Trip BC-4

ANIMAL-SEDIMENT RELATIONSHIPS IN MIDDLE ORDOVICIAN HABITATS

David W. Larson
Department of Geology, Hamilton College, Clinton, New York 13323

INTRODUCTION

In recent years a number of workers have presented arguments to suggest that utilization of infaunal life strategies by marine organisms has varied through the Paleozoic. Evidence for a progressive "infaunalization" of Paleozoic communities comes from functional analysis of trace fossils (Seilacher, 1977), patterns of taxonomic richness of skeletonized bioturbating organisms (Thayer 1979, 1983), and the sedimentary record of the effects of burrowing organisms (Garrett, 1970; Sepkoski, 1982; Larson and Rhoads, 1983). Between the Middle Ordovician and Early Devonian, it seems that the depth of biogenic reworking of sediment in marine shelf settings increased from essentially zero to over 5 cm. Exploitation of buried food resources by deposit-feeders propels this infaunal invasion (Larson and Rhoads, 1983). Miller and Byers (1984) present an opposing view, that infauna are abundant and diverse throughout the early Paleozoic. At present, there is no consensus as to the style and degree of biogenic reworking in the early Paleozoic.

This field trip is meant to provide an opportunity to examine some of the evidence that has convinced me that biogenic reworking in Ordovician sedimentary environments was much reduced in comparison to recent counterparts. We will visit a series of four outcrops of Middle Ordovician carbonate rocks in the Black River Valley of northwestern New York (Figure 1). Our trip will take us on a transect of facies from the intertidal carbonates of the Black River Group through a range of shallow to deep shelf and basinal environments in the Trenton Group. The goal is to examine Ordovician animal-sediment relationships and their sedimentologic and paleoecologic implications.

BIOTURBATION AND DEPOSIT-FEEDING

By definition, all benthic organisms have some interaction with the sediments of the seafloor. Since physical and chemical properties of the bottom sediments are an important ecologic factor in the distribution of both epifauna and infauna, activities of an organism or group of organisms that alter these properties may also influence the ecologic structure of the entire community. The style and extent of biologic modification of the substrate will be preserved as biogenic sedimentary structures.

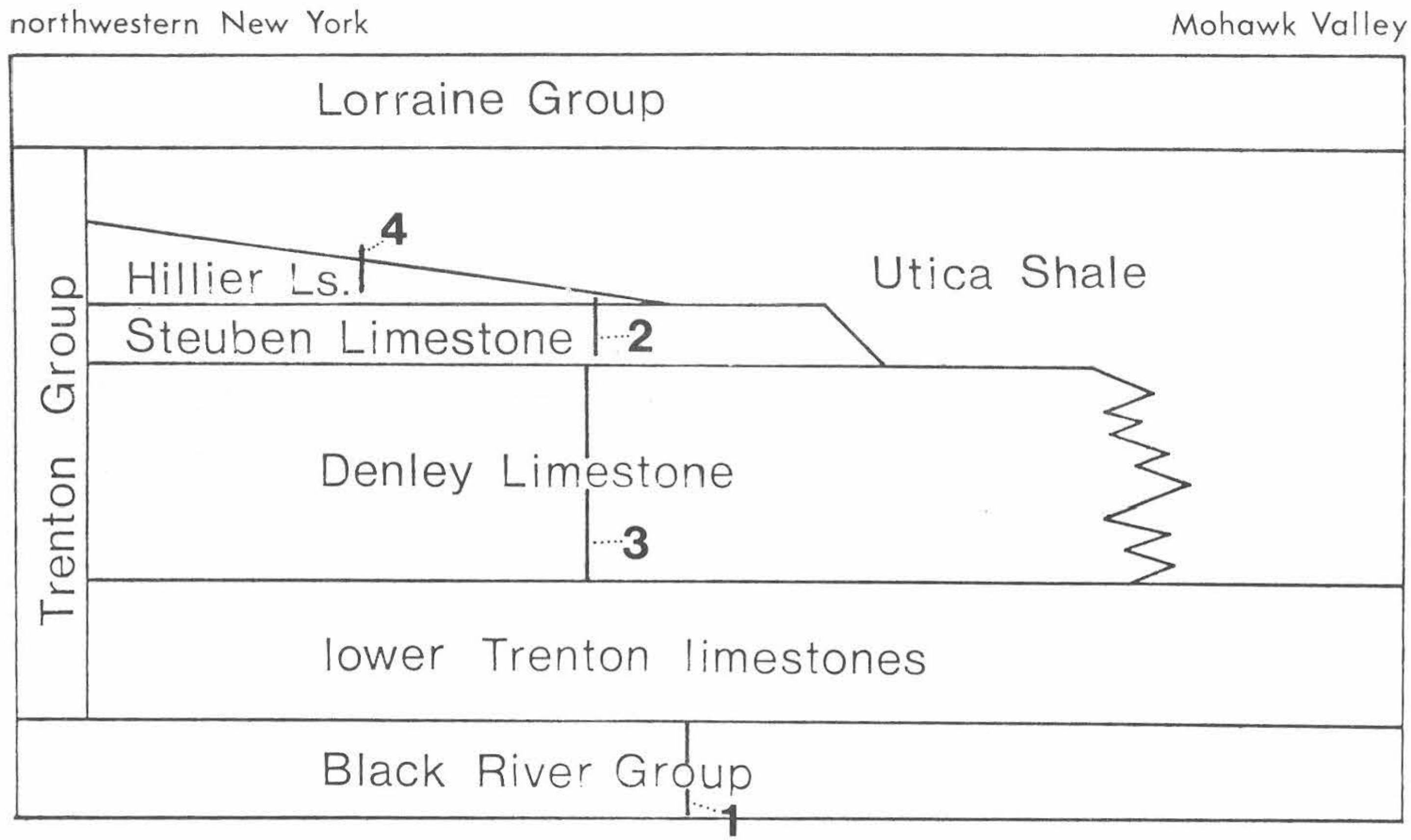

Figure 1. Stratigraphic cross-section of Ordovician rocks in the Black River Valley. Stops for this field trip are indicated by a vertical line and appropriate numeral. Modified from Fisher (1977).

