MIDDLE DEVONIAN TEMPERATE WATER BIOHERMS OF WESTERN NEW YORK STATE (EDGECLIFF MEMBER, ONONDAGA FORMATION)

THOMAS H. WOLOSZ
Center for Earth & Environmental Sciences
SUNY College at Plattsburgh
Plattsburgh, N.Y. 12901

DOUGLAS E. PAQUETTE
Safety and Environmental Protection Division
Brookhaven National Laboratory, Building 535A
Upton, Long Island, N.Y. 11973

INTRODUCTION

The bioherms of the Edgecliff member of the Onondaga Formation are a well known feature of the geology of New York State and the Niagara Peninsula in Ontario, Canada. Over the past thirty to forty years, the Onondaga and its bioherms have been the subject of a number of studies which have greatly increased our understanding of this unit (see Brett and Ver Straeten (1994) for references).

As is the case with "reefy" limestones in general, the Edgecliff has been assumed to represent a warm, tropical, shallow water environment. However stromatoporoids and calcareous algae are rare in the Edgecliff which is unusual for Devonian reefal limestones. The absence of these organisms lead Kissling and his students (Kissling and Coughlin, 1979; Cassa and Kissling, 1982; Kissling, 1987) to interpret these bioherms as deep water structures. The absence of an obvious peritidal facies in the Onondaga was also cited as supportive of a deep water interpretation, suggesting that the shallow water facies which rimmed the basin have since been removed by erosion. More recently Wolosz (1990, 1991) has argued that shallow water facies are present, but have gone un-noticed since they do not fit the standard model for tropical carbonate peritidal facies. However, over the past fifteen years there has been increasing paleontological evidence that the "reefy" Edgecliff Member of the Onondaga Formation represents an example of Devonian temperate water deposition (Koch and Boucot, 1982; Blodgett, et al., 1988). Stromatoporoid biogeographic data and isotopic analyses which further support the temperate water hypothesis are included in this field trip guide.

The field trip will examine a series of Edgecliff bioherms, which are interpreted as representing an on-shore to off-shore trend in biohermal development for this temperate water Devonian limestone.

STRATIGRAPHY AND REGIONAL SETTING

The stratigraphy of the Onondaga Formation has been extensively studied by Oliver (for complete list of references see Oliver (1976)), and recently interpreted in light of both sequence stratigraphic and depositional facies models by Brett and ver Straeten (1994). Only a brief summary of Oliver's Onondaga stratigraphy will be presented here.

In the easternmost part of New York (Fieldtrip Stops 1 thru 4) the Onondaga ranges up to approximately 34 meters in thickness, but with the exception of the basal 2 meter "C1" micrite, it is lithologically a cherty crinoidal packstone/grainstone which is only divisible into members biostratigraphically. In central New York (vicinity of Mt. Tom Reef), the formation thins to roughly 21 meters, but is easily divided on lithologic grounds into Oliver's four members, with the Edgecliff a massive, biostromal, very coarsely

In Garver, J.I., and Smith, J.A. (editors), Field Trips for the 67th annual meeting of the New York State Geological Association, Union College, Schenectady NY, 1995, p. 227-250.

crystalline limestone from about 2.5 to 7.5 meters thick; the Nedrow a thin bedded, very fine grained shaley limestone; the Moorehouse a very fine grained limestone with chert and shaley partings; and the Seneca similar to the Moorehouse lithologically, but with a different fauna. Near Buffalo the formation reaches a thickness of 43 meters with only a very thin Edgecliff grainstone/packstone unit (about 1.5 meters), overlain by a sparsely fossiliferous, fine grained, chert-rich limestone which Ozol (1963) named the Clarence member and interpreted as equivalent to the Nedrow. Brett and Ver Straeten (1994) however, have recently identified the Clarence as a facies within the Edgecliff.

The basal contact of the Onondaga is marked by a widespread unconformity (Rickard, 1975). In the east, the contact with the underlying Schoharie Formation has alternatively been interpreted as gradational (Goldring and Flower, 1942) or disconformable, with the presence of a glauconitic sand bed cited as evidence of a period of nondeposition (Chadwick, 1944). In the central part of the state, the base of the Onondaga is marked by the "Springvale Sand" which overlies either the patchily distributed Lower Devonian Oriskany Sandstone, or the older Helderberg limestones. The underlying units continue to be variable to the west, where the Onondaga rests upon either the Lower Middle Devonian Bois Blanc Formation or Silurian dolomites.

Both Lindholm (1967) and Mesolella (1978) identified the central New York Onondaga as representing the most basinal facies exposed at the surface, and located the topographic axis of the basin through that area.

EVIDENCE FOR A TEMPERATE WATER EDGECLIFF SEA

The observations which led Kissling and his students to interpret the Edgecliff as a deep water limestone have also resulted in an alternative hypothesis - deposition in a warm temperate (as opposed to tropical) environment. Koch and Boucot (1982) made this suggestion on the basis of brachiopod community analysis; while Blodget, et al. (1988) noted that the low diversity gastropod fauna along with the absence of stromatoporoids and algae would suggest temperate water conditions. Recently collected isotope data and an analysis of the distribution pattern of the rare stromatoporoids in the Edgecliff lend strong support to the interpretation of this unit as a warm temperate water limestone.

Isotope Data

Brachiopods collected from the Edgecliff for isotopic analysis comprise a geographically and taxonomically broad-based sample (Table 1), which includes specimens of five different Edgecliff genera collected across New York State and Ontario, Canada (brachiopod identifications are based on Feldman, 1985, and Boucot and Johnson, 1968). Non-Edgecliff brachiopods were collected from the Oriskany Sandstone in the Seneca Stone Quarry at Seneca Falls, N.Y. and the Clarence member of the Onondaga near Buffalo, New York. A total of sixteen brachiopods were sampled - fourteen from the Edgecliff - with one brachiopod from the Clarence Member and one from the Oriskany Sandstone. Thirty-three isotopic analyses were performed, twenty nine on the Edgecliff samples, and two each on the Clarence and Oriskany samples. To check for the possible effects of diagenesis, sixty-one samples of dull luminescent, pore-filling cements were analyzed.

Isotopic analyses yielded δO^{18} values ranging from -1.81 to -7.10 $^{o}/_{oo}$ with 24 of 29 Edgecliff analyses falling into the -1.81 to -3.74 $^{o}/_{oo}$ range (Table 1, Figure 1). Data from the Clarence member sample was in the same range (-1.98$^{o}/_{oo}$, -2.42$^{o}/_{oo}$); as was the Oriskany Sandstone sample (-2.38$^{o}/_{oo}$, -2.41$^{o}/_{oo}$). δC^{13} values ranged from 1.35 to 3.18$^{o}/_{oo}$, with the Clarence sample again in agreement (2.40$^{o}/_{oo}$, 2.25$^{o}/_{oo}$); but with the Oriskany sample at the heavy end of the range (3.26$^{o}/_{oo}$, 3.65$^{o}/_{oo}$). Analyses of the dull luminescent cements yielded δO^{18} values ranging from -11.85 to -4.32 $^{o}/_{oo}$ and δC^{13} from -0.27 to 3.98 $^{o}/_{oo}$ (Figure 2).

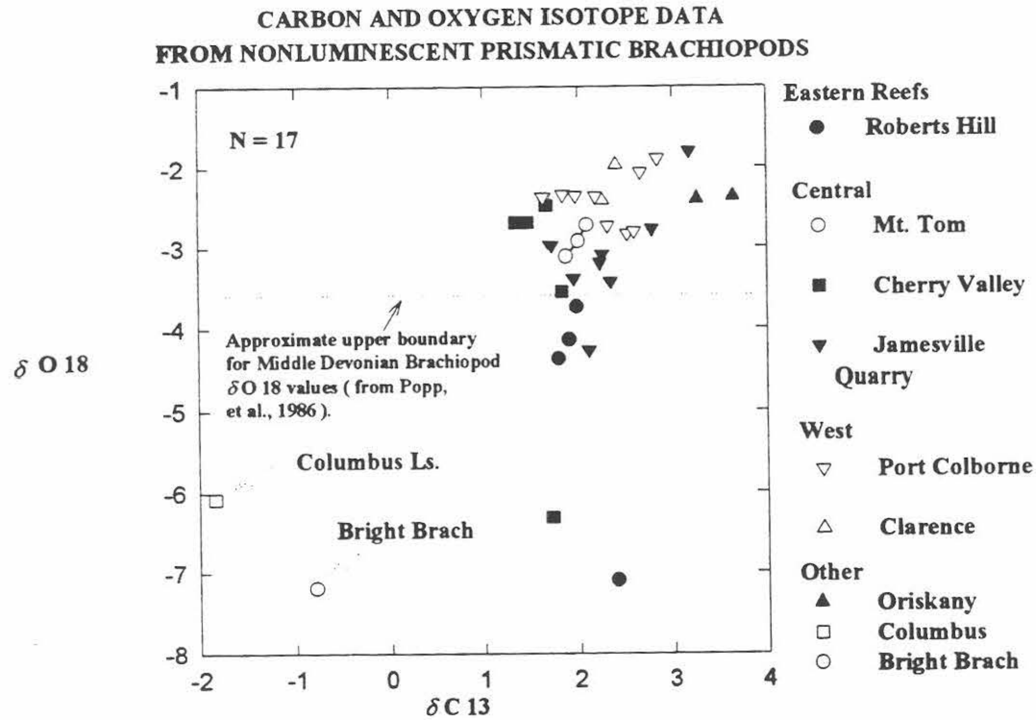

Figure 1. Isotope analyses for non-luminescent brachiopods. Locations as mentioned in text. "Bright brachiopod" (luminescent) sampled from thin dolomite bed at base of Edgecliff in Port Colborne, Ontario, Canada; and Columbus Limestone sample are for comparison.

