ICHNOLOGY AND PALEOENVIRONMENTS OF THE LOWVILLE, NAPANEE, AND LOWER KINGS FALLS LIMESTONES (UPPER ORDOVICIAN), INGHAM MILLS, MOHAWK VALLEY, NEW YORK

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INTRODUCTION

The carbonate rocks of the Black River and Trenton Groups (Upper Ordovician) span a large area of North America, from Southeastern Canada through the Northeastern United States, including New York, Pennsylvania, West Virginia, Virginia, Tennessee, Ohio, and Indiana (Keith, 1988). In New York State, the Black River and Trenton Groups have been the subject of geologic investigation for over 150 years, partly because of their abundant and diverse body fossil assemblages. However, the ichnofauna contained within these rocks has received little attention. The goal of this study was to describe the ichnofaunal assemblages and to interpret the paleoenvironments for the Lowville Limestone (Black River Gp.), Napanee and lower Kings Falls Limestones (Trenton Gp.). An excellent outcrop exposure for several of the Black River and Trenton Group formations is located along East Canada Creek at Ingham Mills, New York, and this was the field area for the research.

FIELD AREA AND METHODS

According to Walker (1973), the Black River Group is composed of three formations in NW New York State; the Pamelia Formation, Lowville Limestone, and Chaumont Limestone. Of these three formations, only Lowville Limestone crops out at the Ingham Mills locality, and, therefore, both the basal and upper Lowville contacts are unconformable. At Ingham Mills, the Lowville overlies the Little Falls Dolomite (Cambrian) and is overlain by the Napanee Limestone (Lower Trenton). The Lowville Limestone previously has been characterized as a transgressive sequence, going from high intertidal to subtidal environments (Walker, 1973).

The Trenton Group in New York State comprises eight formations, and the lowest three of these formations, the Napanee Limestone, the Kings Falls Limestone, and the Sugar River Limestone, are exposed at Ingham Mills (Titus, 1988). The Trenton Group also has been interpreted as a transgressive sequence. The progression of the Trenton Group facies at Ingham Mills is thought to be from nearshore lagoon leading up to a barrier shoal facies (Titus, 1988).

The first stage of this research was a careful inspection of each bed in the Lowville, Napanee, and Lower Kings Falls Limestones at Ingham Mills to determine trace fossil occurrences. Specific information was collected regarding each type of trace fossil, including form, preservational mode, and host rock lithologies. Photographs, sketches, and rock samples were taken of the various units and trace fossils. Further information has been gathered about rock lithologies and burrow morphologies using polished rock sections, acetate peels, and thin section analysis. The information collected from these sources has helped to pinpoint the ichnogeneric and ichnospecific identifications, as well as providing important information regarding other aspects of the paleoenvironments, such as energy levels and nutrient availability. Measurements were made in the field to determine the extent of bioturbation within the various layers using the Droser and Bottjer ichnofabric index. Stratigraphic sections were measured for each formation, and details of the bedding styles, sedimentary structures, and trace and body fossil occurrences were noted for the beds of the three formations.

DISCUSSION

Lowville Limestone

The specific environments for the trace fossil assemblages will be described in terms of their individual ichnocoenosis. In this paper, the following definition from Bromley (1990) for an ichnocoenosis is used, "an ecologically pure assemblage of trace fossils that derive from the work of a single endobenthic community".

Three ichnocoenoses are recognized for the Lowville Limestone, all of which are contained within the Skolithos Ichnofacies, as described by Frey, Pemberton, and Saunders (1990). The first 3.83 m of the Lowville Limestone at Ingham Mills were deposited in an intertidal environment, as indicated by the numerous mudcracked surfaces, algal laminations, birdseye textures, and the *Skolithos*-dominated ichnofauna. The intertidal ichnocoenosis contains an opportunistic trace fossil assemblage containing suspension feeders represented by *Skolithos*, and several types of deposit feeders, that formed *Chondrites* and *?Palaeophycus* (Fig. 1). The trace-making organisms contained within this environment were pioneer animals, quickly able to exploit an unstable substrate and subject to periodic environmental fluctuations such as desiccation. An unusually complex feeding structure, *Beaconites baretti*, was discovered along the surface of a bed which contained evidence for tidal channels within the intertidal ichnocoenosis. This trace fossil has been documented from other tidal channel environments in Silurian rocks of Ireland and Devonian sequences in Antarctica. The discovery of *B. baretti* at Ingham Mills is the first described Ordovician occurrence.

