ichnofacies which range from shallow to deep water depositional environments. However, the authors suggest that based on the ichnogenera found at the site, the sediments of the Pennington Formation could have been deposited on the distal sections of a deep sea fan (i.e., outer fan to basin plain) or on the outermost edges of the then existing continental shelf (see Lemon, 1990, p. 379; Normark, 1978, pp. 927-928; Walker, 1978, pp. 946-947; Reading, 1978, p. 403; Prothero, 1990, p. 114) [Figure 6]. This paleoenvironment would support the tracemaker behavior represented in these sediments.

Figure 4. Photogragh showing a difference in trace maker size between the layers of sandstone. Note the base of an upper sandstone layer contains traces produced from a larger trace maker (perhaps due to greater oxygenation or shallower water depth). Sandstone units above this layer return to the smaller trace makers found beneath this layer.

Figure 5. Closeup of the larger trace maker sole casts.

Sedimentology

Our investigations of the individual sandstone layers have not revealed any differences in their texture or grain size. All the sandstone layers appear to be mineralogically and texturally alike. The sandstone thickness varies from unit to unit. However, no lenticular shapes or changes in thickness in the individual sandstone layers were observed. We noted approximately 40 to 45 sandstone layers, varying from less than 0.5 inches to approximately nine feet in thickness, exposed across the 300-foot long outcrop (Figure 7). Sheehan (1988, p. 21) describes the multiple sandstone layers as:

> . . . gray-brown, well sorted, very-fine-grained quartz arenites. They exhibit few internal sedi-