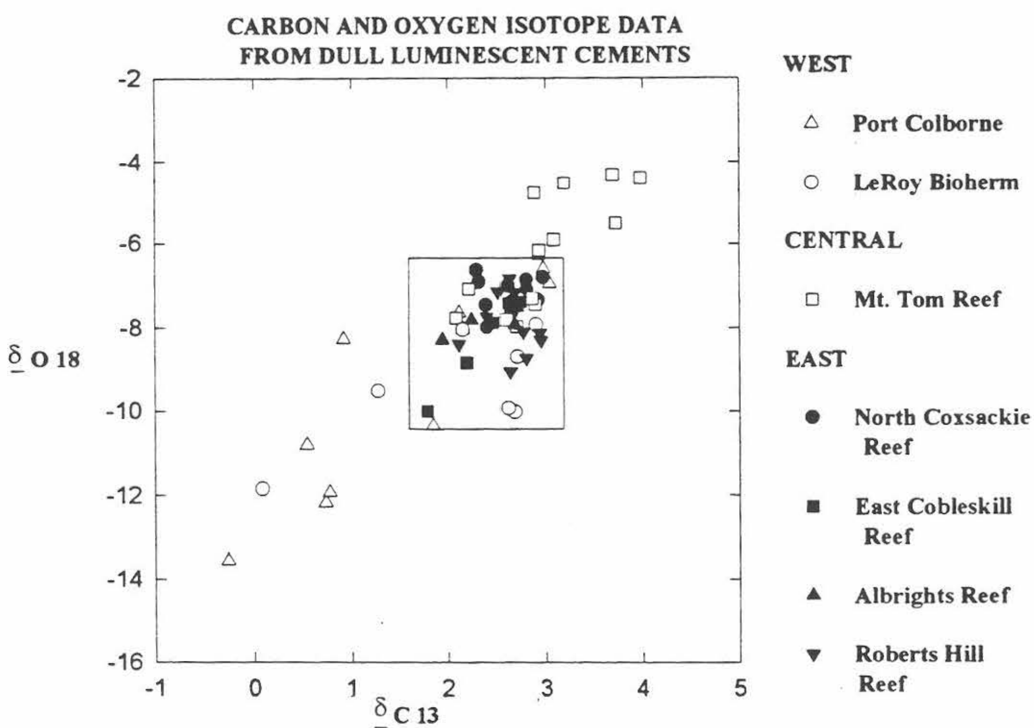

Figure 2. Isotopic analyses of dull luminescent pore filling cements. Locations as noted in text. Area enclosed in box represents restricted range of data from eastern bioherms.

Comparison of these data with the Devonian data of Popp, et al., (1986) and Brand (1989) clearly illustrates that the Onondaga and Oriskany samples are isotopically heavier for δO^{18}, suggesting a cooler Edgecliff depositional environment (Figure 1). The Oriskany data is in good agreement with that of Rush and Chafetz (1990), who interpreted the isotopically lighter signatures of the underlying Helderberg limestones as diagenetically altered. The similarity of the Onondaga data to the Oriskany data may, however, indicate that both the Onondaga and Oriskany were deposited under temperate water conditions as compared to the tropical Helderberg (which includes stromatoporoid-rich facies). Recently, Bates and Brand (1991) and Lavoie (1994) have presented δO^{18} isotope data for the Lower and Middle Devonian which are similar to those from the Onondaga; but in both cases the brachiopods analyzed were from deep water communities, and the interpreted lower temperatures are attributed to greater water depth.

Stromatoporoid Distribution

Stromatoporoids are assumed warm water organisms (Stock, 1990; Nestor, 1984, 1990) and important Devonian reef builders. Because of their rarity in the Onondaga all occurances of stromatoporoids have been noted and when possible specimens collected as part of an ongoing study of Edgecliff bioherms and depositional environments (Wolosz,1992a). These data reveal an apparent trend of increasing size and abundance of stromatoporoid colonies from east to west (Figure 3 and Table 2). Eastern New York stromatoporoids are rare and have most often been noted in thin-sections as either small, juvenile colonies or small encrusting colonies. In western New York and Ontario, Canada stromatoporoids become locally much more common and also more diverse. St. Jean (1986) reported seven species representing three genera collected from large blocks of limestone adjacent to an abandoned limestone quarry at Empire Beach along the shore of Lake Ontario, roughly ten kilometers east of Port Colborne, Canada. Large lamellar colonies (three species and two genera) have been collected by the author from an abandoned quarry to the west of Port Colbourne, Ontario. Domal colonies are also common within the Onondaga near Hagarsville, Ontario; and Lindemann (1988) noted large lamellar stromatoporoids in the capping facies at the LeRoy Bioherm.

Based upon current paleogeographic reconstructions (Scotese and McKerrow, 1990; Witzke and Heckel, 1990), the increase in stromatoporoid abundance across New York and into Ontario would mark a south to north trend of increasing abundance towards the paleo-equator. The paleo-geographic interpretation of Heckel and Witzke (1979) hypothesizes a current flow direction along the same Devonian south to north trend toward the paleo-equator. Gradual solar heating of the originally cool temperate waters flowing towards the equator could explain the apparent trends in stromatoporoid abundance observed across New York and into Ontario.

SHALLOW WATER FACIES

Recent evidence suggests that the assumed lack of peritidal or shallow subtidal facies in the Edgecliff is actually a lack of shallow tropical carbonate facies. Wolosz (1990, 1991) interpreted Edgecliff exposures near Port Colborne, Ontario, Canada as shallow subtidal to near peritidal environments. Figure 4 illustrates a model for Edgecliff shallow water deposition based on data from the Ridgemount bioherm and the Quarry Road exposures west of Port Colborne, Ontario.

In the Ridgemount bioherm quarry, a linear coral ridge is made up almost entirely of displaced and/or fragmentary rugosan and favositid colonies interpreted by Wolosz (1990) as evidence of shallow water storm damage. The coral ridge directly overlies and interfingers with a bioturbated dolomite bed interpreted as a former lime mud. The sparse presence of large crinoid columnals which are considered characteristic of the Edgecliff (Oliver, 1954) confirms that this dolomite is basal Edgecliff.

Table 1. Isotope analysis data by sample.

Location	Genus	N	Sample	δO^{18} (PDB)	δC^{13} (PDB)
Roberts Hill Reef	Meristina	2	A	-4.15	1.90
			A	-3.74	1.98
			A	-4.38	1.79
			B	-7.10	2.40
Mt. Tom Reef	Amphigenia	1	A	-2.73	2.09
			A	-2.93	2.00
			A	-3.12	1.87
Jamesville Quarry	Amphigenia	3	A	-3.43	2.34
			A	-4.28	2.11
			B	-1.81	3.18
			B	-3.20	2.23
			B	-2.78	2.78
			C	-3.39	1.95
			C	-2.98	1.72
			C	-3.1	2.25
Cherry Valley	Megakoz-lowskiella	2	D	-2.48	1.67
			B	-2.69	1.48
			B	-2.69	1.35
	Pentam-erella	1	C	-6.31	1.72
			C	-3.55	1.83
Clarence member Williams-ville NY	Megakoz-lowskiella	1	A	-1.98	2.40
			A	-2.42	2.25
Ridgemount Bioherm	Acro-spirifer	1	A	-2.07	2.66
			A	-1.90	2.84
Port Colborne	Meristina	4	E	-2.38	2.18
			E	-2.37	2.18
			F	-2.74	2.31
			C	-2.35	1.84
			C	-2.36	2.52
			D	-2.84	2.52
			D	-2.81	2.59
Oriskany SS.	Unident. frag.	1	A	-2.38	3.65
			A	-2.41	3.26

Table 2. Distribution of stromatoporoids based on field observations and collections by author.

LOCATION	LARGE COLONIES	SMALL COLONIES	MICROSCOPIC
Roberts Hill	none	1	5
North Coxsackie	none	none	1
Mt. Tom	1	1	
LeRoy Bioherm	present (Lindemann, 1988)	5	
Port Colbourne Quary	common	common	
Hagarsville	common	common	
Formosa Reefs	abundant	abundant	

