PALEOGEOGRAPHY AND BRACHIOPOD PALEOECOLOGY OF THE ONONDAGA LIMESTONE IN EASTERN NEW YORK

RICHARD H. LINDEMANN
Department of Geology
Skidmore College
Saratoga Springs, New York 12866

HOWARD R. FELDMAN
Biology Department
Touro College
New York, New York 10036

INTRODUCTION

During the three plus decades since Oliver (1954) formally divided the Middle Devonian Onondaga Limestone into its Edgecliff, Nedrow, Moorehouse and Seneca Members, the formation has been the focus of considerable attention. However, with the exception of subsurface investigations, research has concentrated on the formation as seen in outcrop (Fig. 1) between Buffalo and the Helderberg/Catskill area. Few geologists have ever examined the Onondaga south of its classic exposure in Leeds Gorge. As an arbitrary measure of this, we note that between 1962 and 1986 more than ten NYGSA field trips concentrated on the Onondaga while only one (Oliver, 1962) was sited in southeastern New York. As a result, stratigraphers and paleontologists alike tend to have a somewhat skewed impression of Onondaga paleogeography, a situation we hope this field trip will partially rectify.

LITHOSTRATIGRAPHY

In the central New York type area the Onondaga unconformably overlies Lower Devonian carbonates of the Helderberg Group. In that area the formation's members are lithologically distinct from one another. The lowermost Edgecliff bed(s) is a calcareous and phosphatic quartz arenite which grades upward into the typical thick-bedded, light-gray, Edgecliff biosparites. The typical Nedrow lithology is a thin-bedded, dark-gray, argillaceous, fine-grained limestone. This grades upward into the coarser grained, thin to medium-bedded, dark-gray, cherty and argillaceous limestone typical of the Moorehouse. The Moorehouse is overlain by the (a) Tioga Bentonite which is succeeded by dark gray, fine to medium-grained limestones of the Seneca Member. While the uppermost Seneca becomes increasingly argillaceous, it includes a regionally extensive "bone bed" and shows signs of erosional truncation prior to deposition of the overlying Union Springs Shale.

Type lithologies of the four members do not extend into eastern New York. Oliver (1954, 1956) found that the lower Edgecliff beds are gradational with the Schoharie Formation in the east and that the contact is best recognized based on fauna. The argillaceous Nedrow beds extend eastward only to the approximate longitude of Cherry Valley, beyond which they grade into an Edgecliff lithology. Similarly, the Moorehouse is much like Edgecliff in the Helderberg area. The Seneca Member pinches out east of Cherry Valley, though Rickard (personal communication, 1980) found it to be present in the subsurface of southeastern New York.

Oliver (1956, 1962) found that lateral facies changes into eastern New York necessitated the use of faunal criteria in recognizing the individual members. He also found a pronounced thickening of the formation into eastern, and to an even greater degree into southeastern, New York (Table 1). Oliver recognized the eastern Edgecliff beds by the presence of large crinoid columnals, the Nedrow on the basis of numerous platyceratid gastropods and the Moorehouse by its brachipod-dominated fauna and abundant black chert. However, Lindemann (1979, 1980) found platyceratids to be more common in the cherty Moorehouse beds than in the Nedrow. Be that as it may, fossils remain the best criteria for correlation, particularly in southeastern New York where outcrops are small and few and the entire formation is fine-grained. There, at least, the Edgecliff's crinoid columnals persist despite the non-typical lithology. These can be traced into the Buttermilk Falls Formation of Pennsylvania (Oliver, 1962). Pronounced facies changes in the Onondaga-equivalent strata of southeastern New York prompted Rickard (1975) to assign those strata to the Buttermilk Falls. While this is prudent lithostratigraphy, we will refer to them as Onondaga due to their significance in paleogeographic reconstruction.

Table 1. Representative thicknesses (in feet) of the Onondaga Limestone and its members in eastern New York.

	Syracuse	Helderbergs	Leeds	Saugerties	Port Jervis
Seneca	25	-	-	-	-
Moorehouse	25	70	37+	100+	190+
Nedrow	15	15	43	34	?
Edgecliff	22	30	36	36	30?
Total	87	115	116	170	200+

LITHOFACIES

To facilitate the interpretation of depositional environments, Lindemann (1980) identified six carbonate lithofacies on the basis of relative abundances of calcisiltite, bioclasts, cement, argillaceous mud and pyrite as pointcounted in thin section. While all of the lithofacies are described below, only three are well-represented in eastern New York and figure directly in this discussion. As the

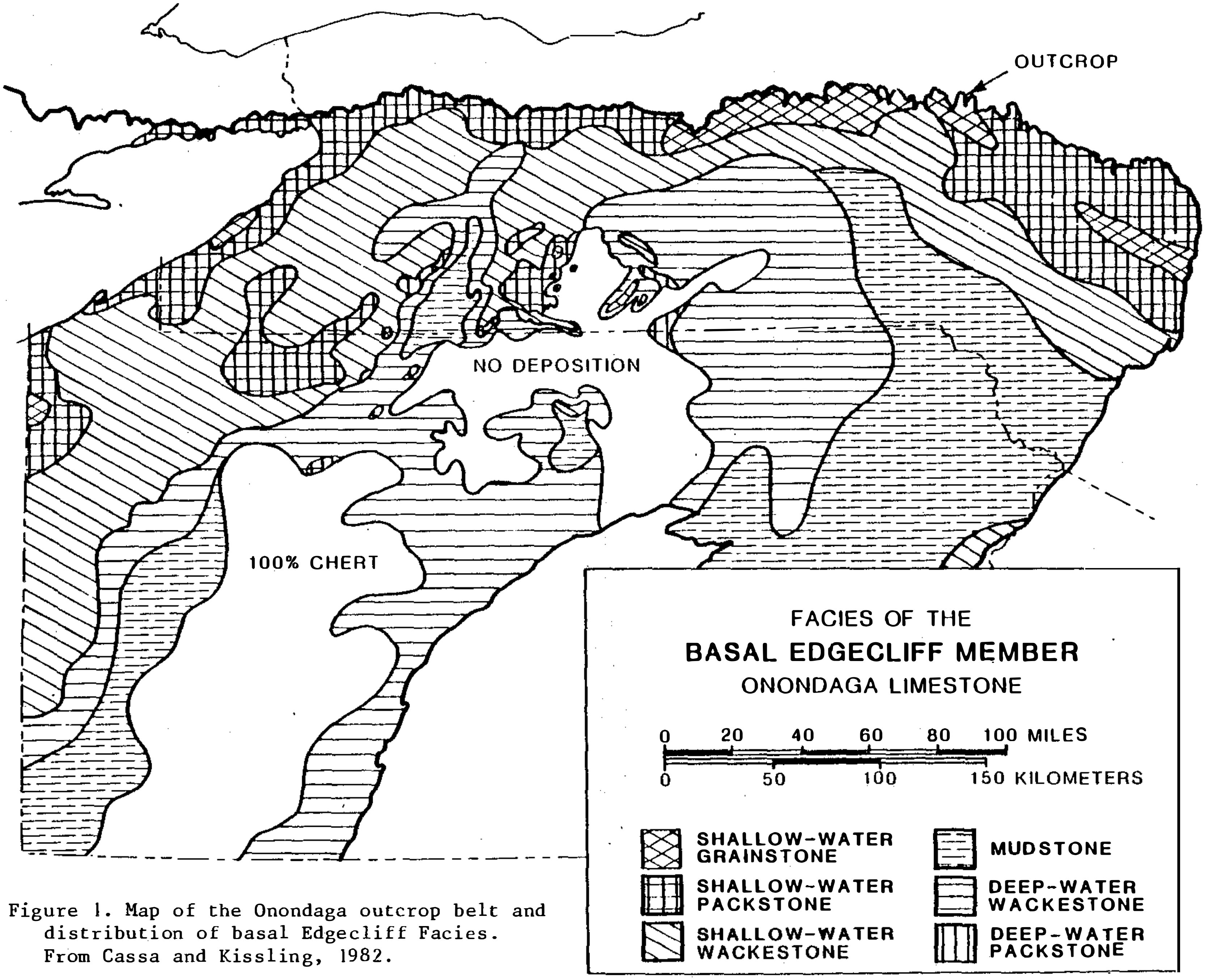


Figure 1. Map of the Onondaga outcrop belt and distribution of basal Edgecliff Facies. From Cassa and Kissling, 1982.

lithofacies do not exactly correspond to formally named carbonate lithologies, they are referred to by Roman numerals and mean abundances of their constituents are shown in Table 2. Note that the Roman numerals used herein do not correspond to those of Lindemann (1979) but do correspond to those of Lindemann (1980) as well as Feldman and Lindemann (1986).

Lithofacies I. Lithofacies I consists of thick-bedded to massive, medium-gray, sparce and packed biocalcisiltites. Terrigenous mud tends to be concentrated in styolites and is otherwise scarce. While crinoids and fenestrate bryozoans are dominant fossils in thin section, the ramose bryozoan Fistulipora dominates the fauna as seen in outcrop. Some specimens are encrusted by a calcareous alga similar in morphology to Sphaerocodium. Chondrites, small vertical burrows, and calcarenite-filled grooves on bedding surfaces dominate the ichnofauna. Intimately associated with Lithofacies II and VI, Lithofacies I occurs most commonly in the Leeds to Saugerties area. Except for occurrences in the Moorehouse of the Helderbergs and westernmost New York it is not commonly encountered.

