NEW PALEONTOLOGICAL INSIGHTS INTO THE EMSIAN–EIFELIAN TROUT VALLEY FORMATION, BAXTER STATE PARK'S SCIENTIFIC FOREST MANAGEMENT AREA, AROOSTOCK COUNTY, MAINE

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ABSTRACT: The Trout Valley Formation of Emsian–Eifelian age in northern Maine hosts evidence of early vascular plant communities interpreted as having colonized wetland, estuarine environments. To date, collections made under permits issued by the Baxter State Park Commission, originate from outcrop along Trout Brook, its tributaries, and poorly exposed lithologies inside the woodlands. Construction of a new roadway in the Scientific Forest Management Area, oriented parallel to Trout Brook, unearthed pavement exposures in which new fossil assemblages were found. These were collected under a salvage and conservation effort.

Plant megafossils, as well as new macroinvertebrates and ichnofossils, were recovered from sandy siltstone and siltstone lithofacies along a west-to-east transect along Wadleigh Mountain Road. Autochthonous plants fossils include erect axes of cf. *Psilophyton forbesii* and vertical rooting structures of unknown affinity. Parautochthonous and allochthonous plants include *Pertica quadrifaria*, *Taeniocrada dubia*, three species of *Psilophyton*, and cf. *Kaulangiophyton* sp., all of which are known from the area. A newly discovered shell ground of a monotypic assemblage of *Modiomorpha concentrica* is accompanied by trace fossils assigned to *Skolithos, Planolites,* and *Spirophyton*. The invertebrates are described to have inhabited shallow, nearshore estuarine to open marine conditions, which are unreported in the area. The co-occurrence of *Modiomorpha*, *Spirophyton*, and allochthonous axes of *Pertica* and *Psilophyton* is used as additional evidence to support a brackish water, estuarine depositional environment for the Trout Valley Formation.

INTRODUCTION

The expansion of terrestrial plant clades in the Devonian set the stage for revolutionary adaptations that impacted the way in which Earth Systems operate, and continue to impact the biosphere, today. Emsian to the Eifelian (407–388 Ma; early Middle Devonian) lithologies preserve a record of plant diversification, which encompassed radical evolutionary innovation and clade differentiation, resulting in the spread of rhizomatous plants across the wetlands in which the animal kingdom followed their lead (Greb et al. 2006). Traits appearing in early land plants allowed for increased stabilization of substrates (e.g., rhizomes), increased nutrient availability in soils (rhizoids and rooting systems), and the development of microclimates at the soil/air interface (dense growth strategies and tiering; Allen and Gastaldo 2006). Shortly thereafter, in the Givetian (late Middle Devonian), taxa increased in their physical size and stature resulting in the establishment of early complex forests (Stein et al. 2007, 2012). One early Early–Middle Devonian locality that has played a fundamental and critical role in our understanding of land plant colonization and early terrestrial ecosystems is the Trout Valley Formation (Andrews et al. 1977), first recognized from collections made along Trout Brook in Baxter State Park, Maine (Dorf and Rankin 1962).

The Trout Valley Formation lies unconformably above a volcanic unit, the Traveler Mountain Rhyolite, formed during the northwestward migration and assembly of the Avalon terrane with the North American plate during the Acadian orogeny (Bradley et al. 2000). The Avalon terrane was a magmatic arc located to the east of the craton and welded onto the continent during collision. The Traveler Mountain Rhyolite is interpreted to represent volcanic flows associated with the caldera of one of these earliest Devonian volcanoes in the island chain (406–407 Ma; Bradley and

Tucker 2002). The Trout Valley Formation to the northwest of the Acadian highlands occurs in a structural syncline and is the result of erosion, transport, and deposition of these rocks. The age of deposition, based on palynological data, is placed between the late Emsian (Lower Devonian) to early Eifelian (Middle Devonian; McGregor 1992), and postdates the main phase of orogenesis (Bradley et al. 2000). The conglomerates and sandstones are interpreted as fluvial and nearshore deposits, whereas siltstones are interpreted as paleosols adjacent to river systems in which coarse-to-fine sediments were brought to a coastal setting under brackish water influence (Selover et al. 2005; Allen and Gastaldo 2006). It is within these wetlands that fossil plant and invertebrate assemblages are preserved.

Dorf and Rankin (1962) first found both plant and invertebrate fossils in rocks exposed along Trout Brook (Fig. 1). Earliest representatives of the plant group colloquially known as "psilophytes", as well as isolated eurypterids, ostracodes, bivalves, and estherids were identified. Due to the abundance of plant fossils versus the scarcity of invertebrates, paleobotanical studies ensued in which major plant groups were circumscribed and the early history of colonization proposed (e.g., Andrews et al. 1977; Kasper et al. 1988; Gensel and Edwards 2001; Gensel 2008). Recent studies have centered on developing an understanding of the plant taphonomic nature of these assemblages in the context of their depositional environments (Selover et al. 2005; Allen and Gastaldo 2006), with materials, to date, also originating from exposures either along Trout Brook or its tributaries, South Branch, Ponds Brook, and Dry Book. 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. During road construction of Wadleigh Mountain Road, new fossiliferous pavement
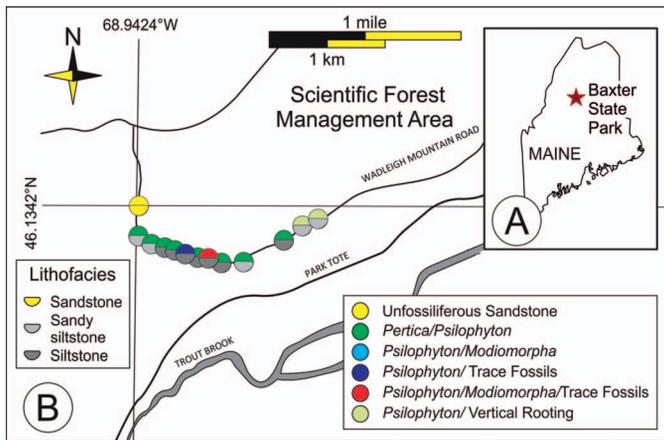
Fig. 1.—General locality maps of study site. **A**) State of Maine with star designating the approximate position of Trout Brook Crossing. **B**) Thirteen sites along Wadleigh Mountain Road in the Scientific Forest Management Area from which samples were collected are shown as circles. The lithofacies are designated by the color of each lower hemisphere, whereas characteristic fossil assemblages are designated by the color of the upper hemisphere. Scale in miles and kilometers.