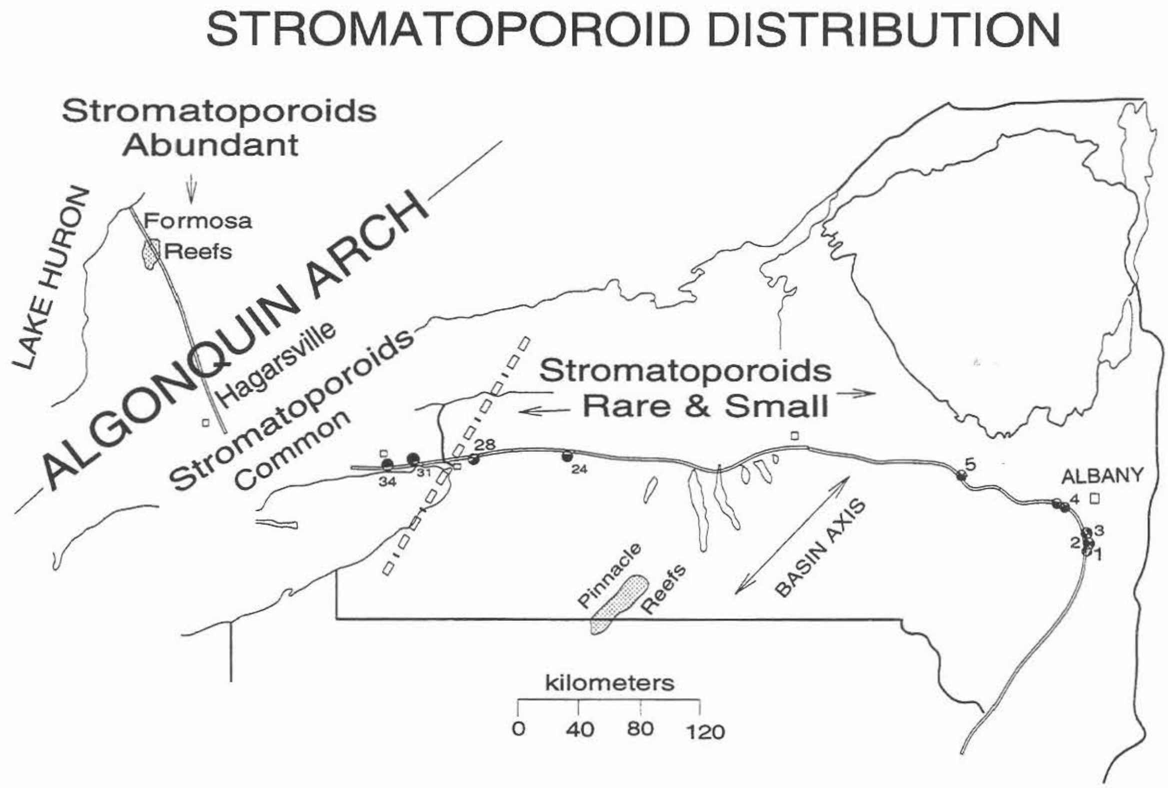

Figure 3. Stromatoporoid abundance across New York State and into Ontario, Canada. Bioherm exposures numbered as follows: Roberts Hill Reef (1), Albrights Reef (2), North Coxsackie Reef (3), Thompson's Lake Bioherm (4), Mt. Tom (5), LeRoy Bioherm (24), Buffalo Country Club Reef (28), Ridgemount Bioherm (31), Quarry Road Mounds (34). Formosa Reefs are approximately equivalent in age to the Edgecliff bioherms.

To the west of Port Colborne (Quarry Road bioherm Stop of Wolosz, 1990), extensive biostromal deposits which vary from dark gray to light gray to buff limestone with varying densities of green clay seams, are characterized by abundant Cystiphylloides, a solitary rugose coral, along with tabulate and colonial rugose coral. This biostrome is well exposed along the east wall of the west quarry but grades westwards across the quarry pit and northwards to the active quarry on the north side of Route 3 (former Law Quarry) into greenish, shaley limestone with clay seams and sparse to common coral which are interpreted as near-shore muds (Figure 4). Oliver (1976, p.10 and 143) noted the presence of these shaley limestone beds and identifyied the upper 16 feet of this 20 foot thick unit as Edgecliff based upon the sparse coral fauna.

The Cystiphylloides-rich biostromal units are overlain by a grainstone bed with abundant coral and stromatoporoids, followed stratigraphically by "reefy" beds containing numerous Small Rugosan Mounds (see reef classification below).

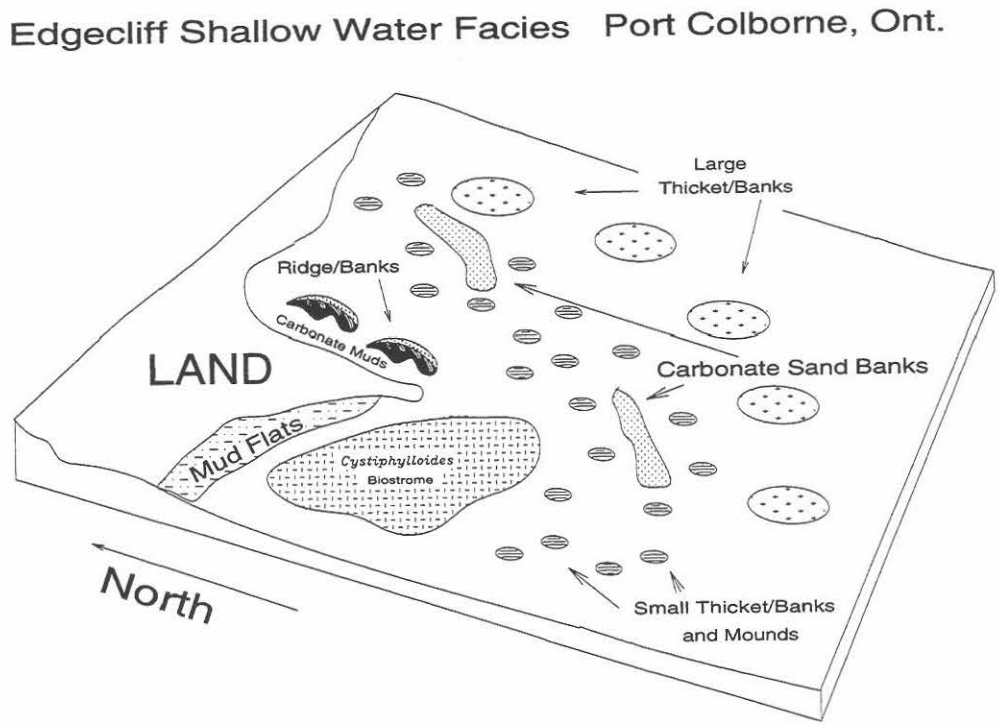

Figure 4. Model of shallow water Edgecliff facies as interpreted from exposures near Port Colborne, Ontario, Canada (see text for details).

Additional evidence for extreme shallow water conditions in the Edgecliff were noted by Wolosz and Paquette (1994) in a study of the LeRoy bioherm in western New York. They interpreted extensive erosion of the bioherm core prior to deposition of the flank beds as due to shallow water (subaerial?) erosion.

REEF PATTERNS AND DISTRIBUTION

Reef Communities

Most Edgecliff bioherms include two distinct communities - the Phaceloid Colonial Rugosan Community and the Favositid/ Crinoidal Sand Community.

The phaceloid colonial rugosan community is made up almost exclusively of colonial rugosans. Common genera include Acinophyllum, Cylindrophyllum, and Cyathocylindrium; with Eridophyllum, Synaptophyllum, and possibly 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 community displays a much higher diversity than the rugosan community. This community 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 community. The crinoids were the greatest contributor to this community - ossicles making up the bulk of the rock and indicating abundant growth of these organisms - but complete calyces are never found.

Reef Classification

Wolosz (1992a) noted that Edgecliff bioherms represent a continuum of growth pattern in which the two above described paleocommunities are the pure end members (the only exception being the LeRoy bioherm "calcisiltite mounds" (see Wolosz and Paquette, 1994)). As a result, the following simple classification of these bioherms was suggested:

Mounds - distinct high relief mounds of the Phaceloid Colonial Rugosan Paleocommunity. Subdivided into: 1) Successional Mounds, and 2) Small Mounds.

Composite Structures - structures formed through interbedding or intergrowth of the two communities. Subdivided into: 1) Mound/Bank, 2) Ridge/Bank, and 3) Thicket/Bank. 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."

Biostrome - bedded Favositid/Crinoidal Biostrome, typical bedded Edgecliff, with no evidence of relief above the sea-floor. Banks of pure Favositid/Crinoidal Paleocommunity have not been found, although some Thicket/Bank structures are, volumetrically, very close to this state.

Rugosan Mounds

The Phaceloid Colonial Rugosan Paleocommunity is the dominant biota. This paleocommunity produced a high relief mound which is onlapped by the bedded grainstone/packstone of the Favositid/Crinoidal Sand Paleocommunity with dips ranging from 8 to 15 degrees.

Successional Mounds. - These structures reach thicknesses of up to approximately 15 m., and are dense accumulations of phaceloid colonial rugosans in a matrix of fine, bioclastic calcisiltite. The mound building colonial rugosan genera exhibit a distinct succession (Wolosz, 1985, 1992b), starting with Acinophyllum at the mound base and progressing upwards and outwards through a Cylindrophyllum and then a Cyathocylindrium dominance stage. As the reef progresses through these dominance stages coral diversity increases as the previous dominants become accessory. Wolosz (1985, 1992b) has argued that these successions are controlled by the degree of water turbulence. Roberts Hill and Albrights reefs (Field Trip Stops 1 and 2) are examples of this reef type, as are the main mounds in Mound/Bank structures (see below). Small Mounds. - Small mounds are commonly monogeneric; but when more than one genus of colonial rugosan is present the placement of colonies is random, with no evidence of rugosan succession. Some small rugosan mounds are bedded, suggesting only small relief above the sea floor and a shallow water environment (Wolosz, 1990), while field relationships in others suggest that these are small satellite mounds which formed in protected backreef environments (Wolosz, et al., 1991; and Field Trip Stop 4 and 7).

Composite Structures

Composite reef structures formed through repetitive (possibly cyclic) intergrowth or interbedding of the two most common paleocommunities.

Mound/Bank. These are the largest of all the Edgecliff reef structures reaching thicknesses of up to 60 m. and areal extents of up to 3 km. by 2.5 km. The repetitive development of Rugosan Mounds interbedded with the Favositid/Crinoidal Sandstone facies led to the development of a large reef structure with flanking biostromal beds having dips of up to 25 degrees. This category includes the Mt. Tom Reef (Wolosz, et al., 1991; and Fieldtrip Stop 5) and the subsurface pinnacle reefs (Wolosz and Paquette, 1988; Coughlin, 1980, pp.139-163).

Ridge/Bank. The Rugosan Paleocommunity and occasional large favositids form a series of small mounds which coalesce laterally to form a ridge-like structure. Biostromal onlap produces a topographically large linear structure, the development of which may have included Rugosan Paleocommunity/Biostrome Cycles. Interpreted as a very shallow water structure by Wolosz (1990), the only known example of this type of Edgecliff Reef structure is the Ridgemount Bioherm located in a quarry approximately 2.4 km. due west of Fort Erie, Ontario, Canada (Cassa and Kissling, 1982; Wolosz, 1990).