Lithofacies I is interpreted as having been deposited in fairly quiet, slightly turbid waters. Occasional reworking of the sediment by storm waves is indicated by thin shell-layers and by the presence of spar cement in some samples. At Leeds this lithofacies alternates with Lithofacies VI and both are associated with a Fistulipora-dominated community which persisted from early Edgecliff to late Moorehouse time. As will be more thoroughly discussed later, the Onondaga in this area is interpreted as a sequence of bryozoan bafflestone biostromes which grew at a rate comparable to that of basinal subsidence.

Lithofacies II. Lithofacies II consists of medium-bedded to massive, medium-gray packed bioclacisiltites. Crinoids and bryozoans dominate the fossils in thin section and in the field. Intimately associated with Lithofacies I and VI, and occurring in the Edgecliff throughout the state and the upper Onondaga to the east and west, Lithofacies II differs from the former and latter in abundances of fossil debris and spar cement respectively. There are additional faunal differences, particularly in western New York, but these do not figure in this description.

Lithofacies II is interpreted as having been deposited under nonturbid carbonate shelf conditions quieter than, but similar to, those of Lithofacies VI. Stratigraphic distribution and association with other moderate energy lithofacies indicate that II was generally deposited just offshore from, or in slightly deeper water than VI. With the possible exception of occurrences in the Clarence Member of western New York, lagoonal conditions are not indicated.

Lithofacies III. Lithofacies III consists of laminated to medium-bedded, dark-gray, argillaceous calcisiltite, fossiliferous calcisiltite and sparse biocalcisiltite. The pyrite content of this lithofacies does not exceed one percent in central New York.

Comminuted crinoids and trilobites dominate the megafossils in thin section and the microfossil Styliolina fissurella reaches its maximum abundance. Fossils are occasionally concentrated in thin stringers associated with argillaceous laminae. However, most fossil fragments were scattered by intense bioturbation. This lithofacies predominates in the Nedrow of central New York and in the Moorehouse elsewhere in the state. It does not occur east of Cobleskill.

Lithofacies III is interpreted as having been deposited in quiet, moderately turbid water offshore from Lithofacies VI and II. Restricted circulation and low oxygen levels are not indicated. The sediment's fine grained nature suggests a flocculent or soupy sediment-water interface, a condition not particularly conducive to colonization by the larvae of sessile organisms. This accounts for the relative abundance of calcisiltites and planktonic styliolines.

Lithofacies IV. Lithofacies IV consists of thin to medium-bedded, dark gray, moderately argillaceous fossilferous to sparse biocalcisiltites. Fenestrate bryozoan and crinoid debris dominate the fossils seen in thin section while brachiopods and trilobites dominate the fauna seen in outcrop. The ichnofauna includes a diverse set of small horizontal burrows and Chondrites. Relatively coarse-grained lag deposits and cross laminae are present in some beds. Lithofacies IV is common only in the Clarence Member of western New York and the Moorehouse of the Cherry Valley-Schoharie area.

Lithofacies IV is interpreted as having been deposited in quiet, moderately turbid waters. Though calcisiltite abundances far exceed those of fossils, it appears that bottom conditions were not as quiet as those of Lithofacies III and that storm-generated waves often reworked the sediment. Occurrences of Lithofacies IV in the Clarence Member are interpreted as lagoonal deposits while occurrences in the Moorehouse at Cherry Valley are interpreted as shelf margin or transitional deposits between the shallow shelf to the east and the Appalachian Basin to the west.

Lithofacies V. Lithofacies V consists of laminated to medium-bedded, dark-gray, highly argillaceous fossiliferous calcisiltites and sparse biocalcisiltites. Trilobites dominate the fossils in thin section and share dominance with brachiopods in field observations. Chrondrites and general signs of bioturbation are abundant. This facies is virtually restricted to the Moorehouse and Seneca members of central New York where it is intimately associated with Lithofacies III. It differs from III in containing about twice as much argillaceous mud and slightly more pyrite (Table 2).

Lithofacies V is interpreted as having been deposited in quiet, relatively deep and turbid water in or near the subsiding axis of the Appalachian Basin. Because this facies occurs in the area representing the lowest rate of sedimentation for the formation, (probably less than half that of some sites to the east for example) the magnitude of real day-to-day turbidity required to attain its approximately 20 percent argillaceous content is uncertain. While fluctuations in argillaceous influx are evident as shale laminae, it appears that the depositional conditions of Lithofacies V differ from those of III primarily in geographic proximity to the relatively carbonate-starved and more restricted axis of the Appalachian Basin.

Lithofacies VI. Lithofacies VI consists of thick-bedded to massive, light-gray, poorly washed to sorted biosparites. Varying abundances of quartz sand, glauconite, and phosphorite nodules are present in samples from the lower beds of the Edgecliff Member. Comminuted crinoids and bryozoans dominate the fossils seen in thin section and macrofossils vary as this lithofacies occurs with both coral- and bryozoan-dominated communities. Rare cryptalgal laminae and calcareous algae are present. While evidence of bioturbation is rarely observed, vertical burrows are common as are shell lag concentrations and cross-laminae. This lithofacies is characteristic of the Edgecliff throughout the state and also occurs higher in the formation in eastern and western New York. It dominates the Nedrow and lower half of the Moorehouse in the Helderbergs and alternates with Lithofacies I at Leeds. It has not been observed at any horizon in the Onondaga south of Leeds.

Lithofacies VI is interpreted as having been deposited under shallow shelf conditions in wave-agitated waters of very low turbidity.

Table 2. Mean percent abundances of Onondaga lithofacies constituents.

Facies	Calcisiltite	Bioclasts	Cement	Detrital Mud	Pryite
I	50	38	2	7	1
II	38	53	3	4	1
III	84	2	0	10	2
IV	74	16	<1	7	1
V	67	10	0	21	2+
VI	15	61	21	4	1

THE ONONDAGA/BAKOVEN CONTACT

Contacts between the Onondaga Limestone and overlying black shale units are few and far between, only one (Locality 7) is known in the area of this field trip. This horizon is deserving of detailed consideration as conclusions drawn from it have far-reaching significance. Oliver (1956) judged the Moorehouse/Bakoven contact to represent only a minor break in deposition. However, Chadwick (1944, p. 103) described the contact as a "calcarenyte of tiny crinoidal fragments, black in color like the shale and containing also comminuted fish remains with an occasional brachiopod shell seemingly reworked from the limestone beneath. The basal (Bakoven) contact here shows this bed bonded into solution pitting in the limestone, indicating a distinct break and disconformity."

The uppermost Moorehouse bed is a medium dark-gray, sparse to packed bioclacisiltite containing trilobite, brachiopod, and crinoid fragments along with a few phosphatic particles. Authigenic quartz and silicified brachiopods are common, while unquestionably-detrital quartz silt is uncommon. Terrigenous mud constitutes less than six percent of the rock's weight and organic matter makes up an additional three to six percent. Typical of the upper Moorehouse in the mid-Hudson Valley, terrigenous mud is concentrated in microstyolites, giving weathered exposures a "shaly" appearance. This is the case at Locality 7 where this uppermost Onondaga bed is a Lithofacies I limestone typical of the area. It is significant that this does not resemble Lithofacies V of the upper Onondaga in central New York.

Chadwick's crinoidal "calcarenyte" abruptly overlies the Moorehouse. This horizon is approximately 1 cm thick and bears little resemblance to the Onondaga below or the Bakoven above. While the rock is packed with crinoid fragments, it is unlike Onondaga lithologies in that both spar cement and calcisiltite are absent. About 7% of the rock volume consists of fish remains; quartz silt and sand constitute an additional 5%. It is worth noting that quartz sand does not occur above or below this horizon. The original thickness and terrigenous percentage of this horizon remain uncertain due to an unusually intense intergranular pressure solution between crinoid particles. What does this "bone bed" represent?

The upper Onondaga of the central Hudson Valley is a sequence of bryozoan bafflestones interbedded with normal sparse to packed biocalcisiltites, deposited marginal to a carbonate shelf. Open circulation in a fairly quiet environment near wave base are indicated by both fauna and lithology. The Bakoven, on the other hand, is a black, carbonaceous shale which emits a petroliferous odor from freshly broken specimens. The fauna is dominated by planktonic forms including Styliolina fissurella and "Tentaculites" cf. gracilistriatus. Signs of bioturbation are absent, to the extent that current-oriented styliolines were not disturbed. These characteristics are consistant with deposition in a stratified, dysaerobic, quiet-water environment. Pedersen, et al. (1976) interpret the Bakoven as a distal basin deposit consisting of the first and stratigraphically lowermost muds of the Catskill Delta complex. They also note that there is a problem with this interpretation. If there is validity to Walther's law of the correlation of facies (Middleton, 1973), as applied to vertical sedimentary sequences, the lithologically abrupt contact between a shallow-water to moderate-depth carbonate and a distal basin black shale facies must represent a disconformity of pronounced magnitude. It is certain that the contact is disconformable and clear that the "bone bed" was deposited on an already lithified Onondaga. However, many Bakoven styliolines contain pyritic steinkerns indicating that they settled to the bottom with their cellular material intact. While we have no data on what might be a soft tissue compensation depth for styliolines, the extremes of distal basin habitat would almost certainly exceed it. We suggest that the Onondaga/Bakoven contact is a disconformity representing a relatively brief time span during which rapid crustal subsidence, to a shallow or proximal basin depth position beneath storm-wave base, resulted in stratification of the water column and a dysaerobic benthic condition conducive to the eradication of a benthic fauna and deposition of black shale. Savarese, et. al. (1986) suggest a deepening event starting at 20-25m and finishing at 100-150m for roughly similar limestone/shale contacts in the Hamilton group of central and western New York. Further interpretation of the contact is presently premature.

