

UNDERSTANDING THE EAST CENTRAL ONONDAGA FORMATION (MIDDLE
DEVONIAN) - AN EXAMINATION OF THE FACIES AND BRACHIOPOD
COMMUNITIES OF THE CHERRY VALLEY SECTION, AND MT. TOM, A SMALL
PINNACLE REEF

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INTRODUCTION

The Onondaga Formation of New York and Ontario, Canada has been extensively studied (see Oliver, 1976 for references), and yet is still poorly understood. It is a unit which is, in the western part of New York and in Ontario, clearly transgressive, and yet it lacks any of the classic peritidal facies associated with shallow water carbonates. It is a "reefy" unit, but the major reef building paleocommunity of the Middle Devonian (stromatoporoids and algae) are either extremely rare or absent. Finally, it has been described as an example of carbonate deposition along a gently subsiding ramp, which would seem to imply symmetry on either side of the basinal axis, and yet the pinnacle reefs - which are so highly sought after by

explorationists - have been found on the western side of the basinal axis, but to date not on the eastern side. Kissling (1987) suggested that these unusual characteristics were due to deposition in deep water, possibly below the photic zone. As an alternative, Wolosz (1990, 1991) has argued that the Onondaga represents an example of a Devonian temperate water limestone.

On this trip we will attempt to come to our own conclusions by examining a nearly complete section of the Onondaga (Cherry Valley) and a small pinnacle reef (Mt. Tom). In the following text, Lindemann analyzes the stratigraphy and depositional environments, Feldman the significance of the brachiopod communities, and Wolosz and Paquette the depositional history of the Mt. Tom reef.

STRATIGRAPHY AND DEPOSITIONAL HISTORY

The Onondaga Limestone is a 21-50+ meter thick unit of lower Middle Devonian marine limestones deposited during the final major phase of carbonate production prior to the influx of siliciclastic sediments shed from the Acadian mountain buildup. This component of the field trip is intended to provide an overview of Onondaga stratigraphy and depositional environments in Otsego County, New York. It centers on a nearly complete composite section of the formation exposed in road cuts on U.S.Route 20 at Cherry Valley (Sprout Brook, New York 7.5'quadrangle). These exposures mark the easternmost extent of

the "typical" Onondaga as defined in central New York by Oliver (1954).

The concept of what is now the Onondaga Formation began to be developed prior to the First Geological Survey of New York (see Eaton, 1832). During the survey Vanuxem (1842) recognized four "formations," the uppermost of which he named the "Seneca limestone," a label which persists today. Hall (1843) recognized a three-fold division and applied the term "Onondaga limestone" to those strata now known as the Edgecliff Member. Through time the "Onondaga Limestone" came to include the entire interval of limestone strata which overlies formations of the Lower Devonian and is itself overlain by the black shales of the Marcellus Formation. Oliver (1954, 1956a) formally subdivided the Onondaga into four members. In the best tradition of the recently canonized Nicolas Steno, the members arranged from oldest to youngest are the Edgecliff, Nedrow, Moorehouse, and Seneca limestones. Descriptions of the members provided herein are specific to the exposures at Cherry Valley, NY. Lithologic terminology corresponds to that of Lindholm (1964).

Biostratigraphy and Correlation

The biostratigraphic basis for correlation of the Onondaga Formation, particularly the Edgecliff Member, to the standard biozones and stages of Europe reads like a "who-done-it?" with the last few pages missing. Brachiopod and coral faunas have long served to place the formation at the base of the Middle

Devonian Series (Rickard, 1975). Dutro (1981) reports that the Edgecliff Member coincides with the base of the Frimbrispirifer divaricatus Subzone of the Amphigenia Assemblage Zone which marks the base of the Southwoodian (=Upper Onesquethawan) Stage. Similarly, Oliver and Sorauf (1981) state that the Edgecliff base coincides with the base of the Acinophyllum segreatum Assemblage Zone and the bottom of the Southwoodian Stage. High in the formation, the Seneca Member is within the Paraspirifer acuminatus Assemblage Zone as well as an unnamed coral assemblage zone (8 of Oliver and Sorauf, 1981), both of which place the Seneca in the Cazenovian Stage. These fossils firmly establish the Onondaga Edgecliff Member as the lowermost Middle Devonian unit in New York State relative to the North American stages. However, Onondaga corals and brachiopods are geographically restricted to North America, a condition which precludes direct correlation with the Eifelian Stage of Europe. Cephalopods do little to facilitate this correlation. Foordites cf. buttsi from the Nedrow Member (Oliver, 1956b; House, 1962) suggests an Eifelian age. However, House (1981) notes that Foordites is a long-ranging genus, and that European zonal taxa are not known from the Onondaga. Furthermore, Foordites has not been reported from the Edgecliff and cannot lend its support to interpretation of an Eifelian age for the lowermost Onondaga member.

The International Union of Geological Sciences recently ratified the decision of the Subcommittee on Devonian Stratigraphy to drive the golden spike marking the base of the Middle Devonian Series and the Eifelian Stage at the first

occurrence of the conodont Polygnathus costatus partitus (Ziegler and Klapper, 1985). The subspecies partitus is the second in a lineage of three. The bottom of the P. c. patulus Zone is high in the Emsian Stage and the bottom of the P. c. costatus Zone is well within the Eifelian. Klapper (1981) reports that the upper Nedrow beds at Cherry Valley yield both P. c. costatus and P. c. patulus, placing the member's top well within the partitus Zone. Noting this along with the fact the P. c. partitus is unknown from the Onondaga, Ziegler and Klapper (1985) suggest, with question marks, that the Edgecliff Member is within the patulus Zone and correlative to the Emsian Stage of the Lower Devonian Series. At the very least, this obfuscates the Lower-Middle Devonian boundary in New York State and speaks for a "handle with care" approach in transatlantic correlation of the North American Stages which abut that boundary.

Recent studies of the Onondaga's styliolinid and tentaculitid faunas have done little to improve upon this situation. A previously unknown nowakid fauna has been discovered in the Nedrow and Moorehouse Members at Cherry Valley, but the taxonomic status of the species is currently undetermined. Lindemann and Yochelson (1984) reported that the first occurrence of Styliolina fissurella (Hall) in the Devonian of New York is coincident with the base of the Edgecliff Member. Indeed, at Cherry Valley this enigmatic microfossil is present in the lowermost bed of the Edgecliff and absent from the subjacent Carlisle Center. S. fissurella (Hall) was a zooplankter reputed to have had a nearly worldwide distribution (Boucek, 1964). The

potential for correlation is obvious. However, Lindemann and Yochelson (in press) have found that many, possibly all, reports of the species from the Devonian of Europe are incorrect. Thus, without specific confirmation reports of S. fissurella (Hall) from the Lower Devonian must be regarded with suspicion. To date the chronostratigraphic placement of the lowermost Onondaga member remains uncertain.

