

Conserving Maine's Fossil Heritage:  
The Trout Valley Formation along Wadleigh Mountain Road, Scientific Forest  
Management Area

Report to the Baxter Park Authority  
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## INTRODUCTION

The advent of plant colonization of the continents during the Devonian Period (419–359 Million years ago) set the stage for revolutionary adaptations that impacted the way in which Earth operates, and continue to impact the biosphere, today. The planet's transition to the Middle Devonian, known as the Emsian to Eifelian (408-387 Ma), witnessed plants undergoing radical evolutionary innovation and clade diversification, resulting in their domination of the continental landscape in which the animal kingdom followed their lead. Traits evolved in early land plants allowed for increased stabilization of substrates, increased nutrient availability in soils, and became the food source for terrestrial arthropods and, subsequently, vertebrate expansion into new ecological space (Allen and Gastaldo, 2006). To understand these revolutionary adaptations and the profound effects they passed onto modern ecosystems, it is essential to study fossil assemblages from this time interval. One internationally recognized locality that plays a fundamental and critical role in our understanding of Middle Devonian ecosystems is the Trout Valley Formation (Andrews et al., 1977, 1985), first recognized along Trout Brook

in Baxter State Park by a USGS geologist, Doug Rankin (Dorf and Rankin, 1962), during field mapping in northern Maine.

The Trout Valley Formation is located unconformably above a volcanic unit, the Traveler Mountain Rhyolite, created during the northwestward migration of the mountain building episode known as the Acadian orogeny (Bradley et al., 2000). The mountain building event marks the collision of a tectonic plate, the Avalon terrane, with the North American plate, during which time a volcanic island chain, or magmatic arc, was located to the east of the land mass. This volcanic island was welded onto the continent during the collision of the tectonic plates and ceased to exist, leaving a thick succession of volcanic and plutonic rocks in Maine. The Traveler Mountain Rhyolite is interpreted to represent volcanic flows associated with the caldera of one of these earliest Devonian volcanoes (406-407 Ma; Bradley and Tucker, 2002). Erosion of these rocks, along with weathering, transport, and deposition of their sediments, resulted in the deposition of the Trout Valley Formation to the northwest of the Acadian highlands in a structural syncline. Based on microfossil (palynological) data, these non-marine deposits, which now include conglomerate,

sandstone, and siltstone, accumulated between the late Emsian (Lower Devonian) to early Eifelian (Middle Devonian; McGregor, 1992), postdating the main phase of mountain building, and leaving them southeast of the deformation front (Bradley et al., 2000). The environments in which these sediments accumulated are interpreted as ancient soils (paleosols) next to river systems transporting coarse-and-fine clastic sediments to a coastline under brackish water influence (estuarine: Selover et al., 2005; Allen and Gastaldo, 2006). It is within these depositional settings that the fossil assemblages are preserved.

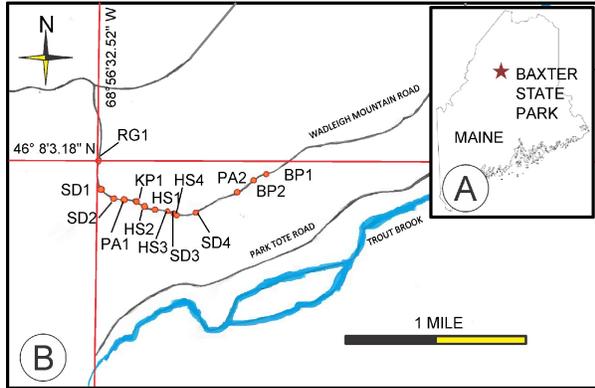
The Trout Valley Formation is renowned for its Devonian-aged fossils, with Dorf and Rankin (1962) first recognizing both plants and invertebrates in rocks exposed along Trout Brook (Fig. 1). Earliest representatives of the plant group colloquially known as “psilophytes,” as well as eurypterids, ostracodes, bivalves, and estherids were identified by them. Subsequently, the plant fossils became the focus of paleobotanical studies from which major plant groups were identified and the early history of colonization evaluated (e.g., Andrews et al., 1977, 1985; Kasper et al., 1985; Gensel and Edwards, 1984, 2001). More recent studies centered on developing an understanding of the plant taphonomic nature of these assemblages within the context of their depositional environments (Selover et al., 2005; Allen and Gastaldo, 2006). Materials that comprise all published studies, to date, originate from rock exposed either along Trout Brook or its tributaries, South Branch, Ponds Brook, and Dry Brook. In 2004, the Baxter State Park Authority developed road extensions in the Scientific Forest Management Area (SFMA), one of which runs parallel to Trout Brook. At that time, new fossiliferous rock was exposed during bulldozing of Wadleigh Mountain Road but, to date, the Park had not commissioned a survey of the

material, nor do they have any record of what fossils exist here.