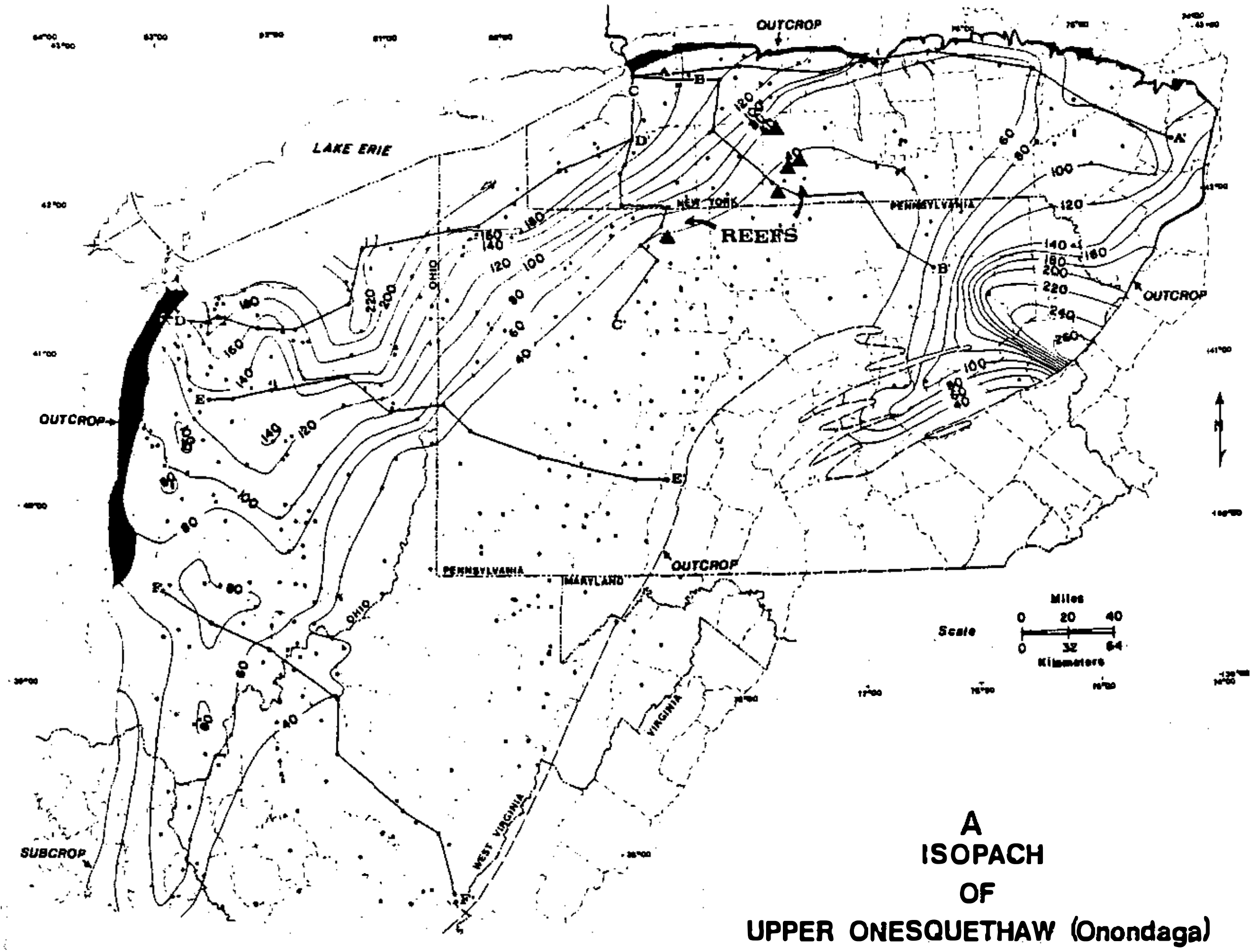
PALEOGEOGRAPHIC SETTING

Buffalo to the Helderbergs

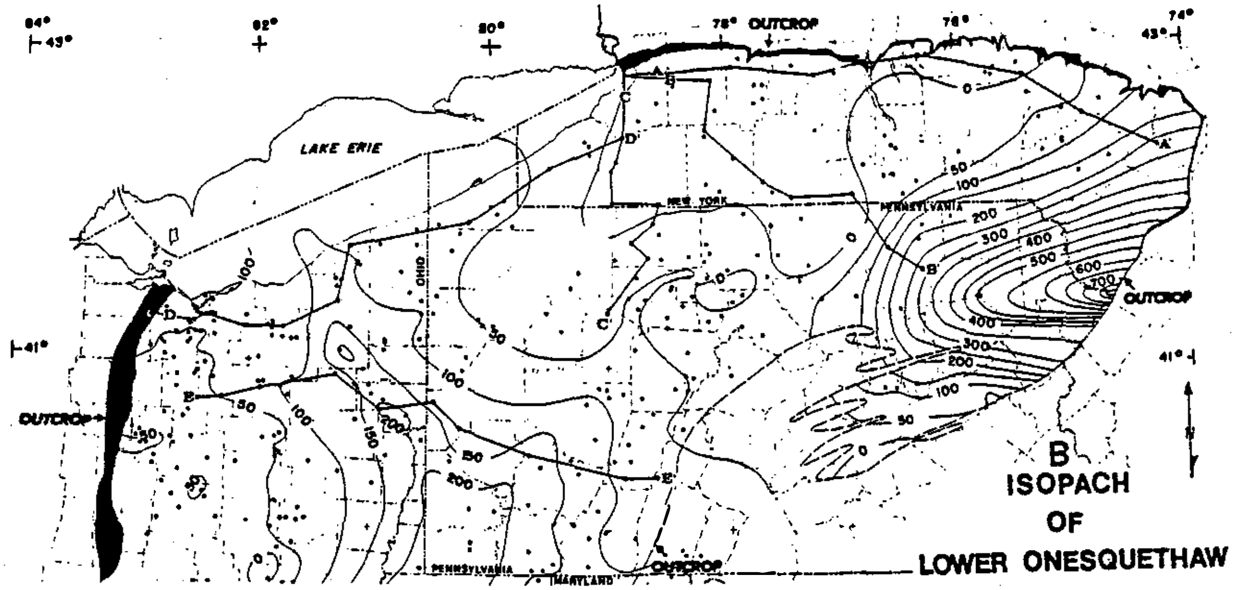
Understanding of Onondaga paleogeography, as studied in east-west outcrop, has not changed substantially since the work of Oliver (1954, 1956), Lindholm (1969) and Laporte (1971). A short-lived late Emsian regression of the sea to a position in eastern New York left the western and central areas of the state subaerially exposed. Early in the Eifelian, assuming that the entire Onondaga is Middle Devonian, a transgression submerged the region initiating Edgecliff deposition in a shallow shelf environment. Shortly thereafter subsidence in central New York, resulting from a northward extension of the Appalachian Basin, brought a deeper water, or offshore, environment to that area. The initial pulses of subsidence are recorded in the Nedrow Member, while continued subsidence is recorded in the Moorehouse and Seneca members of central New York. However, the eastern and western parts of the state remained in shallow shelf conditions throughout Onondaga deposition. Thus, post-Edgecliff paleogeography, as seen in east-west outcrop, consists of a symmetric shelf-basin-shelf pattern. Subsurface studies (Kissling and Moshier, 1981; Cassa and Kissling, 1982) indicate that deposition took place on a carbonate ramp dipping predominantly southward into the Appalachian Basin and that east-west outcrop roughly parallels depositional strike for at least Edgecliff time (Fig. 1).

The Helderbergs to Port Jervis

To understand Onondaga paleogeography in eastern and southeastern New York it is helpful to establish a context in the mid-Silurian and proceed up section. The Middle Silurian Shawangunk Conglomerate thins from approximately 1500 feet in northern New Jersey (Wolfe, 1977) to a pinchout just north of Rosendale, New York. A roughly similar pattern is evident throughout the Upper Silurian and Lower Devonian. As an arbitrary example of what this means in terms of despositional environments and an onshore-offshore orientation, Waines (1976) reports that the Silurian Binnewater Sandstone not only thickens to the south of Kingston, New York, but it also becomes increasingly dolomitic as the unit grades southward from supratidal to intertidal and shallow marine facies. During deposition of the Lower Devonian section the onshore direction



A
ISOPACH
OF
UPPER ONESQUETHAW (Onondaga)



B
ISOPACH
OF
LOWER ONESQUETHAW

Figure 2. Isopach maps of Upper Onesquethaw (A) and Lower Onesquethaw (B) strata. C.I. = 50 ft. From Mesolella, 1978.

shifted to the northwest (Anderson, 1971), an orientation which lithostratigraphy (Rickard, 1975) and subsurface isopachs (Fig. 2B) (Mesolella, 1978) indicate persisted until the Middle Devonian.