was exposed. Rules governing the park stipulate that the area must be maintained under natural conditions, including the weathering and loss of natural heritage materials. With cooperation from Park Directors, Irvin "Buzz" Caverly and Jensen Bissell, and Park Naturalist, Mrs. Jean Hoekwater, three salvage-collection projects (2008, 2011, 2014) were undertaken to conserve these natural heritage materials. The current report presents results of these collection efforts and augments previously published papers with new invertebrate and ichnofossil data, expanding our understanding of this Devonian ecosystem.

MATERIALS AND METHODS

A survey of bedrock exposures and roadway metal (unpaved gravel road) adjacent to Wadleigh Mountain Road (N 46° 08.030′, W068° 56.943′) resulted in the identification of 13 fossiliferous sites located over a distance of 1.1 km (0.68 mi; Fig. 1). Bedrock exposures begin at a thick, unfossiliferous sandstone to the west and end in limited pavement outcrop in the east. GPS coordinates accompany each collection site, and are available from the Baxter State Park Authority, from whom permits must be obtained for any scientific investigation within the park's boundaries. Basic lithologic features, including grain size, color, and the presence or absence of primary structures (e.g., ripples, cross beds, fining up intervals) were recorded. Fossiliferous samples were recovered directly from pavement surfaces or road metal along the margins of Wadleigh Mountain Road, the origin of which were presumed to be within 10 m of their original site as these materials are the roadway aggregate. All fossil-bearing and non-fossil-bearing samples are property of Baxter State Park. Representative systematic samples are to be curated at the Maine State Museum for future studies in paleobiology and natural history of the state; the remainder of collections are housed in the Department of Geology, Colby College.

Exploratory R- and Q-mode cluster analyses were undertaken to determine relationships amongst the fossil assemblages. Randomized data input for clustering applied the Simple Matching 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). Along Wadleigh Mountain Road, a medium-coarse lithic wacke is unfossiliferous. In contrast, silty sandstone, sandy siltstone, and siltstone host fossil material (Fig. 1B).

Lithofacies

Lithic Wacke Facies.—A single sandstone facies is the western most exposure of rock in the area. It consists of medium–coarse angular clasts that are poorly sorted and silica-cemented. The matrix is a medium gray (Munsell Color 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 with ripples present on some upper bounding surfaces.

Sandy Siltstone Facies.—At five collection sites, this lithofacies (Fig. 1B) ranges in color from medium gray (N5) and dark gray (N4) to medium light gray (N6). Weathered surfaces are altered to brownish gray (5YR 4/1) to yellowish gray (5Y 7/2). Towards the east in two localities, color varies from light olive gray (5Y 6/1) to olive gray (5Y 4/1), and mm-scale, carbonaceous, vertical compressions cross cut bedding. Bedding is at the cm scale, and thinner, horizontal bedding occurs locally which fines upward on a mm scale. Both plant and trace fossils are preserved.

Siltstone Facies.—This facies occurs at eight sites where color ranges from medium light gray (N6) to dark gray (N4) on unweathered surfaces. Weathered surfaces are a pale yellowish orange (10YR 8/6). Both coarse and fine siltstone occur, with several hand specimens showing an admixture of fine-sand clasts. Bedding ranges from cm-scale thickness to millimeter-scale lamination, and symmetrical ripple structures are found on bedding surfaces. This lithofacies 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 topographic relief less than one meter, allows for a relative understanding of the stratigraphic relationship between lithofacies along the transect when compared with stratigraphies published by Allen and Gastaldo (2006). The nominal base of the section is the unfossiliferous Lithic Wacke Facies which is overlain by the Sandy Siltstone and a succession of Siltstone Facies, all of which are fossiliferous but of unknown thickness. A distinctive change in lithology occurs more eastward and, interpreted as stratigraphically higher, which is an interval of Sandy Siltstone. It is in this lithology in which all evidence of invertebrates is preserved (Fig. 1). Thereafter, fossiliferous exposures are mainly of the Sandy Siltstone Facies, with a decreasing proportion of sand clasts in an eastern direction. A rooted Siltstone Facies with only the most robust plant taxon is encountered near the end of the transect, and is considered the highest stratigraphic position. Hence, the relative position of lithologies along this transect indicates an overall fining up sequence.