During construction of Wadleigh Mountain Road, bedrock was fractured and materials pushed to the roadside, exposing surfaces that eventually will become weathered, if left to the elements, with the accompanying deterioration and loss of all fossils. A salvage-rescue collection of the assemblages unearthed along a portion of Wadleigh Mountain Road was undertaken in September, 2014, to preserve part of the park’s natural history and supplement previously published research results. The current report is designed to provide the project results to the Baxter State Park Authority, which include an assessment of paleobiodiversity (systematic identification), plant-and-invertebrate taphonomy (processes responsible for fossil preservation), and a paleoenvironmental reconstruction of the area in which the fossils were preserved. Representative samples will be sent to the Maine State Museum where they will be curated for future studies in paleobiology and natural history of the state, with the remainder of collections housed in the Department of Geology, Colby College.

## MATERIALS AND METHODS

A general survey of bedrock exposures and roadway metal adjacent to Wadleigh Mountain Road (N 46° 08.030', W 068° 56.943') was taken and fossiliferous sites reconnoitered over a distance of 1.1 km (0.68 mi), beginning near where Lynx Road joins the roadway in the SFMA and heading westward (Fig. 1). The survey began close to the road juncture (BP01/02) and ended where a thick, unfossiliferous sandstone was encountered (RG 1). In total, thirteen (13) fossil-bearing localities were identified and named, along with their GPS coordinates, from which 161 fossiliferous hand samples were recovered. Where possible, new bedding surfaces were exposed using standard field techniques to search for unweathered specimens. Basic lithologic



**Figure 1**– General locality maps of study site. (A) State of Maine with star designating the approximate position of Trout Brook Crossing. (B) Thirteen sampling sites along Wadleigh Mountain Road in the Scientific Forest Management Area.

features were identified in the field, including grain size and color, and the presence or absence of primary structures (e.g., ripples, cross beds, fining up intervals) noted for each site. Hand samples were numbered (locality plus sample number designation), wrapped and boxed, and transported to Colby College for further analysis and systematic identification. All fossil-bearing and non-fossil-bearing samples are property of Baxter State Park, and their removal was under the supervision of Mrs. Jean Hoekwater, Park Naturalist, and with the permission of Jensen Bissell, Park Director.

Lithologic and taphonomic features of site-specific fossil assemblages, and systematics of plants, invertebrates, and ichnofossils (trace fossils) in hand samples were recorded in an Excel database. Teams of two coauthors were responsible for acquiring the following data sets: plant taphonomy (Lipshultz and Furth), paleobotany (Dougherty and Veth), invertebrate taphonomy (Hartnett and Leaman), invertebrate paleontology (Lamom and Kerin), and ichnology (Markey and Sandreuter). Morphological characters useful in the classification to taxon also were recorded. Morphospecies, a group of fossil specimens possessing the same suite of features, were compared to published literature before systematic identification was finalized.

The primary publications to which specimens were compared include: Andrews et al. (1977), Kasper et al., (1985), and Allen and Gastaldo (2006) for paleobotany; Tasch (1980), RASNY (1998), and Selover et al. (2005) for the macroinvertebrates; and Miller (1991), Seilacher (2007), and Olivero and Gaillard (2007) for trace fossils.

Exploratory R- and Q-mode cluster analyses were undertaken to determine relationships amongst the fossil assemblages. Randomized data input for clustering applied the Sorensen's binary–presence or absence–coefficients using UPGMA (Unweighted Pair Group Method with Arithmetic Mean). Dendrograms illustrating results for both assemblages (Q-mode) and variables (R-mode), along with the original data set, were constructed. Cluster results were plotted on a base map to determine if any trends existed in the collections.

## RESULTS

The Trout Valley Formation consists of conglomerate, sandstone, and siltstone that were subjected to low grade metamorphism (Allen and Gastaldo, 2006). Silty sandstone, sandy siltstone, and siltstone—the finest grain sizes amongst the rock types—are more likely to host fossil material than the coarser-grained sandstone and conglomerate. Therefore, these lithologies were examined along the roadway and found to be fossiliferous.

### Lithologies

*Lithic Wacke Facies:* A single sandstone facies is exposed at RG1 (Fig. 1) near the base of the section. It is comprised of medium–coarse, angular clasts that are poorly sorted in a silica-cemented matrix of medium gray (N5) to medium light gray (N6) silt. The sand:silt ratio is approximately 70:30. The facies consists of stacked, fining up, 30-40 cm thick beds organized

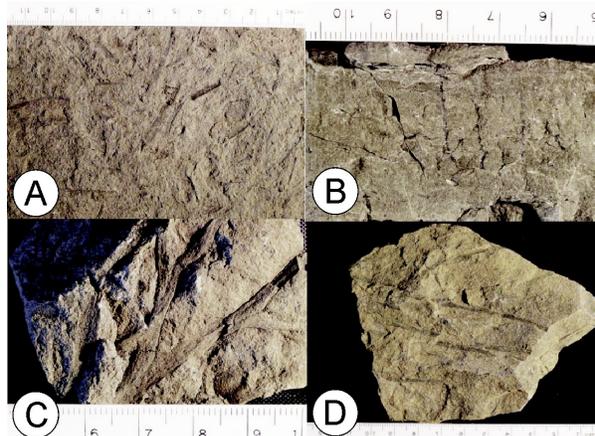
into trough cross beds of undetermined wavelength. This facies is unfossiliferous.

