SEDIMENTOLOGY, GEOCHEMISTRY AND PALEOBIOLOGY OF A MARGINAL MARINE DEPOSITIONAL ENVIRONMENT, THE MANSFIELD FORMATION, MARTIN COUNTY, INDIANA

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ABSTRACT: The Mansfield Formation of southwestern Indiana is comprised of varying sequences of mudstones, sandstones, shales, limestones and coals that date from the Pennsylvanian. Two outcrops in Martin County, Indiana, contain bedded and cross-bedded sandstones and laminated and friable siltstones, with a coal seam in one outcrop. Scouring, ripples and clay drapes are common in both outcrops. Carbon and sulfur analysis reveals total sulfur values consistently below 0.1wt.% and widely fluctuating C/S ratios. Trace fossils include *Sclarituba* isp., *Treptichnus* isp., *Haplichnus* isp., *Skolithos* isp. and tetrapod tracks. Roots and other plant material are common in some units. Palynological analyses of coal samples place the stratigraphically higher of the two outcrops to a position between the St. Meinrad and Blue Creek coals, thus dating the outcrop to the mid-Atokan. Collectively, the data point to a marginal marine depositional environment with brackish and freshwater fluvial influence and occasional sub-aerial exposure.

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INTRODUCTION

The Mansfield Formation consists of a series of mudstones, shales, siltstones, sandstones and coal seams dating from the early Pennsylvanian (Kvale, *et al*, 2004). The formation reflects a broad range of depositional influences and environments over a wide geographic area. Outcrops of the formation can be found in a narrow band ranging from 5 to 20 miles wide and stretching from Cannelton, IN, at the southern boundary of the state, north-northwestward to Attica, IN, near the Illinois border. The formation is composed of sediments deposited near shorelines of an inland ocean ~320-300 million years ago (Mangano, *et al*, 2001). Shallow marine, fluvial, intertidal or subaerial influences are present at different outcrops of the formation. Thus, it is difficult to separate the different environmental influences at work during the deposition of a particular outcrop.

Various locations within the Mansfield Formation have been examined in the past; previous studies address sedimentology and stratigraphy (e.g., Kvale and Barnhill, 1994; Kvale, *et al*, 2004), geochemistry (e.g., Mastalerz, *et al*, 1997, 1999), ichnology (e.g., Archer and Maples, 1984; Mángano, *et al*, 2001) and palynology (e.g. Cross, 1992; Engelhardt and Furer, 1996). All four disciplines—sedimentology, stratigraphy, geochemistry and paleontology—are analyzed in order to present an integrated portrait of the formation. Paleogeographic maps indicate a tropical, near-equatorial depositional environment (Scotese, *et al*, 1979). The analyses provide a more complete understanding of local environmental conditions existing during the deposition of the sediments and fossils, and contribute to a clearer overall picture of the processes at work in the region during the Pennsylvanian.

In this study, Mansfield Formation outcrops in the Naval Surface Warfare Center (NSWC), Crane Division, in Martin and Greene Counties of southern Indiana are examined (Fig. 1). Outcrop locations were plotted on the US Geological Survey 7.5 minute topographic series, Odon Quadrangle (1978), and their specific Universal Transverse Mercator (UTM) locations determined from this plot (Fig. 2). Outcrop HR-150 is named for a gravel road formed when railroad tracks were abandoned and removed. The outcrop is located at the intersection of H-383 and HR-150 near Magazine 2357 and faces HR-150. The UTM coordinates are 16S ET09444 01930 (16S, easting: 05-09-444, northing: 43-01-930) and the approximate elevation is 165 m (540 feet) above sea level. Outcrop H-435, named for the road it faces, runs parallel to railroad tracks that pass directly in front of Magazines 2412 and 2413. The UTM location is 16S ET09099 01190 (16S, easting: 05-09-990, northing: 43-01-190). The elevation is ~207 m (680 feet) above sea level. Geologic maps of the area showing surface elevations and underlying strata show very little stratigraphic tilt between the two locations (Kvale, 1992). Differences in surface elevation between the outcrops correspond to at most 2 m of differences in elevation of underlying strata, with a difference of <1 m most likely. Thus, H-435 is ~40 m stratigraphically higher than HR-150. HR-150 is ~1 km NNW of Outcrop H-435.

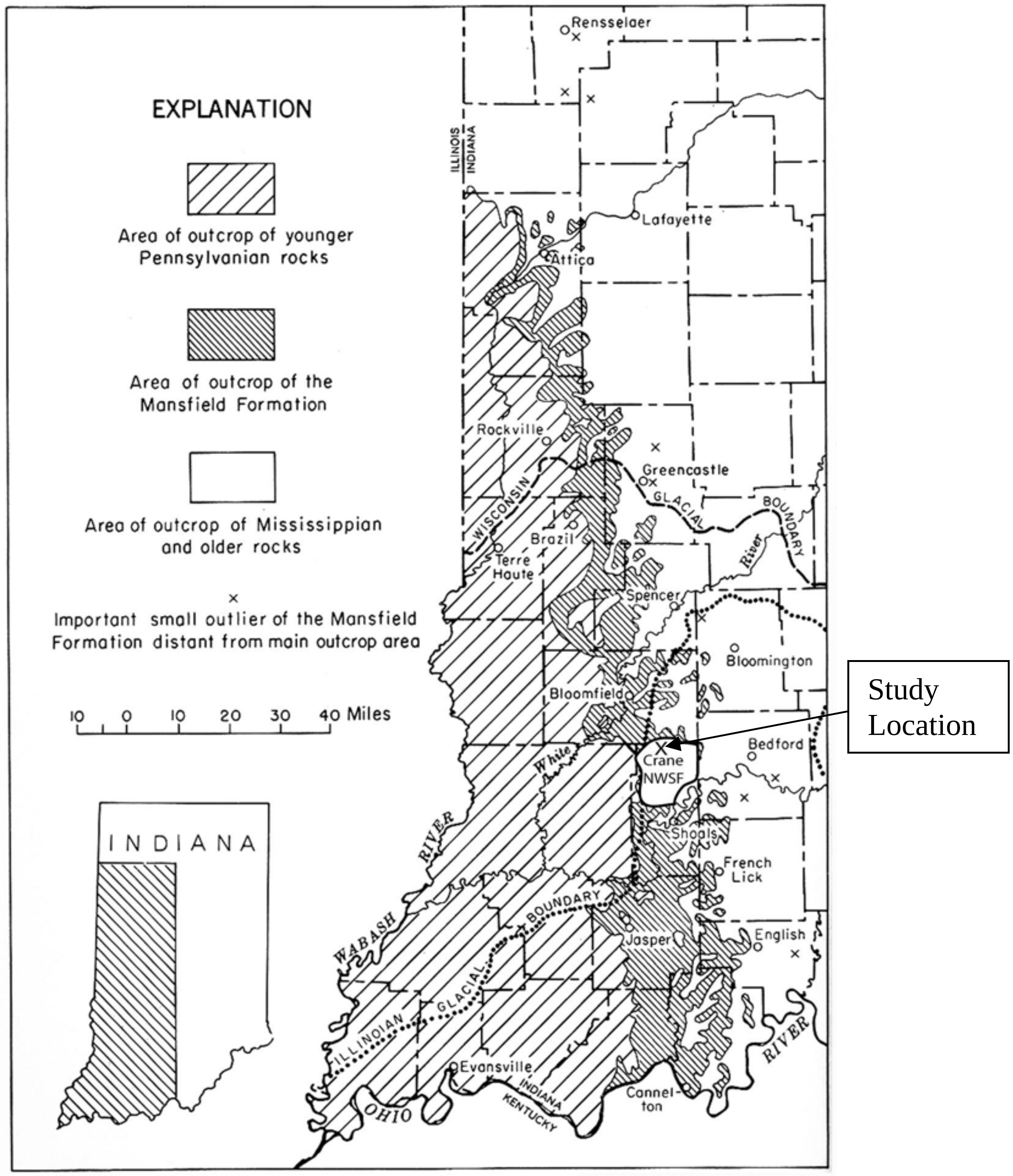

Figure 1: Geographical extent of the Mansfield Formation in Indiana (Gray, 1962). Crane NWSF is due west of Bedford. The approximate location of the two outcrops is marked with a single "X".

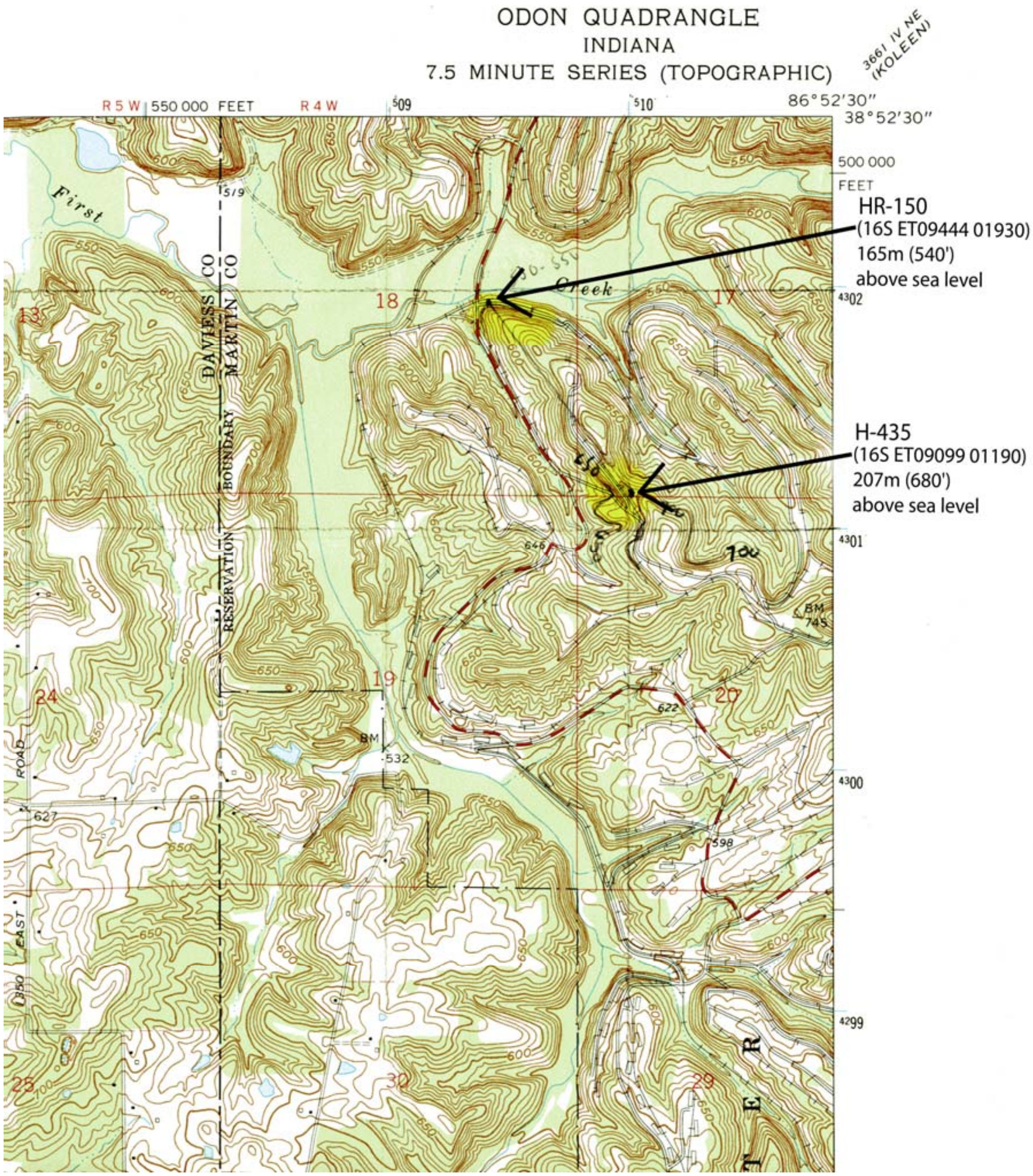

Figure 2: Topographic relief of study area (from US Geological Survey, 1978).

The Mansfield Formation

The Mansfield Formation in south-western Indiana consists largely of sandstones, siltstones, mudstones and gray shales, with several coal beds and an occasional thin limestone bed (Gray, 1962; Hasenmueller and Hutchison 1986). The formation rests unconformably on the Kinkaid Limestone of the late Mississippian at its southern extreme and the Devonian New Albany Shale at the northern reaches of the formations; rocks below the unconformity increase in age from south to north. Because of the uneven nature of the unconformity, underlying rock formations can vary within a short geographical area (Gray, 1962). Rocks of the Brazil Formation of the Early Pennsylvanian mark the upper boundary of the Mansfield Formation. In areas where it is present, the Lower Block Coal marks the lower boundary of the Brazil Formation, identifying the point of contact of the two formations. South of Bloomfield, IN, the Lower Block Coal is absent, and determining the boundary between the two formations can be difficult. Hasenmueller and Hutchison (1986) include the Mansfield Formation as part of the Raccoon Creek Group.

Rocks of the Mansfield Formation were first discussed by Owen (1862). In his survey of the geological resources of Indiana, Owen described the whetstone beds of Hindostan, IN, and their commercial use as sharpening stones. Leslie (1862) described separately the Cannelton Coal, one of the major coal units that run through the formation. Hopkins (1896) described the Mansfield Sandstone in detail and Kindle (1896) included the Hindoston whetstone beds as part of the “Mansfield sandstone formation” (p.347). In the same report, Hopkins and Kindle identified many outcrops of sandstone as belonging to the Mansfield Sandstone and mapped the sandstone as a band stretching south southeast from Attica, in Warren County at the western Indiana border to Cannelton in Perry County at the banks of the Ohio River. The term “Mansfield Formation” first appears on a geological map of coal deposits in southern Indiana by Kottowski (1959), who identified shale, thin coal beds, underclay and limestone as component members of the formation and noted that sandstones were locally present.