It is generally acknowledged that during Onondaga deposition the axis of the Appalachian Basin migrated into central New York. This shows up clearly in the distribution of Onondaga lithofacies and in subsurface isopachs (Fig. 2A). However, to clarify eastern New York paleogeography it is necessary to discriminate between "topographic" and "structural" basins. Mesolella (1978) defines a topographic basin as the area of deepest water and a structural basin as the area of greatest sediment accumulation, implying greatest crustal subsidence. As previously discussed, the preponderance of Lithofacies V in the upper Onondaga in central New York is the direct result of deposition in proximity to the carbonate starved axis of the Appalachian (topographic) Basin. However, Lithofacies V is absent from eastern New York at least as far south as the Mid-Hudson Valley where it is replaced by the coarser-grained and less argillaceous Lithofacies I and II. Even the most offshore Onondaga facies in eastern New York, the Buttermilk Falls Limestone, is interpreted as a "shallow marine basin" (Wolfe, 1977). And yet the greatest sediment accumulation is centered in, or just south of, the Port Jervis (Tristates) area (Fig. 2A). This was the focus of a subsiding structural basin not directly related to the topographic basin of central New York. This structural basin, which had existed since the Middle Silurian, exerted a pronounced influence on Onondaga deposition in eastern New York by establishing a paleogeographic pattern of a shallow carbonate shelf in the Helderberg-Coxsackie area, a thick accumulation of shelf-margin bryozoan bafflestones between Leeds and Saugerties and an even thicker accumulation of sparse to packed biocalcisiltites deposited on a carbonate slope or ramp dipping into the Port Jervis area. Apparently water depths on this slope were never great, at least within the field trip area, prior to the subsidence event which set the stage for deposition of the Bakoven Shale.

MEGAFOSSILS OF THE ONONDAGA LIMESTONE IN SOUTHEASTERN NEW YORK

Collecting megafossils in the Onondaga Limestone in southeastern New York presents certain problems not inherent in the central part of the state. For example, there in no shaly Nedrow facies from which well-preserved specimens weather out and there are few quarries which allow for extensive collecting on bedding surfaces. Most of the exposures in the Mid-Hudson Valley are vertical and weather slowly. The limestone is quite dense with little shale, consequently megafossils, although observable in cross section, are difficult, if not impossible to remove without damage to the specimen. However, one of the advantages of collecting in the southeastern part of the state is the occurrence of silicified fossils in parts of the Mid-Hudson Valley. During this trip we expect to sample some of these silicified outcrops and blocks may be taken for subsequent etching in hydrochloric (or muriatic) acid. Brachiopods (Table 3; Figs. 3,4) and corals (Table 4) are the most dominant megafossils that we will collect from the Onondaga and therefore will be treated in more detail than other taxa (Table 5).

Brachiopods

Acrospirifer duodenaria - Biconvex shells transversely subelliptical in outline; hinge line long and straight; medial open delthyrium with no preserved deltidial plates; pedicle valve bears narrow, triangular, moderately deep, noncostate sulcus; brachial valve bears corresponding fold; five to six rounded plications on each pedicle flank with U-shaped interspaces; anterior commissure uniplicate.

Ambocoelia sp. - Small, ventribiconvex shells; pedicle valve with weak sulcus; beak incurved; hinge line straight, delthyrium open; brachial valve slightly convex with no ornamentation; anterior commissure rectimarginate to uniplicate to slightly intraplicate.

Athyridacean indet. - Small, ovate shells with laterally directed spiralia; crura united with primary lamellae by pair of S-shaped loops; most closely resemble the Meristellidae.

Athyris sp. A -Shells transversely suboval in outline, and subequally biconvex with pedicle valve slightly deeper than brachial valve; ventral beak suberect terminating in, small round foramen; brachial beak smaller and less noticeable; pedicle valve bears shallow sulcus with corresponding low fold on brachial valve; anterior commissure weakly uniplicate; some forms nonsulcate and rectimarginate; fine, concentric growth lines on both valves.

Athyris sp. B - Differ from *Athyris* sp. A in its larger size, subparallel dental plates and narrow muscle field.

Atribonium halli - Shells small, nonstrophic, impunctate and subpentagonal in outline; beak short curved, rounded and suberect; commissure uniplicate with high brachial fold and deep pedicle sulcus; costae weak, rounded; small pedicle foramen and triangular delthyrium.

Atrypa "*reticularis*" - Dorsibiconvex shells with well rounded radial costellae which increase in size and number anteriorly; costellae separated by U-shaped interspaces; concentric growth lamellae cross costellae becoming more distinct and frilly anteriorly; anterior commissure rectimarginate or slightly deflected towards brachial valve.

Atlanticocoelia acutiplicata - Subcircular in outline with length almost equal to width; brachial valve gently convex, pedicle valve slightly more so; weak pedicle sulcus sometimes noticeable on larger specimens; no corresponding dorsal fold; hinge line very short and becomes rounded anteriorly; no interareas present; anterior and lateral commissures crenulate; ten to

Table 3. Brachiopods of the Onondaga Limestone in southeastern New York (from AMNH Loc. 3132 [Thompson's Lake] to AMNH Loc. 3151 [Wawarsing]; See Feldman, 1985, for index map of localities and locality descriptions.)

Taxon	Common	Rare	Very Rare
Acrospirifer duodenaria	X		
Ambocoelia sp.			X
Athyridacean indet.			X
Athyris sp. A		X	
Athyris sp. B			X
Atribonium halli			X
Atrypa "reticularis"	X		
Atlanticocoelia acutiplicata			X
"Chonetes" aff. lineata			X
Coelospira camilla	X		
Cupularostrum? sp. A		X	
Cupularostrum? sp.B			X
Cyrtina hamiltonensis		X	
Cyrtina sp. A			X
Dalejina aff. alsa		X	
Discomyorthis? sp.			X
Elytha fimbriata		X	
Eospiriferid? indet.			X
Gypidula sp.			X
Leptaena aff. "rhomboidalis"	X		
Levenea aff. subcarinata		X	
Megakozlowskiella raricosta	X		
Megastrophia sp.		X	
Meristina cf. nasuta			X
"Mucrospirifer" cf. macra		X	
Nucleospira aff. ventricosa	X		
Orthotetacid indet.			X
Pentagonia unisulcata		X	
Penatmerella arata		X	
Rhipidomella?			X
Rhynchospirina sp.			X
Schizophoria cf. multistriata		X	
"Schuchertella" sp.			X
Strophodonta cf. demissa		X	
Stropheodontid indet.			X

Note: Although this table denotes relative abundance of brachiopod taxa in the central part of the state in terms of common, rare and very rare, it should be noted that some species are more abundant in specific horizons or beds and are relatively rare throughout the remainder of the formation. For example, Levenea occurs abundantly in Wawarsing, New York, but sporadically in the rest of the southeastern exposures of the Onondaga.

Table 4. Corals of the Onondaga Limestone in southeastern New York.

Taxa	Common	Rare
Tabulates		
Aulocystis (=Ceratopora)	X	
Aulopora	X	
Favosites	X	
Striatopora	X	
Rugosans		
cf. Amplexiphyllum	X	
Acinophyllum	X	
Breviphrentis	X	
Cystimorph?		X
Heliophyllum	X	
"Heterophrentis"	X	
cf. Syringaxon	X	

Table 5. Other faunal constituents of the Onondaga Limestone in southeastern New York.

Taxa	Common	Rare	Very Rare
Gastropods			
Platyceras dumosum	X		
Platyceras (Platystoma)	X		
Platyceras sp.	X		
Pseudophoracean indet.		X	
Ecculiomphalus			X
Loxonema			X
Trilobites			
Phacops cf. cristata	X		
Dalmanitid fragments			X
Indet. fragments	X		
Crinoids			
Non-pinnulate inadunate ossicles	X		
Camerate columnals	X		
Bryozoans			
Dyoidophragma			X
Sponges			
Hindia	X		

twelve plications with U-shaped interspaces; concentric growth lines, two or three per shell, common on ephebic forms.

"Chonetes" aff. lineata - Shells small, subsemicircular in outline and concavoconvex in lateral profile; interareas very narrow; no delthyrial structures preserved; greatest width at hinge line or anterior to midlength; valves covered with fine capillae which increase anteriorly by bifurcation.

Coelospira camilla - Small, concavoconvex to planoconvex, subcircular to suboval in outline; small, distinct pedicle foramen on incurved pedicle beak; no interarea evident; maximum width about one-third valve length in adults; pedicle valve bears two medial plications usually at least as large as remaining radial plications on flanks; interspaces U-shaped; brachial valve bears medial plication which generally bifurcates at one-third valve length; median interspace usually flat but sometimes bears small ridge; plications broader on flanks and thinner toward lateral commissure; several well-defined, concentric growth lines evident near anterior commissure in adult forms.

Cupularostrum sp. A - Shells small, equibiconvex, and subtrigonal to to transversely suboval in outline; pedicle beak erect to slightly incurved; delthyrium open, triangular with small foramen located apically; pedicle valev with sulcus and brachial valve with corresponding fold considerably weaker than sulcus; about 15 simple plicae U-shaped in cross section.

Cupularostrum sp. B - Externally identical with Cupularostrum sp. B except for lack of sulcus and fold.

Cyrtina hamiltonensis - Shells small, hemipyramidal in outline with straight hinge line; ventral interarea high, smooth; convex psuedodeltidium covers triangular delthyrium in most specimens; pedicle valve bears triangular, smooth sulcus with two or three rounded plications along flanks; brachial valve bears fold with three to four lateral plications; ornamentation consists of concentric growth lamellae.