*Sandy Siltstone Facies:* This lithology occurs at five localities (SD1, SD2, SD4, BP1, BP2) and ranges in color from medium grey (N5) and dark grey (N4) to medium light grey (N6), and brownish gray (5YR 4/1) to yellowish gray (5Y 7/2) on weathered surfaces. Bedding generally is at the cm scale and thinner, horizontal bedding occurs locally which fines upward on a mm scale. This lithology preserves both plants and ichnofossils. Higher in the section (BP1, BP2) this lithology ranges from a light olive grey (5Y 6/1) to olive grey (5Y 4/1) in color, and vertical structures cross cut bedding.

*Siltstone Facies:* Eight collection sites are represented by the Siltstone Facies (KP1, PA1, PA2, HS1, HS2, HS3, HS4, SD3). Color ranges from medium light grey (N6) to dark grey (N4) on unweathered surfaces, whereas weathered surfaces appear as a pale yellowish orange (10YR 8/6). Siltstones range from a coarse, with some hand specimens showing an admixture of sand clasts, to a fine grained nature. Bedding ranges from cm-scale thickness (i.e., HS1, HS4, SD3) to laminations (i.e., KP1, PA1, PA2, HS3) and symmetrical ripple structures on bedding surfaces (i.e., KP1, HS3). This lithology preserves the greatest concentration of fossils, including plants, macroinvertebrates, and trace fossils.

#### Generalized Stratigraphy

The reliance on pavement outcrops and, in only a few instances, more resistant lithologies with minimal topographic relief, allows for a relative understanding of the stratigraphic relationship between lithofacies along the transect. The base of the section begins with the unfossiliferous Lithic Wacke Facies (RS1; Fig. 1) which is overlain by Sandy Siltstone and a succession of Siltstone Facies, all of which are fossiliferous but



**Figure 2** – Plant taphonomic features of fossils. (A) Fragmented, concentrated degraded axes assigned to *Psilophyton* in an allochthonous (transported) assemblage. Sample KP1-11. (B) Autochthonous (in growth position) roots cross cutting bedding. Sample BP1-9. (C) Sediment-cast *Psilophyton* axis showing a smooth stem surface. Sample SD1-5. (D) Parallel aligned axes of original growth architecture in a parautochthonous assemblage. Sample SD4-1. Scale in cm and mm.

of unknown thickness. A distinctive change in rock type is seen stratigraphically higher, restricted to a Sandy Siltstone interval, in which all evidence of invertebrates is preserved (HS3, SD3; Fig. 1). Subsequently, the fossiliferous rocks are predominantly of the Sandy Siltstone Facies, although with a lower proportion of sand clasts. A rooted Siltstone Facies with only the most robust plant taxon is encountered near the end of the transect (BP1, BP2; Fig. 1). Hence, the relative position of lithologies along the transect indicate an overall fining up sequence.

#### Plant Taphonomy

Plant fossils, primarily stems and roots, are found both parallel and perpendicular to bedding, respectively, in both Sandy Siltstone and Siltstone facies. Plant stems are not abiotically oriented—positions acquired in response to current activity before burial—on bedding planes; they appear to be oriented randomly (Fig. 2A). In several instances, though, plant axes are parallel with one another in sample clusters, which reflects their original growth architecture. All

samples exhibit fragmentation, which is a function of excavation or collection, as larger specimens were reduced in size by bulldozing, weathering, or field-sample preparation.

Plant preservational modes range from compressions, impressions, and adpressions, to sediment-cast axes (Fig. 2C). Most plants lie on the plane of compression, and stems generally are orientated parallel to bedding; fossils have been compressed leaving a carbonaceous film known as a phytolite (Cleal, 1991; Fig. 2D). Some axes are subhorizontal to bedding, cutting across bedding (Martin, 1999), whereas others are preserved perpendicular to the bedding plane and distorted vertically due to compression after burial. These structures average 1-2.5mm in width, are carbonaceous, penetrate hand samples to depths of only 2-5 cm, and are interpreted as roots (Fig. 2B).

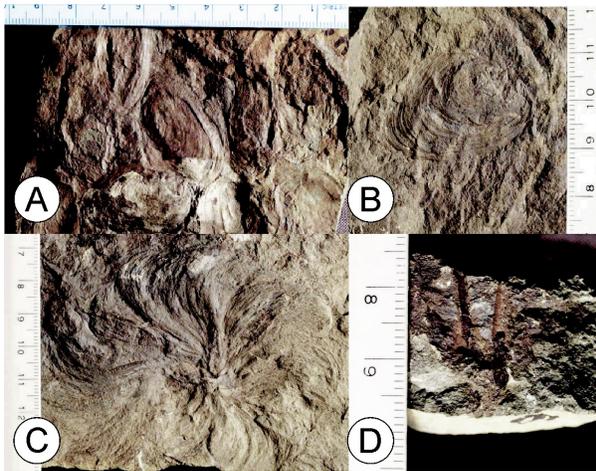
Diverse assemblages exist in which stem widths and axial features vary, indicating that most assemblages are polytypic. Axes that exhibit equal, or dichotomous, branching patterns are thin, ranging between 0.5 – 1 cm in width,

whereas more robust axes may be up to 2 cm in width. Striations that run parallel to the length of a stem reflect original features of plant growth, and presumably are the remains of vascular or supportive tissues. One type of axis shows small, circular markings along its length where “hairs” were located, while others have a prominent, longitudinal central striation that extends the length of the fossil.