Descriptions of the Members

Edgecliff Member - The Edgecliff is seven meters thick and is divisible into two components which correspond to the C1 and C2 zones of Oliver (1956a). The lowermost beds contain quartz sand and silt, glauconite sand, and phosphatic nodules. The limestones associated with these particles and which overlie the beds containing them are thin to medium bedded, dark gray, argillaceous, packed biocalcissiltite. The middle and upper Edgecliff consists of thickly to very thickly bedded, medium gray, poorly washed to unsorted biosparites. While corals dominate the macrofauna, pelmatozoan ossicles and fenestrate bryozoans volumetrically dominate the sediment. The uppermost Edgecliff bed is a poorly washed biosparite which contains an abundance of pyrite. This bed is abruptly overlain by the basal Nedrow.

Nedrow Member - The Nedrow is a four meter thick package of what might be described as coarsening upward cycles. More accurately,

they are cycles of progressive carbonate enrichment without pronounced textural cyclicity. A cycle begins abruptly with a thickly laminated, argillaceous and pyritic, fossiliferous biocalcisiltite and grades vertically into medium bedded, dark gray, sparse biocalcisiltite. The sediments are extensively bioturbated. While pelmatozoans and trilobites are the most abundant biogenic particles, ramose bryozoans and styliolines reach maximal abundances. Crushed styliolines in the more argillaceous beds indicate an overall thickness loss of approximately 75% due to soft sediment compaction. Thus, the original Nedrow sediment may have been 15-20 meters thick. Laminae within the Nedrow beds are the result of compaction of the sediment. They are not primary sedimentary structures.

Moorehouse Member - The Nedrow/Moorehouse contact coincides with the first occurrence of black chert (Oliver, 1956a). Nodules, anastomosing masses, and thin beds of dark gray to black chert are characteristic of the lower and middle Moorehouse. Limestones associated with the chert are a sequence of medium bedded, dark gray, fossiliferous to sparse biocalcisiltites. Terrigenous mud occurs as thin laminae and pyrite is rare. Bioturbation is abundant to pervasive, though individual burrows are indistinctly defined. Pelmatozoans, trilobites, and brachiopods variously dominate the sediment. Fenestrate bryozoans increase in abundance to become a major component high in the middle Moorehouse. Corals such as Aulopora and Thamnopora also increase in abundance, as do goniatite cephalopods.

The uppermost Moorehouse is distinct from the lower and middle sections. Chert is rare to absent. Terrigenous mud is minimal. The limestone itself consists of thickly bedded, medium gray, packed biocalcisiltites and poorly washed biosparites. Cross stratification is present though not common. While the macrofauna is dominated by the encrusting cyclostome Fistulipora and other bryozoans of ramose form, the sediment matrix is dominated by pelmatozoans and fenestrate bryozoans.

Seneca Member - The lowermost bed of the Seneca Member is the Tioga Bentonite (Oliver, 1954). At Cherry Valley the Tioga is ten centimeters thick. It is extremely weathered, producing a deep reentrant between the more resistant Moorehouse and Seneca limestones. The Seneca proper consists of approximately two meters of thickly bedded, medium gray, packed biocalcisiltites and poorly washed biosparites. High angle cross laminae are present and the majority of disarticulated brachiopod valves are in a convex up orientation. Pyrite is virtually absent and terrigenous mud attains a formational minimum for this locality. While the macrofauna is dominated by atrypid brachiopods the sediment matrix is predominantly pelmatozoan debris and fenestrate bryozoans. The top of the Seneca is approximated though not attained.

Depositional History

The Onondaga has long been interpreted as a sequence of limestones deposited in progressively deepening waters and terminated by the progradation of the Marcellus black shales derived from the rising Acadian orogen. Within this model the Nedrow Member represents an influx of terrigenous mud; a hint of greater things to come. The Tioga Bentonite is a single event horizon. The Moorehouse and Seneca Members become increasingly argillaceous as the sea gradually deepened and the Marcellus muds slowly advanced from east to west across the state. Sir Charles Lyell would have found comfort in this model. It's ponderous unfolding would have appealed to his aesthetic tastes. However, to badly paraphrase Mark Twain - Recent study has cast much darkness upon the subject.

To begin with, the fidelity of the Tioga Bentonite has been called into question. For some years now it has been known that there are three separate bentonites high in the Onondaga of western New York. It has been supposed that they converge to one in the vicinity of Syracuse due to a relatively low rate of sedimentation in that area. However, on an NYSGA field trip in 1986 a second bentonite was discovered at Jamesville, NY. How many more are there? The recent report of multiple bentonites in the Lower Devonian Kalkberg Limestone of eastern New York (Shaw, et.al., 1991) suggests that there may be several.

During the above mentioned field trip (Feldman and Lindemann, 1986) a classic Devonian bone bed was found high in

the Seneca Limestone. It was also observed that there is no lithologic gradation between the Seneca and the Marcellus and that the contact between the two units is an erosional truncation surface involving up to three beds of the uppermost Seneca. Lindemann and Feldman (1987) described a comparable disconformity at the top of the Onondaga in the central Hudson Valley of eastern New York. At Cherry Valley the precise top of the Seneca is not exposed, but the beds which can be seen give no indication of gradually giving way to shale. As is the case in the Hudson Valley, a relatively brief time of rapid crustal subsidence and an interruption of sedimentation would seem to be indicated.

Abrupt fluctuations in water depth are also indicated at the lower end of the column. Glauconite sand and phosphatic gravel in the lowermost beds of the Edgecliff Member at Cherry Valley indicate an interruption in sedimentation. It was during this unrecorded interval that deposition of the Carlisle Center ended as the depositional environment shifted to one favoring carbonate production. Since there is no definitive interpretation for the depositional history of the Carlisle Center it is difficult to ascertain what might have transpired during the unrecorded interval. Quartz silt and well rounded grains of quartz sand at the base of the Edgecliff could suggest relatively high levels of water energy, but the abundances of terrigenous mud and calcisilt with which they occur suggest otherwise. Furthermore, the phosphatic gravels at the base of the Edgecliff appear to have been involved in multiple generations of exhumation and reburial. There would seem to be more involved here than was previously

supposed. Considering the absence of a biostratigraphic basis for the correlation of the Edgecliff to either the upper Emsian or the lower Eifelian, this phosphatic diastem is intriguing. Hopefully an ongoing study of this interval will soon yield results.