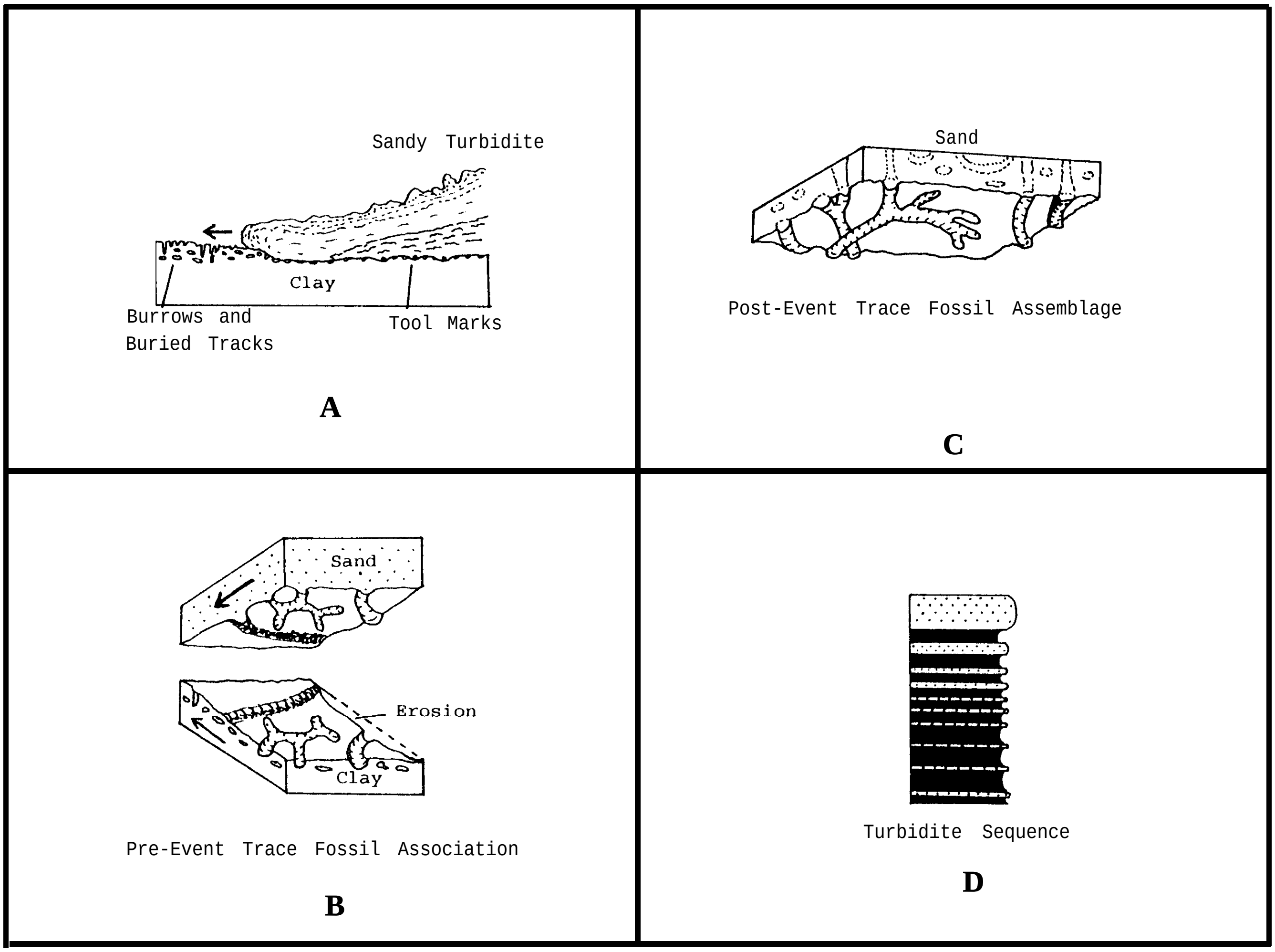

Figure 6. a) Sandy turbidity current as it rapidly passes over a semi-lithified bioturbated clay layer. It serves to remove the upper clay layer and then fill the burrows, trackways, and tool marks with sand. Note Sheehan (1988, p. 26) recognized the occurrence of toolmarks as sole casts. This results in sole cast of the previous pre-event trace fossil association. b) A two-part drawing showing the direction of original sand turbidity current along with the eroded upper clay surface and the resulting sole cast in the bottom of the sand. This is the *pre-event trace fossil association.* c) This is Sheehan's suggested bioturbation model to account for the bioturbation of the sand as sole casts. This is based on the occurrence of traces in the sandstone expressed as sole casts (1988, p. 24, Figure 7—displayed upside down). However, no vertical lined burrows were noted in any of the 40 plus sandstone layers examined at the outcrop. Additionally, most if not all of the ripple marks on the upper surfaces of each sandstone layer would have been removed if this were the actual depositional environment, due to bioturbation. d) This is the classic upward thickening depositional sequence exhibited by turbidity currents (Walker, 1978, pp. 946-948). Figures 6a, 6b, and 6c redrawn and modified from Einsele, 1992, p. 216, Figures 5.15b-f. Figure 6d is redrawn from Lemon, 1990, p. 379.

> mentary structures; the most common intrastratal structures are small, variably distinct shale lamina and discontinuous, planar erosion surfaces that are concordant to bedding.

Our examination of the sandstone units revealed no evidence of cross-bedding, internal bedding planes, or any physical sedimentary features. In contrast, Sheehan (1988, pp. 21-28) noted indistinct bedding features and some indication of bedding.

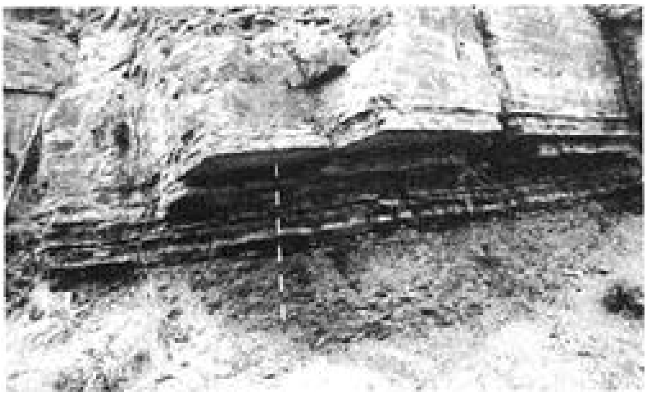

Figure 7. Photograph of the outcrop as it is exposed along West Cove Road. Note the massive nine-foot thick sandstone layer which caps the site and provides the last occurrence of sandstone sole casts of trace fossils. We counted over 40 layers of sandstone which extended across the 300 feet of the outcrop. Each sandstone layer exhibits some degree of sole casts (bottom) and ripple marks (top). Scale is six inch units. Note the "thickening upward" nature of the sandstone units. This is indicative of a nearing sand source in a turbidity current setting (see Walker, 1992, pp. 245-247).

It is interesting to note that no obvious evidence of bioturbation is present in these sand layers as they are exposed across the 300 feet of outcrop. If Sheehan's