### Macroinvertebrate and Trace Fossil Taphonomy

Invertebrate body fossils and ichnofossils occur in two and three collection sites, respectively. Impressions of flattened shells are present in a siltstone matrix and are organized parallel to bedding (Fig. 3A). Shells do not appear to be articulated nor do they show evidence of having been butterflyed. Individual shells may be dispersed—single, isolated individuals—or concentrated, with multiple shells touching each other on the same bedding surface. There is no evidence of shell breakage or fragmentation, and all shells appear intact. Similarly, no evidence is seen to indicate the assemblages are size sorted. Two specimens (HS 3.1, HS 3.19) display clusters of shells within 5 cm of each other, which appear randomly aligned. The shell orientations also appear to be random within the siltstone matrix, but remain parallel to the bedding plane. In two instances, a 3-dimensional shell cast is preserved articulated and crosscutting bedding (HS 2.7, 3.31); small scale ripples can be seen in the siltstone features.

Trace fossils appear either as single, vertical tubes which crosscut bedding (Fig. 3D), or as epireliefs of spirally arranged tubes with evidence of planar spreite (meniscus-shaped, curved laminations in the fill; Fig. 3C). The straight, vertical tubes are burrows, which range from 1–4 mm in diameter, averaging ~1 mm, and infilled with sediment that is of a different character than the matrix (Fig. 3D). The infill color is grayish red (5R 4/2) and



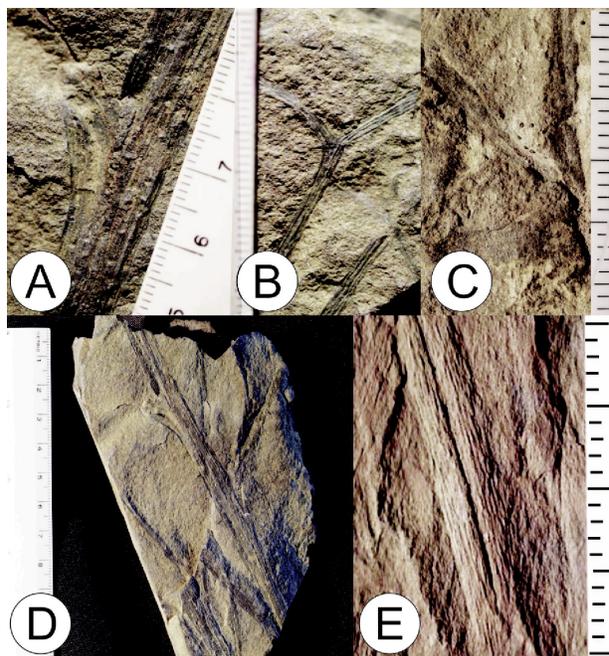
**Figure 3**– Macroinvertebrate and Ichnofossils. (A) Cluster of isolated, disarticulated valves of *Modiomorpha concentrica*. Sample HS3-29. (B) Isolated, flattened shell of *M. concentrica* showing concentric growth lines. Sample HS3-30. (C) Single whorl of *Spirophyton* on bedding surface. Sample SD3-2. (D) Vertical burrows assigned to *Skolithos*. Sample SD3-1. Scale in cm and mm.

concretionary, indicating iron cementation, possibly in the form of siderite. Several burrows attain a length of 2.5 cm and exhibit a slight curvature towards the end of the tube, although not all are preserved in their total length. The ichnofossil on bedding surfaces consists of spiral traces in a whorled pattern with spreite filled tubes. They range in diameter from 5 – 7.6 cm and preserve a central axial point, or origin, from which the spiral arrangement originates. These feeding burrows are preserved as either concave or convex reliefs.

### Systematic Paleobotany

Four different morphotypes were identified in the collections based on axial diameter and morphological features. There are two morphotypes that exhibit wide stems that may be up to 1.5 cm in width; one morphotype displaying a stem of ~1 cm in width; and the last one in which axes ranged between 2–10 mm. These features allowed for the identification of four plant genera: *Pertica*, *Taeniocrada*, *Psilophyton*, and cf. *Kaulangiophyton*. *Pertica* (Fig. 4D) is recognized by the presence of a wider, relatively unmarked stems, whereas the morphotype with a wider axis and a prominent central strand was assigned to *Taeniocrada* (Fig. 4E). Plant fossils with thin stems are placed in the genus *Psilophyton* (Fig. 4A-C), and the last morphotype exhibiting “thorn-like leaves” may belong to the genus *Kaulangiophyton*. Three of the former taxa are monotypic—*Pertica quadrifaria*, *Taeniocrada* sp., and *Kaulangiophyton akantha*—whereas three different morphotypes are recognized as species in the genus *Psilophyton*.