The remainder of the Edgecliff at Cherry Valley is equally intriguing though less cryptic from a paleoenvironmental point of view. The Edgecliff consists of dark gray packed biocalcisiltites (= C1 zone of Oliver, 1956a) overlain by medium gray, coraliferous, biosparites (= C2 zone of Oliver, 1956a). Obviously deposition did not begin in a high energy environment. Wolosz (1985) reported that Edgecliff reefs of the Hudson Valley exhibited evidence of a brief lowering of relative sea level. This was followed by a sea level rise and a resumption of reef growth. Wolosz and Lindemann (1986) correlated the shallowing event to the abrupt onset of biosparite deposition in the Edgecliff throughout eastern New York. This interpretation remains appropriate for the Edgecliff at Cherry Valley.

The top of the Edgecliff is anomalously pyritic. It is immediately overlain by the argillaceous biocalcisiltites of the Nedrow Member. The contact between the two is interpreted to be a diastem resulting from a pulse of crustal subsidence. Pyrite in the Nedrow and the Lower Moorehouse indicate relatively low concentrations of oxygen, possibly due to stratification of the water column. The Nedrow sediments do not suggest an influx of terrigenous mud but rather a shift to an offshore position coupled with a drastic reduction in carbonate production. The

sediments' fine grained nature suggests a flocculent or soupy sediment-water interface, a condition not particularly conducive to colonization by the larvae of sessile organisms. Thus, the Edgecliff reefs were drowned in deep water rather than suffocated in mud.

Moorehouse deposition marks a return to enhanced carbonate production by benthic organisms living at depths well in excess of wave base. This is quite different from the top of the Moorehouse where a carbonate bank environment near wave base is indicated. Unfortunately the Moorehouse is not fully exposed and the transitional beds are not available for study. However, detailed study of polished slabs and thin sections through the lower and middle Moorehouse reveals a symmetry in the sequence of lithologic changes which centers around beds about ten meters from the base of the member. The beds below indicate a progressive increase in water depth and soupiness of the substrate. The beds above show the exact opposite trend. Unlike the remainder of the Onondaga at Cherry Valley, it appears likely that the shallowing upward trend was gradual and not a punctuational event. Lyell would have preferred it this way.

BRACHIOPOD COMMUNITIES

What Is A Community?

Communities are often defined as recurrent associations of taxa which were presumably controlled by a set of environmental

factors such as: substrate, salinity, temperature, pressure, current action, wave action, light penetration, nutrients, dissolved oxygen, and water chemistry. Ecologists are not necessarily in agreement as to what the definition of a community is, nor how to recognize one. Boucot (1981) notes major subdivisions of current conceptualizations of community definition, including those who define "community" as a superorganism that has a virtual life of its own - a living and breathing community. At the other extreme are those who hold that communities are no more than chance aggregations of organisms conducting their affairs quite independently of one another - ships that pass in the night; apartment dwellers who have never been introduced to their neighbors.

Paleoecologists are at a distinct disadvantage in attempting to reconstruct ancient communities, since it is extremely difficult to determine the various relationships of taxa in terms of parasitism, commensalism, mutualism, and other dependent and interdependent variables that are not readily apparent in the fossil record. As Boucot (1981) notes, the paleoecologist is reduced to examining statistical data on relative abundance and presence or absence of taxa in an attempt to infer ecological interaction. There is much biological information important in community reconstruction which cannot be retrieved from the rock record, and this must be kept in mind when coming to conclusions about community make-up. Ecologists who study Recent communities have a distinct advantage in this regard over paleoecologists, and are able avoid dependence solely on hard part data.

Brachiopod Communities of the Onondaga Limestone

When studying the brachiopod communities of the Onondaga Limestone in New York State, other faunal constituents and their fragments, such as trilobites, corals, and gastropods were tabulated (Feldman, 1980; Feldman and Lindemann, 1986; Lindemann and Feldman, 1987). Numbers of brachiopods were determined by counting the most abundant valve. Relative abundance was variable, depending on geographic area and member sampled. For example, collecting in the shaly Nedrow Member in central New York was much more productive than in the dense Moorehouse Member. However, in eastern New York, the silicified Moorehouse yielded many more well-preserved taxa than did the nonsilicified Nedrow. Therefore, relative abundance seems to be a function of: (1) lithology, (2) rate of weathering, and (3) silicification. The Onondaga Limestone is most productive, in terms of brachiopods, when well silicified. Unfortunately, this occurs rarely, notable localities being in the mid-Hudson and Genesee valleys. In the mid-Hudson Valley heavy jointing is associated with silicification. There are many outcrops which do show evidence of weak silicification and collecting from these areas can range from excellent to poor, depending on the degree of silicification (whether surficial or deep). Beekite rings on shells observed in outcrop are usually indicative of weak silicification. The Onondaga brachiopod communities recognized in New York State are briefly described below.

Atrypa-Coelospira-Nucleospira Community. The ACN (= Atrypa-Coelospira-Nucleospira) Community ranges from Leeds to just south of Kingston, New York and occurs predominantly in the Moorehouse Member. Diversity here is great (29 brachiopod genera), but only 13 genera comprise the bulk of the community (Feldman, 1980). Of those, three genera (Atrypa, Coelospira, Nucleospira) represent a trophic nucleus of low-level epifaunal suspension feeders. A similar fauna is found in Lenz's (1976) Lower Lochkovian Howellella-Protathyris Community in an offshore position. Taxa in common include: Atrypa, Schizophoria, Ambocoelia, Coelospira, Nucleospira and "Schuchertella." Lenz's fauna is characterized by similar morphotypes (Table 1).

Atrypa-Megakozlowskiella Community. The AM (= Atrypa-Megakozlowskiella Community recognized from Clarksville to Cherry Valley, New York, is lower in diversity than the ACN Community (22 compared to 29 genera). This may be indicative of a position closer to shore and consequently nearer to wave base. A major faunal element that appears here is the robust spiriferid Megakozlowskiella raricosta, which had a large, triangular delthyrium in the ephebic stage, with lateral bordering ridges indicative of a deltidial plate. If the pedicle had no way of protruding the brachiopod would therefore have lived free on the sea floor. The pedicle valve had deeper ribs and was more convex than the flatter brachial valve, which would have provided a more hydrodynamically stable position for the animal if the pedicle

Table 1

A comparison of Lenz's (1976) Howellella-Protathyris Community with the ACN Community of the Onondaga Limestone.

Morphotype	<u>Howellella-Protathyris</u> Community	ACN Community
Broad, flat	" <u>Schuchertella</u> "	<u>Schuchertella</u>
Relatively smooth	<u>Protathyris</u> , <u>Cryptatrypa</u>	<u>Nucleospira</u> , <u>Athyris</u>
Broad, unequally bi- convex	<u>Schizophoria</u>	<u>Schizophoria</u>
Frially	<u>Atrypa</u>	<u>Atrypa</u>

valve was in an "up" position. Some gerontic shells had secondary shell material deposited in the umbonal region as a counterweight, serving to keep the anterior commissure above the sediment-water interface.