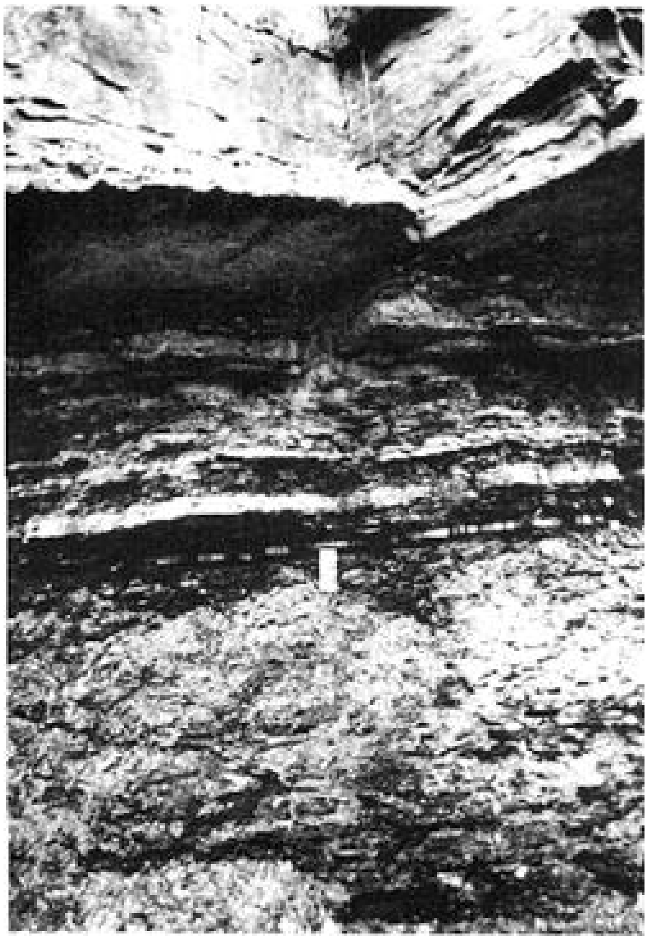

Figure 8. Photograph of the outcrop showing the thin sandstone layers. If bioturbation of the sandstone did occur as Sheehan (1988) has suggested, then the sandstones should have been obliterated by bioturbation, especially the thin layers. However, if the sands were deposited in turbidity currents with the clays serving as the trace maker substrate, then the sandstones would serve as sole casts and would reflect the bioturbated nature of the clays. With eventual sedimentary loading and tectonic input, the clays would be compressed into the shale layers seen today, and all that would remain as evidence for trace maker activity would be preserved as sole casts along the bottoms of the sandstone layers. The sandstone trace maker cast is what is found along the bottom of even the thinnest sandstone layers.

model is correct and these sands were deposited as a result of a crevasse splay, then sufficient time (i.e., tens to hundreds to thousands of years) should have existed between “events” (i.e., breaks in the river channel levees) to permit bioturbation of the sand units by existing flora or fauna, especially the thin units (measured at less than one inch in thickness). Additionally, the time between crevasse splay events should have resulted in the obliteration of the distinct sand/clay bedding contacts (Kuenen, 1967, pp. 230-231). However, even the thinnest sandstone units fail to show any obvious signs of bioturbation, blurring of bedding contacts, or internal bedding features. Rather they appear as homogenized small-grained sandstones (Figure 8).

Kuenen (1967) documented the differences in sand textures between interdistributary bay deposits and turbidite deposits. Using his work as a reference the sandstone units found at Dougherty Gap best correlate to turbidite emplacement based on both lithology and bioturbation (Kuenen, 1967, pp. 230-231). Coleman and Prior (1980, pp. 52 and 59; 1981, p. 151) present photographs of cores taken from a modern interdistributary bay which in no way resemble the stratigraphy or sedimentation found exposed at the Dougherty Gap site.

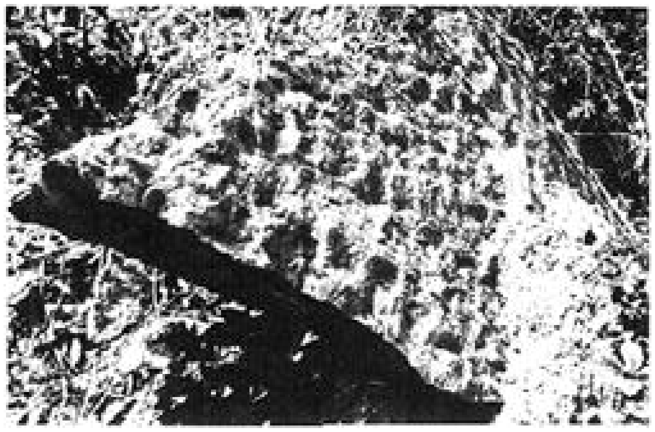

Figure 9. A photograph showing the “asymmetric, linguoid ripples” described by Sheehan (1988). If bioturbation of the sandstone did occur as is proposed then most if not all of these ripples should have been obliterated following the deposition of the sands. The intervening timeframe between “events” should have provided the trace makers the opportunity to completely bioturbate not only the sands but the underlying clays, too. These ripple marks are found on the tops of every sandstone layer exposed at this site, including the thinnest sandstone layers. These bi-directional current ripples are associated with turbidite deposits which have been modified by contour currents. Sheehan fails to supply the evidence necessary to support his “bioturbation of each sand layer.” The fact that current ripples and sole casts are found in each sandstone layer for the 300 feet of outcrop exposed reinforces the turbidity current depositional environment.

Additional evidence for turbidity current deposition versus a river crevasse splay is found in the “thickening-upward succession” of sandstone layers at the outcrop. This type of stratigraphic sequence (i.e., sandstone layers which thicken moving up in section) is a common characteristic of a turbrdite deposit (i.e., Bouma cycle), and is believed to reflect the progradation of submarine fan lobes (Walker, 1992, pp. 245-247; Walker and Mutti, 1973) [Figures 6d, 7, and 8]. The senior author noted the same physical features (i.e., alternating sandstone and shale layers with tool marks, trace fossils preserved as sole casts, and a progressive thickening of sandstone layers moving up the sequence) in the lower Red Mountain Formation at the Ringgold Gap, a formation recognized by Uniformitarians as a turbidite deposit (see Rindsberg and Chowns, 1986, p. 161). Enos (1969) also presents an interesting study of flysch (i.e., turbidity current) deposits, in the Northeastern United States, which directly correspond to what is observed at Dougherty Gap. We find it interesting that both Ringgold and Dougherty Gap contain a significant number of similar features, but are interpreted by uniformitarians in two different depositional settings, all based on the nearby presence of coal layers at one of those locales. Such are the requirements of Walther’s law.