In describing the geology of the Huron area of south-central Indiana (~10km south of the outcrop discussed in this study) Gray, Jenkins and Weidman (1960) first used the terms “upper Mansfield” and “lower Mansfield” to differentiate trough and wedge crossbedded sandstones in the lower section from the wavy, thinly-bedded sand- and mudstones of the upper section. Gray (1962) described the formation in detail and identified “muddy” and graywacke sandstones, gray shales, mudstone, light gray clay, coal, sedimentary iron ore, limestone, and chert as major rock types of the formation. He divided the formation laterally into three distinct lithofacies: the Shoals Lithofacies, dominated by cross-stratified sandstones, the Bloomfield Lithofacies containing mostly gray shales, and the Cannelton Lithofacies comprised of mudstones and thick clays. Ridgeway (1986), identified nine major facies types in the formation: coarse-grained sandstone; coarse-to-medium-grained sandstone; fine-grained sandstone; medium-to-fine-grained sandstone; interbedded shale and sandy siltstone; micaceous gray shale; iron-stained conglomerate; quartz pebble conglomerate; and planar cross-stratified conglomerate.

Hasenmueller and Hutchison (1986) list dark carbonaceous shale and crossbedded sandstone with quartz-pebble and chert conglomerates as major rock types of the lower part of the formation. They divide the upper part of the formation into two units near Shoals and three units in southwestern Indiana. The Shoals part contains a lower sandstone unit and an upper unit of shale and mudstone separated by the Pinnick Coal Member. The 3 units of the southernwestern Indiana part are the Cannelton Lithofacies (siltstone and mudstone), the Shoal Lithofacies (cross-stratified sandstone), and the Bloomfield Lithofacies (gray shales).

Early descriptions of the stratigraphy of the Mansfield Formation concentrated largely on the coal beds. Logan (1922) identified the Shoals Coal and the Kirksville Coal. Franklin (1939) listed Pinnick Coal and French Lick Coal as units within the Mansfield Sandstones, and Gray (1962) listed many additional units, including the St. Meinrad, French Lick, Pinnick, Blue Creek, Mariah Hill and Shady Lane Coals, and the Fulda and Ferdinand Beds of the Lead Creek Limestone. Shaver and Smith (1974) identified and described two additional thin limestone beds near the top of the series. The lower bed, over the Mariah Hill Coal Bed, was described as dark and impure, and the upper bed, directly under the Lower Block Coal Formation in the area of study, as cherty.

The Mansfield Formation dates from the Pennsylvanian (Cumings, 1922). Summarizing earlier fossil studies, Gray (1962) equated the lower units of the formation to the middle of the Pottsville Series. Shaver and Smith (1974) placed the Mansfield Formation in the Morrowan Series, using the Mansfield/Brazil Formation division as the basis of Morrowan/Atokan division. However, Kvale, *et al* (2004) include the upper part of the Mansfield as part of the Atokan series and cite Peppers (1996) in dating it to the Westphalian and Namurian stages, the approximate European equivalents of the Morrowan and Atokan Series, based on palynological analysis.

Cumings (1922) defined the formation as containing all the rock above Mississippian-age rock but below the Brazil Formation. Additionally, he identified the Lower Block Coal Member as the rock directly above the formation, noting that north of Parke County the Lower Block Coal Member is absent or unidentifiable, making it nearly impossible to separate the Mansfield Sandstones from the Brazil Sandstones. Kottowski (1959) used the term “Mansfield Formation” to describe all the rock above the Mississippian-Pennsylvanian unconformity and below the Lower Block Coal Member of the Brazil Formation, a term that has continued in use to this day. He noted that the lower boundary of the formation was marked by an unconformity atop Lower Carboniferous aged limestone, sandstone or shale. Gray (1962) noted that the unconformity marking the base of the Mansfield Formation cut deeper into the underlying rock to the north, reaching down into Late Devonian New Albany Shale at the extreme northern boundary.

Cumings (1922) correlated different units of the Mansfield Formation to the Caseyville Formation and lower part of the Abbott Formation of Illinois, the Caseyville and lower part of the Tradewater Formations of western Kentucky, part of the Pottsvillian series of Appalachia, and the Morrowan Series of the mid-continental area. Wanless (1955) identified units of the formation as equivalent to the Caseyville Formation of western Kentucky and southern Illinois, the Pottsville Formation of northern Illinois, and Coal Division I[1] of Indiana (see also Wanless, 1939 and Wanless and Wright, 1978). Shaver and Smith (1974) equated the upper limestone bed to the Lead Creek Limestone Member of the Tradewater Formation in Kentucky. Thus, the rocks of the Mansfield Formation can be correlated lithostratigraphically to other rock units over a broad area in eastern and central United States.

[1] The term “Coal Division I” has since fallen out of favor.

METHODOLOGY

Outcrops of the Mansfield Formation located at NWSF, Crane Division, were examined in the field and photographed. Individual units were measured from the base of the outcrop and developed into stratigraphic profiles. Rock samples were collected at ~10 cm intervals and brought back to the laboratory for sedimentological analysis. Samples were examined under a binocular microscope for grain size, shape and sorting.

Samples for geochemical analysis of carbon, organic carbon and total sulfur were collected 20 cm apart or less from HR-150 and 10 cm apart or less from H-435. All exposed surfaces were removed before collection, and samples were wrapped in baked aluminum foil prior to grinding and analysis. Total organic carbon (TOC) data were taken from samples immersed in 1N HCL at 80ºC for 12-14 hours then filtered and recovered on baked glass-fiber filters. Total carbon (TC) and total sulfur (TS) data were taken from non-acidified ground samples. The samples were analyzed in an Eltra CS 2000 resistance furnace set to 1,450ºC. The Eltra CS2000 was calibrated with standards USGS SDO-1 (10% C, 5.6% S) and Alpha Resource AR4019 (0.1% C, 0.1% S) and the calibration was checked after every 8 to 10 runs. Samples were analyzed in random order to prevent drifting.

Samples of trace fossils and associated rocks were collected for paleoecological interpretation and are currently housed in the Indiana University Paleontology collection.. All samples were labeled with location and stratigraphic unit data. Fresh coal samples were collected from H-435 and sent to Cortland Eble of the Kentucky Geological Survey for palynological analysis for the purpose of identifying the coal seam as of either Morrowan or Atokan age.

Specimens

The specimens documented in this thesis are kept in the IU Paleontology Collections in the Department of Geological Sciences, Indiana University, Bloomington, IN 47405, USA.

RESULTS

Stratigraphy

Two outcrops of the Mansfield Formation in Crane NWSF are described in this study. HR-150 is most similar to the Bloomfield lithofacies described by Gray (1962) in that cross-stratified sandstones are the predominant lithology. The outcrop extends ~5.5m vertically and 30m laterally. Stratigraphically, this is the lower of the 2 outcrops under investigation.

HR-150 can be divided into two sections (Fig. 3): a lower wavy, flaser- and ripple-bedded siltstone/sandstone section less than 4 meters thick, and an upper section of approximately 1 m of laminated siltstones and bedded sandstones. The sections are separated by 2 layers of dark gray, friable siltstone (Units 13 and 14).

Unit 1 extends below the surface. Notes recorded in the field indicate that the lower siltstone/sandstone unit contains trace fossils at the base that gradually decrease in frequency upward, becoming sparse by the top of Unit 3. Biological activity becomes common again in Unit 4, and then generally remains sparse until the top of the outcrop.

Grains in the units below Unit 13 tend to be sub-angular silt to very fine sand and moderately sorted, with occasional wavy layers of poorly sorted material. Scouring and clay drapes are common in these lower units, with the upper boundary of the drapes often marked by iron staining. Many clay drapes, especially in Unit 3, contain flecks of mica grains. Above Unit 14 the grain size first diminishes to clay and then increases back to very fine sand. Grains become more rounded, and sorting varies from moderate to poor. Bedding planes are wavy, but become less wavy, almost planar, near the top of Unit 18.

Trace fossils return in Unit 18, with a diverse assortment of burrows parallel to sub-parallel relative to bedding planes. Details of the trace fossils are presented in the Ichnology section. The top of unit 18 is covered with ~1m of soil. There are no carbonate rocks in the outcrop.

H-435 (Fig. 4) is ~3.5m in height and spans 10m laterally. Laminated siltstones and thinly bedded sandstones predominate. As such, the outcrop appears to represent a hybrid of the Bloomfield and Shoals Lithofacies as described by Gray (1962).

H-435 contains friable siltstone at the base. This unit extends below the surface. The top of the siltstone unit is marked by root inclusions and scouring, and it is covered by a coal layer that is in turn covered by layers of laminated siltstones and sandstones. Grains in the three layers directly above the coal seam (Units 3-5) tend to be well-sorted rounded silt to very fine sand. Units 5 and 6 are comprised of planar silty sandstone beds with clay settling out in drapes along with current—and occasionally starved—ripples. Beds of Unit 6 become wavy toward the top, and there is evidence of scouring. Iron concretions (1-2 mm) are common in Unit 6. Above these layers grain size and angularity increase while sorting decreases, becoming moderate to poor near the top layer. Evidence of rooting occurs in Units 8 and 9. Repeating cycles of varying lamina thicknesses appear in the middle and upper parts of Units 10 through 12. Laminae thickness averages ~1 mm, but individual laminae are obscured in several units by cyclical appearances of biological activity in the form of vertical burrows. Units 11 and 12 contain planar beds between layers of burrows. Asymmetrical ripples appear in Unit 12, the top of the outcrop.

Further details of the sedimentology and stratigraphy can be found in Appendix A.

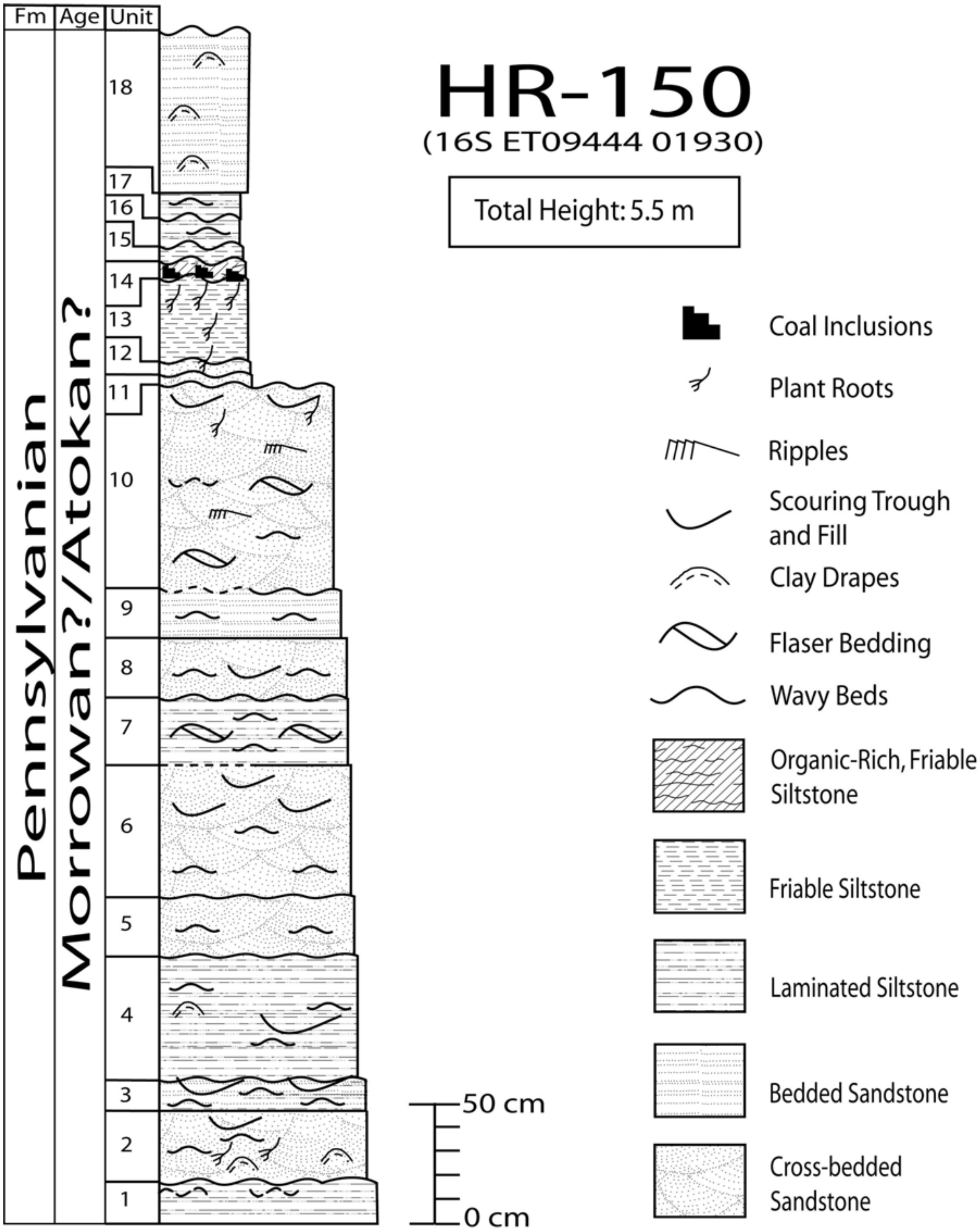

Figure 3: Stratigraphy of HR-150 (UTM coordinates 16S ET09444 01930). The stratigraphic development of trace fossils in this outcrop can be found in the Ichnology section.