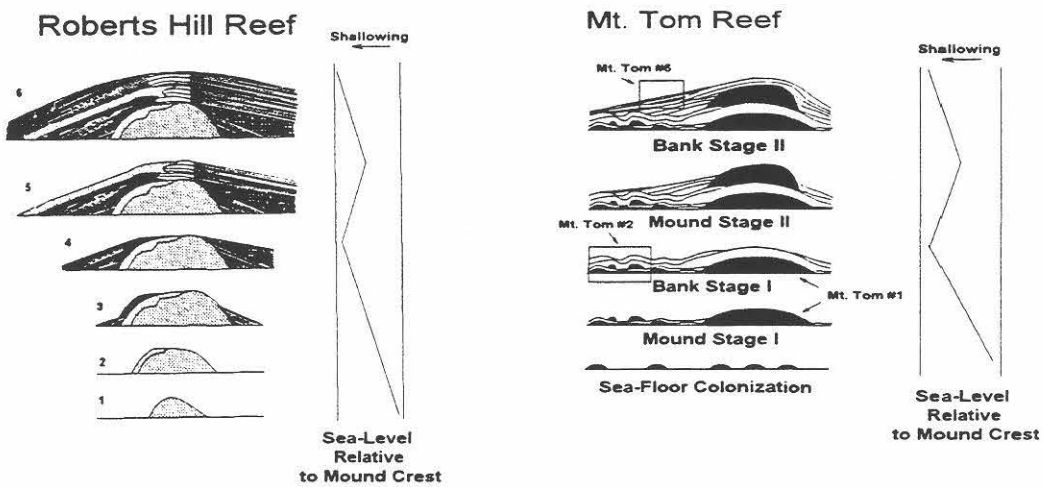

Figure 5. Comparison of development of Roberts Hill and Mt. Tom Reefs. At Roberts Hill, stages 1 - 3 represent the development of the mound through a succession of colonial rugosan genera, stage 4 is a bank stage dominated by the favositid/crinoidal sand community, stage 5 a recolonization of the bank by rugosans, and stage 6 the final bank stage with termination of reef growth. Development of Mt. Tom is similar, but greater subsidence allows development of a second mound stage.

Thicket/Bank. The Favositid/Crinoidal Sand Paleocommunity makes up the main mass of these buildups in the form of gently dipping (5 to 12 degrees), bedded packstone and grainstone with abundant large sheet to domal favositids. The rugosan paleocommunity is reduced to thickets, now less than roughly .3 m. thick, which covered the entire bank, and are now interbedded with the biostromal deposits (Wolosz, 1992b, in press). The resultant structure is a large, low relief, shield shaped mound. The North Coxsackie Reef (Fieldtrip Stop 3) is an excellent example of this reef type, as is the flanking stage of the LeRoy Bioherm (Wolosz and Paquette, 1994; Wolosz, in press).

Tabulate "Calcisiltite Mounds"

This facies is known only from the LeRoy Bioherm complex (Lindemann, 1988; Wolosz and Paquette, 1994). Unlike the other Edgecliff reefs, phaceloid rugosans are absent from the central mound which is dominated by small branching tabulate corals. No bioherms of this type are known in eastern New York.

GEOGRAPHIC DISTRIBUTION AND ECOLOGY

Wolosz (1992a) noted that the geographic distribution (Figure 5) of these bioherms support the hypothesis that the above described patterns of reef growth were controlled by

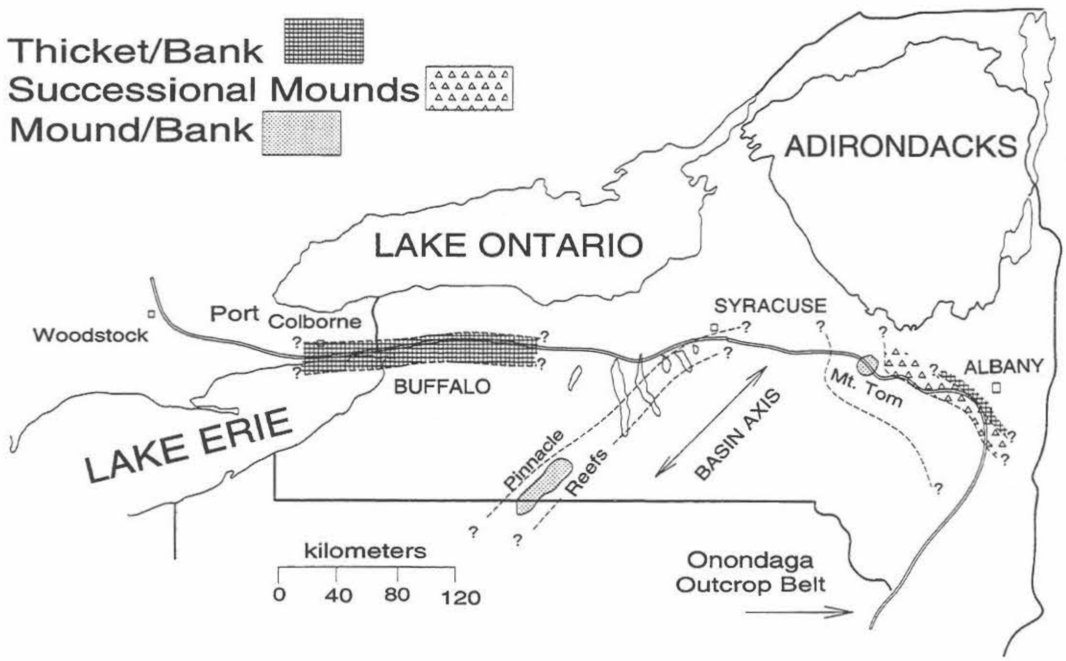

Figure 6. Interpreted distribution of Edgecliff bioherms by type. Mound/bank structures rim the area of major subsidence. Dashed lines represent interpreted boundaries between areas of distinct bioherm types, while patterning indicates confirmed presence of bioherms in either outcrop or subsurface. Question marks indicate limits of interpretable area due to lack of exposure or subsurface information or due to erosional removal of Onondaga (from Wolosz, 1992a).

water depth and rate of basinal subsidence. Wolosz (1985, 1992a, 1992b, in press) and Wolosz and Paquette (1988) have argued that the dominant reef community in Edgecliff Bioherms was controlled by the level of water turbulence at the crest of the reef. Following this model, shifts between the Favositid-Crinoidal Sand Paleocommunity and the Colonial Rugosan Paleocommunity mark "catchup/fall back" growth cycles as the reef community tried to maintain itself at a constant water depth during basinal subsidence. These cycles are illustrated by a comparison of the development of Roberts Hill and Mt. Tom Reefs (Figure 5). The similarity in the interpreted sea-level curves for each reef would support control of reef growth by basinal sea-level fluction. This balance of growth versus subsidence resulted in the great thickness of the pinnacle reefs.

The pinnacle reefs are large mound/bank structures which rim the axis of major basinal subsidence as located by Lindholm (1967) and Mesolella (1978). Shorewards of the pinnacle reefs lie the successional mound bioherms followed by the thicket/bank structures, then the small mounds and finally the ridge bank structures (Figure 5). In the field trip area, the four southeasternmost reefs (Roberts Hill, Albrights, North Coxsackie, Thompson's Lake Bioherm, Figure 1 #'s 1-4)illustrate the off-shore to on-shore trend from successional mounds (Robert's Hill and Albrights Reefs) to thicket/banks (North Coxsackie Reef) to shallow water small rugosan mounds and Cystiphylloides biostrome (Illustrated in part in Figure 6). Roberts Hill and Albrights reefs are rooted in the deeper water C1 Edgecliff facies, while the North Coxsackie reef and Thompson's Lake bioherm are rooted in the typical grainstone/ packstone of the Edgecliff. Further, the transition from the North Coxsackie thicket/bank structure to the small rugosan mounds associated with Cystiphylloides biostromes at the Thompson's Lake exposure represent the same shallow water facies as found near Port Colborne, Ontario (Figure 4).

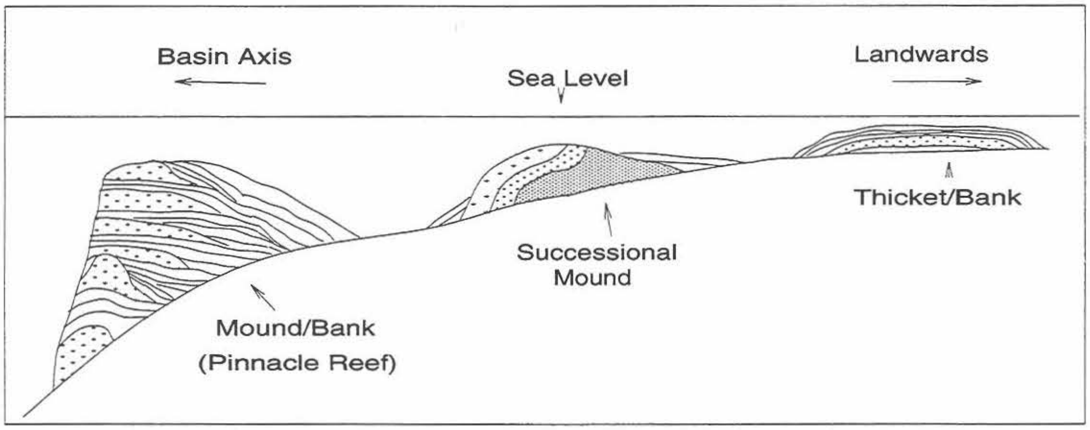

Figure 7. Depth controlled off-shore to on-shore transect showing relative positions of various bioherm types. Shallow subtidal facies (Figure 4) would lie in on-shore (to right) of thicket/bank bioherm (From Wolosz, 1990).

SUMMARY

1) Isotope data derived from nonluminescent brachiopods and analysis of stromatoporoid distribution in the Edgecliff, when added to previously published paleontologic and paleogeo-graphic studies, support the hypothesis that the Edgecliff bioherms grew in cool temperate waters.