The same types of homogenized sandstone deposits found at Dougherty Gap have been reported in sandstone layers recognized as resulting from turbidite deposits (see Shepard, 1951; Kuenen, 1967; Einsele, 1992; Seilacher, 1962 Kuenen and Menard (1952) have suggested that sand-rich turbidity deposits can form non-graded units as a result of either excellent sorting during deposition or as a result of a submarine slide without turbidity flow. Enos (1969, p. 697-701) observed numerous sand layers in flysch deposits which failed to provide any indication of graded bedding. Shepard (1951, p. 58) documented sharp upper and lower contacts between turbidite sand layers and the overlying and underlying clay layers. Additionally, Shepard (1951, p. 58) found that turbidite deposited sands were well sorted units. He stated:

> Good sorting is particularly significant because the sands are found in an environment where, unless deposition is very **fast,** one would expect silt and clay to be contributed as the result of flood waters sweeping out over the sea as suspension clouds of low salinity or as the product of offshore wind transport . . . [emphasis ours]

The thickness of the individual sandstone layers in turbidity current deposits is estimated to be a function of the location of the deposit within the deep-sea fan or along the continental shelf edge (i.e., proximal versus distal; see Walker, 1967). The closer the deposit was to the source, the thicker the sandstone unit and the coarser the grain size. However, while the sandstone units at Dougherty Gap increase in thickness (moving up section) they do not exhibit any increase in grain size from bottom to top or across the 300 feet of exposure.

The intervening shale layers show no indication of any original bedding layers (Figures 7 and 8). Rather, due to their compression they now have parting surfaces which do not correlate to any lithologic variation. Sheehan (1988, p. 25) describes the shale layers between the sandstone units as:

> Dark-gray carbonaceous clayshales having fissile to platy parting . . . intercalated with sandstones as even, laterally continuous strata.

Contacts between the sandstone and shale layers are sharp and show no evidence of gradation. This suggests an “event” type or emplacement for each sand layer. Sheehan (1988, p. 26) comments:

> These surfaces demarcate distinct breaks between adjacent lithologies, even where the soles are intensely burrowed.

In an attempt to explain why the boundaries are so sharp Sheehan (1988, p. 26) states:

> In recognition of their abrupt character, the gently undulose to flat soles of the sandstones are interpreted to have been deposited upon erosional surfaces. This interpretation is further evidenced by scour-and-fill structures and long, straight toolmarks which infrequently punctuate these otherwise completely burrowed horizons.

The reader will note that the tops of the shale units are interpreted by Sheehan (1988) [and we agree] as being both bioturbated and having an erosional surface. How this surface developed is an important difference in the depositional interpretation as we further discuss the physical features of this site.

Stratigraphy

Stratigraphically the alternating sandstone and shale units are placed within the upper portion of the Pennington Formation which is dated to the uniformitarian Mississippian Period (Sheehan, 1988, pp. 9-10). Fossil evidence to support the age of the Pennington Formation is sparse (Sheehan, 1988, p. 12). Approximately 45 feet above the section under investigation lies the Mississippian-Pennsylvanian boundary, which is identified as the contact between the Pennington Formation and the Raccoon Mountain Formation (Crawford, 1989). According to Sheehan (1988, p. 13):

> . . . the Pennington-Raccoon Mountain contact is much more difficult to establish and has long been the subject of much disagreement among geologists.

As previously stated, it is generally believed by uniformitarian geologists that the Mississippian to Pennsylvanian Period transition represents an environmental change from a nearshore marine to a terrestrial swamp setting. Again, according to Sheehan (1988, p. 15):

> As a result of this shift in depositional regimes, the Pennington and Raccoon Mountain formations share a predominantly conformable and entirely gradational contact that exhibits various lithofacies.

With the previous statements by Sheehan in mind, we are now supposed to accept that the strata above our study site exhibits a seemingly continuous change, and that change is purported, by uniformitarians, to reflect the progradation of deltaic deposits over shallow water marine deposits (again based on Walther’s law as a result of the coal deposits).

While we do not disagree with the lithologic or ichnologic descriptions provided by Sheehan, the paleoenvironmental setting and its requiring millions of years to create the stratigraphic column is clearly not acceptable within the young-earth Flood model.

The appearance of a prograding delta paleoenvironment can be explained from a young-earth catastrophic viewpoint if the timeframe for its formation were shortened. For example, the original sediment source area was probably the rapidly rising Appalachian Mountains to the immediate east. This major mountain building event is suggested by the authors as having occurred during the Flood event (possibly Lower Flood Event Timeframe). The appearance of a prograding delta paleoenvironment is easily explained as the remnants of ecological communities that were buried along with masses of vegetation which were washed off of the original Antediluvian (i.e., Pangaean) supercontinent. These deposits were buried immediately adjacent to the uplifted Appalachians in what was then a continental shelf setting due to the onset of the Flood. Hence the sediments, fossils and coal deposits do not reflect any “age” rather, they reflect rapid burial associated with the Flood.