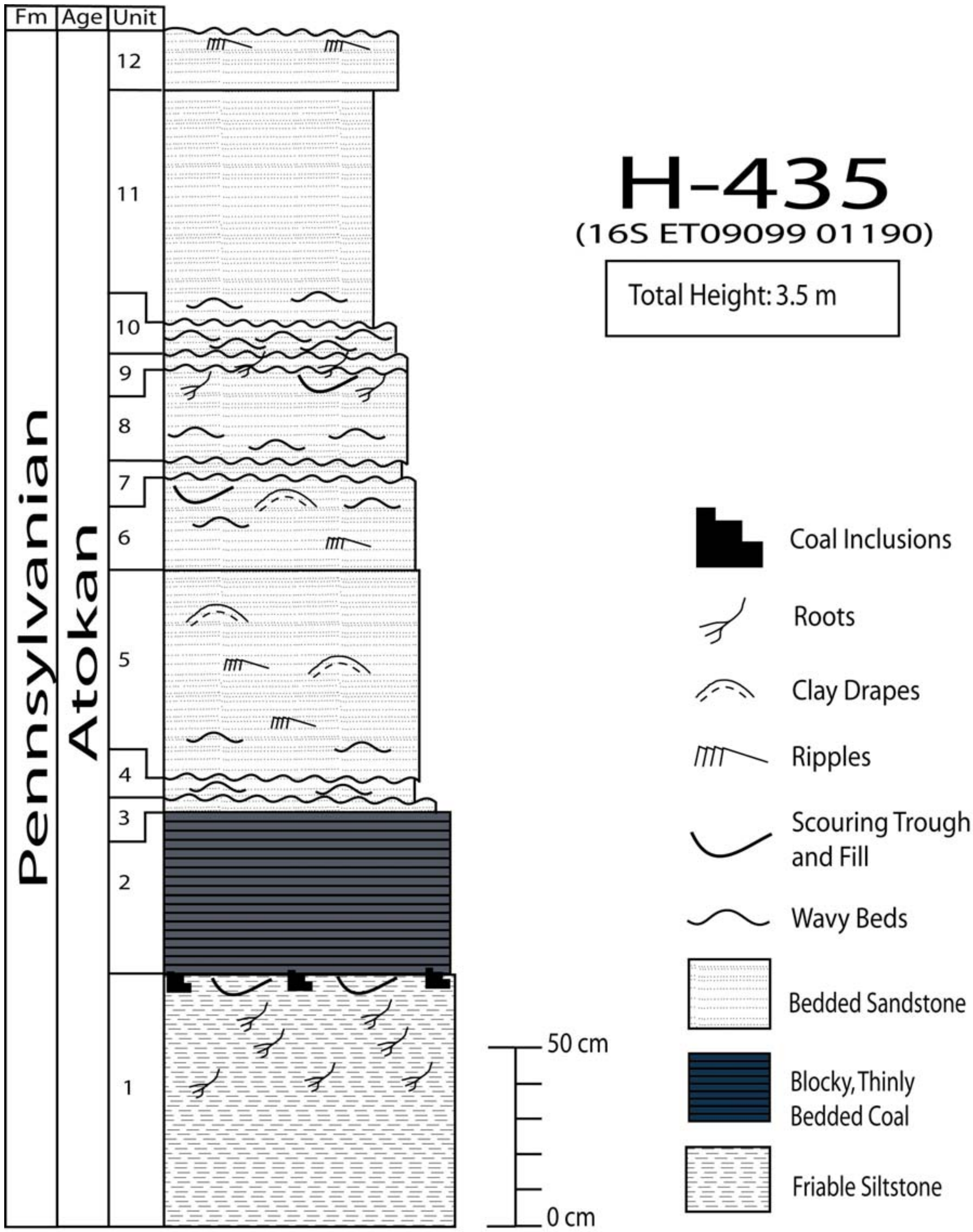

Figure 4: Stratigraphy of H-435 (UTM coordinates 16S ET09099 01190). The stratigraphic development of trace fossils in this outcrop can be found in the Ichnology section.

Geochemistry

The goal of the geochemical analysis was to infer the salinity of the water at the time of deposition. In the study, TS concentrations were used as a proxy for salinity. Sulfate concentration in water tends to vary with variations in salinity; average dissolved sulfate concentrations in marine water are ~28.2‰ compared to <1‰ for fresh water. Results of TC, TOC, and TS are listed in Appendix B.

HR-150**.** TC and TOC from Unit 14, a thin layer of organic-rich friable siltstone with coal inclusions, are slightly under 13% by mass. All other carbon and sulfur values are very low, in many cases near the detection limit of the equipment. Mean TOC is below 0.1% and in no case above 0.4% by mass except for Unit 14. All sulfur values are below 0.2wt%, with most values well below 0.04% by mass. Slightly higher sulfur values were found in Units 1, 3, 8 and 15, but the mean TS value for the entire outcrop is 0.03wt.%.

TOC/TS ratios vary from 76:1 in Unit 13 down to 1:1 in the lower half of the outcrop. The widest variations appear in the upper siltstone and sandstone units. In the lower sandstone units the ratio fluctuates from ~12.5:1 to 1:1, with a mean ratio of 5.5:1. Organic carbon levels closely approximate total carbon. All carbonate carbon values were less than the range of values reported for the low standard. Fig. 5 shows the TOC/TS ratios, TS and TOC percentages and the percent carbonate of TC for HR-150

H-435. Except for the coal seam (Unit 2), both TOC and TS levels are very low. Of 38 different samples collected, 33 samples showed TOC levels well below 1.0wt.%, with most samples at or below 0.2wt.%. Of the 5 exceptions, 4 samples were from Unit 2, a coal seam, where samples ranged from 51.4 to 66.8wt.%. The only other sample containing more than 1.0wt.% TOC was taken from Unit 1, a unit of friable siltstone with rhyzocretians ~25 cm below the base of the coal seam. This unit contained 2.24% TOC by mass. Mean TOC values above the coal seam were 0.15wt.%.

As with HR-150, most of the carbon in the samples was organic in origin. Carbonate values were consistently near detection limits. Only two samples showed any measurable carbonate loss, one from a bedded sandstone unit and one from a laminated siltstone unit. Both samples had very low carbon values. For the sample from the siltstone unit the difference between TC and TOC was within the range of carbon values reported for the low standard. The sample from the sandstone unit showed a carbon loss slightly beyond the range of reported sample values, so it is likely that this sample did experience a small amount of carbon loss; adjacent units did not show any loss under acid treatment.

Non-coal TS levels were all at or below 0.04wt.%, near the detection limit of the Eltra CS2000 TOC/TS analyzer, with the exception of one sample (0.11wt.%) taken from Unit 5, a unit of laminated siltstone notable for the presence of many trace fossils, including tetrapod tracks. The mean TS value above the coal seam was 0.02wt.%. TOC/TS ratios varied widely, from 122.4:1 to 1.7:1, with the highest values in the coal seam and lower siltstone unit. Above the coal seam the highest ratio was 23:1, with 9.5:1 as the mean. Thirty-four of 38 samples had TOC/TS ratios above 4:1, and 21 samples had ratios above 10:1. Linear regression analysis of the ratios using SPSS software shows a correlation of 0.07, which implies almost no correlation; the TOC and TS levels were virtually independent of each other. Fig. 6 shows TOC/TS ratios, percent TS and TOC, and percent carbonate of TC for H-435.

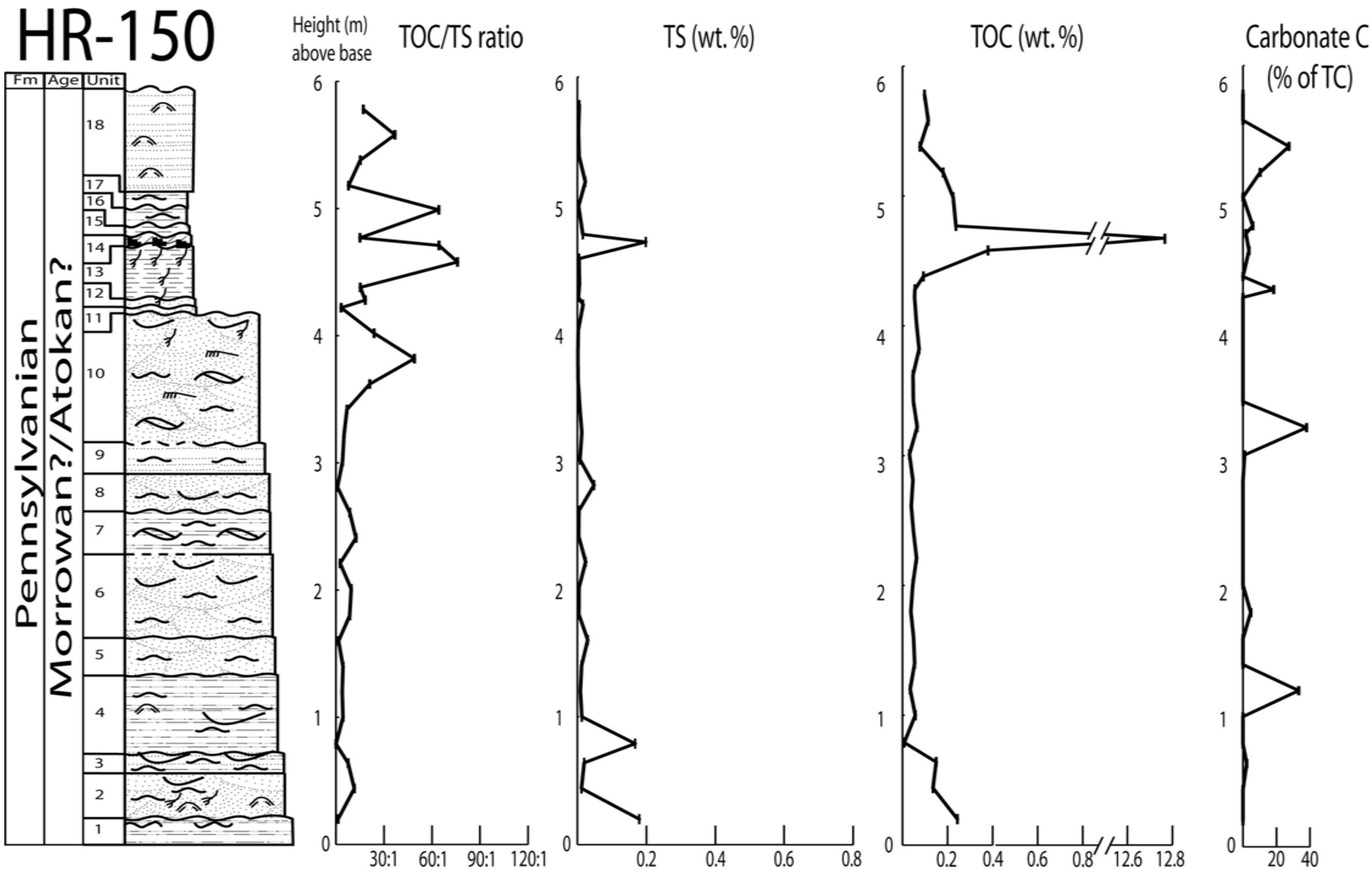

Figure 5: TOC/TS ratios, TS and TOC percent and percent carbonate of HR-15

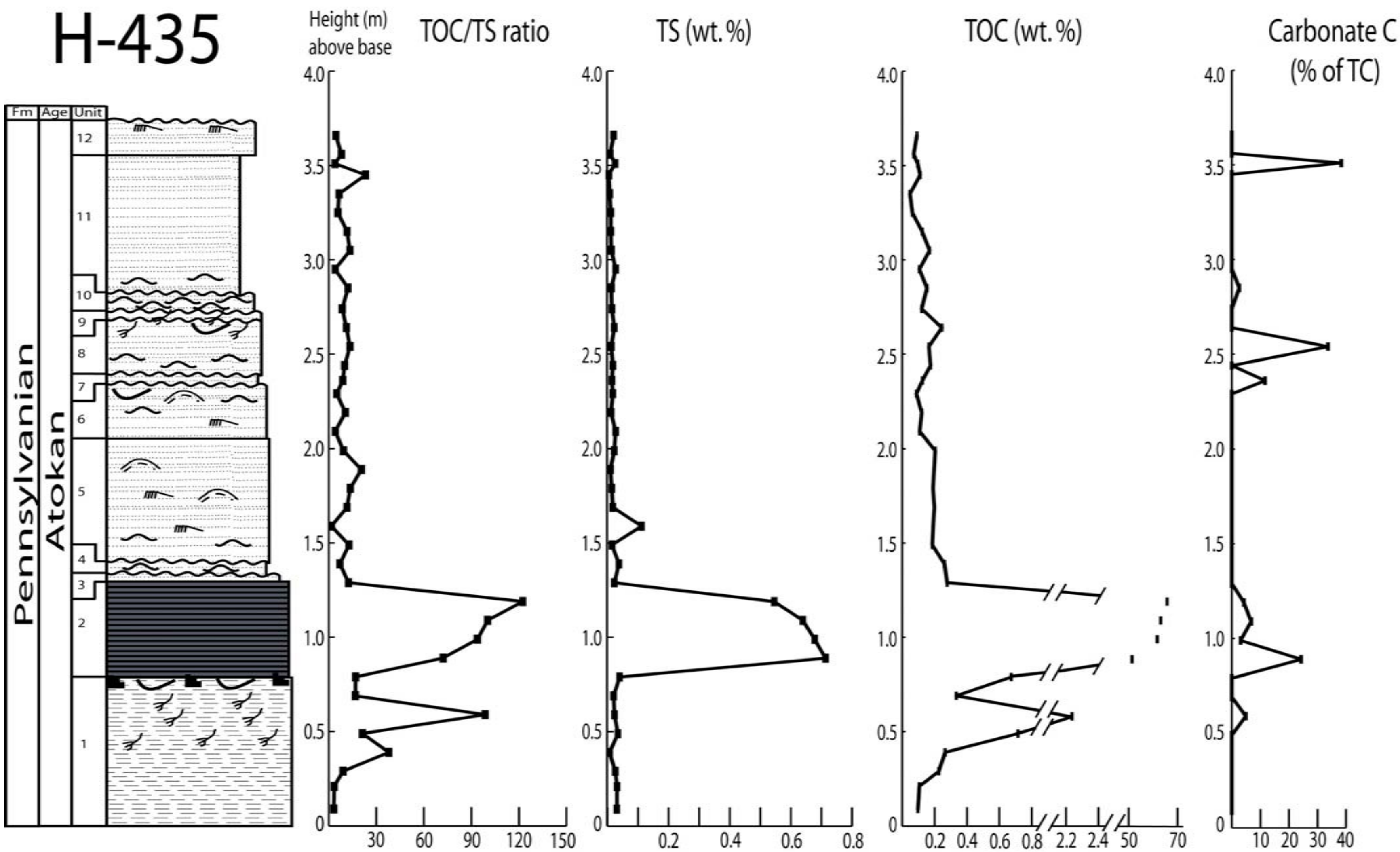

Figure 6: TOC/TS ratios, TS and TOC percent and percent carbonate of H-435

Palynology

Lycopod tree spores are the dominant palynomorph, with significant amounts of tree fern and calamite spores and cordiate pollen. Among the lycopods, *Lycospora granulata* is the predominant form, followed by *L. pusilla*, *L. orbicula* and *L. micropapillata. Punctatisporites minutus* and *Punctatosporites rotundus* are the major tree ferns represented. *Laevigatosporites minor* is the most numerous species of calamite and *Florinites mediapudens* the most common cordaite (C.F. Eble, personal communication, 2006).