Plant Taphonomy

Plant fossils, primarily stems (axes) and roots, are preserved both parallel and perpendicular to bedding, respectively, in both the Sandy Siltstone and Siltstone facies. Prostrate plant stems, preserved parallel to bedding, show evidence for both biotic and abiotic orientation. A few rock slabs have been found on which long (> 30 cm), thin (2 mm), parallel axes of *Psilophyton* are preserved, and hint at a parautochthonous (?autoch-thonous) assemblage as a consequence of an influencing current prior to
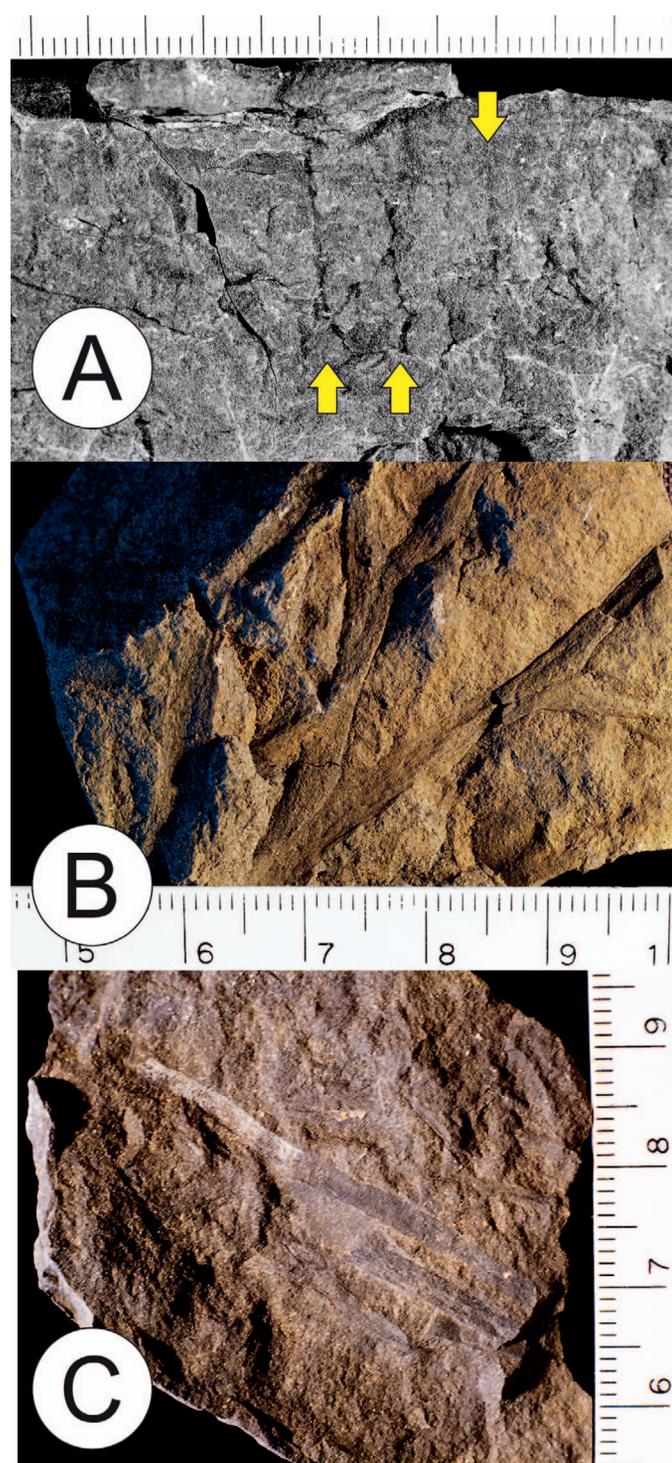
FIG. 2.—Plant taphonomic features. **A**) Autochthonous roots cross cutting bedding and showing vertical compression, sample BP1-9. **B**) Sediment-cast *Psilophyton* axes exhibiting a smooth stem surface, sample SD1-5. **C**) Parallel aligned axes of *P. dapsile* showing original growth architecture in a para-utochthonous assemblage, sample SD4-1. Scales in cm and mm.

burial. These specimens appear to be the most complete, reflecting their original growth architectures. Most larger fossiliferous bedding planes, though, contain small, fragmented axes that are oriented randomly. Plant fragmentation associated with smaller hand samples is a function of

roadway excavation, weathering, or field-sample preparation. Plant parts preserved perpendicular and subhorizontal to bedding include mm-scale, cylindrical axial segments, the long dimension of which is restricted by the hand sample, and thin, ~ 0.5 mm carbonized traces. The latter structures commonly are distorted vertically due to compression after burial (Fig. 2A). Preservational modes range from compressions, impressions, and adpressions, to sediment-cast axes (Allen and Gastaldo 2006; Fig. 2B, 2C).

Diverse plant parts occur in which stem widths and axial features vary, indicating that these are polytypic assemblages. Axes that exhibit equal dichotomous (isotomous) 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 the axis reflect original features of plant development, and are the remains of vascular or supportive tissues. One type of axis shows small, circular markings along its length where trichomes were located, while others have a prominent, longitudinal central striation that extends the length of the fossil. All of these are considered primary features.

Macroinvertebrate and Trace Fossil Taphonomy

Invertebrate body fossils and ichnofossils occur in several sites. Impressions of decalcified, flattened shells are present in the Siltstone Facies and are organized parallel to bedding (Fig. 3A). Shells preserve growth lines, but do not appear to be articulated nor do they show evidence of having been butterflied (Selover et al. 2005). Individual valves may be dispersed or concentrated, with multiple shells touching or overlapping each other on the same bedding surface in the latter circumstance. No evidence is seen of shell breakage or fragmentation; all valves appear intact. All shells fall within a single size distributional range (see below), but the extent to which this bedding surface is exposed prevents any assessment as to whether the shell assemblage is abiotically size sorted. Shell clusters appear aligned randomly and single shells in close proximity to one another also appear to have random orientations. Only two steinkerns of unidentifiable systematic position were found cross cutting a rippled siltstone.