Axes identifiable to *Psilophyton* often are degraded, flattened without the presence of morphological features, or infilled casts, making it difficult to determine the physical features on which species are separated. Several specimens display prominent characters on which



**Figure 4** – Representative fossil-plant taxa. (A) *Psilophyton princeps*; note the small punctae (holes) on the axis where peg-like spines emerged. Sample PA1-6. (B) *Psilophyton forbesii*; note the strong ribbing in the axis. Sample HS3-22. (C) *Psilophyton dapsile*; smooth axes without ornamentation. Sample HS4-4. (D) *Pertica quadrifaria*. Sample PA1. (E) *Taeniocrada* sp. Sample HS2-6. Scale in cm and mm.

individuals can be assigned either to one of the three taxa known from the Trout Valley Formation—*Psilophyton princeps*, *P. forbesii*, or *P. dapsile*. *Psilophyton princeps* is a relatively stout plant in which dichotomized axes may attain up to 1 cm in diameter (equally branched pattern). Short and stout, peg-shaped emergences often are seen along the axes or as very small holes where the spines once existed (Fig. 4A). *Psilophyton forbesii*, the most common taxon, has dichotomously forking primary branches and axes that may be up to 9 mm in diameter. The irregularly arranged axes are unique and characterized by longitudinal striations (Fig. 4B) wherein those along the main axis are more prominent than those found in the lateral branches. *Psilophyton dapsile* also branches dichotomously, but is characterized by the presence of naked axes that attain a maximum diameter of only a few millimeters. The smaller

stem width and dichotomous branching pattern are illustrated Figure 4C.

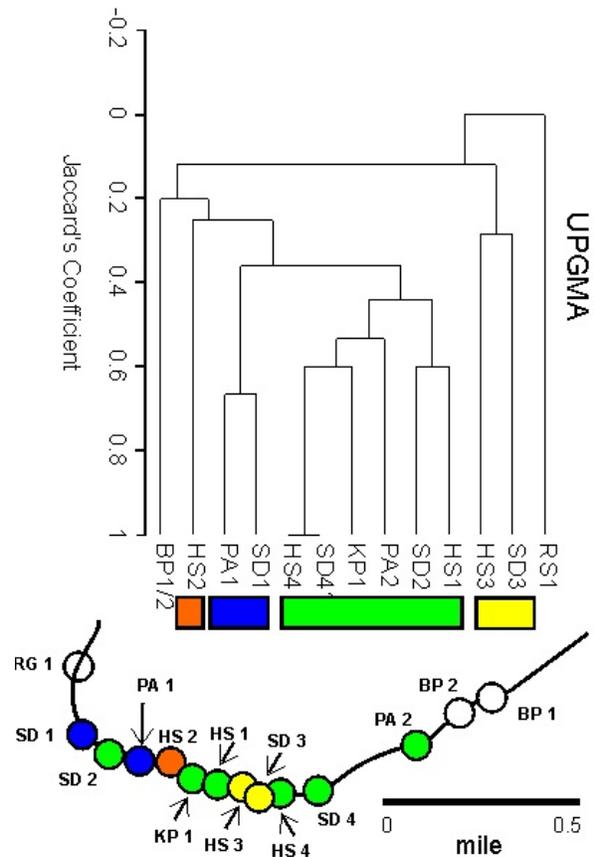
### Systematic Invertebrate Paleontology and Ichnology

Invertebrate fossils can be assigned to a single species of bivalve, *Modiomorpha concentrica*, known from other Devonian localities (Tasch, 1980; Bradshaw and McCartan, 1991). *Modiomorpha* is a medium sized, subovate bivalve with concentric shell sculpture and a rounded anterior end (Fig. 3B). The elongate shell is trapezoidal in shape, exhibiting a linear, or flattened, edge beginning at the apex. Shell proportions of individuals in two collection sites vary from 22.3–46.6 mm in length and 12.6–6.2 mm in width, and the length:width ratio approximates 2:1. The species is distinguished from others in the genus by the presence of a compressed beak and absence of teeth along the hinge line; the latter feature is not observable in the impressions.

Two ichnogenera are identified in the collections. All tubular, vertical burrows that occur perpendicular to bedding are assigned to *Skolithos* (Fig. 3D). The most complete, predominantly straight specimens are ~2.5 cm in length, with a slight curvature near the end of the burrow in some samples. The second ichnogenus is *Spirophyton* (Miller, 1991; Fig. 3C) and only is found as a single spreite planar spiral on bedding planes. There is no evidence for a tiered distribution of feeding structures at multiple levels in any bed, as this behavior reflects the systematic probing of sediment for food (Olivero and Gaillard, 2007).