2) Shallow subtidal facies are present in the Edgecliff, but they are characterized by Cystiphylloides dominated biostromes, small rugosan mounds, and shaley, sparsely fossiliferous limestone deposits - not by classic tropical peritidal facies.

3) The Edgecliff bioherms display patterns of development which follow distinct onshore to off shore trends.

4) The cyclic development of Edgecliff bioherms was controlled by water depth (turbulence) over the crest of the bioherm.

REFERENCES CITED

BATES, N.R., and BRAND, U., 1991, Environmental and physiological influences on isotopic and elemental compositions of brachiopod shell calcite: implications for the isotopic evolution of Paleozoic oceans: Chemical Geology (Isotope Geoscience Section), v. 94, p.67-78.

BLODGETT,R.B., ROHR,D.M., AND BOUCOUT A.J., 1988, LowerDevonian gastropod biogeography of the western hemisphere: *In* McMillan, N.J., Embry, A.F., and Glass, D.J., eds., Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, Canadian Society of Petroleum Geologists, Memoir 14, vol. III, p.281-294.

BOUCOT, A.J., and JOHNSON, J.G., 1968, Brachiopods of the Bois Blanc Formation in New York: United States Geological Survey Professional Paper no.584-B, p.1-27.

BRAND, U., 1989, Global Climatic Changes During the Devonian- Mississippian: Stable Isotope Biogeochemistry of Brachiopods: Palaeogeography, Palaeoclimatology, Palaeoecology, v.75, p.311-329

BRETT, C.E., and VER STRAETEN, C.A., 1994, Stratigraphy and facies relationships of the Eifelian Onondaga Limestone (Middle Devonian) in western and west central New York State: *In* New York State Geological Association, 66th Annual Meeting Field Trip Guidebook, p.221-270.

CASSA, M.R. and KISSLING, D.L., 1982, Carbonate facies of the Onondaga and Bois Blanc Formations, Niagara Peninsula, Ontario: *In*: New York State Geological Association, 54th Annual Meeting, Field Trip Guidebook, p.65-97.

CHADWICK, G.H., 1944, Geology of the Catskill and Kaaterskill Quadrangles, Part II: Silurian and Devonian Geology: N.Y. State Museum Bulletin 336. 251p.

COUGHLIN, R.M., 1980, Reefs and associated facies of the Onondaga Limestone (Middle Devonian), West Central New York: Unpublished M.A. thesis, State University of New York at Binghamton. 194p.

FELDMAN, H.R., 1985, Brachiopods of the Onondaga Limestone in central and southeastern New York: American Museum of Natural History, Bulletin, v.179, p.289-377.

GOLDRING, W. and FLOWER, R.H., 1942, Restudy of the Schoharie and Esopus Formations in New York State: American Journal Science, v.240, p.673-694.

HECKEL, P.H. and WITZKE, B.J., 1979, Devonian world paleogeography determined from distribution of carbonates and related lithic paleo-climatic indicators: *In*: M.R. House, C.T. Scrutton and M.G. Bassett, EDS., The Devonian System, Special Papers in Palaeontology, London, v.23, p.99-124.

KISSLING, D.L., 1987, Middle Devonian Onondaga pinnacle reefs and bioherms, Northern Appalachian Basin: *In* Second International Symposium on the Devonian System, Calgary, Alberta, Canada, Program and Abstracts, p.131. (abstr.)

KISSLING, D.L., and COUGHLIN, R.M., 1979, Succession of faunas and frameworks in Middle Devonian pinnacle reef of south-central New York: Geological Society America, Abstracts with Program, V.11, P.19. (abstr.)

KOCH, W.F. II, AND BOUCOT, A.J., 1982, Temperature fluctuations in the Devonian Eastern Americas Realm: Journal of Paleontology, v.56, p. 240-243.

LAVOIE, D., 1993, Early Devonian marine isotopoic signatures: brachiopods from the upper Gaspe' limestones, Gaspe' Peninsula, Que'bec, Canada: Journal of Sedimentary Petrology, v.63, p.620-627.

LINDEMANN, R.H., 1988, The LeRoy Bioherm, Onondaga Limestone (Middle Devonian), Western New York: *In* H.H.J.Geldsetzer, N.P.James, and G.E.Tebbutt, eds., Reefs, Canada and Adjacent areas, Canadian Society of Petroleum Geologists Memoir 13, Calgary, Alberta, Canada. p.487-491.

LINDHOLM, R.C., 1967, Petrology of the Onondaga Limestone_(Middle Devonian), New York: Unpublished Ph.D. dissertation, Johns Hopkins University. 188pp.

MESOLELLA, K.J., 1978, Paleogeography of some Silurian and Devonian reef trends, Central Appalachian Basin: American Association of Petroleum Geologists Bulletin, v.62, p.1607-1644.

NELSON, H.F., BROWN, C.W., AND BRINEMAN, J.H., 1962, Skeletal limestone classification: *In* Ham, W.E., ed., Classification of Carbonate Rocks, A Symposium: American Association of Petroleum Geologists, Memoir 1, p.224-252.

NESTOR, H., 1984, Autecology of stromatoporoids in Silurian cratonic seas: *In* Bassett, M.G., and Lawson, J.D., eds., Autecology of Silurian Organisms, Special Papers in Palaeontology, London, v.32, p.265-280.

NESTOR, H., 1990, Biogeography of Silurian Stromatoporoids: *In* McKerrow, W.S., and Scotese, C.R., eds., Paleozoic Palaeogeography and Biogeography, The Geological Society Memoir No.12, London, p.215-221.

OLIVER, W.A., Jr., 1954, Stratigraphy of the Onondaga Limestone (Devonian) in Central New York: Geological Society of America Bulletin, v.65, p.621-652.

OLIVER, W.A., Jr., 1976, Noncystiimorph colonial rugose corals of the Onesquethaw and Lower Cazenovia Stages (Lower and Middle Devonian)in New York and adjacent areas: United States Geological Survey Professional Paper no.869, 156p.

OZOL, M.A., 1963, Alkali reactivity of cherts and stratigraphy and petrology of cherts and associated limestones of the Onondaga Formation of Central and Western New York: Unpublished Ph.D. dissertation, Rensselaer Polytechnic Institute. 228pp.

PAQUETTE, D.E., AND T.H. WOLOSZ, 1987, Mt. Tom Reefs #'s 1,2 & 6- A Possible Erosional Remnant of an Edgecliff Pinnacle Reef (Mid. Devonian, Onondaga Formation of New York): Geologic Society of America, Abstracts with Programs, v. 19, no.1, p. 50. (abstr).

POPP. B.N., ANDERSON, T.F. and SANDBERG, P.A., 1986, Brachiopods as indicators of original isotopic compositions in some Paleozoic limestones: Geologic Society of America Bulletin, v. 97, p. 1262-1269.

RICKARD, L.V., 1975, Correlation of the Silurian and Devonian rocks in New York State: New York State Museum and Science Service Map and Chart Series no.24.

RICKARD, L.V., AND D.H.ZENGER, 1964, Stratigraphy and paleontology of the Richfield Springs and Cooperstown Quadrangles, New York: New York State Museum and Science Service, Bulletin 396, 101pp.

RUSH, P.F., and CHAFETZ, H.S., 1990, Fabric-retentive, non- luminescent brachiopods as indicators of original $\delta^{13}C$ and $\delta^{18}O$ composition: a test: Journal of Sedimentary Petrology, v. 60, p. 968-981.

ST.JEAN, J, 1986, Lower Middle Devonian Stromatoporoidea from Empire Beach, southern Ontario, Canada: Journal of Paleontology, v. 60, p. 1029-1055.

SCOTESE, C.R., and MCKERROW, W.S., 1990, Revised world maps and introduction: *In* McKerrow, W.S., and Scotese, C.R., eds., Paleozoic Palaeogeography and Biogeography, The Geological Society Memoir No.12, London, p.1-24

STOCK, C.W., 1990, Biogeography of Devonian stromatoporoids: *In* McKerrow, W.S., and Scotese, C.R., eds., Paleozoic Memoir No.12, London, p.257-266.

WILLIAMS, L.A., 1980, Community succession in a Devonian patch reef (Onondaga Formation, New York) - Physical and Biotic Controls: Journal Sedimentay Petrology, v.50, p.1169-1186.

WITZKE, B.J., and HECKEL, P.H., 1988, Paleoclimatic indicators and inferred Devonian paleolatitudes of Euramerica: *In* McMillan, N.J., Embry, A.F., and Glass, D.J., eds., Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, Canadian Society of Petroleum Geologists, Memoir 14, vol. I, p.49-66.

WOLOSZ, T.H., in press, Thicketing events - a key to understanding the ecology of the Edgecliff reefs (Middle Devonian Onondaga Formation of New York and Ontario, Canada). *In* Brett, C.E. and Baird, G., eds., Paleontological Events - Stratigraphic, Ecological and Evolutionary Implications, Columbia University Press.

WOLOSZ, T.H., 1985, Roberts Hill and Albrights Reefs: faunal and sedimentary evidence for an eastern Onondaga sea-level fluctuation: *In* New York State Geological Association, 57th Annual Meeting, Field Trip Guidebook, p.169-185.

WOLOSZ, T.H., 1990, Shallow water reefs of the Middle Devonian Edgecliff Member of the Onondaga Limestone, Port Colborne, Ontario, Canada: *In* New York State Geological Association, 62nd Annual Meeting Field Trip Guidebook, p.Sun.E1-E17.

WOLOSZ, T.H., 1991, Edgecliff reefs - Devonian temperate water carbonate deposition: American Association of Petroleum Geologists Bulletin, v. 75, no. 3, p. 696.(abstr.)

WOLOSZ, T.H., 1992a, Patterns of reef growth in the Middle Devonian Edgecliff Member of the Onondaga Formation of New York and Ontario, Canada and their ecological significance: Journal of Paleontology, v.66, p.8-15.