Atrypa Community. The Atrypa Community occurs from the mid-Hudson Valley to Cherry Valley and is dominated by Hudson Valley "reticularis" (52.4%), with a relatively high diversity of 18 brachiopod genera (compare with the diversity of the AM Community of 22 genera). This community is very similar to Copper's (1966) European Eifel magnafacies which is composed of calcareous shales, muddy limestones and rare dolomites. Although there are no dolomites within the Onondaga, the Nedrow and Moorehouse members certainly contain a fair amount of mud. Other similarities, in addition to lithology, include the presence of varied brachiopod genera in both environments (such as spiriferids, rhynchonellids, athyrids, meristellids and gypidulids) and the occurrence of rugose and tabulate corals, stromatoporoids and crinoids.

Leptaena-Megakozlowskiella Community. The AM (= Leptaena-Megakozlowskiella) Community is recognized in the Syracuse area of central New York and is dominated by Megakozlowskiella raricosta and the ubiquitous Leptaena "rhomboidalis." Within the Onondaga Leptaena occurs more frequently in "muddier" limestone units and is relatively rare in the Edgecliff Member. A distinct association between the two genera is very evident on bedding

plane surfaces in the shaly Nedrow Member, where they comprise a trophic nucleus of low-level suspension feeders. The diversity is fairly high, with 17 brachiopod genera represented. Crinoidal fragments and Platyceratid gastropods which are common in the ACN Community are absent here; in their place are other gastropod genera such as Straparollus, Liospira and Ecculiomphalus.

"Pacificocoelia" Community. This community has been found at only one outcrop in the Nedrow Member near Syracuse, New York, and is similar to the LM Community in two respects: [1] There is a close association between Leptaena (9.7%) and Megakozlowskiella (8.6%), and [2] Both communities are typically found in the shaly rather than the "cleaner" lime units. They differ in that in the "Pacificocoelia" Community the brachiopod diversity is low (10 genera) and no corals were recovered, whereas in the LM Community 17 brachiopod genera were found as well as 3 rugose and 3 tabulate coral genera.

Levenea Community I. This community occurs in the Edgecliff Member from Cherry Valley southeast to Kingston, New York and is dominated by Levenea sp. A (67.4%), with minor occurrences of Atrypa, Levenea sp. B, Leptaena, Pentamerella and Elytha. In general, the brachiopods are poorly represented in the Edgecliff Member. This may somehow be related to the large amount of chert present in the east, which seems to correlate with a reduced coral fauna. In central New York there is a large coral fauna, relatively little chert and more brachiopods.

Levenea Community II. Found only in the Moorehouse Member of southeastern New York, at an abandoned quarry in Wawarsing, the Levenea Community II consists exclusively of Levenea sp. A (100%). It differs from Levenea Community I in two respects: [1] the diversity is extremely low, and [2] the lithology is very different, consisting of "muddy" rocks interpreted to represent deposition in a more offshore position. This is consistent with the interpretation of a deepening structural basin in Onondaga times southwest towards Port Jervis (Lindemann and Feldman, 1987).

Amphigenia? Community. The Amphigenia? Community is found in the basal Edgecliff near Syracuse, New York and is based on the recovery of only 12 specimens. There is a possibility that these fragmental shells were reworked and transported, since the occurrence of Amphigenia in the sandy facies of the Edgecliff is not compatible with Boucot's (1975) placement of the genus in a Benthic Assemblage 3-5 position.

Hallinetes Community. The Hallinetes Community (Racheboeuf and Feldman, 1990), formerly recognized as a Chonetes Community (Feldman, 1980), occurs only in the Seneca Member of the Onondaga Limestone. Three taxa comprise the chonetacean brachiopods in this community: Hallinetes lineatus (92%), Longispina mucronata (5.4%) and "Eodevonaria" hemispherica (2%). Other brachiopod taxa are present but represent minor faunal constituents (see

Feldman, 1980, p. 40). Based on new observations, it is apparent that the Hallinetes Community is most accurately represented by the shells within the dark mudstone matrix rather than by those distributed on bedding plane surfaces. The community is a low-diversity, "highly dominated" (although not monospecific) community within a quiet water environment (Racheboeuf and Feldman, 1990).

Communities of Western New York

Based on preliminary analysis of material collected from the Moorehouse Member of the Onondaga Limestone in the Genesee Valley of western New York, an almost identical ACN Community to the one found in the mid-Hudson Valley is recognized. Similarities include dominance by the low-level epifaunal suspension feeders Atrypa, Coelospira and Nucleospira as well as very high diversity (39 brachiopod genera, including two new athyrids). The two communities differ in that the ACN Community of the Genesee Valley has a significantly larger proportion of strophomenids, including some genera absent in southeastern New York:

"Brachiprion" aff. mirabilis, Protoleptostrophia perplana, Plicostropheodonta? sp. and Costistrophonella ampla. Also, there are other taxa in the west not recovered from southeastern New York: Camarospira? sp., Alatiformia? sp., Mediospirifer sp.A and B, Paraspirifer sp., Cranaena sp. and Cryptonella sp.

Community Paleogeography

Work is currently in progress which will clarify the relationships of these various communities to one another across New York State. However, a general pattern can be observed (Table 2). Most data have been collected from the Nedrow and Moorehouse members, therefore, by omitting those communities found only in the Edgecliff and Seneca members (Amphigenia, Leveneia Community I, Hallinetes), it appears that during Nedrow-Moorehouse time [1] there was a trend towards increasing diversity away from the basinal axis and, [2] diversity decreased towards a subsiding structural basin.

Lindemann and Feldman (1987) note that in central New York, a transgression submerged the region initiating Edgecliff deposition in a shallow shelf environment. Soon thereafter subsidence in central New York, resulting from a northward extension of the Appalachian Basin, brought deeper water and an offshore environment to the area. The initial pulses of subsidence are recorded in the Nedrow Member, while continued subsidence is evidenced in the Moorehouse and Seneca members of the central region. The eastern and western areas, that is, those areas away from the basinal axis, remained in shallow shelf conditions resulting in a symmetric shelf-basin-shelf pattern as seen in east-west outcrop.

A subsiding structural basin in the Tristates area, (not directly related to the topographic basin of central New York), which had existed since the Middle Silurian was noted by

Table 2

Brachiopod communities in the Onondaga Limestone of New York.