The results of a statistical count of 250 palynomorphs are presented in Table 1. Data from C.F. Eble, 2006.

Table 1: Palynology of coal samples from H-435. Data from C.F. Eble, 2006.

TAXON	%
Lycospora pellucida	1.2
L. pusilla	9.2
L. granulata	37.6
L. orbicula	5.2
L. micropapillata	4.4
Granasporites medius	1.2
Total lycopod tree spores	**58.8**
Cirratriradites saturni	0.4
Endosporites globiformis	0.8
Total small lycopod spores	**1.2**
Punctatisporites minutus	16.0
Punctatosporites minutus	0.8
P. rotundus	7.6
Laevigatosporites minimus	0.4
Total tree fern spores	**24.8**
Granulatisporites adnatoides	0.4
Lophotriletes microsaetosus	0.4
Total small fern spores	**0.8**
Calamospora pedata	0.8
C. microrugosa	0.4
Laevigatosporites minor	6.0
Total calamite spores	**7.2**
Florinites florini	1.2
F. mediapudens	5.6
Total cordaite pollen	**6.8**
Tantillus triquetrus	0.4
Total unknown forms	**0.4**

Ichnology

True fossil data were very sparse in the two outcrops, although fossilized plant fragments were common in some units. Localized trace fossil data, however, were common to abundant in several units of both outcrops.

HR-150. The base of HR-150 contains numerous burrows, most of which appear to be *Scalarituba* isp. (Häntzschel, 1975, pp.W103-W106), (Fig. 7). Burrows are concave epirelief in bedding surfaces, ~6 mm wide and as much as 36 cm long, with backfill ~3 mm that comprise the burrow fill. Burrows are horizontal to oblique to bedding surfaces.

These burrows represent the feeding behavior (fodichnia) of a sediment-ingesting worm or wormlike organism (Häntzschel, 1975).

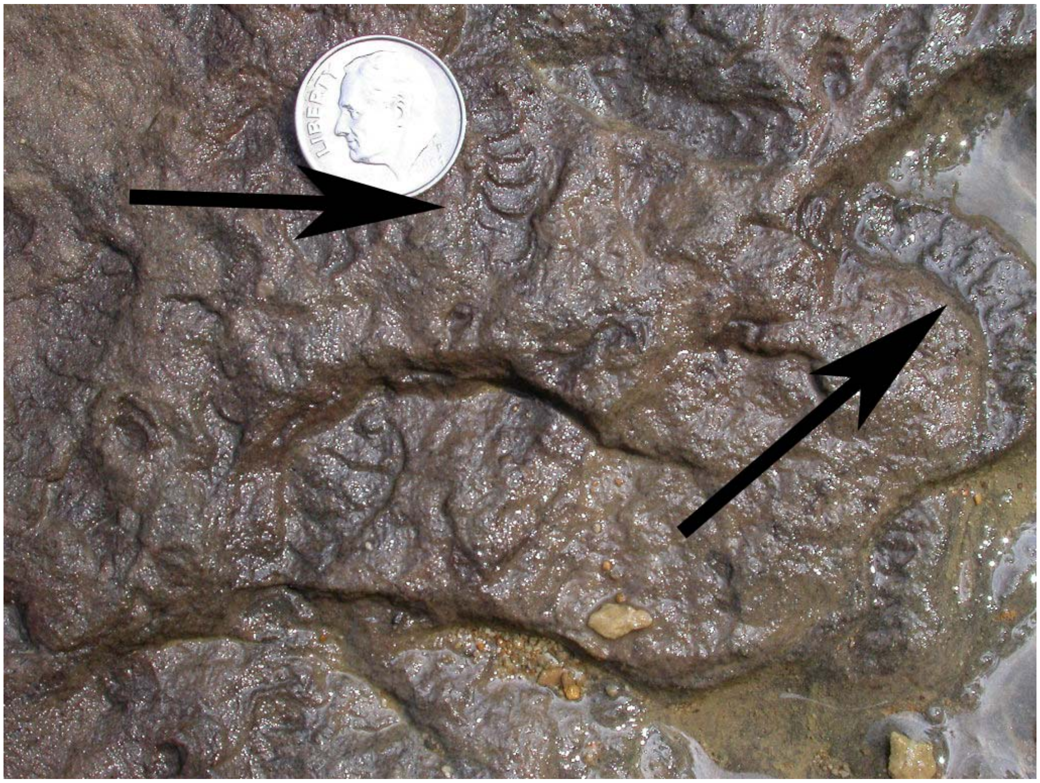

Figure 7: Arrows are pointing to *Scalarituba* isp. at the base of Unit 1 of HR-150. Photograph taken in the field.

Between Units 1 and 4, *Planolites* isp. (~3 mm wide and <6 cm long) and *Skolithos* isp. (~2 mm wide, <3 cm long) appear widely spaced horizontally and vertically. Other larger horizontal and oblique meandering burrows may also be present but are indistinct, and their biological origin is often difficult to confirm (Fig. 8). Plant material, in particular large root structures, is found in Units 1 and 2 (Fig. 9).

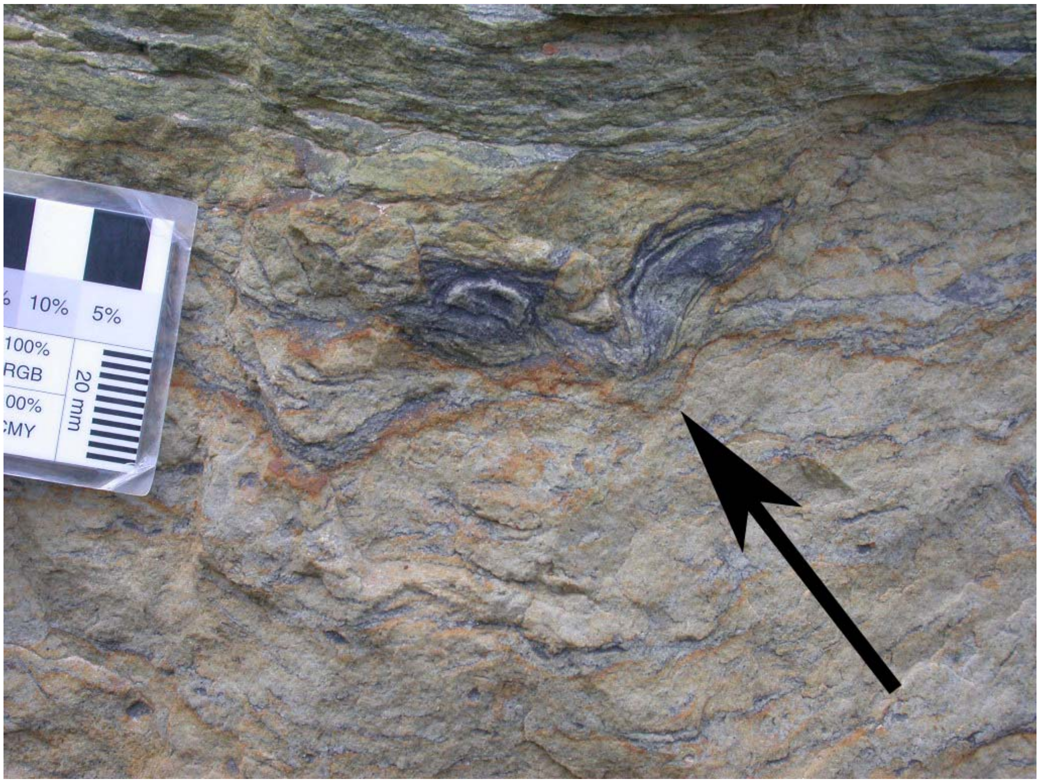

Figure 8: Field photograph of an example of *Asterosoma*, (at arrow) common in Units 1-4 of H-150.

Figure 9: Field photograph of an association of plant roots (center to upper right of photograph) within their trace fossils, rhizoliths, in Unit 2 of HR-150.

Clay drapes in the lower part of Unit 4 contain numerous very small (<0.5 mm diameter) horizontal straight and meandering trails in convex hyporelief on surfaces (Fig. 10). The morphology is somewhat similar to *Treptichnus* isp., but the pattern observed is more discontinuous in these examples. These trails are generally less than 8 mm long, but occasional straight trails extend up to 3 cm. The diameters tend to be consistent across the entire length, tapering to points at the very end of the trail. Grain size and shape inside the burrows does not appear noticeably different from those outside the burrows. Trace fossils are common at the base, but are less common upsection; they are rare above Unit 4.

Figure 10: An example of small horizontal trails assignable to *Treptichnus* isp. in reversed relief in Unit 4 of H-150. Specimen #19000.

A few similar vertical and meandering burrows reappear near the boundary of Units 8 and 9; they are uncommon and widely spaced. Individual *Planolites* (a worm burrow) meandering burrows vary in diameter from 2 to 3 mm over their length. Units 11 through 14 contain abundant *in situ* roots and other unidentifiable plant material. Unit 18 is moderately bioturbated with *Planolites* (Fig. 11) up to 6 mm in diameter and 7.5 cm long, abundant in layers interspersed with groups of thin laminae.

Figure 11: *Planolites*, isp. (at arrows) from Unit 7 of HR-150. Specimen #19007.

H-435. Tree roots and other plant material are common near the top of Unit 1 just below the coal seam. Unit 5 contains plant material and trace fossils, including meandering burrows (convex epirelief, 1 mm diameter, ~4 cm long), *Treptichnus* (Buatois, *et al*, 1998, Fig. 4.6) branching trails (concave epirelief, 3 mm diameter 20 cm total length; Fig. 12), zig-zag trails, attributable to *Haplotichnus*, (concave epirelief, ~1.5 mm diameter; Fig. 13), meandering tracks and trails, interpreted as insect repichnia or pascichnia (Buatois, *et al*¸1997a; 1998), and tetrapod tracks (Colbert and Schaeffer, 1947; Peabody, 1959). Insect tracks are generally 0.5 mm or smaller, forming trails frequently up to 7 cm long (Fig. 14). Tetrapod tracks, assumed amphibian, (Figs. 15 and 16) are 3.5 cm wide at their widest point from inside toe tip to outside toe tip and 2.5 cm long from base of ped to tip of longest digit. The peds contain 5 digits and the manus 4.

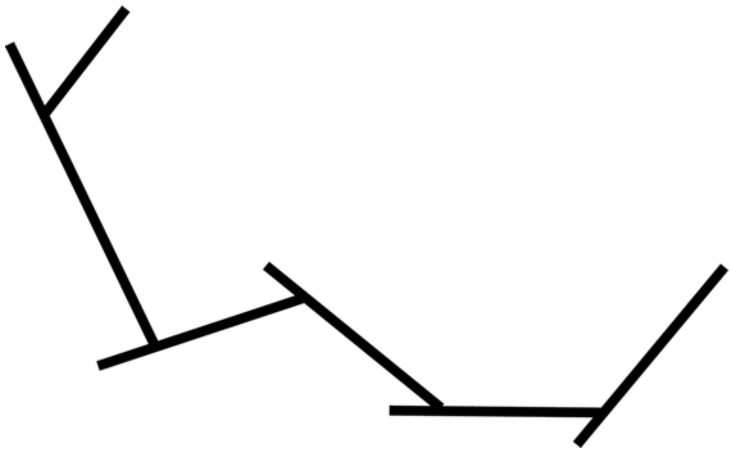

Figure 12: Drawing of *Treptichnus* trail. Total length is ~20 cm.

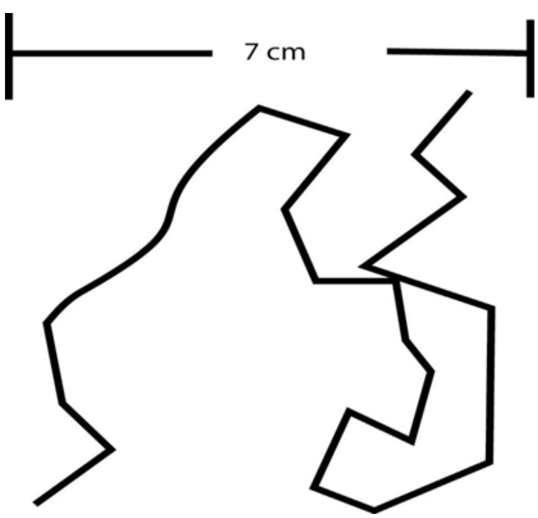

Figure 13: Drawing of zig-zag trail, attributable to *Haplotichnus*.

Figure 14: Close view up of *Treptichnus* isp. from Unit 5 of H-435. (Coin at upper right is a U.S. dime.) Specimen #19001.

Figure 15: Example of tetrapod tracks from H-435. Organized and disorganized trails of *Treptichnus* are also visible on the bedding plane. Specimen housed at Indiana Geological Survey.

Figure 16: Another example of tetrapod tracks from H-435, with cm bars in background. These tracks are the same size as those of Figure 12. Specimen 19002.

Plant material is common at the top of Unit 5 and in Unit 6 in repeating intervals (Fig. 17). Plant roots are also found in Unit 9. Large well-preserved molds of *Lepidodendron* bark are found near the top of Unit 12 (Fig. 18). The preservation of fine details and intact delicate plant parts suggests that these plants were preserved *in situ*.