The subtidal environment of the Lowville Limestone is characterized by diverse body fossil assemblages, an absence of mudcracked horizons, algal laminations, and well developed, vertical branching burrows. Trace fossils formed in stable environments tend to be larger and better developed. The *Phytopsis* burrows, which characterize the subtidal ichnocoenosis, have widths and lengths of 0.5 cm to 4.0 cm and 5.0 cm to 13.0 cm respectively, and they also contain thick wall linings. These abundant (ichnofabric index 3-4) and sizeable feeding and dwelling burrows may well have obscured other types of traces which once were in the subtidal beds of the Lowville Limestone (Fig. 1).

An intermediate ichnocoenosis occurs within the Lowville Limestone, possibly marking the transition between the intertidal and subtidal facies. This unit contains mudcracks, and both the opportunistic *Skolithos* burrows and the more strongly developed, vertically branching *Phytopsis*. The appearance of *Phytopsis* indicates that the environment was more stable than that represented by the intertidal ichnocoenosis. However, the presence of *Skolithos*, as well as a mudcracked horizon, implies that environmental fluctuations were still controlling the establishment of a fully developed subtidal ichnocoenosis.

Several anomalous layers with an apparent absence of trace fossils remain under investigation. Two of the layers in question are probably void of burrowing traces because of a thick covering across the bedding plane surface by the chaetetid sponge, *Tetradium cellulosum*, that prevented penetration of the substrate by infaunal organisms (Walker, 1972).

Napanee Limestone

The Napanee Limestone is a 1.65 m sequence of cyclic, interbedded micritic and fossiliferous limestones and shales, thought to have been deposited in a nearshore lagoonal environment. The cyclic nature of the Napanee Limestone is currently under investigation. Titus and Cameron (1976) described the formation as being deposited in a generally quiet, semiprotected setting because of the fine-grained nature of the rocks. Diverse and abundant faunal assemblages are generally found in such environments; however, the ichnofauna of the Napanee Limestone at Ingham Mills contains only one visible ichnospecies; *Planolites beverleyensis* (see Fig. 2). The lack of ichnodiversity exhibited in the Napanee is most likely the result of biologic and environmental influences; the thorough churning of the sediment by the deposit feeding *Planolites* destroyed other traces, and the sediment was thixotropic and therefore could support only organisms adaptable to an unstable substrate.

Kings Falls Limestone

The Kings Falls Limestone is a variable, transgressive sequence of calcarenites, calcilutites, and shales. These variable beds exhibit a diverse and fluctuating ichnofauna (Fig. 2). The types of trace fossils found within this high energy, bar environment of shoals, large ripples, and cobble-sized clasts, are primarily dependent on the nature of the substrate. For example, the coarsest calcarenites are largely void of trace fossils, except when burrows from units above intersect the tops of the coarser layers, leaving horizontal traces. The large grain size of the coarser calcarenites prevented penetration of the substrate by deposit feeders and infaunal tube dwellers. Poor preservation of the trace fossils and the presence of several erosional surfaces within the Kings Falls Limestone made it difficult to determine ichnogeneric and ichnospecific classifications for many traces.

The result is that the specific ichnocoenoses of this formation are much more difficult to resolve. Many of the trace fossils found in the Kings Falls Limestone were either restricted to individual layers or