Brachiopod Community	Number of Genera*	Member	Geographic Location
ACN	39	Moorehouse	Genesee Valley
ACN	29	Moorehouse	Hudson Valley
AM	22	Moorehouse	Cherry Valley
<u>Atrypa</u>	18	Nedrow-	Hudson Valley,
		Moorehouse	Cherry Valley
LM	17	Nedrow-	Syracuse
		Moorehouse	
<u>Hallinetes</u>	10	Seneca	Syracuse
" <u>Pacificocoelia</u> "	10	Nedrow	Syracuse
<u>Levenea</u>			
Community I	6	Edgecliff	Hudson Valley
<u>Levenea</u>			
Community II	1	Moorehouse	Wawarsing
<u>Amphigenia</u>	1	Edgecliff	Syracuse

* Refers to brachiopod genera; ACN = Atrypa-Coelospira-Nucleospira Community; AM = Atrypa-Megakozlowskiella Community; LM = Leptaena-Megakozlowskiella Community.

Lindemann and Feldman (1987). This basin greatly influenced Onondaga deposition in southeastern New York by creating a

carbonate slope, or ramp, dipping into the Port Jervis area. It is from this ramp that the Levenea Community II was recovered, indicating a trend toward lower diversity in the direction of the deep waters of the structural basin. Further collecting and analysis of brachiopod communities along the ramp will help support or reject this proposed paleogeographic distribution and correlation with basin depth.

MT. TOM - A SMALL EDGECLIFF PINNACLE REEF

Oliver (1956c) described the location and size of Mount Tom, labeled it Mt. Tom #1, and included it among the seven reef exposures comprising the Mt. Tom Reef Group which are scattered over an approximately 9 square mile area at the boundary of the East Springfield, Richfield Springs, Jordanville, and Van Hornesville 7.5 minute quadrangles. Mt. Tom is the largest reef exposure in the group, forming a prominent hill in the northwest corner of the East Springfield 7.5 minute Quadrangle (it is, in fact, the thickest known surface exposure of an Edgecliff reef (Oliver, 1956c, p.21)).

While Oliver considered all seven Mt. Tom Group exposures to represent separate reefs, Paquette and Wolosz (1987) noted that the two exposures closest to Mt. Tom #1 (see Fig. 1) - Mt. Tom #2 reef (approximately due west of Mt. Tom) and Mt. Tom #6

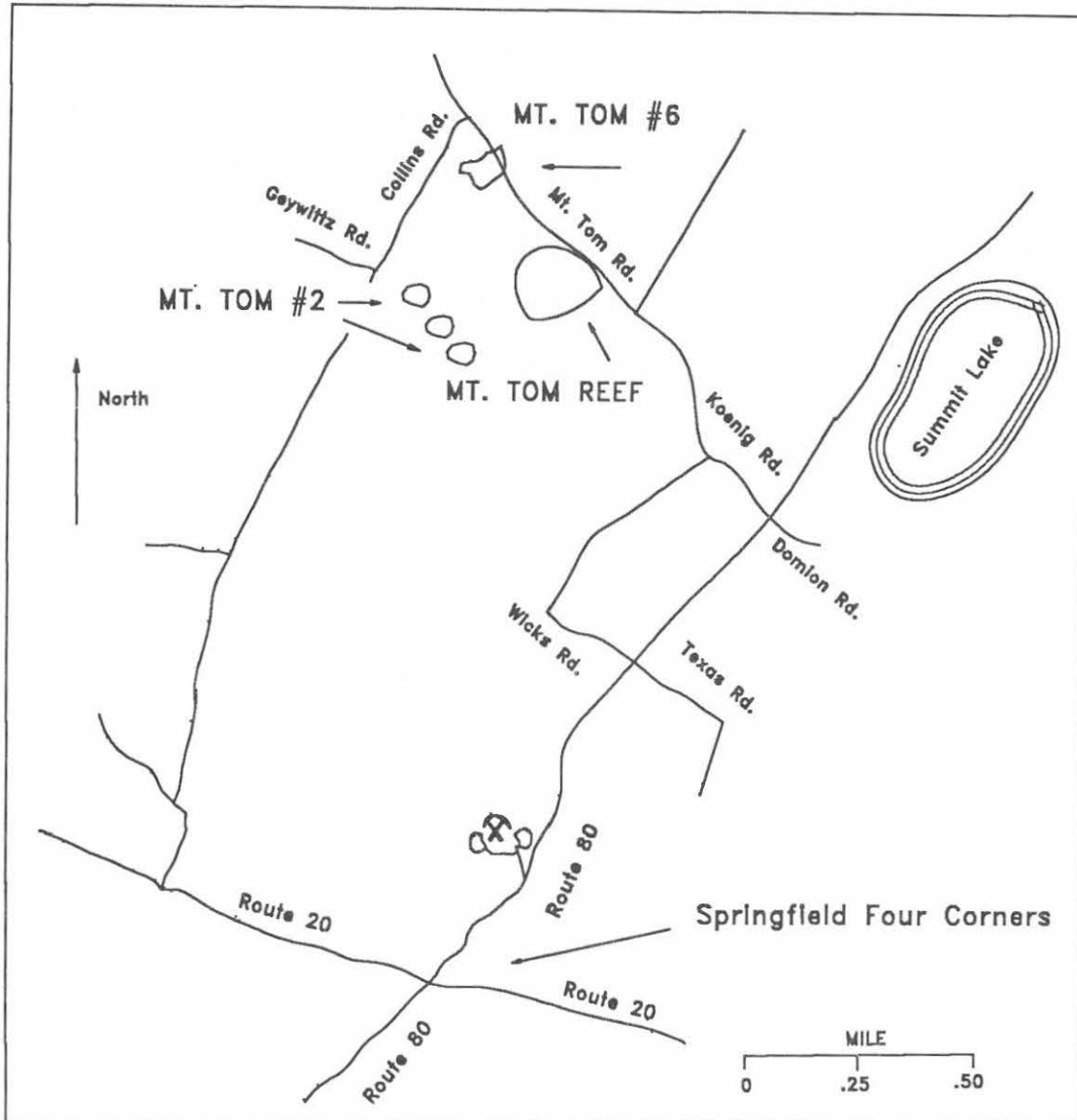


FIGURE 1. Location map of Mount Tom reef #'1, 2 and 6. Note relative positions of reefs.

(northwest of Mt. Tom) - were comprised mainly of crinoidal grainstone/packstone which dipped away from Mt. Tom #1. They argued that these three exposures represent the erosionally dissected remains of a small pinnacle reef, approximated at about 150 acres.

Reef Communities

Typical of Edgecliff reefs, Mt. Tom is made up of two distinct paleocommunities - the phaceloid colonial rugosan paleocommunity and the favositid/crinoidal sand paleocommunity.

The phaceloid colonial rugosan paleocommunity consists almost exclusively of colonial rugosans. Common genera include Acinophyllum, Cylindrophyllum, and Cyathocylindrium; with Eridophyllum, Synaptophyllum, and rare phaceloid colonies of Heliophyllum as accessories. The dense growth of these rugosan colonies appears to have restricted most other organisms to only minor roles, with favositids (both domal and branching) being small and rare, brachiopods uncommon, and bryozoans mainly fragmentary encrusters.