### Spatial Distribution of Fossil Assemblages

Fossil-plant assemblages of varying systematic and taphonomic composition occur across the sampling transect, whereas evidence of invertebrates, or their activity, is restricted to



**Figure 5** – UPGMA cluster analysis results of fossil-presence data analyzed using Sorensen's correlation coefficient, showing the relationships between collection sites. Macroinvertebrate and trace fossil localities, and paleosol sites cluster separately from other fossiliferous assemblages.

three sites based on results of Q-mode cluster analysis (HS2, HS3, SD3; Fig. 5). The following relationships are based on R-mode cluster analysis and not illustrated. *Psilophyton forbesii* is found in all but one collection (SD3), and often is associated with other representatives of the genus that either cannot be assigned to a definitive species or with degraded and unidentifiable plant debris. The presence of *Psilophyton* along with *Pertica quadrafaria*, defines sets of localities that are found either below or above the interval in which both *Modiomorpha* and trace fossils are found (HS3, SD3). In the cases of other trimerophytes, the *P. princeps* and *P. dapsile* often occurs with either one other plant taxon, a lycopsid or plants of problematic affinity, or with

the invertebrate fossils. And, the occurrence of singletons of these other plant taxa restrict their usefulness in the cluster analysis. The presence of the ichnofossils, in association with *Modiomorpha*, define a separate group which differs spatially and systematically (Fig. 5). The last defined cluster of assemblages occur in the easternmost part of the transect and are defined by the presence of vertical roots with only fragments of *P. forbesii* having been preserved.

## DISCUSSION

Bedrock exposures unearthed during the construction of Wadleigh Mountain Road provide additional localities, heretofore unknown, in the Early to Middle Devonian Trout Brook Formation. These occurrences extend the area from which fossils can be recovered to north of the Park Tote Road. To date, all other known fossiliferous sites are reported from either along Trout Brook, its tributaries, or poorly exposed outcrop isolated in the woods, all of which are south of the stream (Kasper et al., 1988; Allen and Gastaldo, 2006). In addition to the discovery of previously reported plant fossils, the current study found both macroinvertebrates and trace fossils associated with these paleobotanical remains. The invertebrates previously reported in the Trout Valley Formation consist of a low diversity, bivalve (*Pthonia*)-dominated assemblage interpreted to have been estuarine in nature (Selover et al., 2005). The occurrence of an additional, monotypic and systematically different bivalve assemblage, associated with other nearshore and estuarine trace fossils (Miller, 1991), reinforces previous interpretations and allows for a better understanding of these Middle Devonian ecosystems.

Plant fossils appear in nearly all collection sites (Fig. 5) along the collection transect, and stratigraphically above a basal sandstone (Lithic

Wacke) facies. This trough crossbedded, unfossiliferous sand body, interpreted as a subaqueous barform, may represent either an estuarine or nearshore marine setting. Its features conform to that of Allen and Gastaldo's (2006) nearshore sand bodies (Facies 4), but its limited exposure precludes a more definitive interpretation. Specimens of *Psilophyton* and *Pertica* occur in the overlying Sandy Siltstone and Siltstone facies, and represent parautochthonous (buried near their growth site) and allochthonous (transported away from their site of growth) assemblages. Parautochthonous assemblages are characterized by plants arranged with nearly parallel stem alignment and little fragmentation or decay. These are similar to Allen and Gastaldo's (2006) tidal flats and estuarine channels (Facies 6), which are a coarser grained sandy siltstone. Plant axes are preserved commonly as casts (SD1, PA1, KP1, HS3, SD4; Fig. 1), and these sites are indicative of active sediment transport, as a result of tidal activity, resulting in the infilling of hollowed stems that were resident at the sediment-water interface prior to burial (Allen and Gastaldo, 2006). Symmetrical ripples at sites KP1 and HS3 reflect bimodal, "ebb and flow," sediment transport, a common feature of tidal influence. Allochthonous plant assemblages differ by the presence of highly fragmented, randomly oriented plant axes that are concentrated on Siltstone bedding planes (Fig. 2A). In only two sites (BP1, BP2), both of which are at the east end of the transect, situated stratigraphically high, does evidence exist for an autochthonous (preserved in growth position) assemblage. Here, vertically oriented roots, preserved perpendicular to bedding, signals the presence of a paleosol (ancient soil horizon). But features of this interval differ from the pedogenically modified siltstone described by Allen and Gastaldo (Facies 5; 2006) in which slickensides and carbonate-cemented soil nodules (glaebules) are reported. No pedogenic modification, other than root penetration, is found in the Wadleigh Mountain Road area.

The interval of monotypic bivalves dominated by *Modiomorpha concentrica*, in association with plant fossils and a low diversity trace-fossil assemblage, occur in the middle of the collection transect. All invertebrates are preserved as flattened impressions with prominent, concentric growth lines, without any evidence for the presence of original shell material. The shells are disarticulated and all but two specimens are preserved as casts perpendicular to bedding. The majority of shells lie parallel to bedding, and isolated valves show no sign of fragmentation once disarticulated. Nor do the bivalves exhibit any evidence of having been butterflyed (Selover et al., 2005), which would indicate on site death followed by rapid burial. The isolated valves indicate their presence at the sediment-water interface for some time prior to burial and preservation. Hence, the undamaged quality of the disarticulated shells indicates that individuals were not transported as either suspension or bedload over any great distance prior to their concentration. Their occurrence is interpreted to represent a parautochthonous assemblage which may have been influenced by shallow water processes in response to storm activity. Dissolution of the original calcite shell, accompanied by flattening during compression and lithification, may have been a consequence of acidic pore waters developed as carbonic acid production occurred in response to decay of plant detritus in this environment.