Systematic Paleobotany

Four morphotypes are identified based on axial diameter and morphological features, and conform to taxa already reported in the area (Allen and Gastaldo 2006; Table 1). Two morphotypes exhibit wide stems that attain a width of 1.5 cm; one morphotype has a stem width of approximately 1 cm; and axial diameters in the fourth morphotype range between 2–10 mm. Morphological features include the presence or absence of strong axial ribbing, axial punctae or reticulation, and enations, many of which are poorly preserved.

Combinations of morphological features result in the identification of four genera: *Pertica*, *Taeniocrada*, *Psilophyton*, and cf. *Kaulangiophyton*. *Pertica* (Fig. 3C) has the widest axis which is relatively unmarked by any ornamentation. Longitudinal striations are common and are a result of axial compression. Axes of similar width but possessing a prominent central strand belong to the genus *Taeniocrada* (Fig. 3D).Those forms with thin stems, of various ornamentation, are assigned to the genus *Psilophyton* (Fig. 3A, 3B), where three morphotypes are recognized in the collections. The fourth morphotype that exhibits enations, albeit poorly preserved, may belong to the genus *Kaulangiophyton*.

Axes assigned 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, though, display prominent characters based on which individuals can be assigned to one of the three taxa previously reported from the 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. Short and stout, peg-shaped emergences often are seen along the axes (Allen and Gastaldo 2006) or as very small
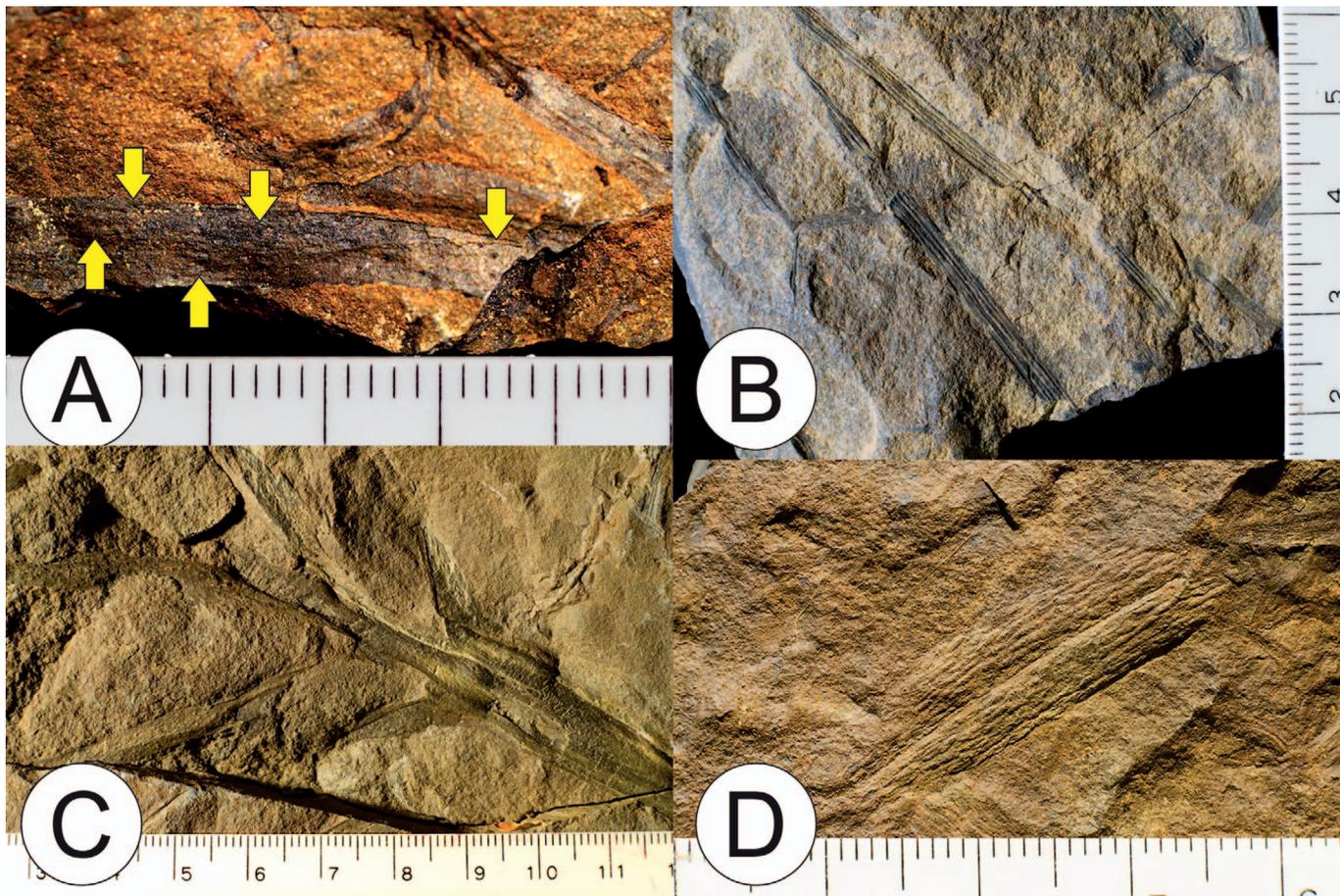
FIG. 3.—Representative fossil-plant taxa. **A**) *Psilophyton princeps*; note the small punctae (holes; arrows) on the axis where peg-like spines emerged, sample D-27. **B**) *Psilophyton forbesii*; note the strong ribbing in the axis, sample HS3-22. **C**) *Pertica quadrifaria*, sample JJJ 4-16. **D**) *Taeniocrada dubia*, sample HS2-6. Scale in cm and mm.

holes where the spines once existed (Fig. 3A), which is the case in these collections. *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 characterized by strong, longitudinal striations (Fig. 3B) wherein those along the main axis are more prominent than those along the lateral branches. *Psilophyton dapsile* also branches dichotomously, but its axes are naked and attain a maximum diameter of only a few millimeters.