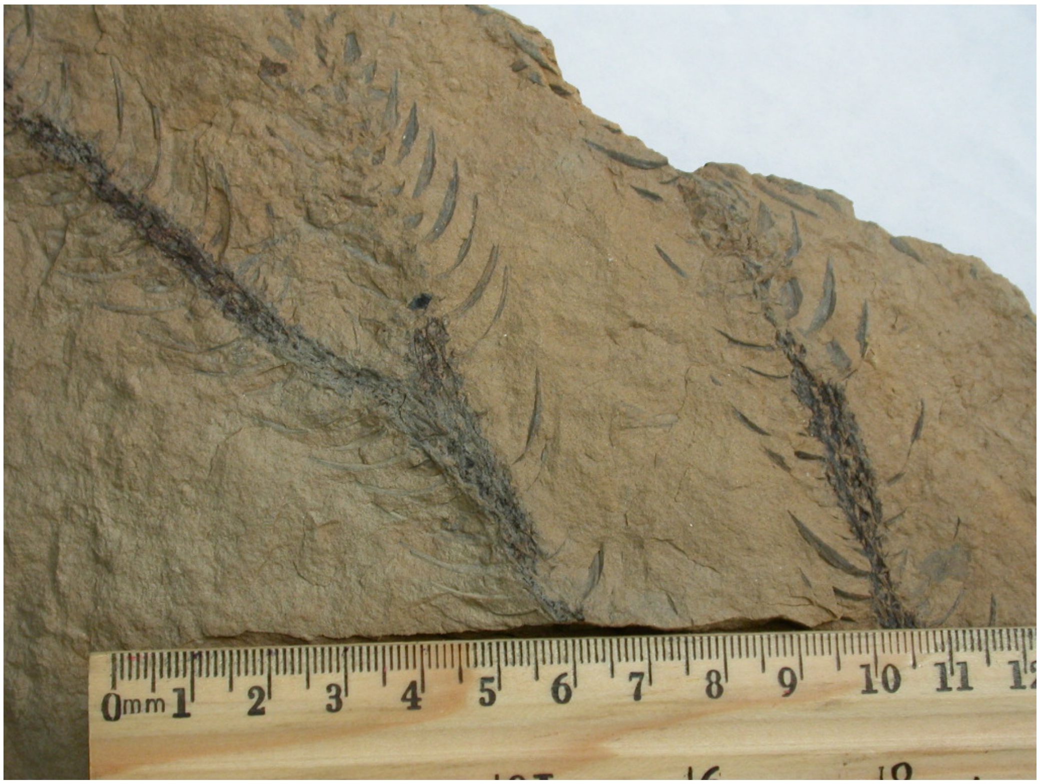

Figure 17: An example of plant material found in Unit 6 of H-435. Numbers in scale bar denote cm. Specimen #19003.

Figure 18: *Lepidodendron* mold from Unit 12 of H-435. Note preservation of fine bark details. Specimen #19004.

Units 11 and 12 display layers of abundant *Skolithos* separated by many thin laminae (Fig. 19). *Skolithos* are vertical to nearly vertical and are very dense in these units; 20 burrows packed together within a square centimeter are not unusual. *Skolithos* in clusters are generally of equal length. The average length of the burrows is ~35 mm but lengths vary from less than 1 cm up to 7 cm. Widths range from 1 to 5 mm, with the average width 1.5–2 mm. Burrows are vertical to nearly vertical. Most are of uniform widths along their lengths, but burrows that broaden near the top are common (Fig. 20). Many burrows are flanged, but most are not. Unflanged burrows may be a reflection of the quality of preservation rather than original morphology. Burrows appear unlined, with the material inside the burrow similar to that outside it. Most burrows form concave epirelief impressions on the surface and convex hyporelief on the soles of the specimens (Fig. 21).

Fig. 22 displays the fossil and ichnology data of both outcrops.

Figure 19: Typical *Skolithos* from Unit 11 of H-435. Specimen #19005.

Figure 20: An example of "flanged" burrows (*Skolithos)* from Unit 12 of H-435. The slight curve of these burrows is unusual. Most are more nearly vertical as shown in Figure 19. Specimen #19006.

Figure 21: Top view of the same *Skolithos* sample as Figure 19, (Specimen #19005) showing concave epirelief where burrows intersect the bedding plane.

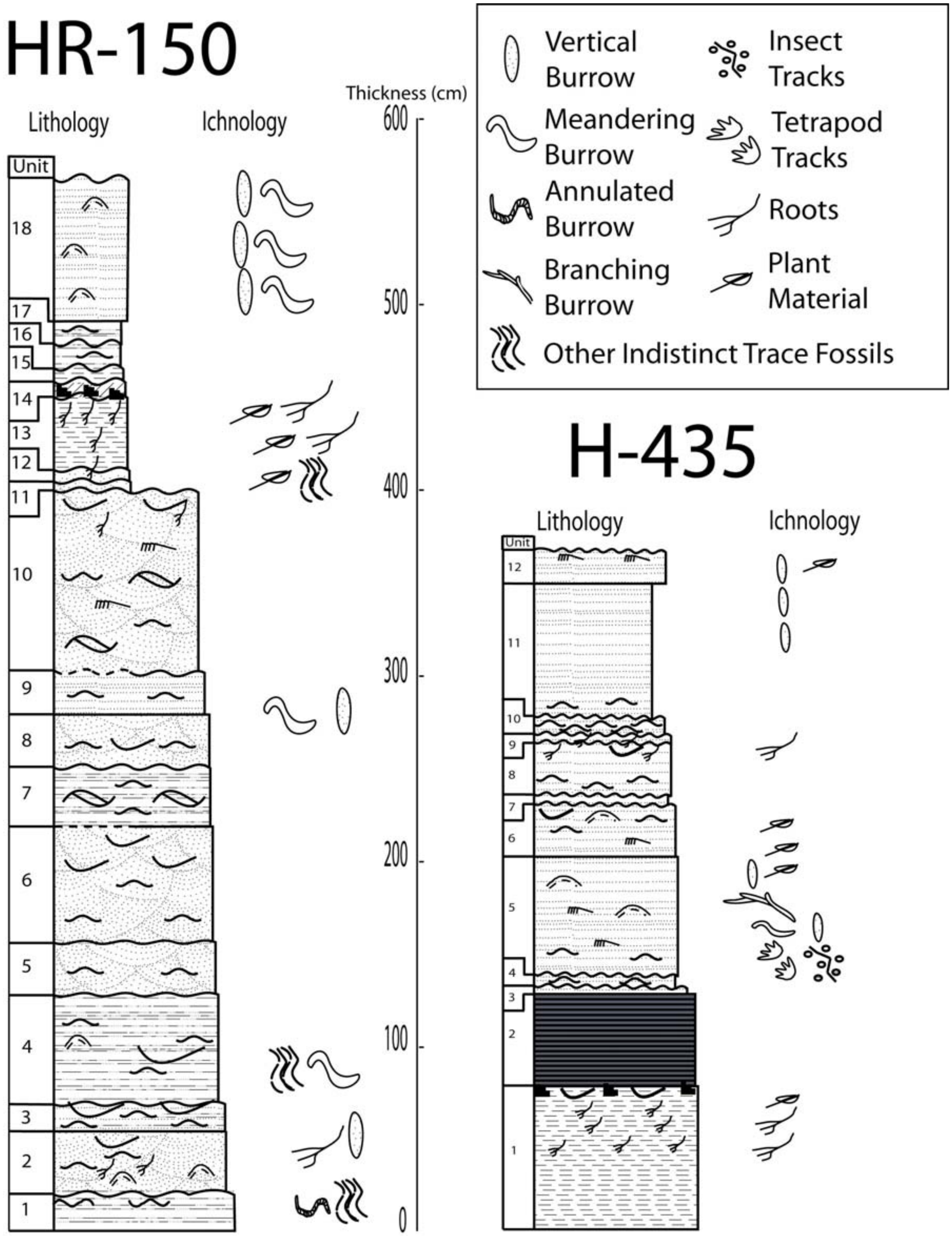

Figure 22: Ichnology of HR-150 and H-435.

DISCUSSION

The most abundant spore identified from the coal samples collect from H-435 (Unit 2) is that of *Lycospora granulata* (37.6% of all identified spores). *Lycospora granulata* predominance is characteristic of the Morrowan and early Atokan stages of the early Pennsylvanian; by the middle Atokan *L. granulata* is succeeded in predominance by *L. micropapillata* (Phillips and Peppers, 1984). Since *L. micropapillata* comprise only (4.4%) of the palynomorphs examined, the upper stratigraphic limit of H-435 is thus constrained to the middle Atokan. Both *Endosporites globiformis* and *Punctatosporites minutus* first appear in Illinois basin coals during the early Atokan (Peppers, 1996), restricting the age of the sample to the early- to mid-Atokan. The coal layer of H-435 from which the samples were taken therefore lies between the St. Meinrad and Blue Creek coals (C.F. Eble, personal communication, 2006), placing the beginning of the Atokan series below the Blue Creek Coal. This appears consistent with evidence cited by Magano, *et al*, (2001) of other outcrops to the south of H-435 that have also been dated via palynology to the Atokan.

The St. Meinrad Coal lies within the lower 1/3 of the Mansfield Formation; the Blue Creek Coal within the top 1/3. Thus H-435 lies somewhere near the stratigraphic middle of the formation. The formation extends between 50m and 100m meters vertically in the area of study (Gray, 1962; Barnhill, 1992; Kvale and Barnhill, 1994). Since HR-150 is ~40m lower stratigraphically than H-435, it can be assumed that HR-150 lies in the lower 1/3 of the formation. As such, HR-150 must date to the same age or older than HR-435.

Low carbon values undermine confidence in using TOC/TS ratios as the sole indicator of salinity (Berner and Raiswell, 1984). Considering TS data as a proxy for salinity in combination with TOC/TS ratios helps to strengthen interpretations. Table 2 is a list of the salinity and sulfur concentration of sediments collected from different locations around the Chesapeake Bay.

Table 2: Sulfur and associated salinity concentrations from Chesapeake Bay sediment samples (from Berner and Raiswell, 1984)

Site	Sediment Depth (cm)	S(wt.%)	Salinity (‰)
FB	40-42	0.14	<1
FB	64-66	0.38	<1
HG	58-59	0.38	<1
HG	59-60	0.13	<1
904N	50-55	0.63	14
904N	55-60	0.38	14
904N	60-65	0.99	14
834G	65-70	1.30	19
834G	70-75	1.18	19
834G	90-95	1.19	19
818P	45-50	1.36	21
818P	60-65	1.30	21

Salinities above 19‰ (average marine concentration is ~28.2‰) show sulfur concentrations above 1wt.%, which are easily distinguished from the concentrations for freshwater (<1‰ salinity). The trend is similar in rocks of the Pennsylvanian. Mastalerz, *et al*, (1997, 1999) examined coals and rocks from the Mansfield Formation. Rock samples containing <0.08wt.% TS were interpreted as reflecting freshwater deposition, whereas those above 0.08wt.% TS as brackish-to-marine depositional environments. Coals bearing <1.0wt.% TS—described as low sulfur—were interpreted as having been inundated by freshwater[2]; coals >2.0wt.% TS reflect subsequent marine influence. In contrast, Algeo and Maynard, (2004) and Algeo, *et al*, (2004) examined marine-

[2] The authors state an exception in the case of coals shielded from marine influences by thick layers of fine-grained sediments; that is not the case with the coal examined in the present study.

influenced shale. TS values of shales analyzed in both studies generally contained between 1 – 3wt.% TS, with the exception of shales formed in dysoxic water that contained between 0.4 - 2.0wt.% TS. The consistently low TS values of the samples analyzed (coal <1wt.%; all other samples 0.2wt.% or less) in this study indicate that marine input, and therefore salinity, was consistently low to negligible during the depositional history of both outcrops.

Although trace fossils generally reveal limited morphological information about the causative organism, they can give insights into behavior (Rhoads, 1975, pg. 147). Often the behavior captured in the traces limits the range of depositional environments under which that behavior can occur. Because trace fossils are virtually always found *in situ*, they can yield precise, detailed information about environmental conditions during the period of deposition (Frey and Pemberton, 1984; Hasiotis, 2002). A lack of positive taxonomic identification of the trace fossils collected at Crane NWSF limits but does not preclude inferences about depositional environments. Both outcrops show evidence of changing environmental conditions, where water levels and current energy appear to vary often over the depositional history of the outcrops.

HR-150

The lower siltstone/sandstone units of the outcrop are indicative of a shallow water environment. Although flaser and wavy bedding are typical of tidal-flat deposits (Archer and Maples, 1984; Buatois, *et al*, 1999), scouring suggests occasional instances of stronger current (or wave) energy. Clay drapes are formed from the settling from suspended loads during slack currents (Buatois, *et al*, 1999). All are typical characteristics of varying paleocurrent strength, possibly reflecting variations in fluvial input due to rainfall or tidal influences (Kvale and Barnhill, 1994). This section (Units 1-9) is similar to Facies I of the Kanawha Formation of West Virginia, described by Martino (1989), and the fine-grained sandstone facies of the Morrow Sandstone described by Buatois, *et al*, (1999), both interpreted as indicative of a fluviodeltaic channel. The section appears to be a hybrid of the rooted mudstone, siltstone and sandstone facies and the wavy-bedded and flaser-bedded sandstone facies described by Barnhill (1992; see also Barnhill and Hansley, 1993 and Kvale and Barnhill, 1994) and interpreted as a shallow, intertidal or supratidal environment. Ripples represent unidirectional current flow, suggesting that this channel can be distinguished from the stratigraphically-similar estuarine channel (Martino, 1994).

Scalarituba, found at the base of HR-150, and burrows in overlying units, are often associated with the *Scoyenia* ichnofacies, which is characterized by low diversity and a preponderance of fodichnia (Frey and Pemberton, 1984; Buatois and Mangano, 2002). The ichnofacies is attributed to shallow, subaqueous environments of very low salinity, relatively high energy, and occasional subaerial exposure (Buatois, *et al,* 1997b), thus correlating well with the interpretation of the stratigraphy.

The TOC/TS ratios and low TS values (Fig. 5) of Units 1 through 9 are indicative of freshwater conditions, with possible brief brackish-to-marine water incursions in Units 1 and 3 as indicated by a slight elevation of TS. The low carbonate levels, which are generally near detection limits, support the interpretation and suggest a strong fluvial influence. This could account for the low amount of carbon and sulfur. Plant roots and other materials often associated with, but distinct from, the *Scoyenia* ichnofacies suggest a temporary reduction of clastic input (Barnhill and Hansley, 1993).