The favositid/crinoidal sand paleocommunity displays a much higher diversity than the rugosan paleocommunity. This paleocommunity is more biostromal than biohermal. Large sheet-like to domal favositids are abundant, but never form a constructional mass. Solitary rugose corals are also extremely abundant as are fenestrate bryozoan colonies. Single colonies of the mound building phaceloid rugosans are occasionally found. Brachiopods and other reef dwellers are also common although never extremely abundant. Stromatoporoids and massive colonial rugosans, while extremely rare in the Edgecliff reefs, when found are part of this paleocommunity. The crinoids were the greatest contributor to this paleocommunity - ossicles making up the bulk

of the rock and indicating abundant growth of these organisms - but complete calyces are never found.

Mt. Tom Reefs #1, 2 and 6

Wolosz (1990a, in press) presented a classification of Edgecliff reef types based on the relative importance of the two reef paleocommunities to the development of the reef structure. Mt. Tom reef is an example of a Mound/Bank Composite Structure. Mounds are distinct high relief buildups of the phaceloid colonial rugosan paleocommunity which occur as either small (generally not more than 1 - 3 meters thick) monogeneric to mixed faunal buildups; or as Successional Mounds up to roughly 15 meters thick which display an internal succession of mound building colonial rugosan genera. The term "bank" follows the definition of Nelson, et al. (1962, p.242): "a skeletal limestone deposit formed by organisms which do not have the ecologic potential to erect a rigid, wave resistant structure." Hence, Mound/Bank Reefs are large structures resulting from the repetitive intergrowth of rugosan mounds and the favositid/crinoidal sand facies. Pinnacle reefs found in the subsurface in New York and Pennsylvania also represent this type of structure and reach thicknesses of up to 60 meters.

The mound\bank nature of Mt. Tom #1 is displayed in the cliff face along the southeast side of the hill (Figure 2). The reef is underlain by the basal Edgecliff calcisiltite (C1 unit of Oliver, 1956a), with the base of the reef marked by thickets of

Acinophyllum. Small phaceloid colonial rugosan mounds (again, mainly Acinophyllum) can be observed along the cliff near the base of the reef. These small mounds and thickets coalesced to begin the formation of the larger structure. Dominance of the initial large mound shifted between Acinophyllum and Cylindrophyllum prior to onlapping by the crinoidal sands of the favositid/crinoidal sand paleocommunity. A second mound stage made up of Cylindrophyllum thickets overlies these grainstones and packstones. In turn, the second mound stage is itself onlapped and eventually swamped by the favositid/crinoidal sand paleocommunity (exposed further back on the top of the hill, not shown in Figure 2). Overall, Mt. Tom #1 is roughly 18m thick as preserved.

Wolosz and Paquette (1988) have interpreted this mound\bank\mound\bank pattern as catch-up\fall back cycles controlled by fluctuations in water depth above the top of the reef. It is important to note that the second mound building stage at Mt. Tom #1 (Figure 2) does not drape the entire pre-existing structure, but is instead restricted to the top of that structure. In effect, during bank stage, the reef was a high relief platform on the sea-floor with its top within the ecologic mound building zone of the colonial rugosans. Upward growth of the reef is mainly due to the repetitive establishment of new mounds on the top of the platform. As sea-level was approached, the mound building colonial rugosans were overwhelmed by increased turbulence conditions and the mounds onlapped by encroaching crinoidal sands producing a bank stage; but with sea-

level rise the mounds became re-established. This shifting

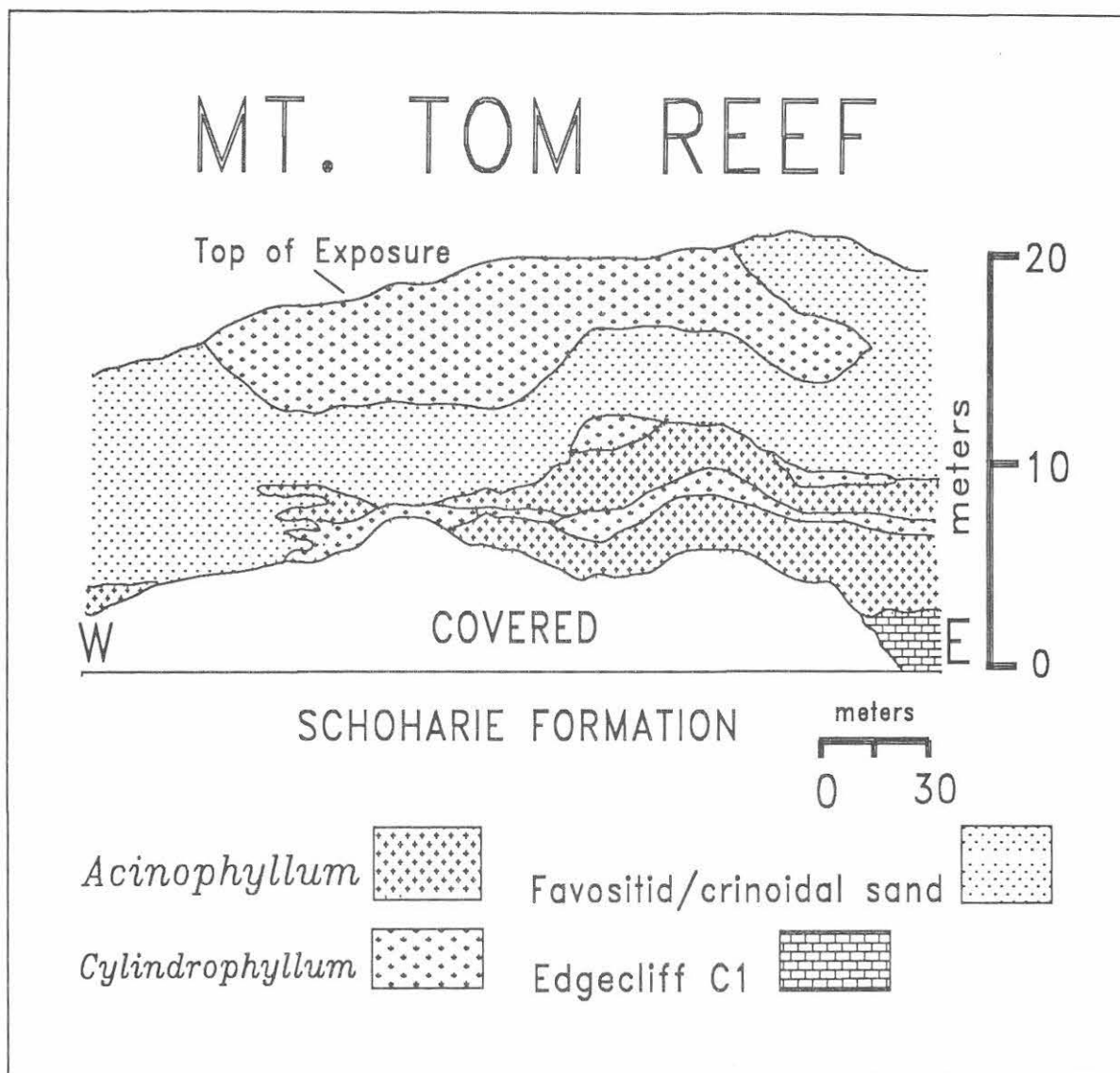


FIGURE 2. Cross-section of cliff face at Mt. Tom #1 reef illustrating mound/bank structure. Two rugosan mound stages are separated by favositid/crinoidal sand facies (bank stage). Note that second rugosan mound stage does not drape entire reef structure (after Wolosz, in press a).