Cyrtina sp. A -May be differentiated from Cyrtina hamiltonensis by larger size and more robust appearance.

Dalejina aff. alsa - Shells ventribiconvex, transversely suboval to subcircular in outline; hinge line very short and straight in apical area but becomes rounded as lateral margins approached; maximum width at or just anterior to midlength; pedicle valve bears slight median depression; brachial valve often bears corresponding median ridge; anterior commissure most often recti marginate to slightly sulcate; ventral interarea short, narrow; numerous radial costellae which increase anteriorly both by intercalation and bifurcation; at anterior commissure there are 18 to 20 costellae per 5 mm, near midline; costellae medially grooved, flat, occasionally crossed by concentric

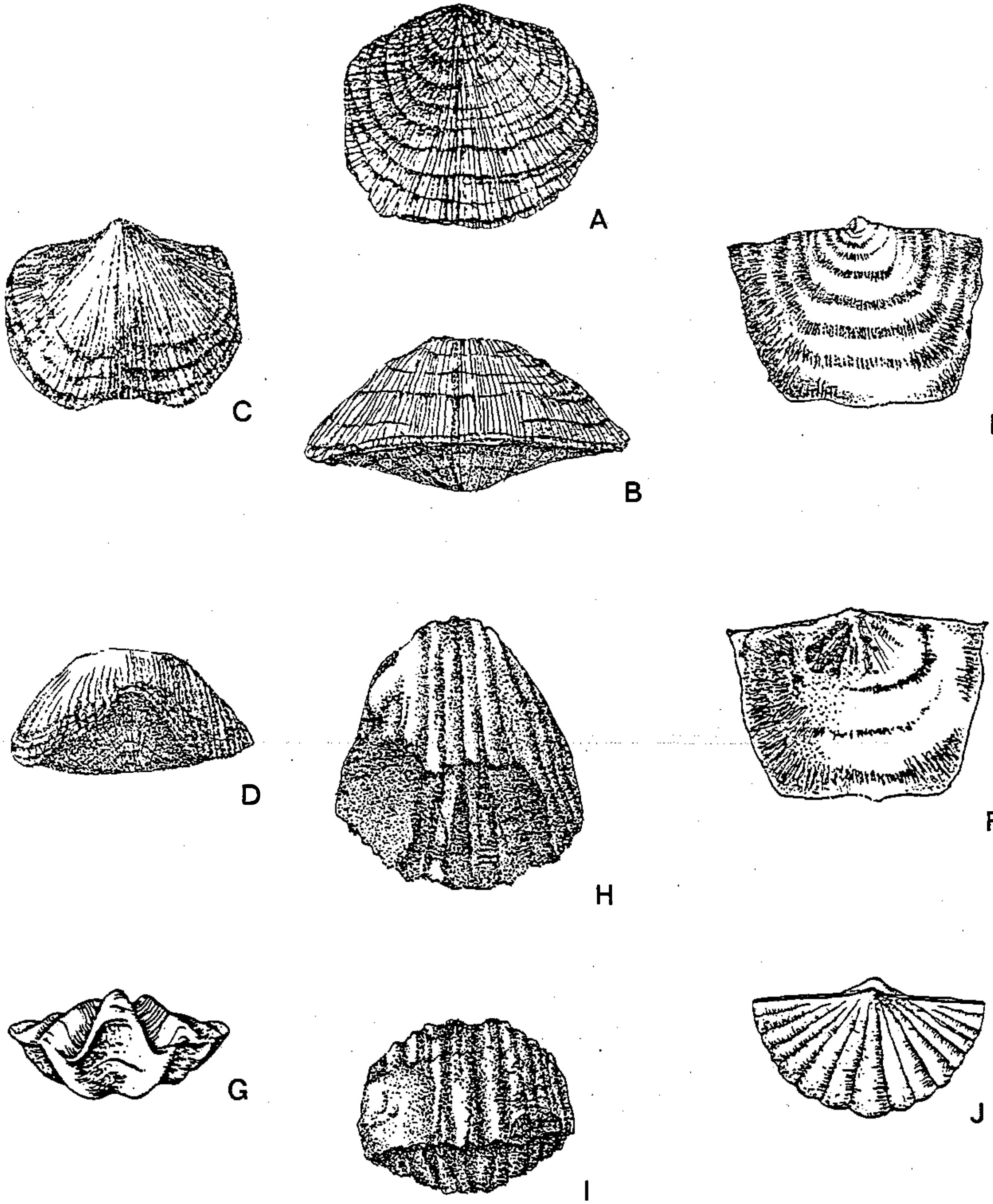


Figure 3. Brachiopods of the Onondaga Limestone in eastern New York. A,B. *Rhipidomella* sp., ventral and anterior views, X3. C,D. *Schizophoria* cf. *Multistriata*, ventral and anterior views, X1.5. E,F. *Leptaena* aff. "*rhomboidalis*," ventral exterior and interior, X1.5. G. *Megakozlowskiella raricosta*, anterior view, X1.25. H,I. *Pentamerella arata*, ventral and anterior views, X1.75. J. *Acrospirifer duodenaria*, dorsal view, X3. Modified from Dunn and Rickard (1961).

growth lines near anterior margins.

Discomyorthis? sp. - Similar to Dalejina in general morphology but may be differentiated by more circular outline and larger ventral diductors; pedicle valve bears well-developed pedicle callist and short, triangular hinge teeth; costellae medially grooved.

Elytha fimbriata - The shells are medium-sized, biconvex in lateral profile and transversely oval in outline; beak short and erect; pedicle valve bears shallow, triangular sulcus with corresponding low, rounded fold on brachial valve; faint plications cover lateral slopes; concentric growth lamallae cross plications and terminate in short, attenuated spines; anterior commissure uniplicate.

Eospiriferid indet. - Extremely rare in the formation and represented by only one pedicle valve which is convex, moderately transverse, sulcate, plicate and covered by fine radiating striae; delthyrium triangular with possible deltidial plates.

Gypidula sp. - Elongate oval to subcircular in outline; pedicle valve swollen; costate to multicostate; almost identical to Pentamerella arata (see description below) but can be differentiated by a pedicle fold and brachial sulcus whereas Pentamerella has a pedicle sulcus and brachial fold.

Leptaena aff. "rhomboidalis" - Transversely subquadrate in outline, concavoconvex to slightly biconvex with pedicle valve strongly geniculate at anterior and lateral commissures; brachial valve correspondingly geniculate within pedicle trail; hinge line straight, pedicle interarea flat; ornamentation consists of radial costellae which extend past point of geniculation and continue on trail of valves; concentric rugae cross costellae becoming larger anteriorly.

Levenea aff. subcarinata - Shells small to medium sized, transversely suboval in outline, ventribiconvex in lateral profile; brachial valve bears shallow, rounded sulcus which broadens anteriorly; maximum width at or just anterior to midlength; ventral interarea short, slightly incurved; triangular delthyrium encloses angle of approximately 60 degrees; delthyrium often widens apically into small, circular foramen; ornamentation consists of rounded, radial costellae which increase in number anteriorly by bifurcation.

Megakozlowskiella raricosta - Shells subtransverse in outline, strophic, medium to large, ventribiconvex; hinge line straight; pedicle interarea moderately narrow with striae which parallel hinge line; brachial interarea extremely narrow; distinct slightly flattened fold on brachial valve and corresponding deep, U-shaped sulcus on pedicle valve; commonly three plications on flanks; delthyrium includes angle of approximately 60 degrees; no deltidial plates preserved; anterior commissure uniplicate; strong, concentric growth lamellae with anterior frills; radial ornamentation consists of very fine striae.

Megastrophia sp. - Medium sized to large, subsemicircular to transversely suboval in outline; somewhat alate, concavo-convex in lateral profile; maximum width attained at hinge line; unequally parvicostellate to subuniformly costellate; psuedodeltidium flat, complete, with narrow median ridge; chilidium flat, complete, with median ridge; hinge entirely denticulate.

Meristina cf. nasuta - Convex, elongate and suboval in outline with no noticeable interarea; Unequally biconvex, with pedicle valve much deeper than brachial valve; maximum width commonly anterior to midlength; delthyrium broad, triangular and opens apically into semicircular foramen; faint pedicle sulcus modified by development of low, rounded medial plication that extends anterior commissure in tongue-like projection; concentric growth lamellae evident at anterior portion of valves but remainder of shell smooth.

"Mucrospirifer" cf. macra - Small to large alate shells transversely subtrigonal to subsemicircular in outline; biconvex in lateral profile with brachial valve slightly flatter than pedicle valve; ventral interarea moderately high, long, somewhat curved; ventral beak, posterior to interarea, short and stubby; open, triangular delthyrium present which divides interarea medially; dorsal interarea long, thin, ribbon-like; brachial valve bears high, medial fold flattened at top; pedicle valve bears corresponding U-shaped sulcus; surface of shells covered by sharply defined plications ranging from U-shaped to subangular in cross section; numerous, concentric, frilly growth lines present; no fine radial ornamentation.

Nucleospira aff. ventricosa - Small, transversely suboval in outline, biconvex in lateral profile with pedicle valve slightly deeper than brachial valve; hinge line curved; brachial beak fits into anterior end of delthyrium which is partially covered by concave pseudodeltidium in some specimens; both beaks erect, no interarea evident; shell surface lacks radial ornamentation; no fold or sulcus present; pedicle valve shows faint median depression in some specimens; concentric growth lamellae present, more concentrated towards rectimarginate anterior commissure.