Systematic Ichnology

Sheehan’s (1988) work provides the systematic ichnology of the Dougherty Gap exposure and will not be duplicated here. However, we do wish to note that the trace makers identified by Sheehan do not in any way solely suggest a deltaic setting. Rather, Sheehan’s (1988, p. 160) environmental setting (i.e., *Cruziana* ichnofacies) is based on his own interpretation of the original environment. Most if not all of the same trace makers identified by Sheehan at the Dougherty Gap exposure are also identified as occurring at other depths in the marine environment, including those of deep water (i.e., *Cruziana, Zoophycos,* and *Nereites* ichnofacies).

For example, Jordan (1985) identifies several traces in black shales in east-central Kentucky which are the same as those found at Dougherty Gap. One of his photographic plates shows a *Planolites* trace (his Figure 5a) which is identical to traces found at Dougherty Gap, with the only difference being the casting material (Jordan, 1985, pp. 284-285). Jordan (1985, p. 285) suggests the original environmental setting for his *Planolites* trace as being from the middle to outer shelf *(Cruziana* and *Zoophycos* ichnofacies).

This raises the issue of the usefulness of trace fossils as paleo-depth indicators. Originally it was thought that they could provide this type of information (Seilacher, 1964, 1967). However, subsequent studies have found this to be untrue (see Frey, 1971, pp. 110-112, and 1975, p. 18; Bromley, 1990, p. 216; Ekdale, 1988; Goldring, 1993; Frey, Pemberton, and Saunders, 1990; Wetzel, 1991, p. 61; Bottjer and Droser, 1992; Bishop and Brannen, 1993, p. 23). So we must consider with caution any attempt to determine paleo-depth from trace fossils without supporting evidence.

Sheehan (1988, pp. 38-142) identified 11 different ichnogenera and various ichnospecies. The large variety seen at this exposure, along with the lack of any lamination within the shale or sandstone, indicates a high level of biogenic activity within the clay layers, perhaps in a short period of time.

Bioturbation in the sandstone layers permits the investigator to determine whether the original traces were created before or after the sandstone was deposited. Sheehan's (1988, p. 24), Figure 7 (displayed upside down) presents what he interprets as evidence of trace maker activity in one sandstone unit measuring 2.5 inches (1 cm) thick. His figure is a freshly cut cross-section of sandstone which exhibits burrows as sole casts (i.e., hypichnia). This is the only way which trace fossils were ever observed at the outcrop by either Sheehan (1988, p. 6) or the authors. We never observed, nor did Sheehan document, the occurrence of lined burrows within any of the sandstone units.

Trace Makers in the Turbidity Current Environment

As previously mentioned, Sheehan (1988, p. 31) describes the preservational sandstone casts of trace makers found at the Dougherty Gap site as being primarily of convex hypichnia with less common convex epichnia. This type of preservation has also been recognized as occurring in the distal portions of deep-sea fans as a result of turbidity currents (see Einsele, 1992, pp. 216-218; Seilacher, 1962).

In a turbidity current environmental setting, any traces found within the **sand layers** would be identified as being a *post-event trace fossil assemblage* (Figure 6c) which developed on and in the sandy substrate following its deposition (Einsele, 1992, pp. 216-218; Seilacher, 1962, pp. 229-232).

We suggest that many of the sandstone layers exhibit sole casts which are best explained as *pre-event trace fossil associations* (Figure 6b). According to Einsele (1992, pp. 216-218) and Seilacher (1962, p. 232) these traces are physically modified when turbidity currents eroded the too of the bioturbated clay layer and subsequently filled the remainder of the burrows with sand. This created "lebensspuren on the sole of the sand bed." This preservational method (i.e., sole casting) is recognized as a common method of trace fossil preservation in a turbidity current depositional environment Bromley, 1975, pp. 403-404; Roniewicz and Pienkowski, 1977, p. 279; Potter and Pettijohn, 1977, pp. 156-157; Einsele and Seilacher, 1991, p. 379). This same type of turbidity current sole casting is recognized in the Mount Messenger Formation deposits of New Zealand (Jordan, Schultz, and Cherng, 1994, p. 159; King, Browne, and Slatt, 1994, p. 180). The size of the pre-event trace fossil makers is believed to reflect the dissolved oxygen levels found within the substrate (Leszczynski, 1991). Hakes (1985, p. 28) suggests that trace maker size could also vary with depth, due to "environmental stresses."