Biogenic structures are produced by a wide variety of activities that include construction of dwellings, crawling and grazing, escape activity, or deposit-feeding (see Osgood, 1970; Schafer, 1972). Crawling and grazing trails, except in regions of very low sedimentation rate, are unlikely to rework large volumes of sediment. Likewise, escape and dwelling traces are discrete structures that ordinarily are not responsible for large-scale reworking of the substrate. Deposit-feeding organisms do extensively rework the sediments on the bottom. In the process of extracting their food, many deposit-feeders produce a layer of pelletized sediment with reduced shear strength and high water-content (review in Rhoads and Boyer, 1982). This sediment is readily resuspended by water motion and may contaminate the feeding and respiratory structures of hapless suspension-feeders. Sediment destabilization by deposit-feeders can also disorient and bury stationary taxa as well as prevent recruitment of juveniles. Such functional-group amensalism (Rhoads and Young, 1970; Brenchley, 1982) is responsible for excluding suspension-feeding taxa from substrates inhabited by errant deposit-feeders. Importantly, we may be able to identify such thoroughly bioturbated sediments on the basis of diffuse, poorly defined burrows produced in high water-content sediments (Rhoads and Young, 1970; Rhoads and Boyer, 1982).

How can we evaluate the degree of biogenic reworking that has affected a sedimentary rock? In a comparison of bioturbation in Ordovician and Devonian rocks, Larson and Rhoads (1983) used the following criteria:

1. Morphology of individual traces

2. Sedimentary fabric of the rock

3. Thickness of preserved bedding units

All three points will be useful in the examination of bioturbation in Ordovician sedimentary environments. The importance and significance of trace fossil morphology needs little elaboration. The size and orientation, that is parallel, sub-parallel, or perpendicular to beddin , of a biogenic structure are important in determining the extent of sedi ment reworking.

The use of the sedimentary fabric of a rock as a guide to bioturbation depends on distinguishing between fabric elements due to physical sedimentary processes and those imposed biogenically. Lamination, grading of grain size, and orientation of elongate grains parallel to bedding are all due to physical processes; these may be disrupted by burrowing. Oddly however, some of the most conspicuous burrows occur in rocks that are not extensively reworked. For example, Figure 2 is a view perpendicular to bedding of a well laminated rock with a prominent series of vertical tubes. Less than 20% of the rock volume has been reworked by organisms. Similarly, burrow networks that appear on bedding planes may actually cause little reworking of the sediment.