Orthotetacid indet. - Small to medium sized shells, generally poorly preserved as internal impressions; hinge line straight; ornamentation finely costellate.

Pentagonia unisulcata - Medium sized, nonstrophic, pentagonal in outline when viewed posteriorly; beak suberect, dorsibiconvex with greatest width attained between midlength and anterior commissure; brachial valve cariniform due to presence of raised, rounded fold bearing narrow, median groove; in some forms groove

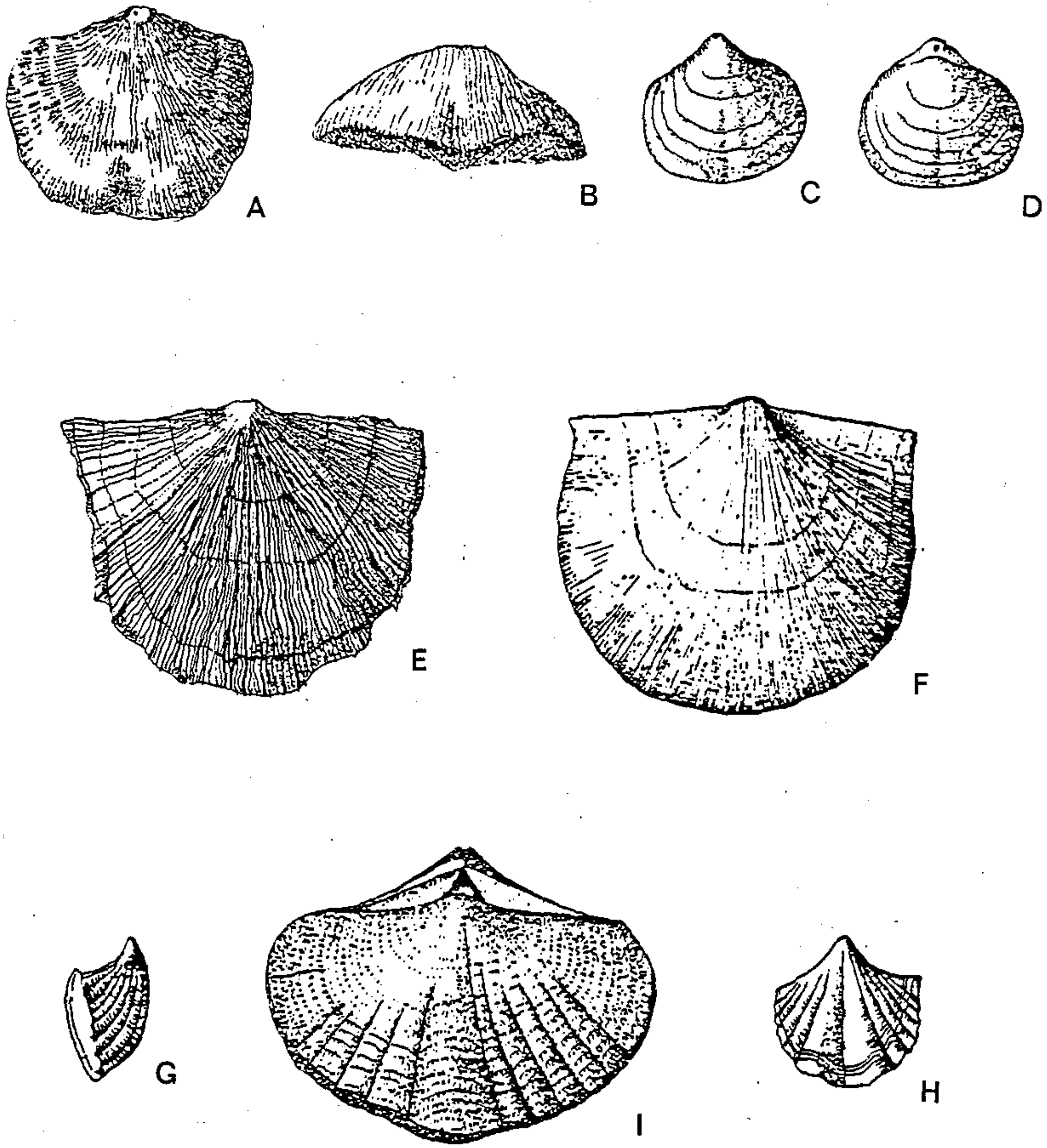


Figure 4. Brachiopods of the Onondaga Limestone in eastern New York. A,B. *Schuchertella* sp., ventral and anterior views, X1.75. C,D. *Athyris* sp. A, ventral and dorsal views, X2. E. *Megastrophia* sp., ventral view, X2. F. *Strophodonta demissa*, ventral view, X3. G,H. *Cyrtina hamiltonensis*, lateral and ventral views, X2. I. *Elytha fimbriata*, dorsal view, X3. Modified from Dunn and Rickard (1961).

widens slightly anteriorly forming two parallel to subparallel ridges extending almost half the valve length; flanks concave, dropping steeply away from sulcate fold; sulcus broad, shallow with two distinct ridges which define sulcus laterally and extend from umbo across posterolateral margins of flanks to uniplicate anterolateral commissure; vague, concentric growth lines on anterior portion of shell.

Pentamerella arata - subglobose and broadly pyriform in outline with strongly convex pedicle valve and weakly convex brachial valve; hinge line short, curved, narrow; no interarea evident; pedicle valve beak short, strong, incurved, not closely pressed against brachial beak; brachial beak small, less erect and less incurved; maximum width attained at or about midlength; weak sulcus present on anterior half of pedicle valve with corresponding fold on brachial valve (note: this morphological feature is the key to differentiating Gypidula from Pentamerella; see Gypidula above); both valves ornamented with numerous, rounded, bifurcating plications which become narrower on lateral slopes than near midline; interspaces between plications U-shaped and wider than plications which tend to become slightly V-shaped in cross section on some specimens; About 5 plications in sulcus and 6 on fold; concentric growth lines more numerous anteriorly.

Rhipidomella - Subcircular in outline, dorsibiconvex, delthyrium open; costellae cylindrical in cross section, not grooved; fold and sulcus weak, if present at all.

Rhynchospirina sp. - Shells small, pyriform in outline and biconvex in lateral profile; pedicle beak erect with small permesothyridid foramen; weak sulcus on pedicle valve but no corresponding fold on brachial valve; anterior commissure slightly uniplicate; normally about eight subangular plications with subangular interspaces.

Schizophoria cf. multistriata - Shells medium sized, suboval to subquadrate in outline, unequally biconvex; brachial valve deeper and more uniformly convex; in juveniles both valves become almost equally biconvex; pedicle valve develops broad, shallow sulcus on adult forms; brachial valve bears indistinct fold; hinge line short, slightly rounded; maximum width attained at or just past midlength; ventral interarea triangular, fairly high in larger shells, relatively narrow in younger ones; dorsal interarea narrower; interareas of both valves equal to about one-half width; ornamentation consists of rounded to subangular radial costellae with broad, flat interspaces; about 11 costellae in a 5 mm space near anterior commissure at midline.

"Schuchertella" sp. - Medium-sized, plano-convex to biconvex, transversely subelliptical in outline but subpyramidal in umbonal region; exterior multicostellate with costellae added by intercalation; interarea flat and broadly triangular; delthyrium covered by convex pseudodeltidium.

Strophodonta cf. demissa - Subcircular to shield shaped shells, concavoconvex in lateral profile; shells wider than long; point of maximum width at hinge line; lateral margins almost straight posteriorly; anterior margins evenly rounded; all margins crenulate; anterior commissure rectimarginate; costellae coarse, bifurcating with angular interspaces in cross section.

Stropheodontid indet. - Small, subcircular in outline, alate; Smooth exterior with irregularly spaced growth lines.

BRACHIOPOD LIFE STRATEGIES

The terminology used in this paper follows Bassett (1984) in which he reviewed the life strategies of Silurian brachiopods. Table 6 summarizes the main strategies under which the brachiopods of the Onondaga Limestone can be categorized but it must be noted that the classification is flexible. It is possible that several taxa may fit into different categories as ontogeny progressed since most brachiopods require an initial post-larval attachment to a hard bottom but may differ in post-larval development, especially in relation to the substrate. Ephebic or mature forms usually fall into a single category while immature forms may pass through more than one catagory during development.

Brachiopod specimens used in this study were collected from a variety of depositional environments and modes of preservation vary from well-silicified, to poorly-silicified to non-silicified forms. In addition, specimens were studied in situ in cases where removal from the field was impossible and successful extraction from the encasing matrix doubtful.

Quasi-infaunal Forms

Rudwick (1970) first used the term quasi-infaunal to describe strophomenid brachiopods that were partially buried or sank into sediment during ontogeny after initial hard-bottom attachment. These forms could become free-lying during burial or remain attached. A concavo-convex morphology is most typical of quasi-infaunal brachiopods found in the Onondaga Limestone. This occurred as a result of an alteration of growth rate later in ontogeny combined with an increased thickening of the convex valve (usually the ventral valve). The effect of this change in growth was to increase stabilization on the sea floor and prevent overturning by current action. In soft sediment, of course, the convex valve would have partially sunk in to a certain degree. During turbulence, sediment falling on the concave valve may have concealed the entire brachiopod except for the crescentic valve edges projecting above the surface of the sediment. If burial was too severe, a quick "snap" of the valves would have lifted it back and up, above the sediment-water interface. There are no known Recent examples of quasi-infaunal brachiopods, however, this mode of life would have been the closest to a truly infaunal habitat known for any of the articulates.