Above the base of Unit 9 the TOC/TS ratio increases and fluctuates more widely. This is typical of freshwater systems (Berner and Raiswell, 1984). The fresh water (with occasional marine or brackish incursions) interpretation of Units 10-18 is supported by a lack of pyrite observed in the samples collected.

Units 13 through 16 are characterized by friable texture and the presence of fossilized plant roots. This is indicative of paleosols (Retallack, 1988), and represents an interfluvial environment (Buatois, *et al*, 1999). An increase in TS value and dip in TOC/TS ratio appears at Unit 14, which contains friable black siltstone with coal inclusions and overlies a paleosol. It is possible this is the result of saline poisoning and sudden burial of the vegetation and inundation with marine water, perhaps due to a storm event or flooding. The organic-rich Unit 14 is overlain by the organic-poor Units 15 and 16. Heavy iron staining in these units suggests a predominantly saturated environment.

Two spikes in the percentage in carbonate carbon appear, one at the Unit 10-11 boundary and the other near the base of Unit 18. These could be interpreted as possible brackish or marine incursions, but that interpretation is not supported by correlative increases in TS values. With overall carbon levels so low, the spikes in the carbonate percentage may not be particularly significant or related to changes in pH of the system.

The return of meandering *Planolites* isp. near the top of the outcrop may point to a return of fluvial or marine tidal activity. However, *Planolites* is a facies-crossing ichnofossil (Hakes, 1976). Thus, the strength of conclusions about depositional environments drawn by its presence in the ichnofossil record must be tempered. The wavy beds of Unit 17 suggest a brief return of periodic siliciclastic input which, by the base of Unit 18, has apparently transformed the region into a shallow tidally-influenced estuarine-like environment (Barnhill, 1992; Barnhill and Hansley, 1993; Kvale and Barnhill, 1994), possibly caused by settling of underlying sediments or increasing sea level. Alternating cycles of thin laminae and abundant bioturbation are typical of seasonal periods of light and heavy sediment input or other biological stresses.

H-435

TOC/TS ratios are generally lower than for HR-150, but are still above fully marine levels in most cases. These ratios are interpreted as representing a fresh-to-brackish water environment. The friable texture and rhyzocretions near the top of Unit 1 are paleosol indicators. In this instance the paleosol is often interpreted as evidence of a subaerial or shallow, tidally influenced subaqueous environment (Retallack, 1988). Iron staining and the marshy environment evident from the overlying coal seam identify a predominantly wet or water saturated environment.

Although above background level, TS in the coal seam is still very low, between 0.6-0.7wt.%, indicating a low sulfur coal. It is generally accepted that Pennsylvanian low sulfur coals represent peat mires inundated by freshwater incursions, yet the sudden increase in TS in this layer above background levels appears to suggest some marine influence. However, it is assumed that Pennsylvanian coal-producing plants did not tolerate prolonged exposure to salt water (Hakes, 1976), implying brackish- to freshwater condition in the immediate area (Martino, 1996). Other possible explanations for the elevated TS levels include organic plant sulfur (Hackley and Anderson, 1986), sulfate reducing bacteria (Spiker, *et al*, 1994), or detrital influx (Eble, *et al*, 1994). The absence of a high sulfur signal (i.e. >~2.0%) suggests that any inundation was by fresh, or possibly brackish, water. This supports the interpretation of a fresh-to-brackish water depositional environment for the overlying strata (Mastalerz, *et al*, 1997).

Coals are interpreted to represent periods of prolonged wetness, whereas siliciclastic flux is more typical of seasonal rainfall (Martino, 1996). Therefore, the change from coal to silty, bedded sandstone may indicate a change in precipitive patterns, although the overall picture is of marine transgression. Kvale and Barnhill, (1994) attribute the association of Pennsylvanian coals and tidal deposits to freshwater, supratidal deposition. The coal seam of H-435 is overlain by thinly bedded sandstones that would presumably allow the migration of sulfur via contact with more highly saline water.

The insect and tetrapod tracks in Unit 5 suggest at least occasional subaerial exposure. One possible interpretation is of a supra- or inter-tidal flat (Mangano, *et al*, 2001). This is consistent with the coal-to-siliciclastic lithology. The predominance of deposit- over suspension-feeding organisms may be indicative of a low-oxygen environment (Beynon and Pemberton, 1992). Martino (1994) reports plant material as common in thinly bedded-siltstone sandstone facies of the Kanawha Formation, which he interprets as a low-mid tidal flat/mouth bar. Despite the sedimentological similarity to that of the Keota site described by Lucas, *et* al, (2004), differences in ichnology, in particular the low diversity and the absence of arthropod trackways, preclude positive classification of the assemblage as representative of an exclusively marine or freshwater environment. Fresh-water tidal flat systems have been identified in other sections of the Mansfield Formation (Kvale, *et al*, 1989; Kvale and Mastalerz, 1998). Low TS concentrations suggest this unit may reflect a similar depositional environment.

Spikes in the percentage of carbonate carbon above the coal seam (Units 7, 8, 11 and 12) may indicate brief marine incursions, although low carbon values undermine confidence in the interpretations. Moreover, TS values are well below those generally associated with marine environments. Taken together, the low sulfur in the coal and overlying strata appear to preclude a marine depositional environment.

The overall sequence of paleosol changing to coal to wavy-bedded sandstone and laminated siltstones evident in Units 1-6 suggests a marine transgression that ultimately created a shallow subaqueous environment influenced by paleocurrents, as indicated by the ripples and starved ripples of Units 5 and 6. These features are all characteristic of shallow inter- and subtidal or sand/mud flats (Barnhill, 1992; Barnhill and Hansley, 1993; Lucas, *et at*, 2004).

The bedded siltstones and sandstones above the coal seam to the top of the outcrop appear to exhibit both current and tidal influences. There is evidence of rooting in the thin, wavy beds of Units 8 - 10. Rooting in tidal-influenced beds is indicative of a vegetated tidal flat (Kvale and Barnhill, 1994).

The change from the horizontally oriented tracks and trails in Units 5 and 6 to vertical burrows in the Units 11-12 suggests a shift from deposit- to suspension-feeding fauna, typical of increasing depth and thus marine transgression (Hakes, 1977). Packets of thin laminae alternating with thick layers of vertical burrows in the two units are taken as evidence of tidal influences and variations in sediment input (Ekdale, *et al*, 1984, pg.90), typical of tidal flats (Kvale and Barnhill, 1994; Martino, 1994; Mangano, *et al*, 2001). Beynon and Pemberton (1992) attribute this type of lamina/bioturbation alternation to variations in energy, with laminated zones reflecting higher-energy events, and consequent higher siliciclastic input, and bioturbated zones indicative of lower current velocities. The ichnology of the two upper units is typical of the *Skolithus* inchnofacies, which is characterized by high abundance and low diversity of ichnofossils (Frey and Pemberton, 1984). This ichnofacies is associated with intertidal zones, shifting sand (Ekdale, *et al*, 1984, pg. 75), brackish water (Pemberton and Wightman, 1992; Martino, 1994; Buatois, *et al*, 1998), fluctuating salinity and energy (Martino, 1994), and episodic sedimentation (Maples and Suttner, 1990). Such characteristics are typical, although by no means conclusive, proof of brackish-water, back-estuarine systems (Buatois, *et al*, 1999). The asymmetrical ripples of Unit 12, indicative of a low-energy environment, suggest a decrease in current influence, also typical of estuarine environments.

CONCLUSIONS

The two outcrops of the Mansfield Formation at Crane, NWSF, examined in this study show evidence of changing environmental conditions during the time of their deposition. The stratigraphy of HR-150 is typical of fluvial channels in Units 1-12. Low TS and carbonate values suggest fresh water influence. Ichnology indicates shallow water; trace fossil diversity is moderate, but density is low, supporting a fresh water interpretation. Units 13-16 contain friable siltstone, interpreted as paleosols, and plant roots. TS remains low despite one small spike at organic-rich Unit 14. Such evidence is consistent with a subaerial vegetated interfluvial zone. The upper section of the unit consists of packets of thin laminated siltstones interspersed with thick layers of densely packed vertical burrows, typical of fresh-to-brackish tidal flats.

H-435 has a friable siltstone layer at the base, with abundant plant roots toward the top of Unit 1, which is overlain by a coal seam. Low TS values indicate freshwater influence. A reasonable interpretation is of a subaerial vegetated interfluvial zone becoming marshy. Alternating packets of thick and thin laminated silty sandstones overlie the coal seam to the top of the outcrop. Trace fossils in Unit 5 are typical of occasional or periodic subaerial exposure, suggesting a tidal flat. Packets of laminated silty sandstone alternating with thick layers of abundant vertical burrows in Units 11 and 12 point to periodic variations in siliciclastic input and possible changes in salinity, although TS remains low in these units. These upper units are interpreted as a shallow fresh-to-brackish water environment.

Both outcrops are typical of Pennsylvanian marginal-marine environments. The change in HR-150 from fluvial channel to vegetated flat to tidal flat to shallow subaqueous flat is partially duplicated in H-435, which appears to change from vegetated flat to marsh to tidal flat to shallow subaqueous flat. Taken together, these changes suggest pulses of marine transgression over the periods of deposition.

Appendix A: Sedimentology of Outcrops, Crane NWSC

HR-150

Unit	Lithology & Color	Thickness	Boundaries	Lamina/ bed thickness range	Lamina/ bed shape	Grain size	Grain shape	Sorting	Notes
18, top ----- mid ----- base	Silty, bedded sandstone; beige, with Fe staining ------------------- Light gray, with Fe staining ------------------- Reddish-brown	76 cm	Wavy upper, horizontal lower	1-60 mm, alternating series of thin to thick to thin ------------ ------------ Lamina thinner at base	Horizontal, continuous	Silt to fine sand ------------------ Silt to very fine sand ------------------ Clay, some silt, very little very fine sand. Coarsening upward	Sub-rounded --------------- Sub-rounded --------------- Sub-angular	Moderate ------------ Well sorted ------------ Well sorted	Clay drapes throughout, possible tidallites
17	Muddy laminated siltstone, brownish-gray to orange	11 cm	Horizontal upper, wavy lower	3-12 mm	Horizontal	Clay and silt	Rounded	Well sorted	Friable
16	Muddy laminated siltstone, medium gray with Fe staining	14 cm	Wavy upper and lower	1-3 cm	Wavy	Clay to very fine sand	Sub-rounded	Poorly sorted	Very friable
15	Friable, muddy siltstone, gray, with extensive Fe staining	6 cm	Wavy upper and lower			Clay, some silt, some very fine sand	Angular	Moderate	Very friable

HR-150

Unit	Lithology & Color	Thickness	Boundaries	Lamina/ bed thickness range	Lamina/ bed shape	Grain size	Grain shape	Sorting	Notes
14	Organic-rich friable siltstone, black, with Fe staining	Varies, 2.5 cm average, thickens to 10 cm	Wavy upper and lower			Clay		Well sorted	Extensive coal inclusions
13	Muddy friable siltstone, greenish-gray at base, gray at middle, dark brownish-gray at top, with Fe staining	39 cm	Wavy upper and lower			Clay to fine sand, less sand above base		Very poorly sorted	Very friable, coalification, rhyzocretions
12	Silty sandstone, gray with brown staining	5 cm	Wavy upper and lower			Clay to fine sand	Sub-rounded	Poor	Plant (root?) inclusions
11	Silty sandstone, orange	4 cm	Wavy upper and lower			Silt to very fine sand	Sub-rounded	Well sorted	
10	Cross-bedded sandstone, beige to reddish-tan	94 cm	Wavy upper and lower, upper boundary scoured		Wavy, discontinuous, some ripple structures, some flaser bedding	Silt to very fine sand at base, very fine sand at top	Sub-rounded	Moderate at base, well sorted at top	Massive scouring at 47 cm and 67 cm from base
9, top ----- base	Muddy, silty, bedded sandstone; reddish-brown ------------------- gray	23 cm	Wavy upper, horizontal lower; upper boundary indistinct in places	Up to 5 cm ------------ Lamina, up to 1 mm	Wavy, discontinuous	Silt to very fine sand ------------------ Clay to fine sand	Sub-angular --------------- Angular	Moderate ------------ Poorly sorted	

HR-150

Unit	Lithology & Color	Thickness	Boundaries	Lamina/ bed thickness range	Lamina/ bed shape	Grain size	Grain shape	Sorting	Notes
8	Cross-bedded sandstone, light gray to tan to reddish brown	29 cm	Horizontal upper, wavy lower	Lamina to thin beds	Wavy, non-parallel, discontinuous, often indistinct	Silt to fine sand	Angular	Poorly sorted	Evidence of dramatic scouring
7	Laminated siltstone, light gray	29 cm	Wavy upper, horizontal lower, often indistinct in places	Less than 1 mm to 5 cm.	Wavy, non-parallel, discontinuous	Silt to very fine sand	Sub-rounded	Moderate	Beds thinner at top and bottom, thicker in middle
6	Silty cross-bedded sandstone, light tan, Fe staining	60 cm	Horizontal upper, indistinct in places, slightly wavy lower		Wavy, discontinuous, non-parallel, ripples	Silt to very fine sand	Sub-angular	Moderate	Wavy amalgamation surface, 30-41 cm from base; evidence of scouring, deep in places
5	Silty cross-bedded sandstone, light brown	21 cm	Slightly wavy upper and lower	2 mm to 9 cm	Wavy, discontinuous, non-parallel	Silt to very fine sand	Sub-rounded	Moderate	Upper boundary marked by 10-12 layers of thin, discontinuous lamina, indistinct in places
4	Laminated siltstone, light gray	58 cm	Slightly wavy upper and lower	Less than 1 mm to 5 cm	Wavy, non-parallel, discontinuous	Silt	Sub-rounded	Well sorted	Alternating series of thick, then thin, then thick beds, hummocky?
3	Bedded sandstone, light gray	17 cm, widens to 30 cm north, pinches out south	Wavy upper, horizontal lower	Less than 5 mm, with very dark clay drapes, less than 1 mm	Wavy, non-parallel, discontinuous	Very fine sand	Sub-angular --------------- Angular	Well sorted ------------ Poorly sorted	

