Biostratigraphy and Paleoecology of the Upper Devonian Ithaca Formation near Cortland, New York

by

Jonathan W. Harrington
Geological Consultant
Groton, New York

and

W. Graham Heaslip
State University College at Cortland
Cortland, New York

It is particularly appropriate that we examine the Ithaca Formation in the Cortland area during the Golden Anniversary Meeting of the New York State Geological Association. The rocks of this region are of considerable historical interest, having received attention since the earliest days of geological investigation in New York State. In fact, the presence of fossil shells in the Devonian rocks of New York was first noted in 1751 at a hillside outcrop in Cortland County by John Bartram, a member of the Lewis Evans Onondaga expedition (Wells, 1963).

The New York Devonian is unique in its completeness, fossil content, numerous outcrops, and relatively undisturbed nature. It is the standard reference section for North America and displays a classic example of facies transition. Stratigraphic and paleontologic investigation over the past century has produced a wealth of information, but "Despite this, perhaps another century of rigorous study will be required before a thorough understanding of its paleontology, lithology, stratigraphy and paleoecology can be attained." (Rickard, 1964).

The early stratigraphic work in the Upper Devonian of New York was done mainly by James Hall, J. M. Clarke, and H. S. Williams between 1840 and 1915. These workers subdivided the succession, described the faunas and attempted to correlate along the strike. Due to complex interfingering of the argillaceous western sequence with the thicker arenaceous eastern sequence, correlations proved difficult. Only in the 1930's with the work of Chadwick (1935) did it become apparent that the major facies had migrated across the basin of deposition as the Catskill Delta prograded.

Since 1942 investigation of the Upper Devonian has emphasized physical stratigraphy. The works of Sutton, J. F. Pepper, W. deWitt, Jr. and G. W. Colton have outlined the stratigraphy of the Senecan Series. The cyclic repetition of widespread black shales in western New York has been used to subdivide the succession. Paleontologic studies have, until recently, consisted of clarification and classification of forms originally described by Hall and Clarke between 1847 and 1915. The rarity of new discoveries testifies to the accuracy of their monumental works.

Biostratigraphy

The Ithaca Formation falls within the ammonoid zones of *Ponticeras perlatum* and *Manticoceras simulator*, correlative with the upper part of the Iα and the lowermost portion of the I(β)δ zones in Europe. The distribution of these goniatites has been documented with precision throughout western New York (Kirchgasser, 1975). In the type area, the zone of *Manticoceras* begins approximately 100 feet above the base of the sequence. Although rare in the eastern strata, these goniatites are present in the Cortland County area and provide the most reliable biostratigraphic framework.

Over the past 60 years, a nearshore zonation of the New York Upper Devonian has evolved based on the presence or absence of brachiopod species (Harrington, 1972). Early work by Williams (1913) documented the presence of four recurrent *Tropidoleptus* zones with *Rhipidomella* and "*Spirifer*" *marcyi* (= *Platyrachella?*) which periodically replaced the 'general Ithaca' faunas. Any extensive zonation of benthonic organisms must be critically evaluated. However, these zones seem to be quite reliable within certain limits and may be easily recognized in the field. They are clearly time-transgressive, their limits changing across the basin of deposition.

The zones, in fact, are closely tied to sedimentary types and consist of discrete fossil communities whose areal extent is compatible with the biotic attributes. These communities may be considered in terms of (1) feeding types and vagility, (2) species diversity and population density, (3) animal-sediment relationships and (4) morphologic adaptations of specific forms.

Communities

Many faunas present in the Ithaca Formation appear to represent minimally altered, life or near-life communities (*sensu* Fagerstrom, 1964). Many brachiopods may have self-buried in the fashion shown by Menard and Boucot (1951). Definitely authochthonous are all trace fossils, rarely preserved delicate fossils (asteroids, ophiuroids, and crinoid calices), soft-bodied forms (i.e., the scyphomedusa, *Plectodiscus*) and forms occurring in life position, such as the brachiopods, *Warrenella* and *Leiorhynchus mesacostale*, and the pelecypod, *Grammysia*.

Several community schemes have been proposed for portions of the New York Upper Devonian (McAlester, 1960; Sutton, *et al.*, 1966, 1970; Harrington, 1970; Bowen, *et al.*, 1970; Thayer, 1974; and Bowen, *et al.*, 1974). In the Cortland area, we recognize at least five communities present in the Ithaca strata. These benthic communities, or biotopes, partially intergrade or overlap. The order of these biotopes is essentially one of increasing complexity reflecting increased diversity and specialization. Primary controls on distribution of taxa appear to be sediment type and substrate mobility--factors only indirectly related to bathymetry. In general, the community distribution pattern seems to conform to the tectonically active Model 2 of Anderson (1971) characterized by a high-low pattern of kinetic energy release.