WOLOSZ, T.H., 1992b, Turbulence controlled succession in Middle Devonian reefs of eastern New York State: Lethaia, v. 25, p. 283-290.

WOLOSZ, T.H., FELDMAN, H.R., LINDEMANN, R.H., and PAQUETTE, D.E., 1991, 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: *In* New York State Geological Association, 63rd Annual Meeting Field Trip Guidebook, p. 373-412.

WOLOSZ, T.H., and PAQUETTE, D.E., 1988, Middle Devonian Reefs of the Edgecliff Member of the Onondaga Formation of New York: *In* McMillan, N.J., Embry, A.F., and Glass, D.J., eds., Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, Canadian Society of Petroleum Geologists, Memoir 14, vol. II, p. 531-539.

WOLOSZ, T.H., and PAQUETTE, D.E., 1994, The LeRoy Bioherm Revisited - Evidence of a Complex Developmental History: *In* New York State Geological Association, 66th Annual Meeting, Field Trip Guidebook, p. 443-454.

ROAD LOG

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Exit 21B from NYS Thruway. Left turn onto Route 9W
0.6	0.6	Right turn onto Schiller Park Road
2.0	1.4	Right turn onto Limnkiln Road
3.0	1.0	**STOP 1. Roberts Hill Reef** Park cars and proceed east onto hill.

NOTE: Private Property. **DO NOT** enter without first obtaining permission at house on north side of hill.

Roberts Hill Reef

Roberts Hill Reef is the best known example of a Successional Mound in the Edgecliff, and has been described in detail by Wolosz (1985). This exposure allows for examination of the typical Edgecliff bioherm growth pattern of interbedded Colonial Rugosan and Favositid/crinoidal Sand Paleocomm-unities (Figure 9).

The outer edge of a central rugosan mound is exposed along the east side of a small valley which runs southwards across the hill (refer to Figure 8), while the west side of the valley exposes bedded packstone flank beds with large favositid colonies. Further to the east, south and southeast a second stage of rugosan growth (Recolonization Stage of Wolosz (1985)) can be observed to cap the flank beds. This cyclic intergrowth of paleocommunities was controlled by sea-level fluctuation (see Figure 5; and Wolosz, 1985, 1992b). Evidence for changing turbulence levels during reef growth can be directly observed at the outcrop and includes the following: 1) development of rubble apron along the northeast side of the hill which wedges out into the flank beds between the two stages of rugosan growth. This facies is dominated by the small solitary rugosan Cystiphylloides, and is interpreted as the result of an extreme shallow water stage during which the top of the mound was covered by a meadow of these small solitary rugosans. Interpretation of water depth is based on the similarity of this facies with the shallow water Cystiphylloides biostromes at Thompson's Lake Bioherm and in the Port Colborne area. 2) A rubble ring surrounding the central rugosan core and large overturned favositids in the adjoining flank beds. 3) Pods of colonial rugosan rubble at the toe of the Rugosan Recolonization Zone at the southernmost edge of the reef along the east cliff face of the hill. The large colony fragments in these rubble pods indicate elevated turbulence levels during the demise of the reef.

This reef is also tightly cemented with little observable porosity as is common for the eastern reefs of the Edgecliff.

		Return to cars. Continue north.
3.4	0.4	Right turn onto Reservoir Road.
4.1	0.7	Left turn onto Roberts Hill Road.
5.5	1.4	**STOP 2. Albrights Reef.** Park cars and proceed east onto reef.

NOTE: Private Property. **DO NOT** enter without first obtaining permission at house on north side of hill.

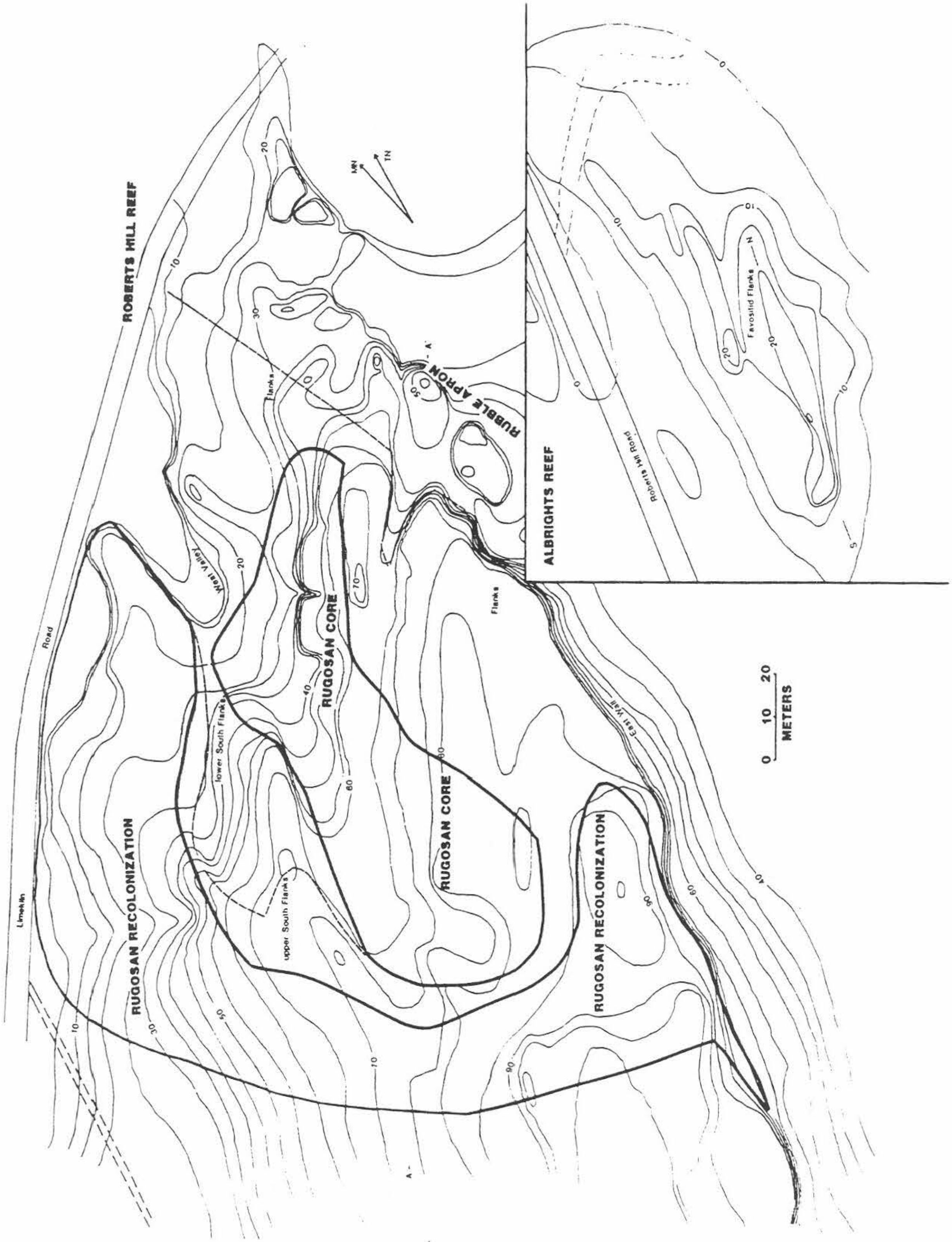

Figure 8. Map of Roberts Hill and Albrights reef illustrating location of core facies and flanking beds. Rugosan Recolonization facies marks re-establishment of colonial rugosans on mound. (From Wolosz, 1985).

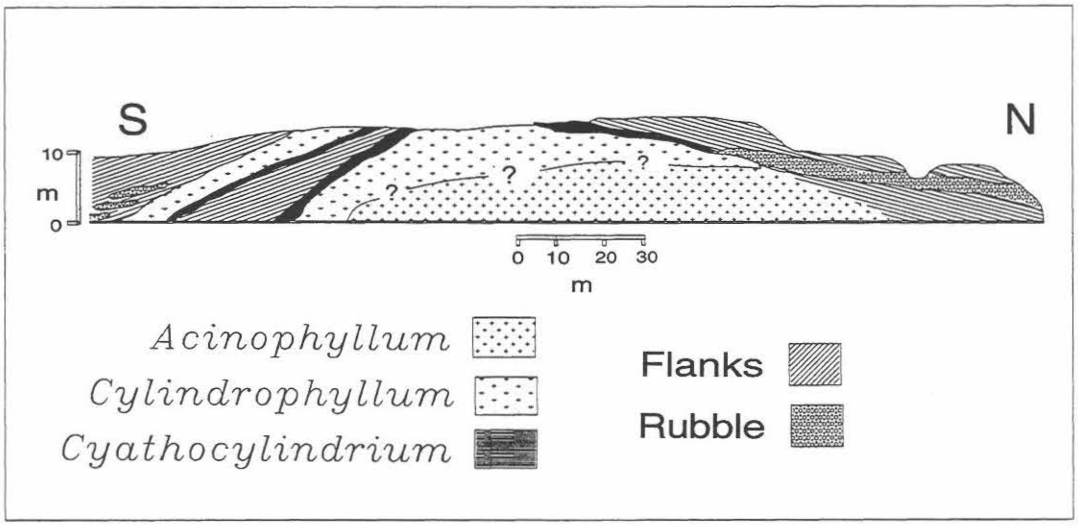

Figure 9. Fore- to back-reef cross-section through Roberts Hill Reef. Core facies is a rugosan successional mound. Note sequential development of colonial rugosan biofacies. (From Wolosz, 1992).