HR-150

Unit	Lithology & Color	Thickness	Boundaries	Lamina/ bed thickness range	Lamina/ bed shape	Grain size	Grain shape	Sorting	Notes
2	Silty cross-bedded sandstone, medium gray, with FE staining	40 cm	Horizontal upper, slightly wavy lower	1 – 4 mm	Wavy, non-parallel, discontinuous	Silt to very fine sand	Sub-angular to sub-rounded	Well sorted	Dark brown clay drapes
1	Laminated siltstone, medium gray	24 cm	Slightly wavy upper	Ca. 1 mm	Wavy, non-parallel, discontinuous	Silt	Sub-angular	Well sorted	

H-435

Unit	Lithology	Thickness	Boundaries	Lamina/bed thickness range	Average lamina/ bed thickness	Lamina/ bed shape	Grain size	Grain shape	Sorting	Iron/ manganese staining?	Notes
12	Bedded sandstone	18.5 cm	Flat at base, rounded at top	Bottom 12 cm – many smaller beds, 4–11 mm. Thicker toward center of unit	?	Wavy	Fine at base to medium at top	Sub-angular at base to angular at top	Well sorted at base, moderately sorted at top	Yes, at top 1.5 cm. Also vertical staining	Organic material at top. Top ledge-forming, resistant to weathering. Straight vertical burrows, 5-55 mm long, 1.5-2 mm wide.
11	Bedded sandstone	70 cm	Wavy at base, flat at top	4-70 mm Packages of alternating think and thin beds, 8-11 cm thick	12 mm	Flat, horizontal	Fine	Sub-rounded	Well sorted	Yes, top 2 cm, thinly laminated. Contains occasional vertical layers	Straight vertical burrows start 18 cm from base, 5-55 mm long, 1.5-2 mm wide Some mica
10	Silty, bedded sandstone	10 cm	Wavy	4-20 mm, thinning upwards	5 mm	Slightly wavy, distinct tops and bottoms	Silt to fine sand, some medium sand at base	Sub-rounded at base to sub-angular at top	Well sorted at base to moderately sorted at top	Yes, at top, fine grained	De-watering structures? Some clay
9	Bedded sandstone	4 cm	Wavy	<1-2 mm	1 mm	Thin, wavy	Fine	Angular	Poorly sorted	Yes, throughout	Some clay, organics

H-435

Unit	Lithology	Thickness	Boundaries	Lamina/bed thickness range	Average lamina/ bed thickness	Lamina/ bed shape	Grain size	Grain shape	Sorting	Iron/ manganese staining?	Notes
8	Silty, bedded sandstone, interbedded red and gray	28.5 cm	Wavy	4-50 mm	?	Flat	Silt to fine sand at top, some medium sand at base	Sub-angular at base to sub-rounded at top	Moderately sorted at base to well sorted at top	Yes, at top	Some scouring at top
7	Silty, bedded sandstone	3.3 cm	Wavy	<1-2 mm	1 mm	Wavy	Silt to medium sand	Angular	Moderate	Yes, throughout	
6	Silty, bedded sandstone	28 cm	Flat at base, wavy at top	5-40 mm	18 mm	Wavy	Silt to fine sand	Sub-angular	Moderate to poorly sorted	Yes, inter-bedded, <1-2 mm lamina	Sandstone partings, draped rippled and scoured
5	Silty bedded sandstone	57 cm	Wavy at base, flat at top	1-10 mm at base, 1-30 at top, thickening upward, alternating thin and thick	5 mm at base to 12 mm at top	Flat, horizontal	Silt, coarsening upward to fine sand and silt, with some clay	Rounded at base to sub-angular at top	Very well sorted at base to moderately sorted at top	Yes, inter-bedded	Thinner beds not finer grained
4	Bedded sandstone	Varies, 12-14 cm	Wavy	Less than 1 mm variation	~1mm	Wavy, some scouring	Top and bottom - very fine middle - fine to very fine	Rounded	Top and bottom - very well sorted. Middle - well sorted	No, but top slightly more brownish	Gray at bottom, brownish-grey at top
3	Bedded sandstone	Varies from 2.5 cm to 4.5 cm	Flat at base, wavy at top	Less than 1 mm variation	~1mm	Wavy	Very fine	Rounded	Very well sorted	No	Bluish-grey tint, some organics

H-435

Unit	**Lithology**	**Thickness**	**Boundaries**	**Lamina/bed thickness range**	**Average lamina/ bed thickness**	**Lamina/ bed shape**	**Grain size**	**Grain shape**	**Sorting**	**Iron/ manganese staining?**	**Notes**
2	Coal, blocky, thinly bedded	45.5 cm	Flat, horizontal	1-3 mm	1.5 mm	Flat, horizontal				No	Variable coalification, different amounts of organic matter
1	Friable siltstone	69 cm	Flat, some scouring at top	2-5 mm, thicker at top 8-9 mm	?	Flat, horizontal - some dipping ~5°	Fine	Angular	Moderately	No,	Micaceous, rhysocre-tions, coal inclusions, oxydized around roots

Appendix B: Geochemistry of Outcrops

HR-150

Sample	Unit	Height Above Base, in cm	Weight, in mg	% Total Carbon	% Total Sulfur	Sample	Weight, in mg	% Organic Carbon	% Insoluble Sulfur	TOC/TS
2/797	1	20	251.4	0.24	0.18	2a/759	251.8	0.24	0.14	1.36
4/793	2	44	250.9	0.12	0.01	4a/776	247.1	0.14	0.03	11.46
6/815	2	64	252.0	0.15	0.02	6a/772	252.7	0.15	0.03	7.57
8/773	3	79	252.7	0.20	0.17	8a/818	247.3	0.01	0.00	0.05
10/779	4	100	251.6	0.05	0.01	10a/806	248.6	0.06	0.03	4.39
12/811	4	120	251.2	0.05	0.01	12a/767	251.5	0.03	0.03	3.90
14/768	4	140	250.1	0.04	0.01	14a/765	253.0	0.05	0.03	4.40
16/785	5	160	252.4	0.04	0.03	16a/770	250.4	0.05	0.03	1.63
18/766	5	180	253.6	0.04	0.00	18a/792	249.2	0.04	0.01	8.58
20/789	6	201	250.7	0.03	0.00	20a/778	248.4	0.05	0.03	9.52
22/783	6	221	253.0	0.04	0.02	22a/782	253.9	0.06	0.03	2.59
24/791	6	241	250.0	0.04	0.00	24a/816	253.1	0.05	0.03	12.51
26/795	7	261	250.0	0.03	0.00	26a/822	252.2	0.04	0.03	8.60
28/821	8	281	249.9	0.03	0.05	28a/826	251.9	0.05	0.04	0.95
30/764	8	301	251.7	0.03	0.01	30a/794	250.7	0.03	0.02	4.09
32/819	9	322	250.0	0.10	0.01	32a/814	250.0	0.07	0.04	5.04
34/799	10	342	251.0	0.02	0.01	34a/784	250.2	0.05	0.04	6.86
36/787	10	362	252.0	0.03	0.00	36a/802	253.9	0.05	0.03	21.09
38/807	10	382	250.7	0.02	0.00	38a/763	252.6	0.07	0.01	49.00
40/803	10	402	253.7	0.04	0.00	40a/798	250.0	0.06	0.01	23.81
42/781	11	422	250.9	0.05	0.02	42a/823	249.5	0.05	0.04	3.23
43/813	12	428	250.3	0.07	0.00	43a/774	253.4	0.05	0.02	18.30
44/775	13	438	252.4	0.07	0.01	44a/788	251.1	0.09	0.01	15.18
46/805	13	458	251.8	0.39	0.01	46a/808	251.5	0.38	0.03	75.92
48/760	15	471	248.7	12.98	0.20	48a/796	250.4	12.74	0.21	64.33
49/771	16	477	253.1	0.25	0.02	49a/804	249.5	0.24	0.04	14.99
51/809	17	499	250.7	0.22	0.00	51a/825	252.1	0.22	0.02	64.20
53/777	18	518	250.2	0.20	0.02	53a/812	254.2	0.18	0.08	7.83

HR-150

Sample	Unit	Height Above Base, in cm	Weight, in mg	% Total Carbon	% Total Sulfur	Sample	Weight, in mg	% Organic Carbon	% Insoluble Sulfur	TOC/TS
55/817	18	538	252.8	0.11	0.01	55a/761	250.0	0.08	0.04	15.18
57/801	18	558	250.6	0.08	0.00	57a/786	249.7	0.11	0.03	36.81
59/762	18	578	250.3	0.10	0.01	59a/824	249.0	0.10	0.03	17.12

H-435

	Sample #	Height Above Base, in cm	Weight, in mg	% Carbon	% Sulfur	Sample	Weight, in mg	% Organic Carbon	% Sulfur	TOC/TS
1u1-1-9/011	1	9	237.7	0.07	0.03	1a	251.6	0.10	0.02	3.18
1u1-2-21/020	2	21	235.4	0.09	0.03	2a	250.4	0.11	0.02	3.41
1u1-3-29/050	3	29	242.1	0.18	0.03	3a	250.8	0.23	0.03	8.97
1u1-4-39/013	4	39	255.7	0.21	0.01	4a	251.2	0.27	0.03	37.86
1u1-5-49/063	5	49	254.1	0.69	0.03	5a	249.3	0.72	0.04	21.23
1u1-6-59/028	6	59	249.6	2.35	0.02	6a	250.1	2.24	0.03	98.67
1u1-7-69/044	7	69	249.8	0.31	0.02	7a	249.7	0.33	0.03	16.78
1u1-8-79/016	8	79	253.6	0.60	0.04	8a	251.0	0.67	0.04	16.96
1u2-9-4/032	9	89	244.1	67.89	0.71	9a	250.5	51.44	0.44	72.11
1u2-10-14/040	10	99	221.5	65.59	0.68	10a	249.5	63.57	0.47	93.80
1u2-11-24/015	11	109	229.9	68.75	0.64	11a	249.3	64.10	0.52	100.30
1u2-12-34/088	12	119	235.6	69.73	0.55	12a	250.4	66.79	0.54	122.42
1u3-13-1/042	13	129	240.1	0.15	0.02	13a	250.1	0.28	0.04	12.37
1u4-14-5/055	14	139	240.5	0.21	0.04	14a	250.6	0.26	0.04	7.02
1u5-15-6/018	15	149	245.0	0.16	0.01	15a	249.1	0.19	0.01	12.67
1u5-16-16/034	16	159	249.8	0.16	0.11	16a	250.7	0.19	0.06	1.72
1u5-17-26/012	17	169	242.9	0.17	0.02	17a	250.3	0.20	0.05	11.48
1u5-18-36/059	18	179	236.5	0.15	0.01	18a	250.5	0.19	0.06	13.61
1u5-19-46/053	19	189	234.2	0.14	0.01	19a	249.1	0.20	0.05	20.52
1u5-20-56/083	20	199	242.3	0.16	0.02	20a	250.3	0.20	0.05	9.25
1u6-21-8/077	21	209	238.6	0.06	0.03	21a	250.0	0.11	0.06	4.10
1u6-22-18/072	22	219	229.6	0.10	0.01	22a	249.9	0.12	0.03	10.41
1u6-23-28/068	23	229	255.6	0.04	0.02	23a	249.7	0.09	0.04	5.05
1u7-24-2/065	24	236	232.6	0.14	0.01	24a	249.8	0.13	0.04	8.80
1u8-25-8/074	25	244	242.3	0.13	0.02	25a	250.1	0.17	0.04	9.91
1u8-26-18/014	26	254	243.5	0.25	0.01	26a	249.7	0.16	0.04	13.38
1u9-27-1/046	27	264	231.2	0.23	0.02	27a	250.0	0.24	0.08	11.08
1u10-28-6/070	28	274	234.1	0.08	0.01	28a	249.5	0.12	0.03	8.48
1u11-29-5/037	29	285	234.7	0.16	0.01	29a	250.2	0.15	0.05	12.09
1u11-30-15/003	30	295	247.0	0.05	0.03	30a	249.8	0.11	0.04	4.01

H-435

	Sample #	Height Above Base, in cm	Weight, in mg	% Carbon	% Sulfur	Sample #	Weight, in mg	% Organic Carbon	% Sulfur	TOC/TS
1u11-31-25/081	31	305	224.9	0.13	0.01	31a	250.4	0.17	0.06	13.36
1u11-32-55/061	32	315	226.1	0.09	0.01	32a	249.0	0.12	0.05	11.52
1u11-33-45/079	33	325	233.1	0.04	0.01	33a	251.1	0.06	0.05	5.76
1u11-34-55/025	34	335	233.7	0.03	0.01	34a	249.6	0.05	0.05	6.52
1u11-35-65/007	35	345	256.6	0.05	0.00	35a	249.2	0.11	0.06	23.13
1u11-36-71/005	36	351	239.3	0.16	0.02	36a	249.7	0.10	0.03	3.89
1u12-37-5/022	37	356	229.0	0.02	0.01	37a	250.0	0.07	0.04	7.94
1u12-38-15/085	38	366	223.2	0.04	0.02	38a	250.6	0.09	0.04	4.50

Appendix C: Collected Samples

<u>IU #19000</u>
Study number: S-05-1-3-4
Fossil Name: *Treptichnus* isp.
Location: HR-150
Stratigraphic Horizon: Unit 4
Collected on: June 8, 2005
Collected by: Glenn Simonelli
Identified by: Glenn Simonelli
Number of Specimens: 1
Notes:

<u>IU #19001</u>
Study number: S-05-1-1-5(a)-6
Fossil Name: *Treptichnus* isp.
Location: H-435
Stratigraphic Horizon: Unit 5
Collected on: August 17, 2005
Collected by: Glenn Simonelli
Identified by: Glenn Simonelli
Number of Specimens: 1
Notes:

<u>IU #19002</u>
Study number: EK-43B
Fossil Name: Tetrapod track.
Location: H-435
Stratigraphic Horizon: Unit 5
Collected on: ca. 1980
Collected by: Erik Kvale
Identified by: Erik Kvale
Number of Specimens: 1
Notes: This fossil has broken into 3 pieces since being photographed.