Table 6. Life strategies of ephebic brachiopods from the Onondaga Limestone.

LIFE STRATEGIES	NATURE OF SUBSTRATE
Endofaunal habits	
Quasi-infaunal	Partial burial in soft botttom
Epifaunal habits	
Fixosessile	
Plenipedunculate	Usually hard bottom
Rhizopedunculate	Hard or soft bottom
Epiphytic	Plants or plant-like structures
Liberosessile	
Ambitopic	Hard or soft bottom
cosupportive	Mutual support in dense clusters

Some forms, such as Cymostrophia cf. patersoni and Strophodonta demissa display a strong increase in curvature in adults so that the commissure was raised as burial increased. The most extreme increase in curvature is shown by Leptaena cf. "rhomboidalis" and Strophonella sp. which are both geniculated. It is conceivable that these brachiopods lived almost buried within the sediment with the commissure extended for feeding. A "snapping" action may not have been periodically necessary.

Leptaena depressa from the Silurian of the Anglo-Baltic region displays both both geniculation and folding, with the dorsally deflected anterior shell bearing a median fold. This fold is, in many instances, developed as a long trail able to extend well above the sediment-water interface. Indications of a trail are sometimes evident in Leptaena cf. "rhomboidalis" from the Onondaga. The brachiopod's efficiency in separating inhalant and exhalant water currents would have been increased by the presence of a trail.

Plenipedunculate Forms

The brachiopod pedicle was once thought to be a rather simple, relatively short, fleshy projection with a more or less constant diameter. However, recent workers have shed light on the tremendous variation in pedicle morphology (Bromley and Surlyk, 1973; Curry, 1981; Richardson, 1979, 1981). Variation in thickness and length is considerable, with expansion and contraction often occurring outside the shell so that foramen size is not necessarily a reliable guide to functional diameter or strength (Bassett, 1984). Nevertheless, the presence of an open pedicle foramen throughout life is indicative of a functional pedicle, presumably in all ontogenetic stages. Bassett

(1984) used the term plenipedunculate for brachiopods in which the pedicle is a single, unbranched muscular structure apart from its distal tip (included in which are groups 1 to 4 of Bromley and Surlyk [1973, pp. 350, 351]).

Most Recent brachiopods attach to hard bottoms by mucal adhesion of the distal tip of the pedicle which usually possesses hold-fast papillaeor terminal rootlets that are able to etch and penetrate carbonate substrates for additional attachment strength (Bromley and Surlyk, 1973). Specimens of Athyris collected from the Onondaga Limestone near Saugerties, New York, have an open, rounded pedicle foramen throughout ontogeny. The structure of the pedicle opening is very similar to that of Recent terebratulids and rhynchonellids, and therefore suggests a similar pedicle function.

Rhizopedunculate Forms

Bassett (1984) uses the term rhizopedunculate for those brachiopods in which the pedicle is branched into fine filaments throughout much of its length rather than only at the distal tip (eqiuvalent to groups 6 and 7 of Bromley and Surlyk [1973, p. 351]). Bromley and Surlyk (1973) studied the pedicles of Recent brachiopods and found that they etch a very characteristic trace, composed of a number of pits, into hard calcareous substrates. The trace in rhizopedunculate forms consists of a series of widely scattered pits corresponding to the rootlets of the pedicles. The fact that the pedicle is so variable and that it is able to dissolve carbonates implies that many brachiopods are capable of attaching themselves to a wide variety of substrates. This, in effect, means that many brachiopod-substrate relationships in paleoecology must be re-evaluated.

A well-known Recent example of a rhizopedunculate brachiopod is Chlidonophora, a terebratulacean, in which the pedicle rootlets have been found to penetrate Globigerina tests (Rudwick, 1970) and thereby become rooted into the foraminiferal ooze. The importance of this lies in the fact that the size of the pedicle foramen alone would not indicate the pedicle length (which is rather long in Chlidonophora chuni, for example) or the branching, root-like character of the pedicle. It is clear that this type of attachment may have been more common among Devonian articulate brachiopods than assumed by earlier workers. However, it is difficult to confirm that any Devonian forms were in fact rhizopedunculate, or even plenipedunculate, but it is possible to draw certain conclusions based on morphology and substrate.

The Moorehouse Member of the Onondaga Limestone in the Mid-Hudson Valley is though to represent a very soft-bottomed, lime mud substrate. It displays the greatest faunal diversity of all members of the Onondaga Limestone in the area. Many forms may have existed with rhizoid pedicles which were able to attach to local hard bottoms, such as shell fragments. For example, Atrypa "reticularis", Athyris and Leptaena "rhomboidalis" showed traces of a small pedicle foramen early in ontogeny which may have accomodated pedicles that acted in the capacity of tethers and which may have very well been rhizoid. This type of attachment would have permitted the brachiopods to utilize a wide range of substrates during Onondaga time.

All adult specimens of Mucrospirifer collected from the Onondaga Limestone had an open delthyrium with no evidence of a stegidium or modifying plates. It is therefore assumed that a functional pedicle was probably absent throughout all ontogenetic stages although the dimensions of the pedicle are unknown. Cowen (1968) correlated the decrease in function of the pedicle with an increase in the development of alae which acted to stabilize the shells on the substratum. Mucrospirifer may have possessed an inert pedicle, as described by Richardson (1981), similar to that of the Recent Magadina cumingi from southern Australia, in which the pedicle acted as a pivot around which the shell moved by contraction of the pedicle muscles. The inert pedicle may also have branched into fine filaments. Richardson's (1981) criteria for determining the relationships between pedicle and shell characters are useful for Recent forms but are not yet proven valid for fossil specimens. She noted that a straight beak with a wide, high deltidium is characteristic of species with an inert motile pedicle. This description is compatible with Mucrospirifer in that the deltidium is relatively high but the beak ranges from straight to suberect.

Epiphytic Forms

There have been reports in the literature (Rudwick, 1961, 1970; Foster, 1974) of brachiopods attaching themselves to various structures for support. Rudwick (1961) found shells of Terebratella sanguina dredged from a muddy bottom off the coast of New Zealand attached by their pedicles to the tangled, horny tubes of Phyllochaetopterus socialis, a chaetopterid worm. Hosts such as these would not normally be preserved as fossils but it appears probable that they were used in the past as they are used now. Some workers noted that certain thin-shelled, light weight brachiopods, such as Aegira grayi, could have floated or attached to drifting algae. Bergstrom (1968) believed that Shagamella ludlovensis was epiphytic on benthic algae. Silurian forms from England, such as Dicoelosia biloba, have been described (Wright, 1968) that were attached to a stick-like organic fragment (Bryozoan?).

Thin-shelled forms of Atribomium halli, Coelospira camilla and Ambocoelia found in the Moorehouse Member may have been epiphytic. However, it seems clear that even if they were epiphytic, the majority of forms found in the Middle Devonian Onondaga Limestone were predominantly benthic.

Ambitopic Forms

Ambitopic brachiopods were attached at early growth stages and subsequently became detached and capable of resting on soft bottoms (Jaanussen , 1979). As adults all ambitopic forms were liberosessile, but some liberosessile forms are not adapted to living on soft bottoms. There are some Recent brachiopods that became detached and remained on hard bottoms, although these forms appear to have a reduced life expectancy as noted by Doherty (1979).

Some brachiopods, such as Costistrophonella punctulifera, Schuchertella and indeterminate strophodontids collected from the Nedrow and Moorehouse members of the Onondaga near Kingston, New York, display weak curvatures and are relatively thin-shelled, indicating that they most likely rested on the sediment surface. Thus, there was intergradation between those forms and the more strongly curved types, such as Leptaena, Cymostrophia, Megastrophia and Strophonella that sank into the sediment.

Atrypa "reticularis" from the Moorehouse Member of the Onondaga developed a frilly border thought to function as a snowshoe in preventing adults from sinking into the sediment. Specimens from the underlying Nedrow and Edgecliff members had no frills possibly indicating a less muddy, higher energy environment.

An unnamed species of Cyrtina from the Moorehouse Member near Leeds, New York, appears to have an atrophied pedicle in addition to a broad ventral interarea upon which the animal rested. This, in effect, spread the weight in order to again prevent sinking into the substrate. Alate species of Mucrospirifer from the same member show a more extreme variety of this morphotype.

The concavo-convex Chonetes lineata, found by the thousands in the "Chonetes" Zone ten feet above the Tioga Bentonite in central New York but also recovered from upper Moorehouse strata in the Mid-Hudson Valley, apparently closed its pedicle opening early in ontogeny and rested convex side down witht he spines acting as restraints in preventing sinking. Poor preservation precludes exact determination of spine morphology.