While Sheehan (1988, p. 26) recognizes the evidence of scour-and-fill structures along with the erosional surface of the original clay, he suggests that the sand, and not the clay, was the bioturbated substrate (1988, p. 173):

> . . . this sequence (alternating shales and sandstones) exhibits a complete restriction of ichnofossils to arenaceous (sand) beds and lenses. Because these structures represent autochthonous records of animal activity, it can be surmised that biotic conditions were associated with sand deposition. In contrast, both the dark-gray shales within and immediately below the study interval appear to have been deposited under abiotic conditions. The conspicuous absence of both trace and body fossils from these shales, therefore, suggests that metazoans were incapable of accommodating the environmental conditions associated with clay deposition. [parentheses ours]

As previously mentioned, support for his position is based on a polished section of sandstone which exhibits trace-bearing sole casts (Sheehan, 1988, p. 24, Figure 7—displayed upside down). While it is acknowledged that some of these traces could have formed following the deposition of the sand layer, we suggest that these traces would only represent an attempt made by a *post-event trace fossil assemblage* to recolonize a freshly deposited sand layer. It does not prove that the sand was the dominant substrate and that the clay layers were anoxic as has been suggested by Sheehan (1988, p. 151). We view the sandstone sole casts as trace fossil structures which resulted due to scour-and-fill turbidite deposition associated with pre-event trace fossil associations (Figures 3, 4, 5, and 6b). These sole casts were originally tracks and burrows made in the clay substrate (not sand as Sheehan has reported) which were partially eroded and filled with sand, thus forming sandstone sole casts.

In support of the turbidity current model, the writers found evidence of sole casts along the bottom of the thinnest layers of sandstone (Figure 8). These layers were barely thick enough to surround the diameter of the trace makers and this does not lend support to the position that the sands served as the substrate of choice, as Sheehan (1988, p. 173) has suggested. These thin sole casts are better explained as being a pre-event trace fossil association. Additionally, current ripple marks exist along the tops of these thin sandstone layers. These marks should have been destroyed due to bioturbation if Sheehan's (1988, p. 173) sand layers were the substrate of choice. According to Peres (1993), these same bi-directional ripple marks are recognized in thin, very fine, well sorted sandstones of turbidites from the Campos Basin, in Brazil. He suggests that these bi-directional ripple marks are turbidite deposits reworked by contour currents (Peres, 1993, p. 82; see also Carminatti and Scarton, 1991, p. 244; Shanmugam, Spalding, and Rofheart, 1993; Stanley, 1993).

Support for our interpretation can also be found in the lack of any escape structures in the sand layers. Howard (1975, p. 135) states:

> If bed thickness is less than 30 cm (11.8 inches) or so, the sequence of rapid sedimentation may be less obvious because of organisms that reestablish themselves in the bed following deposition, or move upward from below; given sufficient time, **these completely destroy the original physical structures** . . . [emphasis and parentheses ours]

If these sand layers represent crevasse splay deposits then why are there no escape structures present? Most of the lower sandstone and clay layers do not exceed the 11.8 inches suggested as representing the maximum escape structure distance. The authors found no evidence of escape structures at this outcrop and Sheehan (1988) does not discuss their occurrence at this site. The lack of escape structures is expected if the sand sole casts represent a pre-event trace fossil association in either a turbidity current or crevasse splay setting.

The creation of the sole casts is suggested by the authors as representing sandy turbidites which were deposited in pulses on distal portions of what might have been a deep-sea fan, or on the outer sections of a continental shelf (Figure 6a). Peres (1993) has proposed a shelf-fed turbidite system model which appears to satisfy many of the depositional features observed at this outcrop. As these sand-bearing turbidites moved across the soft clays they destroyed the uppermost bioturbated clay layers, filling the remaining traces with sand. The weight of the sands in combination with subsequent additional elastic overburden further served to compact the clay into a shale. This compaction resulted in the destruction of the traces within the original clay layer which were not filled with sand. This mechanism is suggested by the type of preservation found at Dougherty Gap and is consistent with that proposed by Einsele (1991 and 1992) and Seilacher (1962) for turbidite sand deposition. Again this is counter to that suggested by Sheehan (1988 pp. 172-174).

Another problem we observe with Sheehan's interpretation is presented in the uppermost sandstone layers found at this exposure. These sandstone layers also exhibit sole casts and are capped by what Sheehan (1988, pp. 26-27, Figure 8) identifies as "asymmetric linguoid ripples" If bioturbation of the sand were occurring with the intensity suggested by the underlying sole casts, then there should be much more evidence both within and along the tops of the sandstone units (e.g., lined tubes in the sandstone, bioturbated sand and clay zones along the contacts, elimination of the bi-directional current rippled sandstone tops, etc.). Instead what we find are current ripples on top of the sandstone layers and intense bioturbation as sole casts. Additionally, the topmost sandstone unit (measured at approximately nine feet in thickness) has sole casts at its base and no obvious evidences of bedding or bioturbation. To create these sole casts along the base of this nine foot thick sandstone unit would require that trace makers burrowed through (up to) nine feet of sand until reaching its base. However, we have not observed any evidence of bioturbation or bedding features in the entire nine feet of sand, and would suggest its emplacement via a turbidity current with the sole casts of trace makers reflecting a pre-event trace fossil association.