<u>IU #19003</u>
Study number: S05-1-1-6-43
Fossil Name: Plant material
Location: H-435
Stratigraphic Horizon: Unit 6
Collected on: August 17, 2005
Collected by: Glenn Simonelli
Identified by: Glenn Simonelli
Number of Specimens: 1
Notes: Specimen currently kept in "Local Fossils" display case on 2^{nd} floor of Indiana University Geology Building.

<u>IU #19004</u>
Study number: S-06-1-1-12
Fossil Name: *Lepidodendron* mold
Location: H-435
Stratigraphic Horizon: Unit 12
Collected on: January 27, 2006
Collected by: Glenn Simonelli
Identified by: Glenn Simonelli
Number of Specimens: 1
Notes:

<u>IU #19005</u>
Study number: S-05-1-1-11-38
Fossil Name: *Skolithos*
Location: H-435
Stratigraphic Horizon: Unit 11
Collected on: August 17, 2005
Collected by: Glenn Simonelli
Identified by: Glenn Simonelli
Number of Specimens: 1
Notes:

<u>IU #19006</u>
Study number: S-05-1-1-12-16
Fossil Name: "Flanged" burrow
Location: H-435
Stratigraphic Horizon: Unit 12
Collected on: August 17, 2005
Collected by: Glenn Simonelli
Identified by: Dr. Erle G. Kauffman
Number of Specimens: 1
Notes:

<u>IU #19007</u>
Study number: S-06-1-3-7
Fossil Name: *Planolites* isp.
Location: HR-150
Stratigraphic Horizon: Unit 7
Collected on: January 27, 2006
Collected by: Glenn Simonelli
Identified by: Dr. Erle G. Kauffman
Number of Specimens: 1
Notes:

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Wanless, H.R., 1955. Pennsylvanian rocks of Eastern Interior basin. Bulletin of the American Association of Petroleum Geologists, 39(9), pp. 1753-1820.

Wanless, H.R., and C.R. Wright, 1978. Paleoenvironmental Maps of Pennsylvanian Rocks, Illinois Basin and Northern Midcontinent Region. Bolder, CO: Geological Society of America.

Curriculum Vitae

Glenn Simonelli **6405 S. Main St., Bloomington, IN 47401** **812-824-4231**
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Education:

Doctor of Education. Indiana University School of Education, Department of Curriculum and Instruction, Science Education. Dissertation: *A Validation Study of the Fifth Grade Science ISTEP+ Test*, 2006.

Master of Science, Indiana University Department of Geological Sciences. Thesis: *Sedimentology, Geochemistry and Paleobiology of a Marginal Marine Depositional Environment, the Mansfield Formation, Martin County, Indiana*

Master of Science, Indiana University Elementary Certification/Graduate Program. Thesis: *Using Expository Writing to Foster Mathematical Problem-Solving Skills.*

Bachelor of Arts graduated with honors from Indiana University, in telecommunications with an emphasis on audio/video production and a minor in music composition.

Certification:

Indiana Multiple Subject Professional Teaching License (grades 1-8), science endorsement (grades 1-9), gifted and talented endorsement (grades 1-9).

Professional Experiences: Classroom Teaching:

Fall, 2006 to present – **Assistant Professor, Visiting**, Franklin College, Franklin Indiana.

SCI 344: Science and Elementary Teaching. Instructor for undergraduate elementary science education methods class.

EDE 384: Field Experience in Elementary Education. Field supervisor of undergraduate elementary education students.

EDE 445: Advanced Educational Technology. Instructor of senior level educational technology class.

Summer 2006 – **Associate Instructor,** Indiana University, Bloomington, IN

G103: Earth Science Materials and Processes. Lab instructor for undergraduate geology class. Responsible for developing and supervising student lab assignments.

Fall 2003 to Spring 2006 - **Associate Instructor**, Indiana University, Bloomington, IN

E328: Science in the Elementary School. Instructor of undergraduate elementary education students. Responsible for development, implementation and delivery of curriculum, emphasizing a hands-on, inquiry-based approach to elementary science instruction.

Summer 2005 – **Associate Instructor,** Indiana University, Bloomington, IN

G105: Earth, Our Habitable Planet. Lab instructor for undergraduate geology class. Responsible for setting up and supervising student lab assignments.

<u>Professional Experiences: Classroom Teaching, continued:</u>

Fall 2003 - **Co-instructor**, Indiana University, Bloomington, IN.

S105: The Search for Habitable Planets. Collaborated with an Indiana University astronomy professor to create a freshman-level seminar examining issues affecting the habitability of objects in the universe, using non-traditional, interactive teaching methods.

Fall 1997 to Summer 2002- **Elementary teacher**, grades 4 - 6. Lakeview Elementary School, Bloomington, IN.

Developed many curricular and pedagogical innovations, including <u>Disaster at Lake Nyos</u> and <u>Like Dawn at Midnight</u>, two role-playing, hands-on science investigations, and the Snarkle Economy, a mathematics-based classroom economy designed to promote mastery of integer, decimal and percent concepts.

Spring 1997 - **Elementary teacher**, grades 3 and 4. Harmony School, Bloomington, IN.

Filled a temporary position in a diverse, multi-age classroom. Developed a mathematics curriculum for the class that allowed students to progress at their own pace. Created written problem-solving exercises to teach beginning algebra. Developed and taught units in beginning physics, 3-dimensional geometric construction, and 2-dimensional geometric art. Initiated Comet Day to coincide with the appearance of comet Halle-Bop.

Fall, 1996 – **Inclusion Aide**, grades 1-6. Lakeview Elementary School, Bloomington, IN.

Full-time position teaching students with IEPs, both individually and in small groups. Responsible for teaching reading and mathematics. Developed materials specifically tailored to individual students needs and abilities.

<u>Other Professional Experiences:</u>

January 2005 to present – **Educational consultant** and scriptwriter – NASA Astrobiology Institute (NAI), Bloomington, IN.

Advised and assisted in the production of an educational DVD for high school biology classrooms based on the work of the Indiana-Princeton-Tennessee Astrobiology Initiative (IPTAI). IPTAI collects deep sub-surface organisms and analyzes their potential as analogues for life on Mars. Aligned the DVD content with state and national science educational guidelines and wrote the final production script. Currently writing accompanying materials for classroom use.

Spring 1997 - **Technical assistant**, distance learning. Indiana University, Bloomington, IN.

Assistant in a graduate-level science methods class for elementary teachers. Taught a Project Wild class on evolutionary adaptation to groups of elementary teachers at three different sites simultaneously via distance learning technology.

<u>Other Professional Experiences, continued:</u>

Fall 1996 - **Field researcher**, math education, Research In Teacher Education. Indiana University and Lakeview School, Bloomington, IN.

Worked with the teachers at a public elementary school to facilitate change in their mathematics curricula. Collected data for a university professor researching the process of reforming mathematics curricula. Helped support graduate students having practicum experiences at the school.

August 1994 - June 1995 - **Connected Math Project**. Indiana University, Bloomington, IN.

Part of a team responsible for the assessment of a new, middle school level mathematics program funded by the **National Science Foundation**. Collected, condensed and reported data received from elementary and middle school teachers field-testing the program.

January 1991 - August 1994 - **Creative Audio Enterprises (CAE, Inc.)**, Bloomington, IN.

General manager for an audio production facility and recording studio. Responsibilities included the general supervision of operations, including office and financial management, inventory control and purchasing, bookkeeping, payroll and payroll taxes. Other responsibilities included tape re-mastering and duplication, composing and producing musical "jingles" for radio and television, writing and producing radio advertising, and audio engineering.

August 1984 - August 1989 - **Indiana University Archives of Traditional Music (IUATM)**, Bloomington, IN.

Technical specialist for one of the largest recorded sound archives in the United States. Responsibilities included the audio preservation of recorded materials and the maintenance of the audio labs and equipment. Helped design and install an international video and two audio laboratories, and supervised the audio transfer and preservation work of the graduate students employed by the archives. Returned to the IUATM in the summer of 1995 to fill a temporary opening for the same position.

<u>Publications, Peer Reviewed:</u>

Print:

Helping Your Students Colonize the Solar System, in The Hoosier Science Teacher, Spring, 2004.

Electronic:

Life in Space: An Astronomy/Astrobiology Unit for Upper Elementary and Middle School Students. Available: http://www.astro.indiana.edu/~gsimonel

<u>Publications, Peer Reviewed:</u>
Electronic, continued:
First-Year College Students' Ideas about Astronomy: A Pilot Study, in Astronomy Education Review. Available:
http://aer.noao.edu/AERArticle.php?issue=4&section=5&article=2

Modeling the Motions of the Earth, Sun and Moon, in Practical Uses of Math and Science (PUMAS).
Document #03_10_04_1, accepted June, 2004. Available:
http://pumas.jpl.nasa.gov/examples/layout.asp?Document_Id=03_10_04_1

The Cause of the Phases of the Moon, in Practical Uses of Math and Science (PUMAS).
Document #03_10_04_2, accepted June, 2004. Available:
http://pumas.jpl.nasa.gov/examples/layout.asp?Document_Id=03_10_04_2

The Cause of the Earth's Seasons, in Practical Uses of Math and Science (PUMAS).
Document #03_10_04_3, accepted June, 2004. Available:
http://pumas.jpl.nasa.gov/examples/layout.asp?Document_Id=03_10_04_2

The Mathematical Implications of Lying, in Practical Uses of Math and Science (PUMAS).
Document #12_04_02_1, accepted February, 2003. Available:
http://pumas.jpl.nasa.gov/examples/layout.asp?Document_Id=12_04_02_1

The Rubber Band Problem, in Practical Uses of Math and Science (PUMAS). Document #01_13_03_1, accepted May, 2003. Available:
http://pumas.jpl.nasa.gov/examples/layout.asp?Document_Id=01_13_03_1

<u>Publications, Other:</u>
Print:
Retrieving the Orson Welles' Radio Broadcasts, in Resound: A Quarterly of the Archives of Traditional Music, Volume 8, Number 2, April, 1989.

<u>Presentations:</u>
Workshops:
Astrobiology and the Search for Life in Space. Co-developer and co-presenter of a hands-on workshop in astrobiology for middle and high school science teachers, Bloomington, IN, June, 2006.

<u>Presentations:</u>

Workshops, cont.:

The Universe in the Infrared. Co-developer and co-presenter of a hands-on astronomy and physics workshop for high school science teachers, Bloomington, IN, August 2005.

Hands-on Discovery-Based Science. Developed and presented an inquiry science workshop for elementary teachers, Bloomington, IN, October 2004.

Papers:

Sedimentology and Geochemistry of the Mansfield Formation in Martin County, Indiana, presented at the Geological Society of America North-Central Meeting, Akron, OH, April, 2006.

Assessing Student Ideas of Astronomy, presented at the Association of Elementary Science Teachers Convention, Nashville, TN, January 2004.

Helping Your Students Colonize the Solar System, presented at the Hoosier Association of Science Teachers, Inc. (HASTI) Convention, Indianapolis, IN, February 2003.

Posters:

Imaging the Deep Sub-Surface, presented at the NASA Astrobiology Conference, Boulder, Coloroado, April 2005.

Life in Space: An Astronomy/Astrobiology Unit for Middle Grade Students, presented at the Bioastronomy, 2004: Habitable Words Conference, Reykjavik, Iceland, July 2004.

Other:

When Did Astrobiology Become Respectable? Presented at Family Star Night, Eastern Greene County Elementary School, Greene County, IN, January 2006.

Get Your Hands-On Science with Saturday Science QUEST for Kids Program, presented at the NSTA regional convention, Chicago, IL, November 2005.

Life in Space: An Astronomy/Astrobiology Unit for Middle Grade Students, presented at the NSTA national convention, Dallas, TX, April 2005.

Build Your Own Planet: An Astrobiology Unit for Upper Elementary and Middle School Students, presented at the HASTI convention, Indianapolis, IN, February 2005.

Share-a-Thon, NSTA regional convention, Indianapolis, IN, November 2004.

<u>Grants/Awards Received:</u>
Indiana SpaceGrant Consortium April 2006.
Geological Society of America travel grant, April 2006.
Indiana Professional Geologists research grant, January 2006.
LAPLACE Winter School participant, January 2006.
NASA Earth Science Education Roadmap Community travel grant, May, 2005.
NASA Astrobiology Institute (NAI)
<u>Scholarship and travel grant to:</u>
Josep Comas i Sola International Summer School in Astrobiology, Santander, Spain, July, 2006.
<u>Travel grants to:</u>
NASA Astrobiology Conference, Boulder, Colorado, April 2005.
Bioastronomy, 2004: Habitable Worlds Conference, Reykjavik, Iceland, July 2004.
Chancellor's Fellowship, Indiana University, August 2002 to May, 2006.
NASA EPO supplement to NAG5-11964 Durisen research grant, August 2002 to June 2005.
NFS Research Experiences for Teachers (RET), June 2002 to August 2002.

<u>Other Accomplishments:</u>
Member of the NASA Earth Science Education Roadmap Community responsible for drafting NASA's 10-year plan for Earth Science educational outreach.
Judge for the Ancient Coins for Education annual essay contest.
Designed and presented a hands-on activity about logic circuits for local school Science, Technology, Engineering and Mathematics Day celebration.
Volunteer assistant in local multi-age elementary classroom, presenting weekly geobiology lessons based on the fossils available in the local area and lessons in 3-D geometry.
Helped students prepare presentations for "Astronomy Night" at local elementary school.
Developed and presented a series of discovery-based geology lessons culminating in a geology merit badge during a week-end jamboree of regional Boy Scout troops.
Developed and presented a series of hands-on physics lessons to local Cub Scout troop.
Presented a paleontology presentation and led a fossil-hunting field trip for local Boy Scout troop.
Event coordinator and judge for the **National Science Olympiad**, national finals, held at Indiana University, Bloomington, IN, multiple times.
Baseball Coach for the Smithville Youth Baseball Association, Smithville, IN.
Former Court Appointed Special Advocate (CASA) for Monroe County, IN.
Current member of the Rural Community Advisory Committee for Monroe County, IN.

<u>Hobbies:</u>
Ancient numismatics
Hiking and backpacking
Music composition and performance