The presence of both plant-and-invertebrate material at sites HS-2 and HS-3 (Figs. 1, 5) indicates that there was a mixing of terrestrial and marine components in response to, most likely, storm events. Plant detritus in sufficient quantity to be preserved was transported from emergent soils to a subaqueous depositional environment during high discharge river flow, normally associated with increased rainfall. Once plant parts were carried to the site, they settled out of suspension and accumulated at the sediment water interface. There, they remained

in the taphonomically active zone or were buried shallowly, transferring them from an oxygen-rich setting. The fact that wetland plants (Andrews et al., 1977; Kasper et al., 1988; Allen and Gastaldo, 2006) comprised of a broad systematic affinity are preserved with a monotypic bivalve assemblage is interpreted to indicate a brackish water setting for these sites (HS2, HS3; Figs. 1, 5).

The genus *Modiomorpha*, assigned to the extinct Modiomorphidae, is reported from other Middle Devonian localities in North America (e.g., Carter and Tevesz, 1978; Bonuso et al., 2002) and is known from Arctic Canada (Johnston and Goodbody, 1988) to Antarctica (Bradshaw and McCartan, 1991) and Australia (Cook, 1993). The more cosmopolitan taxon, *Modiomorpha concentrica*, was a shallow shelf dweller, adapted to infaunal feeding (Bradshaw and McCartan, 1991), and commonly found as part of a fully marine fauna. Bonuso et al. (2002) identify the taxon as part of their *Devonochonetes/Mucrospirifer* group, a brachiopod-dominated offshore community. But, Baird and Brett (1988) note that the co-occurrence of the eurytypic *Modiomorpha*, other bivalves, and brachiopods in New York's Hamilton Group were in response to increased turbidity and sedimentation rates. These taxa are interpreted to have been more tolerant of changes in these physical variables. Hence, the monospecific assemblage of this taxon in the Trout Valley Formation may indicate that *Modiomorpha concentrica* also had a wider physiological tolerance, capable of osmoregulation in brackish salinities as well as in fully marine waters. This interpretation may be supported by the low diversity trace-fossil assemblage.

The trace fossils collected along Wadleigh Mountain Road represent an autochthonous community which inhabited the sediment-water interface when water conditions were amenable to colonization. *Skolithos* and *Spirophyton* were preserved in shallow marine settings, with the

latter differing from a similar, radially organized trace fossil, *Zoophycos*, generally associated with deep water deposits (Miller, 1991). In New York State, Miller and Woodrow (1991) note that *Spirophyton* is associated with stratigraphic intervals characterized by red beds, and interpreted the organism to have lived under freshwater and estuarine conditions. Miller (1991) used paleoenvironmental evidence from the Catskill sequence to interpret these opportunistic behaviors as an adaptation or a physiological tolerance to stressful, changing habitats. The co-occurrence of *Spirophyton* in close proximity to the monotypic *Modiomorpha* assemblage in which terrestrial plants are preserved supports her interpretation for the taxon.

The collection transect along the Wadleigh Mountain Road, beginning in the west and continuing eastward, conforms to the overall, fining up stratigraphy reported by Dorf and Rankin (1962) and detailed by Allen and Gastaldo (2006). A nearshore or estuarine sand body is overlain by shallow water deposits in which river-transported plants are preserved. Some plant fossils occur as infilled, cast axes indicating that these remained resident at the sediment-water interface for some time during which hollowed stems were filled with silt. The presence of silt-filled axes in association with symmetrical ripples indicates an oscillatory current, indicative of tidal processes. In other instances, compressions and poorly preserved impressions dominate the collections, indicating that variable physico-chemical conditions existed in the depositional setting. The occurrence of *Spirophyton*, *Skolithos*, and a monotypic bivalve community of *Modiomorpha concentrica*, in association with terrestrial plants, indicates either an inshore or nearshore depositional setting near the middle of the transect. When compared with data published by Selover et al. (2005) and Allen and Gastaldo (2006), lithofacies and assemblage characteristics conform to their

interpretations for an estuarine depositional setting. Hence, the majority of collections also are considered as having been deposited inshore, within a coastal estuary. The presence of roots in a poorly developed paleosol at the easternmost collection sites indicates the presence of subaerial conditions, and colonization by terrestrial plants of unknown affinity.

## CONCLUSIONS

Bedrock exposed along Wadleigh Mountain Road in the Scientific Forest Management Area, Baxter State Park, preserve a series of fossiliferous intervals interpreted to have been deposited in a coastal, estuarine paleoenvironment. The most common environment in the area was a shallow water, brackish estuary. Sporadic, high discharge flood events probably were the primary transporting agent responsible for bringing the flora to the depositional setting, and providing the sediment in which it is buried. The fact that plants are found along the roadway, reflecting different relative stratigraphic levels, and associated with disarticulated invertebrates points to successive storm events as the likely agent. The presence of ichnofossils midway in the transect indicates that the original sediment-water interface is conserved in the section. And, the presence of *Spirophyton* is used to interpret a relatively shallow, inshore or nearshore environment that, ultimately, was filled with sediment as the coastline built seaward. This coastline was colonized by wetland plants as evidenced by the presence of a rooted soil at the top of the stratigraphy. These results enhance our understanding of Deep Time Maine.