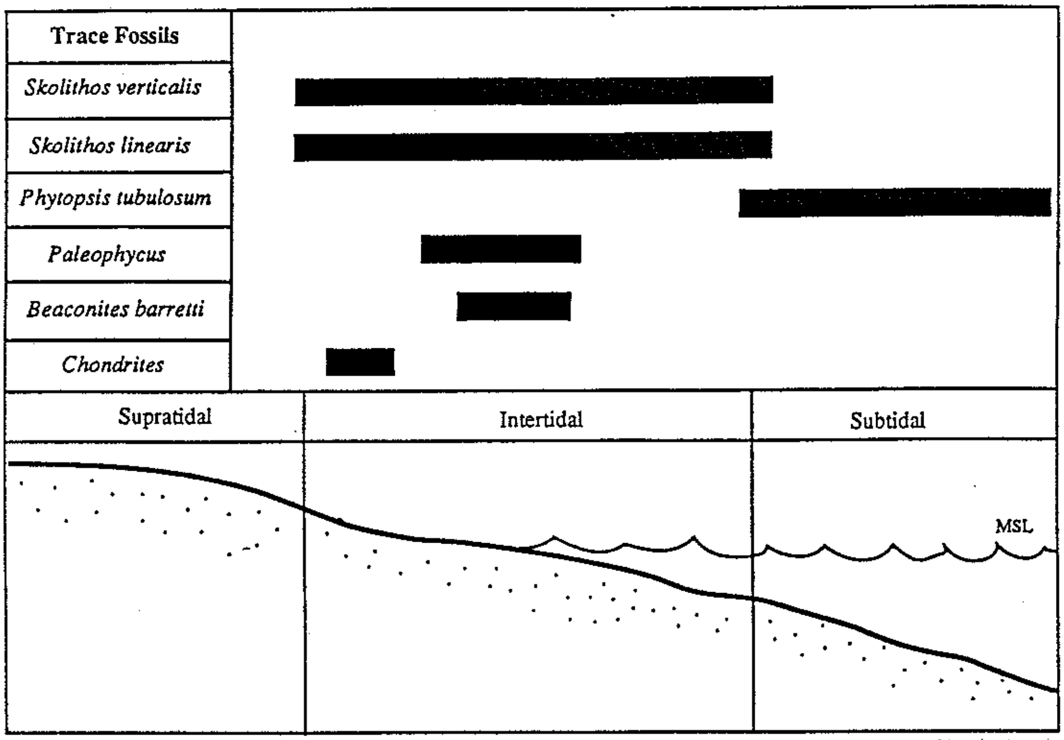

Figure 1: Generalized view of the ichnofaunal assemblages, correlated with their paleoenvironments, in the Lowville Limestone, Ingham Mills, New York.