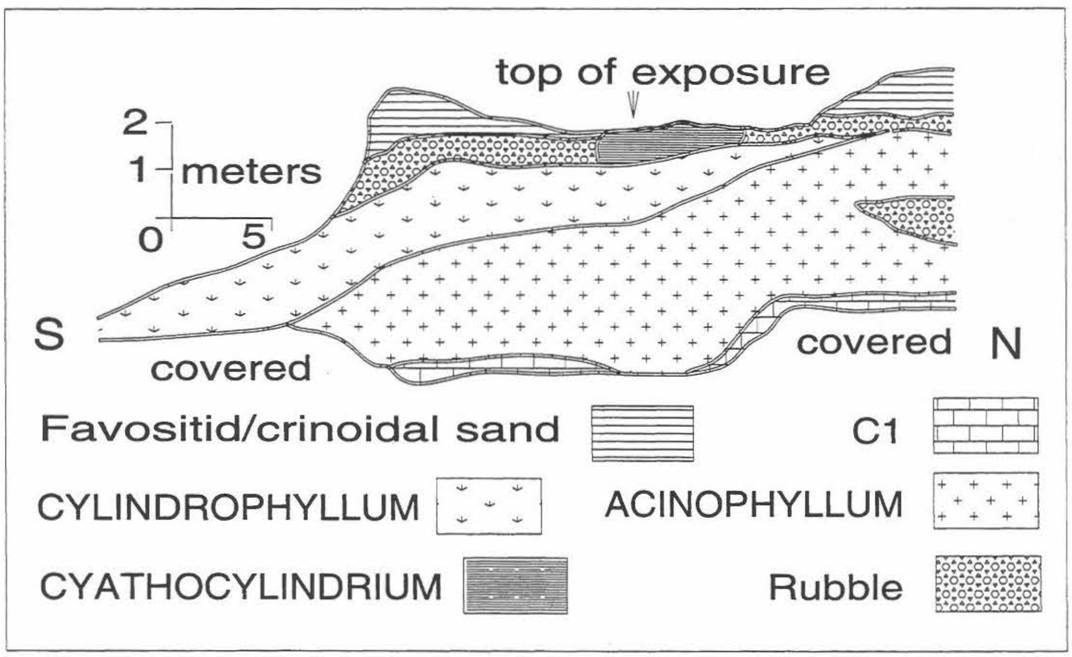

Figure 10. Interpretative cross-section of eastern cliff face core exposure at Albrights Reef. Note successional facies patterns of rugosa community development. (From Wolosz, 1985).

Albrights Reef

This exposure is a small erosional remnant of a large successional mound similar to Roberts Hill (Wolosz, 1985). It is an important exposure because it offers an excellent cross-section through the rugosan mound itself, exposes the basal contact of the mound with the underlying Edgecliff C1 facies, and allows direct observation of the successional patterns among the rugosan fauna during development of the mound (see Figure 10).

		Return to cars. Continue north.
5.9	0.4	bear left on Route 51
6.0	0.1	bear right onto West Dean's Mill Road bear right
7.65	1.65	
8.05	0.4	left turn onto Dean's Mill Road
8.5	0.45	left turn onto Aquetuck Road
9.15	0.65	left at stop onto Route 143
10.15	1.0	bear right onto Route 102
12.15	2.0	bear left onto Route 102
12.3	0.15	**Stop 3. North Coxsackie Reef**. Enter using dirt road on south side of road.

NOTE: Private Property. **DO NOT** enter without first obtaining permission at house on north-west side of intersection of Route 102 and 106 (approx. 0.7 mile south).

North Coxsackie Reef

The North Coxsackie reef (Figures 11 and 12) is rooted in Edgecliff crinoidal grainstone/packestone - the C1 unit is absent. The main mass of the reef is a Composite Thicket/Bank reef roughly 280 meters long (north-south) by 220 meters wide (east-west) with an estimated thickness of 15 meters. Volumetrically, the Favositid/Crinoidal Sand Paleocommunity dominates this reef, having formed a bank, with beds dipping gently (5 to 12 degrees) away from the center of the structure. Interbedded with the favositid/crinoidal sand facies are two roughly 0.3 meter thick horizons of the Phaceloid Colonial Rugosan Paleocommunity - each representing a single thicketing event which covered the entire mound. These thickets are dominated by Cyathocylindrium, although Cylindrophyllum and Acinophyllum are common.

A cliff along the northwestern edge of the reef exposes an approximately 6 meters thick by approximately 60 meters long Acinophyllum mound, underlain by crinoidal grainstone/-packstone. This small structure is located to the west of, and stratigraphically just above, a well defined rubble horizon exposed along the northeastern edge of the main reef, indicating that it grew on the down-current side of the mound. This mound is similar to the early Acinophyllum stage of reef growth exposed at Albrights reef, with the exception that the calcisilt-packstone matrix surrounding the corallites is more finely bioclastic, containing debris transported from the larger mound to the south.

		Return to cars. Continue North on Route 102.
15.2	2.9	left turn onto Route 396
15.9	0.7	straight onto Route 301 (396 ends)
19.7	4.5	right onto Route 301
21.2	1.5	left onto rout 443
23.1	1.9	right turn onto Route 85
25.25	2.15	left turn onto Route 157
32.75	7.5	right turn onto Ketchum Road
32.9	0.15	**Stop 4. Thompson's Lake Bioherm**

NOTE: Private Property. **DO NOT** enter without first obtaining permission at house to the southwest of hill on Route 157.

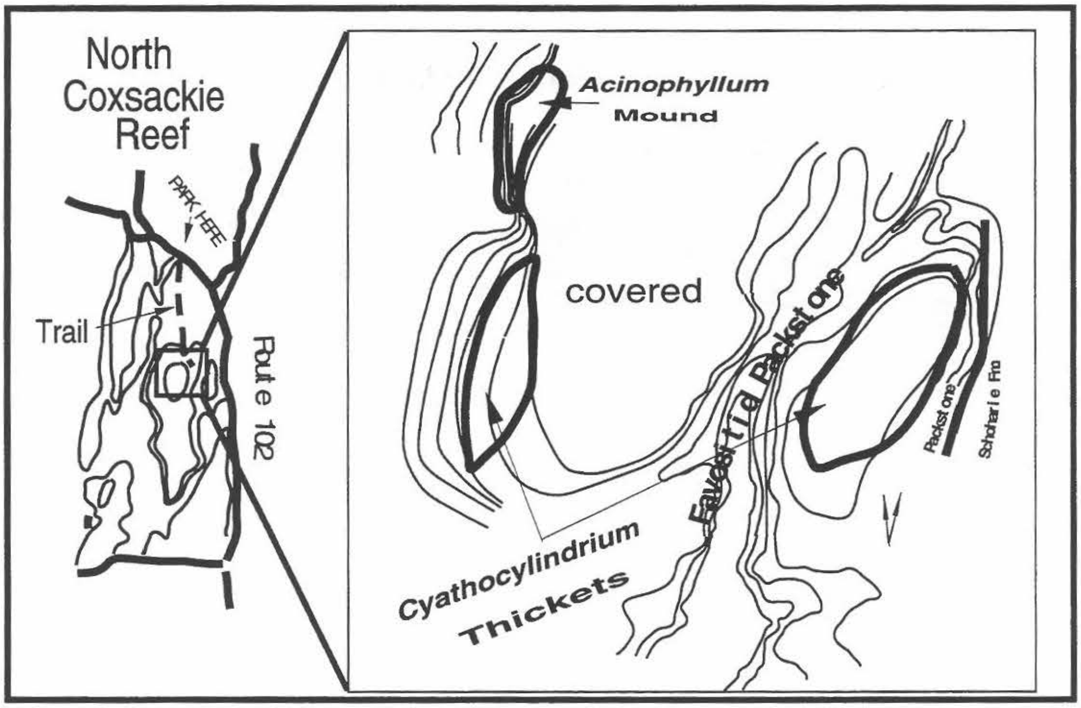

Figure 11. Map of North Coxsackie Reef.

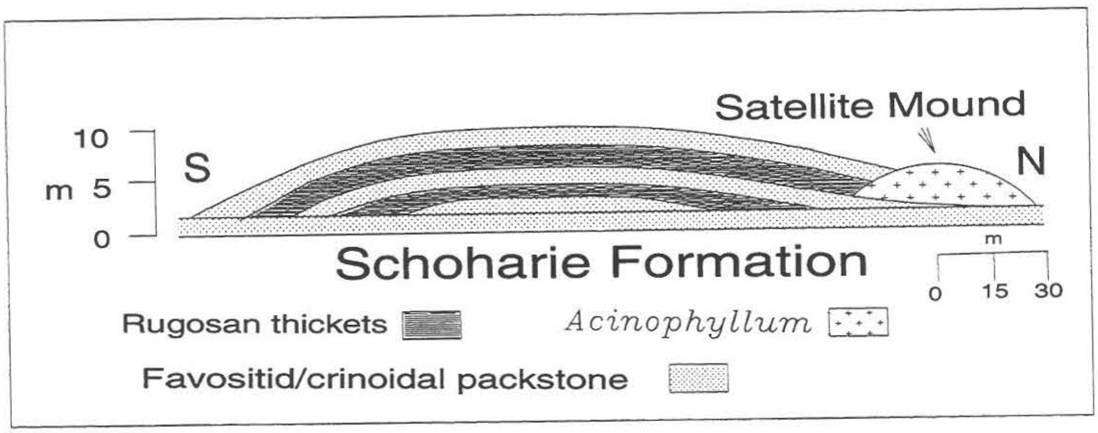

Figure 12. Cross-section of North Coxsackie Reef. Dark horizons (with thickness greatly exaggereated) represent thickets of *Cyathocylindrium.* Other beds are Favositid/crinoidal sand facies. Note presence of *Acinophyllum* mound in back-reef (From Wolosz, 1992a).