This research project has furthered the mission of the Baxter State Park Commission, protecting natural resources from deterioration and loss, while conserving their intrinsic value for current and future generations. Representative specimens will be deposited with the Maine State Museum in Augusta, preserving evidence of these extinct plants and animals before natural weathering

processes removed them from the park's landscape. The inclusion of this report in the Park's yearly report may naturally spark the interest of future visitors, as it may inspire support for the continued preservation of natural heritage sites like Baxter State Park. In this way, the yet unknown secrets locked away in Baxter State Park may still be discovered someday.

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### LITERATURE CITED

- ALLEN, J.P., AND GASTALDO, R.A., 2006, Sedimentology and taphonomy of the Early to Middle Devonian plant-bearing beds of the Trout Valley Formation, Maine: Geological Society of America Special Papers, v. 399, p. 57-78. doi: 10.1130/2006.2399(03).
- ALLISON, P.A., AND BRIGGS, D.G., 1991, Taphonomy; Releasing the Data Locked in the Fossil Record: Plenum Press, New York and London, 560 p.
- ANDREWS, H.N., KASPER, A.E., FORBES, W.H., GENSEL, P.G. AND CHALONER, W.G., 1977, Early Devonian flora of the Trout Valley Formation of northern Maine: Review of Palaeobotany and Palynology, v. 23, p. 255-285.
- BAIRD, G.C., AND BRETT, C.E., 1983, Regional Variation and Paleontology of Two Coral Beds in the Middle Devonian Hamilton Group of Western New York: Journal of Paleontology, v. 57, p. 417-446.
- BONUSO, N., NEWTON, C.R., BROWER, J.C., AND IVANY, L.C., 2002, Statistical testing of community patterns: uppermost Hamilton Group, Middle Devonian (New York State: USA): Palaeogeography, Palaeoclimatology, Palaeoecology, v. 185, p. 1-24.
- BRADSHAW, M.A., AND MCCARTAN, L., 1991, Palaeoecology and systematics of Early Devonian bivalves from the Horlick Formation, Ohio Range, Antarctica: Alcheringa, v. 15, p. 1-42.
- CARTER, J.G., AND TEVESZ, M.J.S., 1978, Shell microstructure of a Middle Devonian (Hamilton Group) bivalve fauna from central New York: Journal of Paleontology, v. 52, p. 589-880.
- COOK, A.G., 1993, Two bivalves from the Middle Devonian Burdekin Formation, north Queensland: Memoirs – Queensland Museum, v. 33, p. 49-53.
- DORF, E. AND RANKIN, D.W., 1962, Early Devonian plants from the Traveler Mountain area, Maine: Journal of Paleontology, v. 36, p. 999-1004.
- JOHNSTON, P.A., AND GOODBODY, Q.H., 1988, Middle Devonian bivalves from Melville Island, Arctic Canada: Devonian of the World: Proceedings of the 2nd International Symposium on the Devonian System — Memoir 14, Volume III: Paleontology, Paleoecology and Biostratigraphy, p. 337-346.
- KASPER, A.E., GENSEL, P.G., FORBES, W.H., AND ANDREWS, H.N., 1988, Plant paleontology in the state of Maine: A review: Maine Geological Survey, Studies in Geology, v. 1, p. 109-128.
- MILLER, M.F., 1991, Morphology and paleoenvironmental distribution of Paleozoic *Spirophyton* and *Zoophycos*: Implications for the *Zoophycos* ichnofacies: PALAIOS, v. 6, p. 410-425.

MILLER, M.F., AND WOODROW, D.L., 1991, Shoreline deposits of the Catskill delta complex, New York: New York State Museum and Science Service Bulletin, 469, p. 153-177.

OLIVERO, D., 2007, *Zoophycos* and the Role of Type Specimens in Ichnotaxonomy: *in* Miller, W., ed., Trace Fossils: Concepts, Problems, Prospects: Elsevier, Amsterdam, p. 466-477.

OLIVERO, D., AND GAILLARD, C., 2007, A Constructional Model for *Zoophycos*: *in* Miller, W., ed., Trace Fossils: Concepts, Problems, Prospects: Elsevier, Amsterdam, p. 466-477.

ROCHESTER ACADEMY OF SCIENCE, New York (RASNY): Key to mollusk identification, 1998,  
<http://www.rasny.org/fossil/pdfs/mollkey.pdf>:  
Checked October 2014.

SEILACHER, A., 2007, Trace Fossil Analysis: Springer-Verlag Berlin Heidelberg, New York, 266 p.

SELOVER, R.W., GASTALDO, R.A., AND NELSON, R.E., 2005, An Estuarine Assemblage from the Middle Devonian Trout Valley Formation of Northern Maine: PALAIOS, v. 20, p. 192-197.

TASCH, P., 1980, Paleobiology of the Invertebrate: Data Retrieval from the Fossil Record: Wiley and Sons, New York, 975 p.