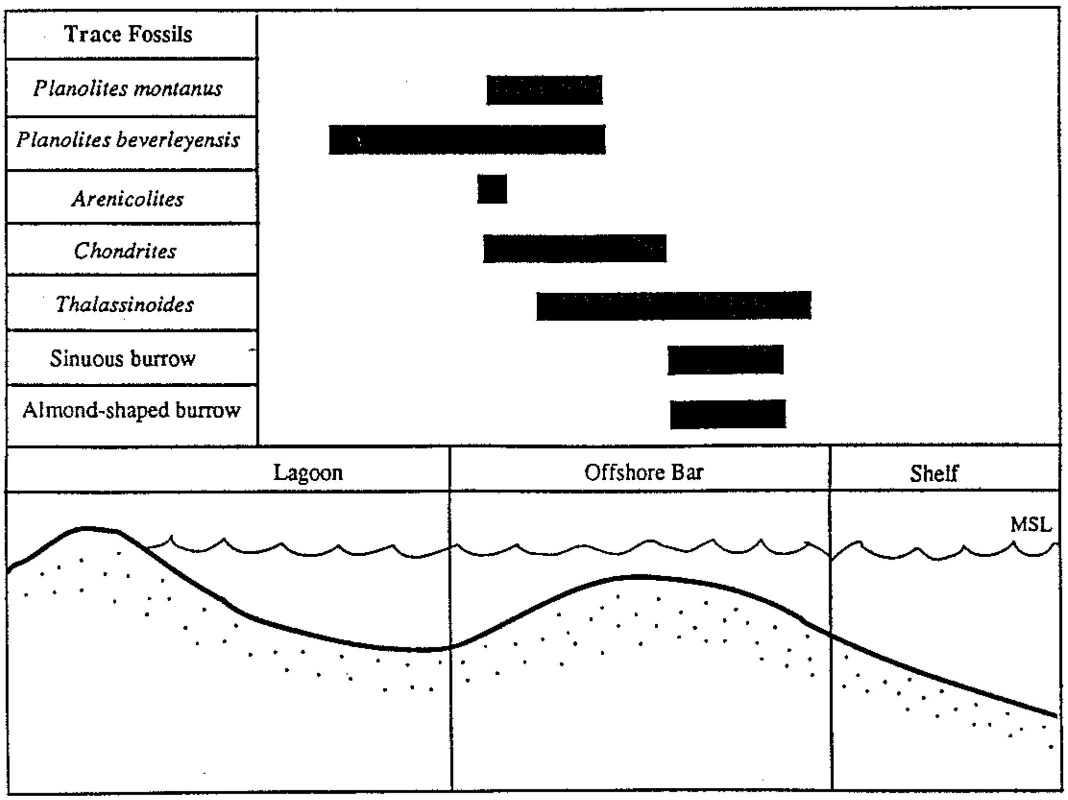

Figure 2: Generalized view of the ichnofaunal assemblages, correlated with their paleoenvironments, for the Napanee and Kings Falls Limestones (Trenton Group). Chondrites specimens have been grouped together for this analysis.

were singular occurrences. Therefore, trying to attribute descriptions of paleoenvironments according to an ichnocoenosis based on individual trace fossils is difficult and probably not useful.

The lowermost beds of the Kings Falls Limestone sequence at Ingham Mills are representative of a quieter water environment because of the fine-grained layers, the intact body fossils, and the ichnofaunal assemblage. These beds contain a relatively diverse assemblage of trace fossils including *Arenicolites*, a suspension feeder, and *Planolites beverleyensis*, *P. montanus*, and *Chondrites*, deposit feeders. The diversity of the organisms and the types of trace fossils indicate that the environment was relatively stable with low turbulence to allow both deposit and suspension feeders.

A blue gray limestone with abundant buff-colored mottling occurs 1.37 m from the base of the Kings Falls Limestone. The origin of the mottling within this limestone is interpreted as burrowing by *?Thalassinoides*, with the morphology having been obscured by the entrance of a second deposit feeding organism, *Planolites beverleyensis*. The depth of the *?Thalassinoides* within the limestone layer, and the abundance of the *P. beverleyensis* burrows, indicates a fairly stable substrate in a quiet water depositional setting.

The remaining seven meters of the Kings Falls Limestone examined in this study represent high-energy deposits containing large ripples, brachiopod and trilobite fragments, *Prasopora* bryozoans, and cobble-sized clasts. The ichnofauna of these beds was relatively diverse for such a high energy environment. However, several of the trace fossils were preserved as concave markings on horizontal bedding planes, indicating that the trace-making organism intersected the tops of these layers while working down from units above. The identifiable trace fossils were *Chondrites succulens*, *Chondrites* spp., *Planolites beverleyensis*, and *Thalassinoides*. Two other trace fossils were also discovered; a sizeable almond-shaped burrow and a large, sinuous trace fossil, both preserved in concave epirelief. The preservation of many of the burrows in concave epirelief indicates that the trace-making organisms occurred primarily in layers above the preserving medium in beds which subsequently have been eroded. At least five erosional surfaces are visible in the Lower Kings Falls Formation according to the presence of trace fossils preserved in concave epirelief.

CONCLUSIONS

The beds of the Gull River, Napanee, and lower Kings Falls Limestones collectively contain a diverse assemblage of trace fossils. An ichnological study of these formations has led to several significant conclusions:

1. The Lowville Limestone contains three distinctive ichnocoenoses from intertidal and subtidal settings. The intertidal ichnocoenosis is characterized by mudcracks, birdseye texture, tidal channels, and the trace fossils *Skolithos*, an infaunal tube dweller, *Chondrites*, and *?Paleophycus*, two deposit feeders. The subtidal ichnocoenosis is represented by *Phytopsis*, a well-developed, vertical, branching burrow, indicating a more stable environmental setting. A combination of *Skolithos* and *Phytopsis* indicates a transitional zone between the fully intertidal and fully subtidal settings. The trace fossil *Beaconites baretti* was found on the surface of a unit containing evidence of tidal channels, which correlates with previous environmental settings for this burrow found in Paleozoic rocks of Ireland and Antarctica.

2. Cycles of micritic limestones and shales are characteristic of the Napanee Limestone which has previously been described as representing a nearshore, generally quiet, lagoonal environment, with relatively high paleobiologic diversity. However, *Planolites beverleyensis* was the only visible trace fossil in the Napanee Limestone at Ingham Mills. This lack of ichonodiversity can possibly be attributed to two causes; a highly thixotropic sediment, inhospitable to many infaunal, trace-making organisms, and the destruction of previously formed traces by the complete reworking of the substrate by the *Planolites* organism.