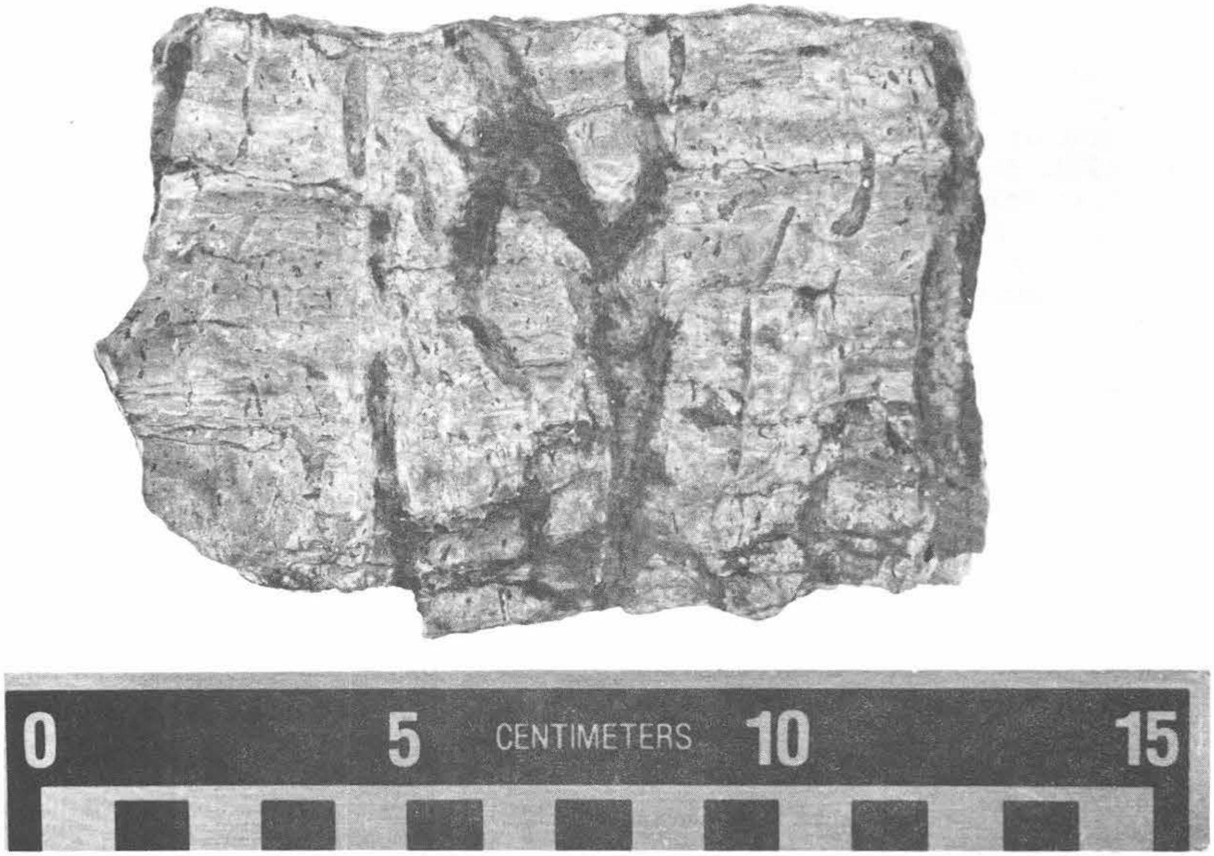

Figure 2. Vertical burrow in a finely laminated carbonate mudstone. Lowville Formation, Black River Group, from Ingham Mills, New York.

Thickness of preserved bedding units may be useful in determining the depth of bioturbation. Sedimentary units thinner than the average depth of reworking are unlikely to be preserved as distinct layers in the sedimentary column. Thus, the absence of beds thinner than 5 cm thick may indicate a depth of reworking of 5 cm. Comparison of bedding unit thickness is best done on a within-habitat basis to ensure that differences in sedimentary regime are not responsible for major differences in bed thickness. Since our traverse today takes us across habitat boundaries, we should use bedding thickness only as a guide to degree of bioturbation.

Sedimentary Fabrics and Environments

Mobile infauna greatly influence the sedimentary record of Recent shelf environments. In nearshore settings, physical structures dominate under the influence of high sedimentation rates and wave and current processes. Offshore in less turbulent waters, physical structures are replaced by burrows. Sediments lying in water below the depth of storm wave base are thoroughly bioturbated (Moore and Scruton, 1957; Howard and Reineck, 1972; 1981). It is important to note that it is the rapidity of physical reworking in the nearshore and burrowing in the offshore that produces the dominant sedimentary fabric. The increase in bioturbation in the offshore direction is a feature of Recent shelves dominated by detrital clastics (see Howard and Reineck, 1972; 1981) as well as carbonates (Ginsburg and James, 1974; James and Ginsburg, 1979). Figure 4 includes a general representation of the distribution of physical and biogenic sedimentary structures in Recent shelf environments.

How does sediment reworking in Ordovician habitats compare to the Recent? Figure 4 also includes my interpretation of the relative importance of biogenic reworking of sediment in the Ordovician carbonates of the Black River Valley; we will be examining the field evidence for this interpretation. Unlike Recent shelves, maximum reworking occurs nearshore in wave-influenced waters. There is no trend of increasing bioturbation in an offshore direction--sediments at and below storm wave base do not show evidence of extensive reworking. What is the style of substrate utilization in this habitat? The Denley Limestone at Stop 3 is an excellent locale to consider this point.

The Denley Limestone contains graded packstones interbedded with carbonate mudstones and shaly partings. (Figure 4). Following the criteria of Kreisa (1981), I have interpreted these as storm deposits. The alternation of turbulent and quiet water builds many fine scale bedding units into the sedimentary column. As seen in Figure 4, the effect of burrowing in reworking these deposits has been minor. The burrows that are present are either restricted to upper bedding surfaces, penetrate less than a few centimeters, or fail to rework large volumes of sediment. Unlike Recent sediments accumulating in similar conditions, the Ordovician material is not reworked by deposit-feeders and retains its physical sedimentary fabric.