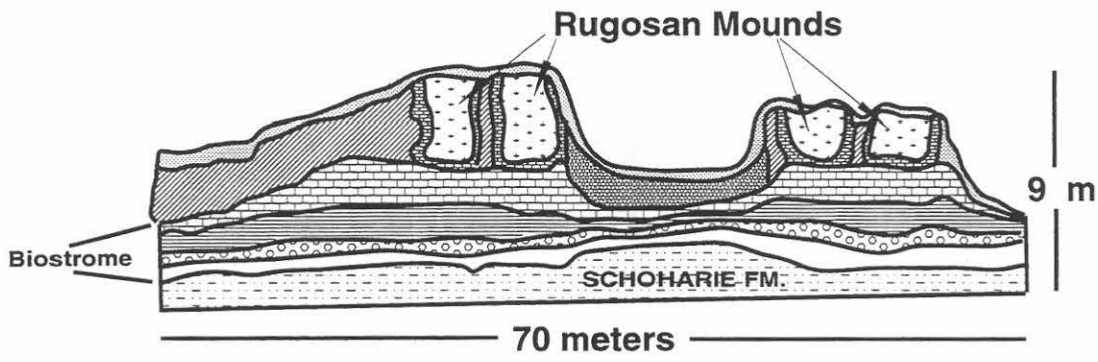

Figure 13. Thompson's Lake Bioherm. View looking south from Ketchum Road. Redrawn from, and with patterning following, Williams (1980).

Thompson's Lake Bioherm

This exposure has been described by Williams (1980), who divided the exposure into eleven different micro-facies, discussion of which is beyond the scope of this report. Simply put, most of the small elongate hill is made up of packstone with abundant favositid colonies. Along the roadcut two small rugosan mounds can be observed (Figure 13), underlain by roughly 2.6 meters of Edgecliff biostomal deposits, including a well developed Cystiphylloides biostrome which can be followed around the entire hill as a recessive bed. These facies are analogous to the shallow water deposits found near Port Colborne, Ontario, Canada as described in the text.

The underlying contact with the Schoharie Formation is easily observable, and represents initial shallow water deposition with grainstone as the basal Edgecliff facies.

Return to cars. Turn around and proceed west on Ketchum Road.

33.05	0.15	right turn onto Route 157
34.75	1.7	right turn onto Route 156
38.15	3.4	left turn onto Route 146 West
38.45	0.3	right turn onto Route 397
41.55	3.1	left turn onto Route 20
86.75	45.2	Right turn on Route 80.(see Figure 14)
88.25	1.5	Left turn onto Koenig Road.
88.85	0.6	Bare left onto Mt. Tom Road
88.95	0.1	**STOP 5. Mt. Tom Reef**. The reef makes up the large hill to the south of the road.

NOTE: Private Property. **DO NOT**enter without first obtaining permission at house at intersection of Koenig and Mt.Tom roads. Examination of Mt.Tom #6 requires permission from farm on Koenig Road to the north of hill. Examination of Mt.Tom #2 requires permission from Mercy Hill Farm.

MT. TOM REEF

NOTE: Private Property. **DO NOT**enter without first obtaining permission at house at intersection of Koenig and Mt.Tom roads. Examination of Mt.Tom #6 requires permission from farm on Koenig Road to the north of hill. Examination of Mt.Tom #2 requires permission from Mercy Hill Farm.

Paquette and Wolosz (1987) argued that three reef exposures - the Mt.Tom, Mt. Tom #2, and Mt. Tom #6 (Figure 14) - represent the extensively eroded remains of a single large mound/bank reef. The .6 by .8 km. areal extent of this structure would make Mt. Tom both the largest exposed Edgecliff reef and the only known surface exposure of this reef type (these reefs are commonly referred to as pinnacle reefs in the subsurface).

The mound\bank nature of Mt. Tom #1 is displayed in the cliff face along the southeast side of the hill (Figure 15). The reef is underlain by the basal Edgecliff calcisiltite, 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 inital 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.

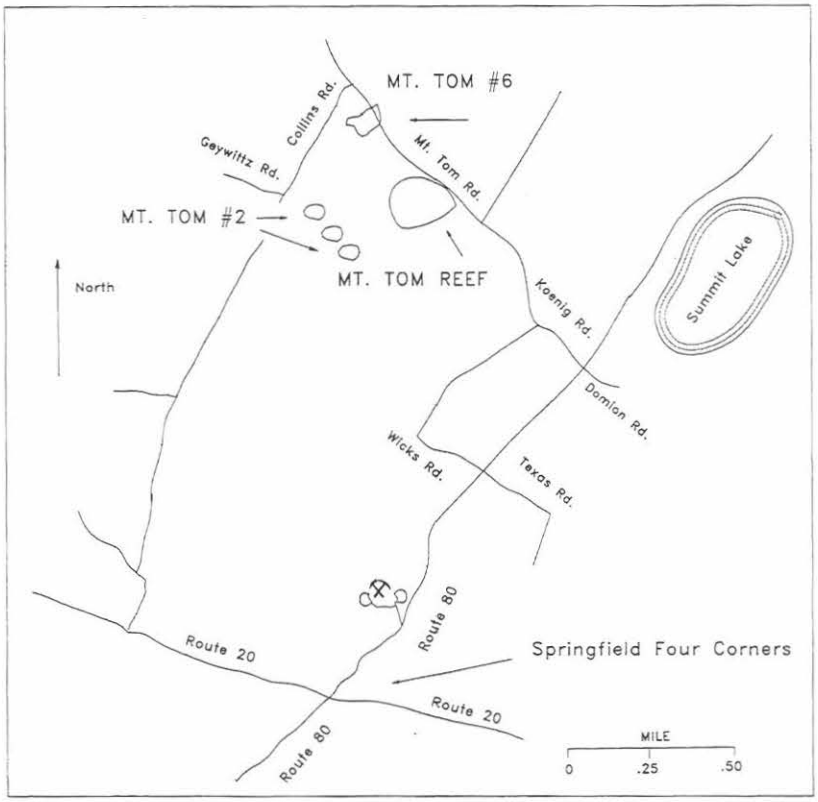

Figure 14. Location map of Mt. Tom reef #'s 1, 2 and 6. Note relative positions of reefs.

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 between rugosan mound/thicket construction and the favositid/crinoidal sand paleocommunity has been attributed to a water turbulence controlled community succession (Wolosz, 1992b).

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).

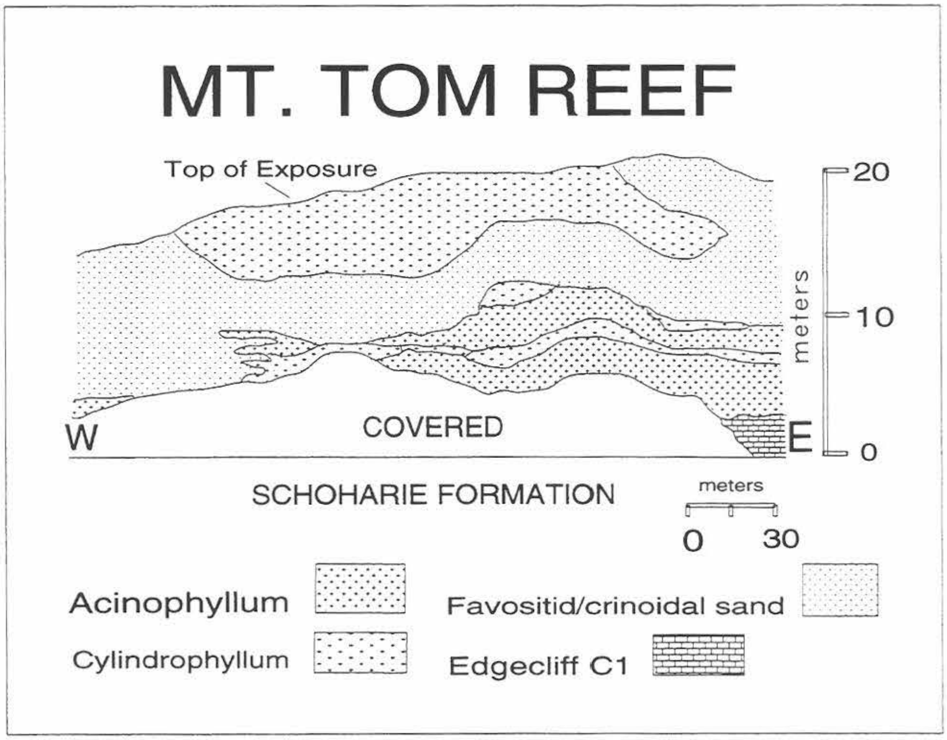

Figure 15. Cross-section of cliff face at Mt. Tom reef illustrating a mound/bank structure. Lower mound develops through two colonial rugosan successional cycles before being swamped by crinoidal sands. Second appearance of rugosan paleocommunity occurs as a mound within area of crinoidal sandstone, and does not drape entire reef structure (from Wolosz, 1992).

Diagenetic patterns in Mt. Tom are similar to those in subsurface pinnacle reefs. The initial mound facies (base of reef) is tightly cemented, as is Mt. Tom #2; while the upper parts of the reef and Mt. Tom #6 exhibit a small primary porosity.

		Return to cars and continue northwest on Mt.Tom Road.
89.45	0.5	**STOP 6. Mt. Tom #6** forms the low, wooded ridge to the southwest of Mt.Tom Road.

Mt. Tom #6

Mt. Tom #6 is a small ridge which consists mainly of bedded crinoidal grainstone/packstone. Randomly distributed small overturned favositids are common as are both solitary and phaceloid rugosans, but no evidence of mound formation is present. 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. However, when one observes Mt. Tom #6 from Collins Road (see map, Figure 14), 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.

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.

		Return to cars and continue northwest on Mt. Tom Road.
89.6	0.15	Left turn onto Collins Road.
90.1	0.5	**STOP 7. Mt. Tom #2.** Intersection of Collins and Geywittz Roads. Mt. Tom #2 Reef.

Mt. Tom #2 Reef.

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. In contrast to Mt. Tom #2 lies to the west of Mt. Tom #1 and is topo-graphically 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 packestones 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 (FROM WOLOSZ, ET AL., 1991)

Figure 5 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.

End of trip. Return to cars follow Collins Road back to Route 20.