3. The lowermost portion of the Kings Falls Limestone was deposited in a low energy, more stable environment consisting of fine-grained limestones, intact body fossils, and relatively diverse ichnofaunal assemblages. *Arenicolites*, *Planolites beverleyensis*, *P. montanus*, *Chondrites*, and *?Thalassinoides* represent the primarily quiet water environment of the lowest section of the Kings Falls Limestone.

4. The upper beds of the Kings Falls Limestone contain megaripples, brachiopod and trilobite fragments, and cobble-sized clasts characteristic of a high energy environment. Six types of trace fossils were found, including *Chondrites succulens*, *Chondrites* spp., *Planolites beverleyensis*, *Thalassinoides*, an almond-shaped burrow, and a large, sinuous burrow. Several of these trace fossil types were preserved in concave epirelief, indicating that the original bed occupied by the burrowing organism had been eroded away.

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DIAGENESIS OF THE ROCKLAND, KINGS FALLS AND SUGAR RIVER FORMATIONS,TRENTON GROUP, MIDDLE ORDOVICIAN; CENTRAL NEW YORK

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Introduction

The purpose of this study is to understand the diagenesis of the Rockland, Kings Falls and Sugar River Formations of the Trenton Group limestones by means of petrographic analysis. The Trenton Group was studied as early as June, 1836, by Conrad, and has been extensively examined since. Most notable of the geologists who have worked on the Trenton is Marshall Kay, who studied these limestones for over three decades (Kay, 1937, 1968). However, no recent petrographic study of the Trenton Group, as it is exposed at Inghams Mills, has been done using modern techniques.

By combining thin section and acetate peel analysis with recorded stratigraphic positions of samples within the outcrop, a chronology of events can be established to describe the diagenetic processes of the Trenton Group.

Field and Laboratory Methods

The information for this study was gathered through fieldwork and laboratory examination of the Rockland, Kings Falls and Sugar River Formations of the Trenton Group at one continuous section at Inghams Mills, Fulton County, New York. A detailed stratigraphic section was developed by establishing a baseline (0.00 m) and measuring upsection to noted horizons. These horizons were designated by observing distinct changes in lithology and faunal content. To aid our sampling process, a portable coring drill, property of Smith College, was used to sample units where a vertical cross-section was necessary and otherwise difficult to collect.

Laboratory work at Smith College provided the opportunity for immediate processing of thin sections and acetate peels. The peels were made following the techniques described by Wilson and Palmer (1989) and are useful because of their short preparation time, low cost and accurate representation of the etched surface of a carbonate sample. After completion of the field study, additional thin sections were professionally prepared by Pioneer Thin Sections, Inc. The thin section blanks were then repolished and acetate peels were made corresponding to the thin sections. The study of the initial thin sections and acetate peels under Nikon Labophot-Pol petrographic microscope led to the preparation of more thin sections using the equipment available at the College of Wooster. After attaining the proper thickness of the second set of thin sections through examination of the birefringence of quartz, some were stained with potassium ferricyanide for the detection of ferroan cement and with alizarin red-S to check for the presence of dolomite.

Results and Discussion

The pre-lithification conditions of the Trentonian sediments are well understood through both field and laboratory study (Barton, 1992; Titus, 1989). The depositional environment was one of significant biological and physical activity. Burrows and large ripples are present at the outcrop, as are fossils of organisms capable of disturbing sediments (trilobites), indicating some of the pre-diagenetic processes at work on the sea-floor. As this redistribution of sediments was taking place, some units were cemented with low-magnesium calcite while either still exposed to the marine waters, or while just below the sediment-water interface. Given the high fossil content and the types of organisms known to have been present, the dissolution of aragonite shells, such as gastropods, could have provided at least part of this early cement. Aragonite has been found to be more soluble than calcite under some marine conditions, and is often reprecipitated into calcite (Walter, 1985); this has been previously noted in carbonate rocks of the Ordovician (Palmer et al., 1988). Some of the rippled and burrowed units did not undergo immediate cementation. Continued deposition preserved these sedimentary features until cementation in the burial diagenetic environment.

Iron was also a component of the depositional and diagenetic environment. Several iron-based minerals (siderite, hematite and pyrite) were identified in the thin sections.