Pentagonia unisulcata from the Moorehouse Member of the Onondaga is a thick-shelled, biconvex brachiopod which probably depended on weight to maintain stability on the seafloor. Pentagonia was posteriorly weighted and possesssed a minute pedicle foramen in some ephebic specimens and none at all in others, indicating pedicle atrophy. Secondary shell material was developed posteriorly in mature individuals further increasing stability. Curry (1981) noted that Neothyris lenticularis, a Recent brachiopod from New Zealand, had a posteriorly weighted shell, minute foramen, and atrophied pedicle and could be considered an ideal adaptation for the high energy subtidal habitats of the species which is frequently disturbed by bottom currents. The morphology and adaptive features of Pentagonia may be indicative of a similar habitat in Moorehouse time.

Cosupportive Forms

Bassett (1984) introduced the term cosupportive to describe those ambitopic brachiopods which maintain an umbo-down posture and are packed tightly together often growing on one another. This type of growth afforded the brachiopods some degree of mutual support from the time of pedicle atrophy. Examples in the Onondaga Limestone are rare, with clusters of Atrypa "reticularis" possibly showing this type of life strategy. Occasional specimens retrieved from Moorehouse strata near Leeds, New York, display deformation indicative of crowding. Pentamerella arata from the Nedrow and Moorehouse members observed in situ near Saugerties, New York, also show evidence of deformation indicating a possible cosupportive life strategy.

FIELD TRIP OUTCROP LOCALITIES

Below is a list of outcrop localities, mostly in the Mid-Hudson Valley, which illustrate how Onondaga deposition in the southeastern part of New York varied from a shallow carbonate shelf in the Helderberg-Coxsackie area to shelf-margin bryozoan bafflestones between Leeds and Saugerties, and relatively thick sparse to packed calcisiltites depositied on a shelf-to-basin ramp deepening into the Tristates area. The trip begins in Wawarsing, New York, where we believe that the accumulations are indicative of the deeper part of a second basin, the first, well-known to geologists, located across the state (east-west) with the basinal axis near Syracuse. As we progress northeast up the Mid-Hudson Valley, the outcrops show a progressively shallower water facies, correlative with movement up a ramp towards strandline.

LOCALITY 1: The trip begins in Wawarsing, New York, approximately 0.5 miles northeast of Vernooy Kill, 100 feet north of Route 209, on the property of Steve and Sue Caruso (Be sure to ask permission before entering outcrop area). The Onondaga/Schoharie contact can be observed in an abandoned quarry (AMNH [American Museum of Natural History] Locality 3151B; see Feldman, 1985) where the Edgecliff Member with characteristic large crinoids, trilobites and some Amplexiphyllum is accessible. The Edgecliff here is finer grained than in the Mid-Hudson Valley and represents the deepest part of the basin to shelf lithology we will see today. Proceed north on Route 209 for 14 miles (note turnoff to Ulster County Highway 26) and continue for another 3.0 miles.

LOCALITY 2: Pull off on the west side of Route 209 (wide shoulder). On the east side of the road note a transitional, deeper water facies, similar to that found at Locality 1, about 1 meter thick, with 0.5 meter of shallower water, "cleaner" Edgecliff Limestone. The fauna here consists of large crinoids, ?Amplexiphyllum, ?fenestrate bryozoans (weathered), and Syringopora. Note storm layers and a sharp break between two facies. Continue on Route 209 north for 2.6 miles where the Onondaga outcrops on the west side of the road.

LOCALITY 3: Here we are higher in the Edgecliff (about 4 meters thick). The water was shallower and the brachiopods larger. Chondrites is evident here but not further southeast due to the fact that as the ramp deepened (to the southwest) the sediment became too "soupy" for tubelike or tunnel structures. Continue to Route 199 east and exit at Route 32 south (7.2 miles). [Note that along Route 199 we are passing through the entire Lower Devonian section, from the Thacher at the base, to the Schoharie, which underlies the Onondaga in this part of New York State.] Make a left turn at the stop sign and continue south on Route 32. On the west side of the road note complex thrust slices oblique to the section and, about one-eighth of a mile further south, an angular unconformity between the Wilbur Limestone Member of the Rosendale Formation (Late Silurian) on Normanskill (Austen Glen aspect) strata. After 2.7 miles make a left turn onto Route 9W south (= Frank Koenig Boulevard), continue for 1 mile, and stop at the Delaware Avenue sign.

LOCALITY 4: Note the gradational nature of the Onondaga/Schoharie contact which is placed at the uppermost buff-weathering band. Ranging through the upper Schoharie into the lower Edgecliff are massive cyclostome bryozoans often encrusting (e.g. crinoids). Other faunal constituents here include brachiopods, particularly Atrypa "reticularis," and Fistulipora. The stratigraphy at this locality is complicated by faulting and repetition due to thrusting (note slickensides and slip-fiber sheets), thus making the Edgecliff seem to be thicker than it actually is. According to Marshak (1986) there are two major thrusts which display a relatively large stratigraphic throw along Route 9W. The upper one, now covered by the exit ramp, emplaces Esopus Formation on Onondaga Limestone while the lower one, exposed further to the north along the roadcut, emplaces Onondaga Limestone on Schoharie. The upper fault may be the continuation of the Fly Mountain Thrust. In general, there is an absence of favositids between here and Wawarsing, but north of here, especially in Leeds, they are abundant. Note the light-weathering chert. Exit at Delaware Ave., make a left turn at the light, and re-enter Route 9W north. Proceed to Route 32, turn right (north),and continue for 8.3 miles; pull into McDonald's parking lot for a brief lunch stop.

LUNCH STOP - McDonald's, Route 32.

Upon exiting the lot turn north and continue on Route 32 passing through the town of Saugerties. Cross the New York State Thruway and note Howard Johnson's on the right, 3.4 miles from McDonald's. (If time permits we will pull into the parking lot and observe well-weathered blocks of Onondaga with silicified fossils [bryozoan bafflestone].) Continue north on Route 32 for another 1.6 miles until the turnoff for Old King's Highway (= Old King's Road). Pull off on the right just before the turnoff.

LOCALITY 5: On the east side of Route 32 note a large outcrop of Edgecliff which shows, for the first time on this southwest-northeast transect, typical coarse-grained Edgecliff lithology. This is the southernmost exposure of the crinoidal biosparites which are so characteristic of the Edgecliff Member. Turn onto Old King's Highway (Greene County Route 47) and proceed 5.2 miles to High Falls Road. Make a left turn and pull over to the right just before the sharp bend (.3 miles).

LOCALITY 6: DO NOT COLLECT AT THIS STOP; IT IS ON PRIVATE PROPERTY AND THE OWNERS DO NOT WANT ANY SPECIMENS OR BLOCKS REMOVED! This outcrop, on the Kaaterskill (AMNH Locality 3137; see Feldman, 1985), known as Quatawichna-ach, takes its name from the Indian "place where all the water goes in a hole" referring to the chert seams and massive joints which take the water underground as it passes through the limestone (Chadwick, 1944). A stratigrphic placement of upper Moorehouse is indicated by [1] shale chips in the adjacent woods (probably Bakoven, since it outcrops a short way downstream], [2] dark-weathering chert, and [3] faunal similarity with upper Moorehouse strata from the Leeds area, specifically, Platyceras dumosum and Atrypa "reticularis." The fauna here is moderately to well-silicified probably due to the diagenetic action of percolating groundwater through the numerous joints. At this locality Feldman (1980) recognized a highly diverse Atrypa-Coelospira-Nucleospira Community containing the following morphotypes:

[1] Orthotetacids, Schuchertella (broad, flat)
[2] Nucleospira, Athyris (smooth spiriferids)
[3] Schizophoria (unequally biconvex)
[4] Atrypa (with frills)

There is a great similarity here with Lenz's (1976) Lower Lochkovian Howellella-Protathyris Community from the northern Canadian Cordillera in which he found similar faunal elements in an offshore position. A similarity is also evident to Copper's (1966) biotope of primitive, abundant Atrypidae in which variably sized atrypids occur with spiriferids and schizophorids in fine-grained sandstones, siltstones and shales with thin limestone interfingerings. Proceed back up High Falls Road and turn left onto Old King's Highway. Continue for 2.1 miles to Route 23A. Turn left for .3 miles and just before crossing Kaaterskill Creek pull onto right-hand shoulder.

LOCALITY 7: Descend steep embankment to Kaaterskill Creek where the only known exposure of the Bakoven/Onondaga exists. Whereas Oliver (1956) considered the Onondaga/Bakoven contact to represent a minor break in deposition we believe that the contact is a disconformity, albeit a minor one in this part of the state, representing a time period during which rapid crustal subsidence, to a shallow or proximal basin depth position below storm wave base, resulted in stratification of the water column and dysaerobic bottom conditions. We found evidence of a more substantial disconformity in central New York, near Syracuse, where the Union Springs Shale (lateral equivalent of the Bakoven) truncates westwardly dipping Seneca strata. At that contact there exists a substantial bone bed with reworked (?) crinoids and brachiopods, and current-sorted fish spines and/or teeth. Proceed up the hill (east) on Route 23 and pick up Route 9W north through Catskill, New York. Pass under the trestle and go 8.1 miles (from Locality 7), turn left (west) onto Route 23. Follow signs to New York State Thruway (exit and make right turn), and head into Leeds (Green County Route 23B). In Leeds turn left on Gilfeather Park Road, drive to the end and park.

LOCALITY 8: Overlooking Catskill Creek, to the east, note the Schoharie/Onondaga contact, to the east of which the Onondaga lies in an (overturned?) thrust-faulted syncline. If time permits we will examine the typical Edgecliff lithology at the waterfalls where trilobites, corals, and brachiopods are evident.

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