Shallow Water Versus Deep Water

This point is one of "interpretation." The physical evidence presented at this outcrop tends to better "fit" turbidity current deposition in a distal (deep water?) setting. Uniformitarians are limited in their paleoenvironmental analysis because their model is restricted by the occurrence of coal deposits. If this is a crevasse splay depositional environment then the sediments and trace makers should reflect that fact. According to Hasiotis and Bown (1992, p. 86) the crevasse splay complex contains:

> . . . overprinted ichnofaunal populations of hydrophylic (high water table) an terraphylic (low water table organisms. When the crevasse splay is deposited, it is completely saturated with water. Initial infaunal components are those that are fully aquatic and semi-aquatic in behavior like crawling traces, and horizontal and shallow u-shaped burrows of mud-loving beetles, insect larvae, and aquatic worms. Following infiltration and evaporation of the standing water, much lower sediment moisture allows organisms such as annelids, beetles, and other insects (e.g., in the Eocene Willwood Formation) to construct *Edaphichnium* and quasi vertical burrows, respectively, in mud-rich and sand-rich crevasse splay deposits, signifying a low water table.

This type of trace maker activity should be preserved as a *post-event trace fossil assemblage* within each of the sandstone layers. However, evidence to support this interpretation is not found in the sandstone layers. The reported occurrence of trace-bearing sandstone represented by hypicnial sole casts (Sheehan, 1988, p. 24, Figure 7—displayed upside down) fails to provide the expected evidences of bioturbation necessary to satisfy the crevasse splay depositional model (e.g., lined burrows, mixed sand / clay contacts, bioturbated sand and clay units, etc.).

The upper surfaces of all of the sandstone layers, no matter how thick or thin, were found to contain "asymmetric, linguoid ripples" (Sheehan, 1988, pp. 26-27) [Figure 9]. According to Sheehan (1988, p. 26):

> . . . these structures formed in response to unidirectional currents which occurred either contemporaneously (at the same time) or penecontemporaneously (immediately following with sediment deposition. [parentheses ours]

We fail to see Sheehan's logic in explaining these features associated with the long stasis—short term events associated with a crevasse splay depositional environment. If Sheehan (1988, p. 173) is correct in assuming that the sands were the original substrate of bioturbation, then bioturbation associated with feeding activity should have served to destroy any evidence of the original current ripple marks seen along the upper surfaces of the sandstones (see Kuenen, 1967).

However, if the sands were deposited on the distal portions of a deep-sea fan or continental shelf via turbidity currents, then the trace makers would be preserved as sole casts, and the upper surfaces of the sand layers would reflect the currents which served to deposit and shape them. These underwater currents are reflected on the upper surfaces of each sandstone layer at the Dougherty Gap site as ripple marks (see Walker, 1973, p. 29). These bi-directional current ripples have previously been suggested as reflecting both the original turbidity current depositional direction and subsequent reworking by contour currents (see Lovell and Stow, 1981). We suggest that additional clays were then flocculated and deposited (see Kuenen, 1965, pp. 59-60; Olphen, 1963, pp. 45-50) above the sand layers and subsequently bioturbated. These clays contained the organic material and substrate in which the trace makers developed. The sands themselves may not have contained enough organic material to attract sediment ingesting organisms away from the richer clays. Therefore, the trace makers would **NOT** have penetrated downward through the current-rippled tops of the previously deposited sands en masse, and would not have served to destroy the "asymmetric, linguoid ripples." This is why each sandstone layer retains its bi-directional rippled top surface, and the trace maker activity record remains preserved in the form of sole casts on the bottoms of each sandstone layer. This would also explain the lack of escape structures following each sand layer depositional event.

Salt Water Versus Fresh Water Environment

One key to understanding the environment of deposition at the Dougherty Gap site is to distinguish between fresh water and salt water environments, and their respective traces. In a fresh water environment burrows are usually not lined with clay or other materials (See Chamberlain, 1975; Hasiotis and Bown, 1992). However, in a brackish or marine environment lined burrows are often found. All investigators of this site agree that this was a marginal marine to marine setting. Therefore, lined burrows should be found at Dougherty Gap. They are not found in any lithology here.

Sheehan (1988, p. 173) states that the sandstone units were the substrate of choice for the trace-making animals at this site. If this were true then some evidence of lined burrows should be present in and throughout the sandstone units. Again, they are not found in the uniformitarians' most likely location. In fact, if sand was the substrate of choice for the tracemakers, at the very least there should be found some burrows in the sand connected to the hypichnial burrows that are present at this site. This is not the case.

The fact that no vertical burrows are found at the Dougherty Gap site argues against a nearshore depositional environment (Skolithos ichnofacies). Vertical burrows are often found in the nearshore environment since the high energy levels there require the endobiontic animals to anchor themselves within the substrate to keep from being washed away. Instead, only horizontal feeding burrows and traces (along with various tool marks) are found at Dougherty Gap.

The authors suggest that the lack of any lined burrows in the sandstone units supports the turbidity current depositional environmental, where the hypichnia represent a pre-event trace fossil association.

Conclusions

Many uniformitarian interpretations are based on the time/facies development requirements of their model. The Dougherty Gap site provides evidence of one such instance. However, we believe that by using many of the same principles and new concepts, we can propose and defend a more catastrophic interpretation or much of the stratigraphic record. This interpretation better fits within the framework and timeframes of the young-earth Flood model.