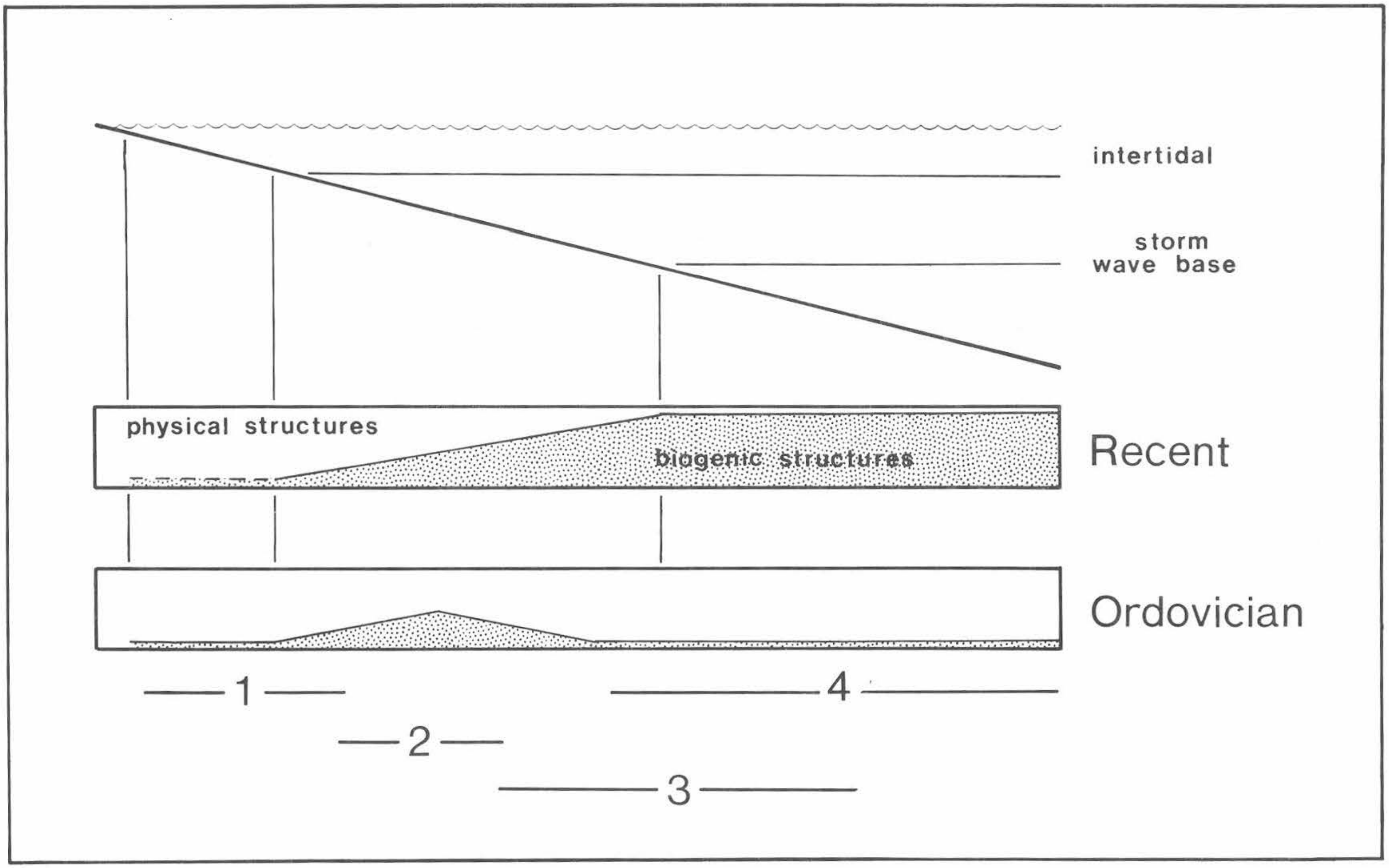

Figure 3. Comparison of the effects of burrowing along an onshore-offshore gradient. Recent near-shore settings are underlain by sediments bearing physical sedimentary structures. Biogenic structures increase in importance in the offshore direction. Below storm wave base very few physical structures are preserved. Ordovician carbonates of the Black River Valley show a different pattern. Shallow subtidal environments show the greatest degree of biogenic reworking. Deeper shelf settings show only minor bioturbation. The lines and numerals beneath the Ordovician bar indicate the environmental range at the field trip stops.