Systematic Invertebrate Paleontology and Ichnology

Invertebrate fossils are assigned to a single bivalve taxon, *Modiomorpha concentrica*, known from other Devonian localities (Fig. 4; Williams and

TABLE 1.—*Morphological characteristics used to systematically identify compression/impression material in Wadleigh Road collections.*

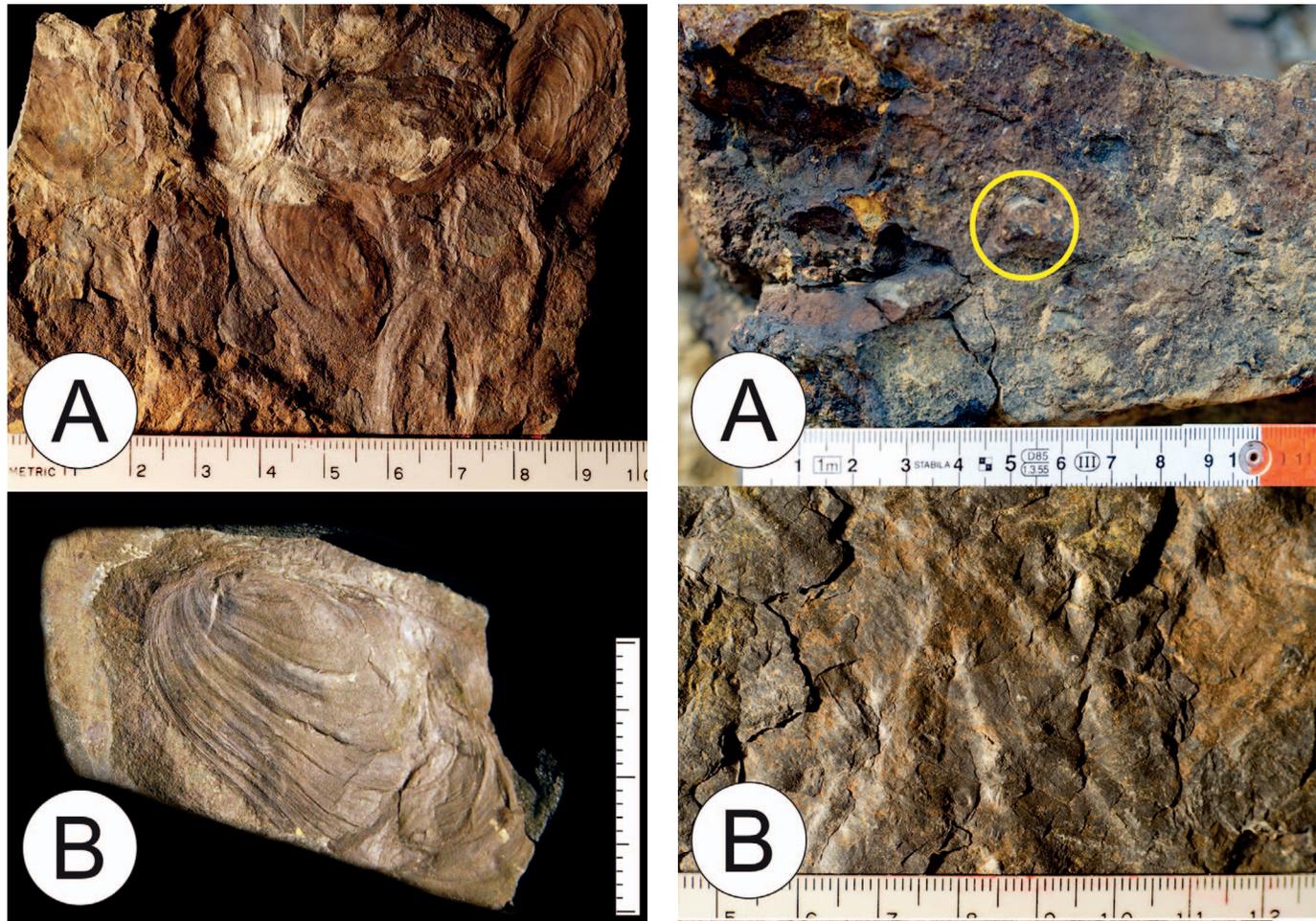| Genus	species	Avg. Axis Width	Isotomous	Pseudomonopodial	Ribbing	Branching	Axis Ornamentation
Psilophyton	*forbseii*	< 1 cm; variable		Yes	Longitudinal; strong	Dichotomous, irregular	None; naked
Psilophyton	*dapsile*	< 3 mm	Yes	Weakly	none		None; naked
Psilophyton	*princeps*	< 1 cm; variable		Yes, distinct	none	Dichotomous; sparce	Random trichomes; peg-like
Pertica	*quadrifaria*	1.0–1.5 cm		Yes, distinct main axis	Compression striae	Helically arranged; tetrastichous, abundant	Striated, small punctae
Taeniocrada	*dubia*	1.5–2 cm; flat/wide	Occassional	No	Central depression	None	Random trichome bases
Kaulangiophyton	sp.	< 1 cm	Yes	No	none	Wide dichtomous; H-like	Helically arranged spines
Drepanophycus	*spinaeformis*	~ 1 cm	Yes	No	none	Dichotomous	Distinct central strand
Leclereqia	*complexa*	< 1 cm	Yes	No	none		Helically arranged, 5-parted leaves

FIG. 4.—Macroinvertebrates. **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. Scale in cm and mm.