We suggest that Sheehan (1988) fails to adequately explain the lack of evidence of traces (i.e., lined burrows) within the individual sandstone layers. It appears that he cannot decide if the sole casts were formed as a result of the scour-and-fill and erosional clay surface (1988, p. 26), or if they are a result of the bioturbation of just the sandstone layer (1988, p. 173). Additionally, we found evidence of sole casts in the thinnest sand layers, and these layers are not thick enough to surround the tracemakers as they were proposed to have existed in this substrate.

Sheehan's (1988) defense of the Appalachian prograding delta model using the Dougherty Gap trace fossil assemblage is ineffective. While several observed features are suggestive of an interdistributary bay depositional environment, many more are not. None of the ichnogenera identified at this exposure are indicative of this specific type of environment. Rather, Sheehan's (1988, p. 160) *Cruziana* ichnofacies has a wide range and can be also interpreted as occurring on the outer shelf (Ekdale, Bromley, and Pemberton 1984, p. 187; Cowart and Froede, 1994, p. 119) which could easily fit with our suggested model of turbidity current deposition on the distal sections of a deep-sea fan or continental shelf.

We believe a turbidity current depositional environment on the distal sections of a deep-sea fan or continental shelf can better explain the physical and biogenic features seen at this outcrop. This interpretation better fits with all of the physical evidence presented at the Dougherty Gap exposure. Additionally, the turbidity current depositional environment fits within the time and energy requirements predicted for its formation within the young-earth Flood model. This turbidity current postulate uses the same physical data in a geologically reasonable manner to explain and defend a catastrophic interpretation for this exposure.

The young-earth catastrophist interpretation is not limited by Walther's law of facies succession, and offers a more defendable explanation based on the physical evidence. Our model will develop using the same physical data as our uniformitarian counterparts. The difference in interpretation will be one of time and energy.

The Dougherty Gap site presents evidence that turbidity currents formed the exposure seen at this site. These deposits and trace fossils were probably formed during the Lower to Middle Flood Event Timeframe (see Froede, 1995a). This is suggested due to the tectonic forces and sedimentary overburden which occurred following the development and burial of the traces.

Glossary

Biogenic — applied to material, processes, or activities of living or once-living organisms (Allaby and Allaby, 1990, p. 40).

Clastic — Pertaining to a rock or sediment composed principally of broken fragments that are derived from preexisting rocks or minerals, and that have been transported some distance from their places of origin. Term is usually used in the plural; e.g., the commonest "clastics" are sandstone and shale (Bates and Jackson, 1987, p. 121).

Continental shelf — That part of the continental margin that is between the shoreline and the continental slope. It is characterized by its very gentle slope of 0.1 (Bates and Jackson, 1987, p. 143).

Deep-sea fan — (also known as submarine fan) A terrigenous, cone- or fan-shaped clastic deposit located seaward of large rivers and submarine canyons (Bates and Jackson, 1987, p. 657).

Distal turbidites — A sedimentary deposit consisting of fine grained clastics and formed farthest from the source area (modified from Bates and Jackson, 1987, p. 190).

Endichnia — Traces within the casting medium; i.e., not in contact with the upper surface (Cowart and Froede, 1994).

Endobiontic — Said of an organism living in bottom sediments (Bates and Jackson, 1987, p. 213).

Epeiric Sea — A sea on the continental shelf or within a continent. Syn: inland sea; epicontinental sea (Froede, 1995b; 1995c).

Facies — The aspect, appearance, and characteristics of a rock unit, usually reflecting the conditions of its origin (Bates and Jackson, 1987, p. 232). Can be singular or plural depending upon its usage.

Hypichnia — Traces in primary contact with the lower surface (sole) of the casting medium: may appear as a ridge or a groove (Cowart and Froede, 1994).

Ichnofacies — A characteristic assemblage of trace fossils.

Prograding Delta — A river delta which is being built outward into a water body by the deposition and accumulation of continentally derived sediments (modified from Bates and Jackson, 1987, p. 530).

Proximal turbidites — A sedimentary deposit consisting of coarse clastics and formed nearest the source area (modified from Bates and Jackson, 1987, p. 534).

Substrate — For the purposes of this paper, this term is defined as the subaqueous stratum on or in which an organism lives.

Turbidity current — A bottom-flowing current laden with suspended sediment, moving swiftly (under the influence of gravity) down a subaqueous slope and spreading horizontally on the floor of the body of water, having been set and / or maintained in motion by locally churned- or stirred-up sediment that gives the water a density greater than that of the surrounding or overlying water. They originate in various ways, such as by storm waves, tsunamis, earthquake-induced sliding, tectonic movement, over-supply of sediment, and heavily charged rivers in spate with densities exceeding that of sea water (Bates and Jackson, 1987, p. 706).

Walther's law — An important statement relating to the manner in which a vertical sedimentary sequence of facies develops. Walther's law of facies implies that a vertical sequence of facies will be the product of a series of depositional environments which lay laterally adjacent to each other. This law is applicable only to situations where there is no break in the sedimentary sequence (Allaby and Allaby, 1990, p. 398).

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