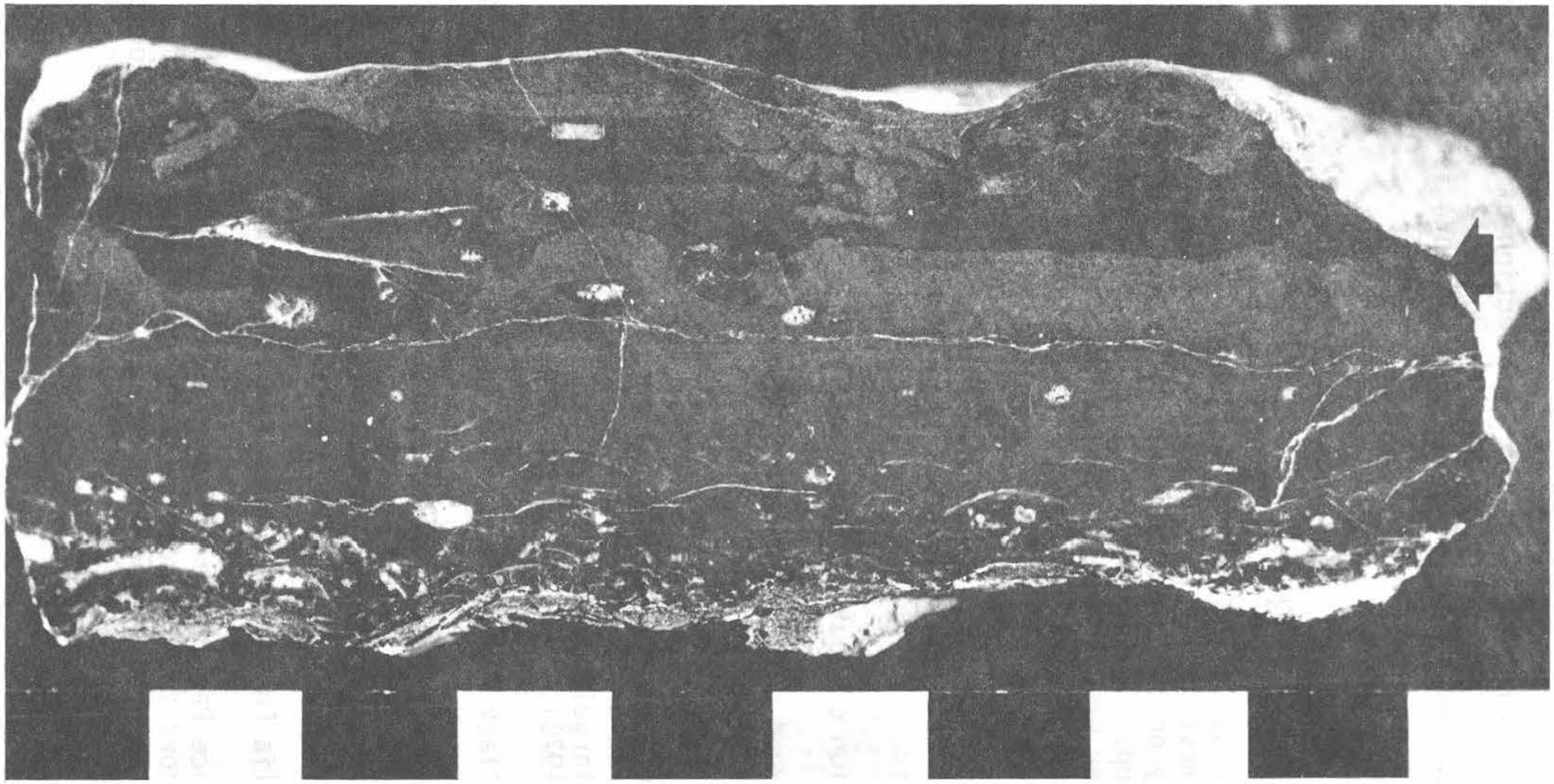

Figure 4. Sample of the Denley Limestone from exposure along Roaring Brook, Stop 3. Burrowing at the contact (arrows) occurred before deposition of the upper unit. This surface marks a former sediment-water interface at which burrows penetrated less than 1 cm into substrate. The lower unit is a storm deposit that grades from a packstone with fragmented, imbrivated fossils to a laminated mudstone. Centimeter scale.

ROAD LOG AND STOP DESCRIPTIONS

Road Log begins in Boonville at the intersection of Routes 12 and 12D. This point is 32 miles north of Utica on Route 12. Stops 1, 2, and 3 are located on the Glenfield 7.5' quadrangle. Stop 4 is on the Rodman 7.5' quadrangle.

Mileage

0.0 Intersection of Routes 12 and 12D. Proceed north on Route 12.

3.3 Bridge across Sugar River. Upstream is an excellent exposure of the limestones in the lower portion of the Trenton Group. The quarry on the right side of the highway is in the Black River Group. Downstream, solution cavities and channels in the Black River Group cause subsurface drainage of Sugar River. At low discharge all of Sugar River disappears into the streambed.

Our route north parallels the channel of the Black River and runs at or near the contact of the Black River Group on the Precambrian.

11.0 Intersection of Route 12 and Turin Road. Turn left.

11.1 Stop 1. Road cuts in the Black River Group on north and south side of Turin Road.

The Black River Group is a well documented example of tidally influenced carbonate deposition. This discussion of the stratigraphy and sedimentology of the Black River Group is largely drawn from Walker (1973) and Walker and Laporte (1970).

Here the Black River Group is divided into three formations:

Chaumont Formation: burrowed, fossiliferous wackestone.

Lowville Formation: fenestral, laminated mudstone, wackestone, and packstone.

Pamelia Formation: dolostone and dolomitic sandstone.

The sequence Pamelia/Lowville/Chaumont is interpreted by Walker (1973) to record the progressive transgression of the Middle Ordovician sea onto an eroded Grenville terrane. From base to top the Black River Group records the transition from supratidal to intertidal to shallow subtidal conditions.

The Lowville Formation includes a number of sedimentologic features indicative of an intertidal origin: mudcracks, fenestral fabric, and algal laminations. In addition, oolites, intraformational conglomerates, and fragmented mounds of Tetradium indicate vigorous stirring of the bottom.

The Chaumont Formation contains fewer sedimentologic criteria on which to base an environmental interpretation. Walker (1973) bases his assignment of the Chaumont to the shallow subtidal on the presence of brachiopods and bryozoa in the Chaumont and the interbedding of Lowville and Chaumont lithologies.

A striking feature of the outcrop is the contrast in sedimentary fabrics between the Lowville and Chaumont Formations. Burrows are rare in the Lowville. The sedimentary structures that permit such a straight-forward facies assignment are barely altered by biogenic reworking. Chaumont sedimentary fabrics on the other hand are dominated by burrows. In many cases the outlines of individual burrows are distinct; in others, the burrow outlines are diffuse. Importantly, other than laterally discontinuous bedding units, the biogenic structures have very nearly obliterated the depositional features. This style of bioturbation is characteristic of deposit-feeding communities (Rhoads and Young, 1970; also Rhoads and Boyer, 1982).

Here then we are able to see that for these Ordovician habitats, like their recent counterparts, the effects of bioturbation increase in an offshore direction. A deposit-feeding community was clearly active in this shallow subtidal setting.

Mileage

Continue uphill on Turin Road.

12.0 Intersection with East Road. Bear right onto East Road.

12.3 South Lewis High School on right.

14.2 T-intersection, continue on East Road.

16.1 T-intersection, continue on East Road.

16.5 T-intersection. Turn right onto Houseville Road.

16.8 Stop 2. Abandoned railroad cut through the Steuben Limestone of the Trenton Group. From this vantage point you can see the Tug Hill Plateau, underlain by the Utica Shale and Lorraine Group, to the west. To the east across the Black River Valley are Grenville rocks of the Adirondacks.

At this exposure we will examine a ten meter section of the Steuben Limestone (Figure 6). About 40 cm of Hillier Limestone is exposed at the top of this cut. We will see a much thicker section of the Hillier at Stop 4.