between rugosan mound/thicket construction and the favositid/crinoidal sand paleocommunity has been attributed to a water turbulence controlled community succession (Wolosz, 1989a, 1989b, in press b).

Following the initial mound building stage, lateral growth of Mt. Tom appears to have been due mainly to deposition of crinoidal debris flanks with occasional small mound structures (satellite mounds) growing in those flanks (see discussion of Mt. Tom #2). A similar, but less well developed mound\bank\mound sequence has been described at Roberts Hill Reef south of Albany (Wolosz, 1985).

To the northwest, Mt. Tom #6 is a small ridge which consists mainly of crinoidal grainstone/packstone but with more abundant fossils. Small overturned favositids are common as are both solitary and phaceloid rugosans, but no evidence of mound formation is present. However, when one observes Mt. Tom #6 from Collins Road (see map, Figure 1), the questa-like nature of this small ridge is evident, with the dip slope pointing to the north-northwest, directly away from the main mass of Mt. Tom.

Topographically, Mt. Tom #6 is at the same elevation as the present top of Mt. Tom. Since the regional southwest dip of about 18 meters/kilometer (Rickard and Zenger, 1964, p.5) would not greatly alter this topographic relationship, the elevations of the Mt. Tom #6 exposure and the top of Mt. Tom were probably also equivalent at the time of deposition. Paquette and Wolosz (1987) cited this as evidence that the two exposures are parts of one reef, with Mt. Tom #6 consisting of distal flank beds. Mt.

Tom reef would then be at least 0.8km. long on an northwest axis from Mt. Tom #1 to Mt. Tom #6.

In contrast, Mt. Tom #2 lies to the west of Mt. Tom #1 and is topographically roughly 18 meters below #6. Stratigraphically older beds can be examined here, with the Edgecliff/Carlisle Center contact marked by the appearance of a spring just east of the intersection of Collins and Geywittz Roads. A small quarry visible from the road exposes bedded Edgecliff with overturned colonial coral. To the southeast of this quarry is an exposure of a small colonial rugosan mound roughly 17 meters across and of indeterminate thickness. East from the quarry, along the south side of the creek, there are numerous outcrops of bedded crinoidal grainstone/packstone with abundant favositids. Small patches or lenses of colonial rugosans within the bedded packstones are common, and represent small satellite thickets or mounds which appear to range stratigraphically from near the C1/C2 contact (roughly the point at which growth of Mt. Tom #1 began), upwards to about 6 meters above that contact. The packstones surrounding these upper mounds dip away from Mt. Tom #1 at roughly 15 degrees.

Tying The Exposures Together -
Development of the Mt. Tom Pinnacle Reef

Figure 3 illustrates an interpreted developmental history for the Mt. Tom (small) pinnacle reef. As sea-level dropped from possible deep water conditions of Carlisle Center deposition

through the early Edgecliff (C1), abundant small rugosan thickets and mounds began to form in the late C1 calcisilts. By the beginning of C2 deposition these thickets and small mounds had begun to coalesce to form the initial large mound at Mt. Tom #1 (Mound Stage I), while an abundance of other small mounds dotted the crinoidal sand sea-floor as satellites to the growing reef. Crinoidal debris of the favositid/crinoidal sand paleocommunity lapped up onto the large mound, eventually forming flank beds which spread outward from the main mass of the reef. Small satellite mounds continued to develop along distal flank beds (Mt. Tom #2), contributing to the overall volume of the reef structure, but never coalescing into a large central structure similar to Mt. Tom #1. Continued sea-level drop resulted in the cessation of rugosan mound growth and the eventual swamping of the mound by the crinoidal sand beds, resulting in Bank Stage I. A second cycle of sea-level rise resulted in the establishment of new rugosan thickets and mounds on the top of the bank (Mound Stage II), but later shallowing over the crest of the reef again caused the demise of the colonial rugosans and the re-establishment of the favositid/crinoidal sand paleocommunity in Bank Stage II.