Breger 1916; Bradshaw and McCartan 1991). *Modiomorpha* is a medium sized, subovate bivalve with concentric shell sculpture and a rounded anterior end (Fig. 4B). The elongate shell is trapezoidal in shape, exhibiting a linear or flattened edge beginning at the apex. Shell proportions vary from 22.3–46.6 mm in length and 12.6–6.2 mm in width, with a length:width ratio approximating 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 Trout Valley Formation impressions.

Trace fossils appear either as single, vertical tubes which crosscut bedding (Fig. 5A), or as epireliefs of spirally arranged tubes with evidence of planar spreite (Fig. 5B, 5C). The straight, vertical burrows range in diameter from 1–4 mm, averaging approximately 1 mm, and are filled with slightly coarser sediment that has been altered diagenetically (Fig. 5A). The infill color is grayish red (5R 4/2) and several are concretionary in aspect. The most complete 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. Surficial ichnofossils consists of spiral traces in a whorled pattern with spreite filled tubes, preserved as either concave or convex epireliefs. Spiral structures range from 5–7.6 cm in diameter, and preserve a central axial point from which the spiral tubes originate.

Three ichnogenera occur in the collections. All tubular, vertical burrows that are perpendicular to bedding are assigned to *Skolithos* (Fig. 5A), whereas horizontal, cylindrical burrows are assigned to *Planolites* (Fig.
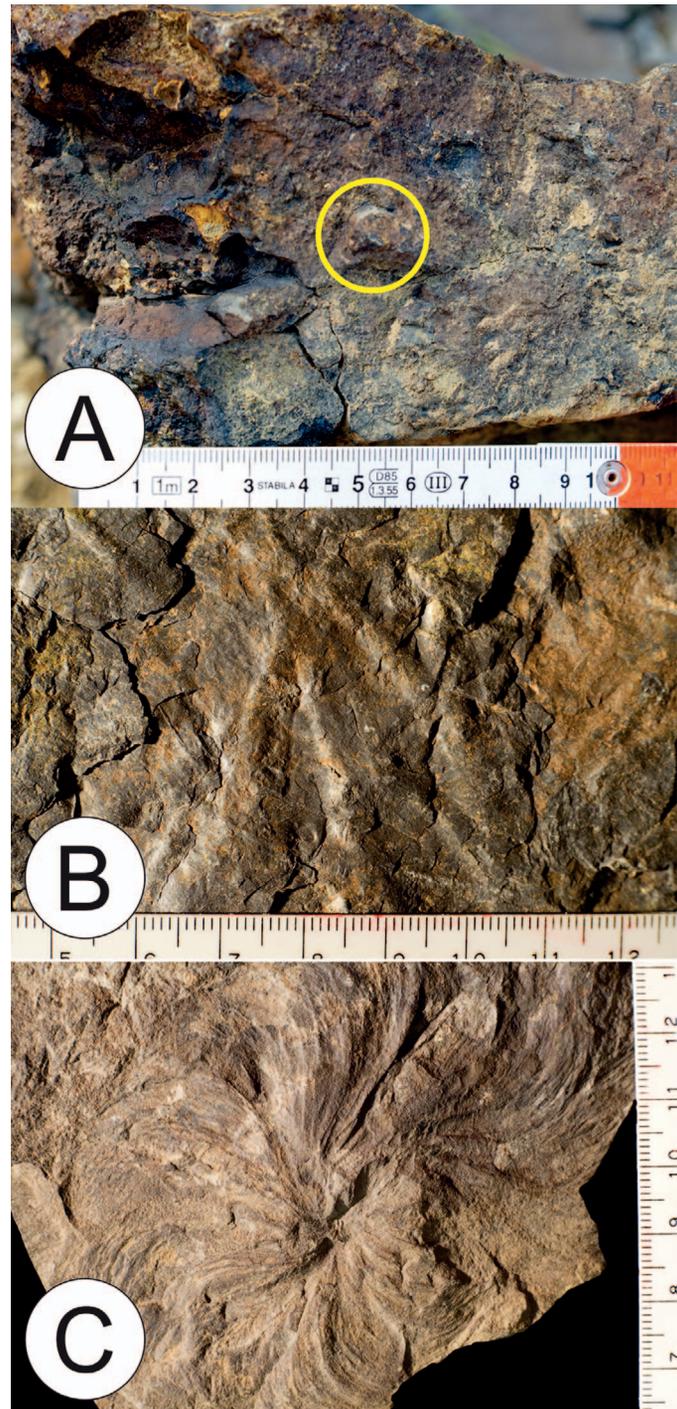
FIG. 5.—Ichnofossils. **A**) Field image of vertical burrows assigned to *Skolithos*. **B**) Horizontal burrows assigned to *Planolites*, sample HS3-32. **C**) Adjacent whorls of *Spirophyton* on bedding surface, sample SD3-2. Scale in cm and mm.