The Steuben Limestone is generally a thickly bedded fossiliferous packstone with some important variations in lithology. Near the base of the exposure, fossiliferous mudstones and wackestones are interbedded with centimeter thick argillaceous mudstones. Both grainsize and bed thickness increases upward through the Steuben. Midway through the section are cross-laminated grainstones and packstones, some with mega-rippled upper bedding surfaces. There are shaly partings near the top of the Steuben, but no interbedded lime or argillaceous mudstones. The upper portions of the Steuben accumulated in more turbulent, more frequently agitated waters than the sediments at the base of the exposure. On the onshore-offshore gradient, I assign the Steuben to an open marine shelf subject to occasional stirring by currents or waves (Figure 3). Certainly the Steuben was deposited in a more exposed environment than the Chaumont of Stop 1.

Trace fossils are prominent throughout the Steuben. Near the base of the exposure are examples of Palaeophycus, Planolites, and Chondrites. These burrows are confined to bedding surfaces or generally penetrate the sediment only several cm. Monocraterion, a vertical sediment filled tube one cm in diameter and up to 8 cm long, is common in the crinoidal packstones near the top of the Steuben.

The style of bioturbation also varies vertically in the Steuben. Although nowhere is the Steuben completely burrow reworked, it seems that the greatest degree of biogenic alteration of the sedimentary fabric occurs in the upper Steuben with Monocraterion. This trend runs counter what we would expect from the modern: rather than finding the greatest degree of biogenic reworking in fine-grained sediments at depth, here the coarser-grained, shallow-water environments are more reworked. Consequently, at this point Figure 3 shows the divergence in bioturbation trends for the Recent and Ordovician.

Mileage	Continue on Houseville Road, heading downhill.
18.1	Intersection with Duncan Road. Turn left.
19.5	Intersection with Lee Road. Turn right.
19.8	Intersection with Glendale Road. Turn left.

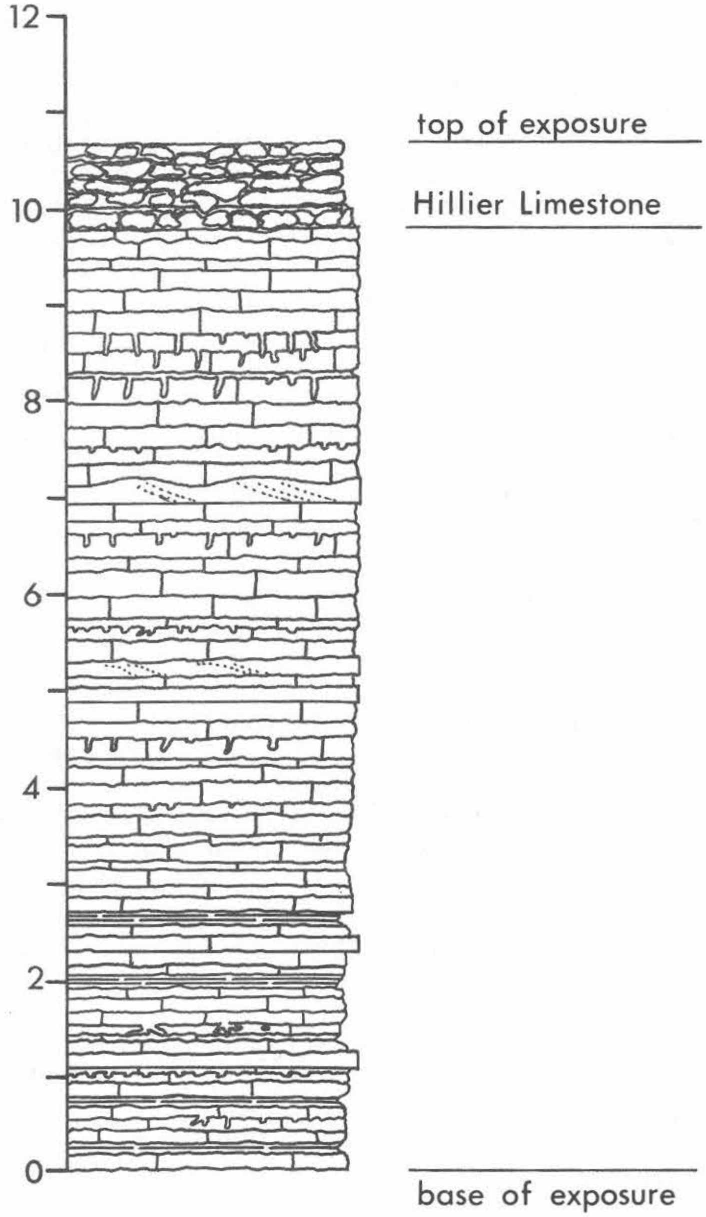

Figure 6. Stratigraphic column of Steuben Limestone at Stop 2. Scale on left side is in meters.

Mileage

20.7 Bridge over Roaring Brook. Denley Limestone of Trenton Group in creek bed.

20.9 Stop. 3. Entrance to Whittaker Falls Park. Turn right.

Nearly all of the Trenton and Black River Groups are exposed along Roaring Brook. In a combination of rapids, falls, and level stretches, the rocks are exposed in both vertical section and on bedding planes. A long, nearly continuous exposure of the Denley Limestone is the focus of our attention.