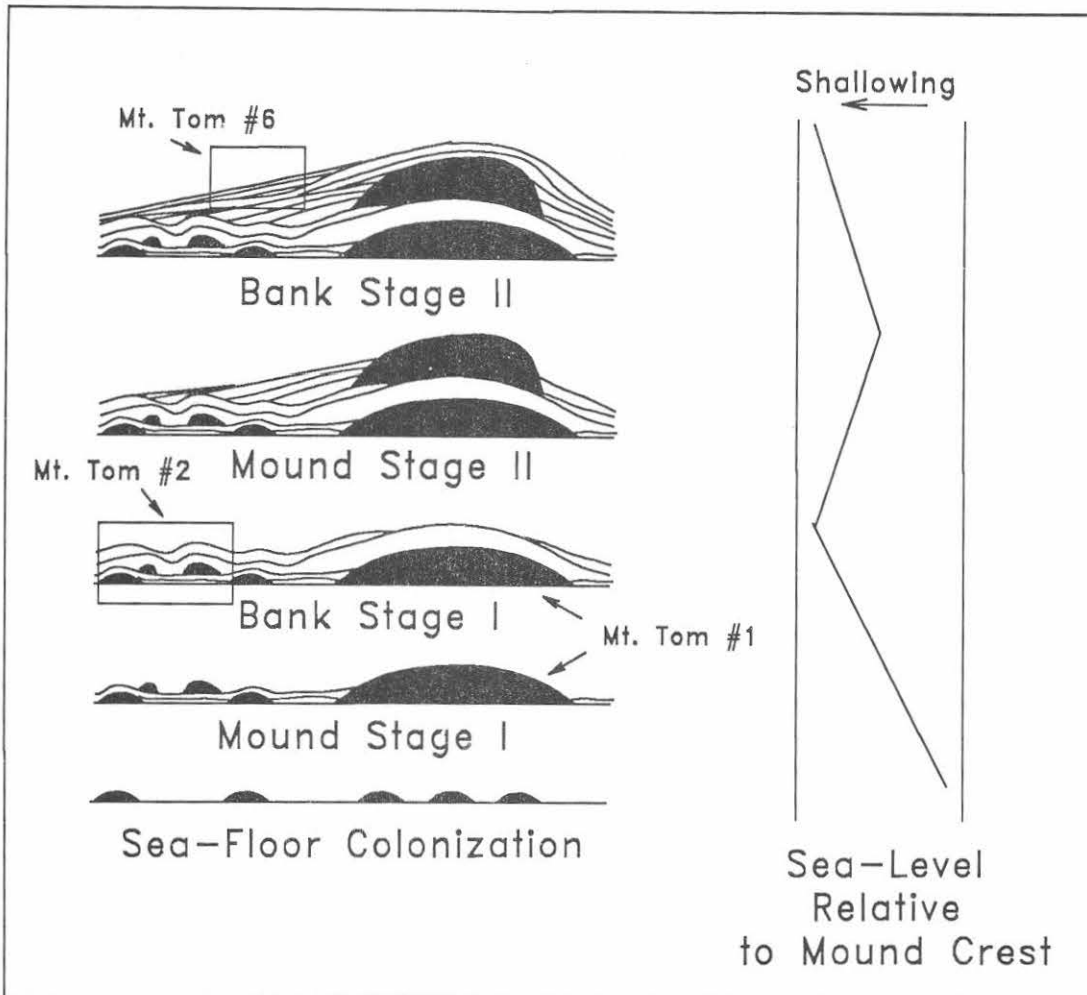


FIGURE 3. Sequential model for growth of the Mt. Tom pinnacle reef. Interpreted sea-level changes shown at right. Boxes indicate interpreted position of Mt. Tom #'s 2 and 6 exposures. Main mound is Mt. Tom #1 exposure. See text for further details.

In Figure 3, Mt. Tom #6 is illustrated as distal flank beds. While this is correct, the illustration is not to scale and somewhat misleading. When the distance from #6 to Mt. Tom #1 is considered (roughly 0.8km.), along with the 15° to 25° dip of the

beds at #6, and the already noted paleo-topographic equivalence of the present top of #1 and #6; the conclusion that, if totally preserved, Mt. Tom reef would be much thicker than the present erosional remnant is easily arrived at. Unfortunately, there appears to be no way to achieve a valid estimate of that thickness.

Any attempt to directly correlate the reef growth cycles preserved at Mt. Tom with the non-reefal Onondaga (for instance at Cherry Valley) would require a detailed micro-stratigraphy which is, unfortunately, not available. However, the following statements can serve as a basis for discussion and further research.

The first mound/bank cycle at Mt. Tom follows the shallowing trend from C1 to C2 deposition in the Edgecliff. The initial pattern here is similar to that described at Roberts Hill (Wolosz, 1985; Wolosz and Lindemann, 1986). However, as sea-level begins to rise, leading to the second mound/bank cycle, the environment at the crest of the reef (or the top of the bank) becomes decoupled from that of the surrounding sea-floor. In order to produce the large pinnacle structure, the top of the bank must be maintained within a fairly narrow environmental range suitable for the two reef building paleocommunities (see Wolosz, in press b, for discussion). If we assume that by the second bank stage (current top of Mt. Tom #1) the reef was roughly 18m thick with bank top at least 10m above the surrounding ocean floor (given that the C2 at East Springfield is roughly 4m thick (Oliver, 1956a) and allowing for a 50%

compaction of the carbonate sediments); and also assume that the Edgecliff/Nedrow contact marks a starvation boundary (see discussion of stratigraphy), then at this point much lateral growth of the bank would occur since large amounts of crinoidal debris from the favositid/crinoidal sand community would be washed off the bank onto the flanks while upward growth would be limited by sea level. Such a scenario would leave a well developed bank with the potential for continued upward growth once renewed subsidence led to the onset of Nedrow deposition. In effect, environmental conditions characteristic of the Edgecliff would continue on the bank top while Nedrow sediments were being deposited on the surrounding sea-floor.

The Edgecliff Reefs - Cool Water Structures?

As mentioned in the introduction, Kissling and his students have pointed to the lack of stromatoporoids and calcareous algae, in conjunction with the absence of clear peritidal deposits to suggest that the Edgecliff reefs may have been deposited in deep water. An alternative hypothesis to the deep water model is for the Edgecliff to have been deposited under cool water conditions. Wolosz and Paquette (1988) suggested a cool water environment for the Edgecliff, as have Koch and Boucot (1982) based on the Edgecliff brachiopod fauna; Blodgett, et al., (1988) based on gastropod faunas; and Wolosz (1990b, 1991) based on stromatoporoid abundance trends.

The cool water model for Edgecliff deposition supplies

answers to many of the questions listed in the Introduction. The C2 facies is a shallow water facies, but one more akin to modern FORAMOL deposition (Lees, 1975) than to tropical carbonate deposition. The reefs are then analogous to modern ahermatypic coral banks, built by relatively slow-growing colonial rugosans poorly adapted to high energy conditions - hence their replacement by the favositid/crinoidal sand community under high energy conditions. The cool waters would also explain the rarity of stromatoporoids and the absence of algae - both groups being restricted to warm waters.

In conclusion, the paleo-biological evidence appears to support a model of the Edgecliff as a temperate water carbonate.

ACKNOWLEDGEMENTS

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FIELD TRIP STOPS

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Intersection of Routes 20 and 10, Sharon Springs. Proceed west along Route 20.
7.0	7.0	STOP 1. Cherry Valley Section. Park along road at top of west end of road cut. An almost complete section of the Onondaga Limestone is exposed along this cut. (See discussion of

		Stratigraphy and Brachiopod Communities). Return to cars, proceed west along Route 20.
13.2	6.2	Right turn on Route 80.(see Figure 1)
14.7	1.5	Left turn onto Koenig Road.
15.3	0.6	Bare left onto Mt. Tom Road
15.4	0.1	STOP 2. Mt. Tom Reef. makes up the large hill to the south of the road (See discussion of Mt. Tom). Return to cars and continue northwest on Mt. Tom Road.
15.9	0.5	STOP 3. Mt. Tom #6 forms the low, wooded ridge to the southwest of the road (See discussion in text). Return to cars and continue northwest on Mt. Tom Road.
16.05	0.15	Left turn onto Collins Road.
16.55	0.5	STOP 4. Intersection of Collins and Geywittz Roads. Leave cars and proceed east from the intersection. Mt. Tom #2 forms the low hill to the south of the small creek, and numerous small outcrops may be examined along the south side of the creek valley or on the hill itself. A small quarry on the northwest edge of the hillside exposes bedded Edgecliff facies, while a small rugosan mound is located just to the southeast of the quarry among the trees. (See text for discussion). Return to cars follow Collins Road back to Route 20.

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