5B). The most complete, vertical and straight specimens are approximately 2.5 cm in length, with a slight curvature near the end of the burrow in some samples that may be a function of sediment compaction. A single bedding surface of *Planolites* is found overlying a thin, fine wacke, in which the burrows are variously oriented and overlap each other. The third ichnogenus is *Spirophyton* (Miller 1991; Fig. 5C). It only is found as a singular, spirally arranged spreite arms on bedding planes. There is no evidence for a tiered distribution of feeding structures at multiple levels in
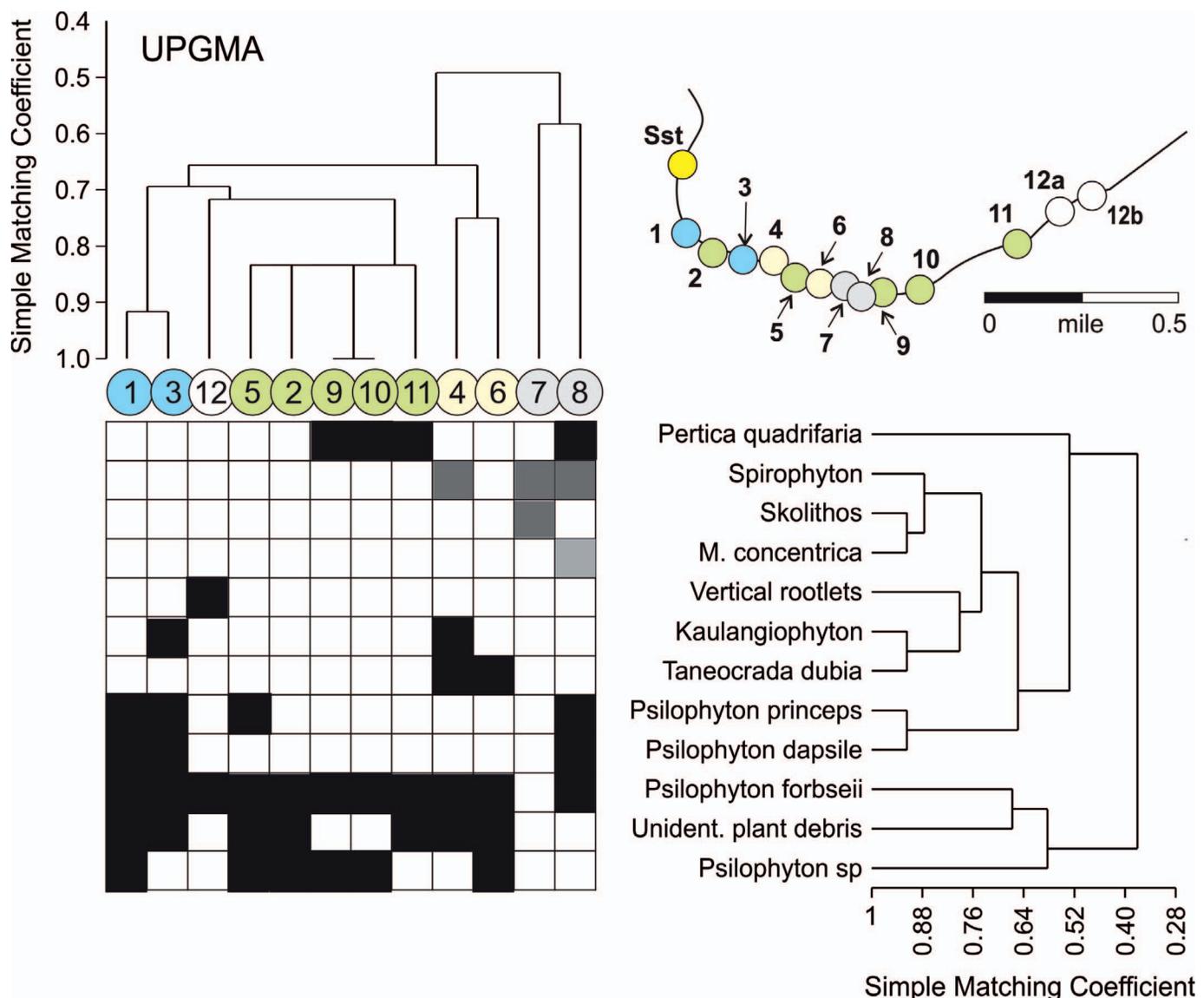
FIG. 6.—Q- and R-mode cluster analysis of collections made along Wadleigh Road pavement exposures. Exploration of binary data used UPGMA (a simple agglomerative hierarchical method) and a Simple Matching Coefficient in MVSP (Kovach Computing, v. 3.22). Clusterings are plotted with original data matrix to visualize the variables responsible for all relationships. Insert map shows the spatial relationships of clustering results along the west-to-east transect.

any bed, which reflects the systematic probing of sediment for food and is associated with *Zoophycos* (Olivero and Gaillard 2007).

Spatial Distribution of Fossil Assemblages

Results of both R-mode and Q-mode cluster analysis parallel what are obvious trends in the field. Fossil-plant assemblages of varying systematic and taphonomic composition occur across the sampling transect, whereas evidence of invertebrates, or their activity, is restricted (Fig. 6). R-mode clustering shows that *P. forbesii* is found in all but one collection site and 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* in association with *Pertica quadrafaria* is constrained to localities that occur immediately east of the interval in which both *Modiomorpha* and trace fossils are found. *Psilophyton princeps* and *P. dapsile* often occur with either one other plant taxon or plants of problematic affinity, or with the invertebrate fossils. And, their occurrence as

singletons in collection localities 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. 6).

Q-mode analysis shows that collections in which macroinvertebrates and trace fossils are preserved cluster outside of the remaining localities in which *P. forbesii* and dispersed plant debris is found, and spatially occur in the middle of the transect. Sites stratigraphically west and east of these collections are dominated by plant fossils, with those lower in the succession without evidence of *P. quadrifaria*. *Pertica* is a common taxon higher in the succession. Rooted samples, which represent the eastern most collection site, cluster close to plant-dominated localities, controlled by the presence of *P. forbseii* (Fig. 6).

DISCUSSION

Bedrock exposures unearthed during the construction of Wadleigh Mountain Road provide additional localities, heretofore unknown, in the

Early to Middle Devonian Trout Valley Formation. These occurrences extend the area from which fossils have been recovered to north of the Park Tote Road (Fig. 1). 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 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 either were of isolated, scattered impressions (Dorf and Rankin 1962) or of a low diversity, bivalve (*Pthonia*)-dominated assemblage (Selover et al. 2005), both reports interpreting these as estuarine in nature. The occurrence of an additional, monotypic and systematically different bivalve assemblage, associated with trace fossils that commonly occur in nearshore and estuarine environments (Miller 1991), reinforces previous interpretations (Allen and Gastaldo 2006) and allows for a better understanding of these Middle Devonian ecosystems.