On the basis of smaller grain size and fewer indications of turbulent conditions, I have assigned the Denley to a position further offshore than the overlying Steuben Limestone. The upper 50 m of the Denley contains mega-rippled and cross-stratified grainstones interbedded with finer-grained lithologies. This portion of the Denley was deposited within the reach of storm wave base. Because the basal 9 m of the Denley lack these grainstones, this portion of the formation appears to have accumulated below storm wave base.

The Denley Limestone contains a diverse fauna including brachiopods, bryozoa, crinoids, and trilobites. Many of the body fossils apparent on outcrop here are fragmented, abraded, and occur in grainstone or packstone units. Overturned heads of the bryozoan Prasopora attest to disturbance and relocation of many of the fossils. Figure 7 is an illustration of the role of turbulent events, major storms, in producing both the sedimentary structures and the fossil assemblages in the Denley.

Not all of the fossils are reworked, however. Adhering to the tops of limestone beds, or entombed within centimeter thick shaly partings are some fossil assemblages that indicate in place accumulation. Evidence for in place accumulation includes lack of abrasion and fragmentation and the co-occurrence of fossils ranging in size from .1 to 1.5 cm. In addition, several specimens of juvenile crinoids, complete with holdfast, suggest in place burial rather than transportation before burial.

Trace fossils are abundant here. Palaeophycus and Chondrites are the most conspicuous. Again, despite the presence of burrows, the sedimentary fabrics of the Denley retain their original features. Maximum depth of burrowing is about 3 cm.

Return to park entrance and turn right onto Glendale Road.

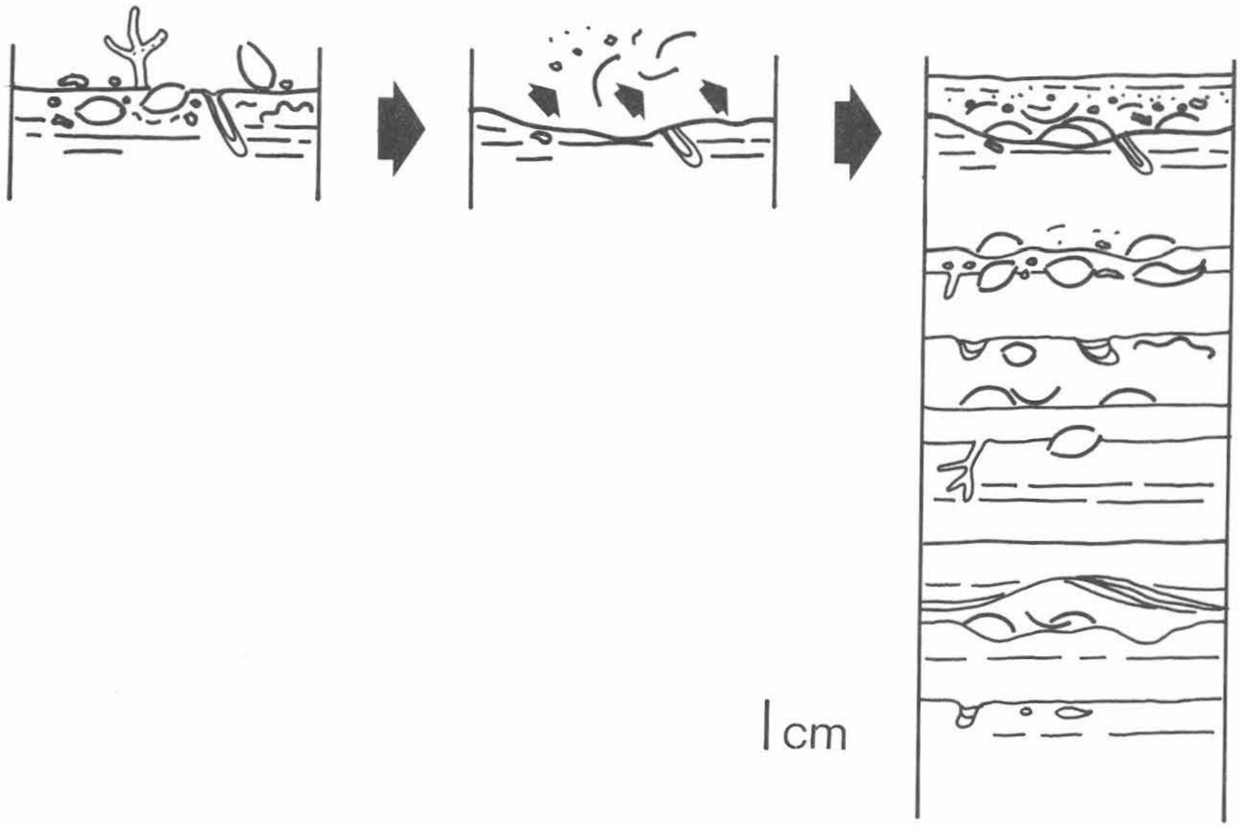

Figure 7. Forming a storm deposit in the Denley Limestone. Turbulence of a storm suspends sediment and disarticulates fossils. Commonly, a graded fossiliferous packstone is formed as sediments settle from suspension, illustrated in Figure 4. Depending on conditions, a storm may winnow sufficient sediment to produce a mega-rippled grainstone or may bury a fossil assemblage in place.