Plant fossils appear in nearly all collection sites (Figs. 1, 6) along the collection transect, and stratigraphically above a basal 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) Facies 4 interpreted as a nearshore sand body, but its limited exposure precludes a more definitive interpretation and correlation. 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, characterized by plants arranged with nearly parallel stem alignment and little fragmentation or decay, are similar to Allen and Gastaldo's (2006; their Facies 6) tidal flats and estuarine channels which are a coarser grained sandy siltstone. Plant axes are preserved commonly as casts of hollowed (decayed) stems. These features indicate that residence time of axes at the sediment-water interface was accompanied by active sediment transport prior to burial (Allen and Gastaldo 2006). Symmetrical ripples at sites reflect bimodal oscillatory sediment transport, a feature that may be in response to tidal influence. Allochthonous plant assemblages differ by the presence of highly fragmented, randomly oriented plant axes that are concentrated on Siltstone Facies bedding planes. In only two sites, both of which are at the eastern end of the transect, is there evidence for an autochthonous assemblage. Here, vertically oriented roots, preserved perpendicular to bedding, and what appear to be *Psilophyton* axes signal the presence of an immature paleosol. 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.

Bedding surfaces dominated by a monotypic bivalve-dominated interval in association with plant fossils and a low diversity trace-fossil assemblage occur in the middle of the collection transect. *Modiomorpha concentrica* shells are preserved as flattened impressions with prominent, concentric growth lines, without any evidence for the presence of original material. The shells are disarticulated and only 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 butterflied (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 resulting in their concentration. However, without better outcrop exposure, the monotypic

shell concentration might represent a biogenic assemblage of even-aged individuals. Dissolution of the original calcite shell, accompanied by flattening during compression and lithification, would have been a consequence of acidic pore waters developed as carbonic acid production occurred in response to decay of plant detritus in these sediments.

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). In Maine, the only other report of the taxon comes from the 500-foot thick Chapman Sandstone, a part of the Mapleton sandstones near Presque Isle, which represent offshore sand bodies that accumulated under marine conditions in which a wide range of brachiopods (e.g., *Leptaena*, *Rhynchonella*, *Spirifer;* Williams and Breger 1916) are preserved. The cosmopolitan *Modiomorpha concentrica* is considered a shallow shelf dweller, adapted to infaunal feeding (Bradshaw and McCartan 1991), and commonly a 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 (1983) 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 ichnofauna recovered from pavement exposure, representing an autochthonous benthic community, is not known from any other locality in the Trout Valley Formation. *Skolithos* and *Spirophyton* both are reported from shallow marine settings, and interpreted to represent infaunal elements with opportunistic behaviors. *Skolithos* is known from a wide-range of marine environments, with Seilacher's (2007) *Skolithos* ichnofacies archetypal of a softground nearshore setting. *Spirophyton* differs from a similar, radially organized trace fossil, *Zoophycos*, which is associated with shallow (Bottjer et al. 1988) and 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 in settings influenced by freshwater discharge (i.e., brackish water), but not in freshwater settings per se (i.e., continental). Miller (1991) used paleoenvironmental evidence from the Catskill sequence to interpret these opportunistic behaviors as an adaption 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 a nearshore or estuarine interpretation for the taxon.

The presence of both plant-and-invertebrate material (Fig. 6) indicates that there was a mixing of terrestrial and marine components in response to, most likely, storm events. Plant detritus from emergent soils was transported in sufficient quantity to be preserved in a shallow subaqueous depositional setting during high discharge river flow, normally associated with increased rainfall. Once settled out of suspension load, they remained in the taphonomically active zone or were buried shallowly, promoting preservation. The fact that wetland plants (Andrews et al. 1977; Kasper et al. 1988; Allen and Gastaldo 2006; Greb et al. 2006) of a broad systematic affinity and of various taphonomic states, are preserved with a monotypic bivalve and associated ichnofaunal assemblage is interpreted to indicate a brackish water setting.

The collection transect from west to east along the Wadleigh Mountain Road 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 fluvially

transported plant parts 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 (Allen and Gastaldo 2006). The presence of silt-filled axes in association with symmetrical ripples indicates an oscillatory current, which may be associated with tidal processes. In other instances, compressions and poorly preserved adpressions 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, in an 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. Whether the plants occupied substrates that were tidally influenced and, hence, subjected to brackish waters, or colonized sediments with sufficient relief in which a freshwater soil profile was maintained is unclear based on the data presently available.

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. Their collection and curation further the mission of the Baxter State Park Commission which is to protect natural resources from deterioration and loss, while conserving their intrinsic value for current and future generations. These collections also lend additional support to a brackish water, estuarine setting for these plants.

The most common depositional environment of the Trout Valley Formation was of a shallow water, brackish estuarine nature. Sporadic, high discharge flood events were the primary transporting agent responsible for bringing megafloral elements to the site of accumulation, and providing the sediment in which they are buried. The fact that plants are found all along the roadway, reflecting different relative stratigraphic levels, and associated with disarticulated invertebrates at only one collection site, points to successive storm events as the likely taphonomic agent. The presence of ichnofossils midway in the transect, associated with a shell ground consisting of a monotypic *Modiomorpha* assemblage, indicates that the original sediment-water interface is conserved. The presence of *Spirophyton* is used to interpret a relatively shallow, inshore or nearshore environment for the interval 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 paleosol in the eastern locality.

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