Mileage

30.0 Y-intersection, bear left.

30.6 Intersection with Route 26. Turn right into village of Martinsburg.

31.4 Crummy roadcut on left is Steuben Limestone.

33.9 Entering Lowville. Routes 12 and 26 join. Continue straight ahead on 12 and 26.

34.5 Downtown Lowville. Turn left on Route 12. Time and temperature on bank on right side of road.

35.2 Bridge over Mill Creek. Excellent exposures of Trenton Group.

37.2 West Lowville. Junction with Route 177. Bear left onto 177. We are climbing to the top of the Tug Hill Plateau.

48.0 Crossing Deer River at New Boston. Continue straight.

51.8 Barnes Corners. Continue straight.

59.0 Village of Rodman. Turn right.

59.2 Right turn onto Creek Road.

59.6 Bridge over Gulf Stream.

59.7 Stop. 4. Park off of road on left-hand side. Cut along Gulf Stream where we can examine the contact between the Utica Shale and the underlying Hillier Limestone of the Trenton Group.

Watch out! Poison ivy is abundant and lush here, especially on the Utica Shale.

This is a 13 m section that records the transition from wave influenced shelf to deep, anaerobic basin (Figure 8). Illustrating this trend through the Hillier Limestone is a decrease in grainsize, loss of mega-rippled and cross-laminated beds, and an increase in number and thickness of shaly partings in the limestone.

Here the transition to deeper water is marked by an increase in burrowing. Palaeophycus, Planolites, and Chondrites are present, but evidence of a bioturbating, deposit-feeding

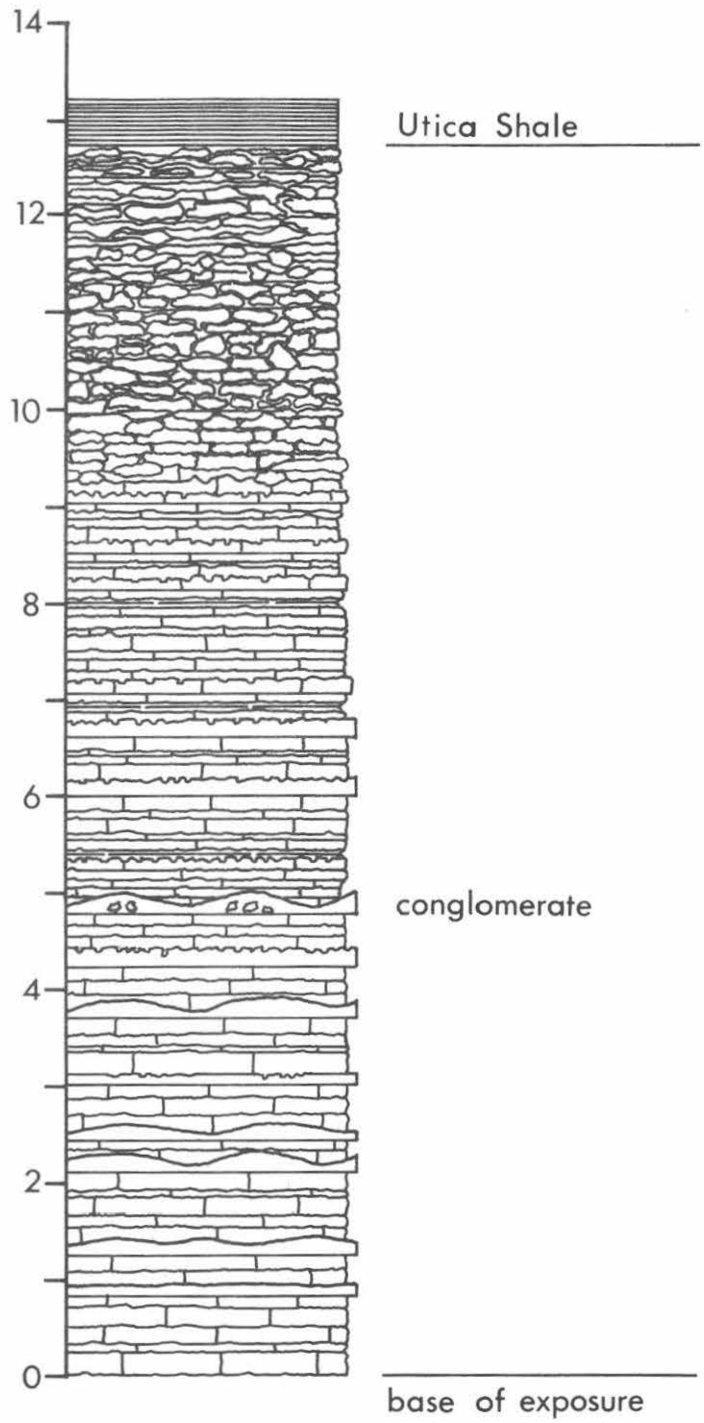

Figure 8. Stratigraphic column of Hillier Limestone at Gulf Stream, Stop 4. Scale on left is in meters.

community is absent. Here, too, the conspicuous body fossils are brachiopods, bryozoa, and crinoids although the gastropod Liospira is locally abundant.

The uppermost Hillier is an interesting lithology with lumpy nodular bedding. The fauna here includes mostly phosphatic forms: trilobites, conularids, and lingulids with setae preserved around the margin of the valves.

The Utica Shale is a black, fissile, argillaceous mudstone. Careful collecting can turn up cephalopods, graptolites, and the trilobite Triarthrus.

End of trip. Reverse direction to return to Clinton. Follow 177 to junction with Route 12. Follow Route 12 to Utica and New York State Thruway. Follow 12B from Utica to Clinton.

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