Lateral changes in the faunas reflect onshore-offshore gradients. An offshore increase in epifauna results from decreased environmental stress. Sessile taxa are concentrated offshore, with the nearshore zone dominated by vagile genera. Primarily stenotopic brachiopods are progressively replaced shoreward by eurytopic (and infaunal) pelecypods.

Due to the predominance of epifaunal species, many workers (e.g., Ziegler, _et al._, 1968) have suggested a relative independence of Paleozoic marine benthos from sediment type. In the New York Upper Devonian, high sedimentation rates and distance from shore as a function of rate of deposition appear to have influenced specific aspects of the development and composition of communities. For these reasons, community patterns do not compare favorably in all aspects with those described in other areas, as in the work of DeKeyser (1977) in Western Canada and Iowa.

Most pedunculate brachiopods were somewhat elevated above low velocity currents near the sediment-water interface and were thus able to colonize a wide range of environments. However, as previously noted (Harrington, 1969, 1970), many Ithaca brachiopods were non-pedunculate, free-living forms or were merely attached to, but not supported above, the substrate in the ephebic stage. Consequently, a number of morphological adaptations occurred in response to problems of support and the separation of inhalent and exhalent currents.

The presence of a well-developed fold and sulcus (i.e., _Platyrachella_), frilly or spinous projections (i.e., _Atrypa_), thickened strut-like antero-lateral costae (i.e., _Hadrorhynchia_), or secondary thickening of the posterior portion of the shell (i.e., _Leiorhynchus globuliforme_), are alternate means of elevating inhalent currents above the interface. In this way, a series of discrete, well defined trophic levels were occupied in Ithaca time.

The following biotopes are recognized in the Ithaca Formation of the Cortland area:

I. _Warrenella_ biotope.

This association is characterized by a mixture of benthic and pelagic forms adapted to poorly oxygenated, offshore mud bottoms. Brachiopods typically develop low, expanded outlines (i.e., _Warrenella_ and _Leiorhynchus mesacostale_). Deposit feeding pelecypods, such as _Palaeoneilo_ and _Pterochaenia_ are abundant. Linguloid brachiopods and small crinoids (i.e., _Taxocrinus_) are locally present, as are the microphagous carnivores(?) _Plumularia_ and _Conularia_. Species diversity and population density are low.

Perhaps, due to its position in the outer neritic, outer prodelta zone, this community does show affinity to those of other areas. In fact, there appears to be a good basis for recognition of a Warrenella Community, at least in North America, that persistently maintained a soft substrate habitat in a low energy and moderately deep water environment (Ludvigsen and Perry, 1975). In addition to its recognition in New York (Harrington, 1970), Johnson (1971) noted low species diversity and extreme abundance of few taxa (Warrenella kirki and Leiorhynchus meriami) in the upper fauna of the W. kirki zone from Nevada and referred to it as the "Warrenella Community." Furthermore, Noble and Ferguson (1971) recognized a similar "Warrenella-Rhynchonellid Community" from the Headless/Nahanni Formation of the southern Mackenzie Mountains. They placed this community seaward of communities dominated by tabulate corals and stromatoporoids and landward of the pelagic community.

II. Ithaca biotope.

This community was well developed on prodelta mud grade bottoms in areas of moderate currents. It is characterized by a highly diverse epifauna of brachiopods, many of which display morphological adaptations to a soft mud substrate in the presence of reduced sediment influx (.e.g, frilled atrypoids). This biotope is sporadically associated with a rich encrusting epifauna of bryozoans and auloporoid corals. The presence of these forms precludes rapid burial and indicates rather slow and discontinuous sedimentation. The genera present represent an admixture of forms from the Ithaca and Tropidoleptus biotopes. Some faunal similarities exist between this biotope and the Atrypa-Schizophoria community recognized by DeKeyser (1977) in Western North America.

III. Tropidoleptus biotope.

This community represents an adaptation to a delta platform with silt and mud bottoms. It is characterized by an abundant brachiopod epifauna, with especially large numbers of the spiriferid, Platyrachella. Other abundant genera are: Productella, Cupularostrum, Atrypa, Hadrorhynchia, Ambocoelia, and Tropidoleptus. In New York, Tropidoleptus occupies slightly finer grained environments than elsewhere. Isaacson and Perry (1977) consider this to be typical of sandstone-siltstone facies in presumably fairly turbulent, moderate to high energy environments characterized by low diversity and high dominance. Tropidoleptus was free living--the concavo-convex shell would achieve maximum stability with the brachial valve down. The dorsal sulcus would serve to lift the anterior commissive above the water-sediment interface.

IV. Leptodesma biotope.

On silt and shale substrates in delta platform areas of moderate current activity are developed communities of large numbers of filter-feeding epifaunal species, with smaller numbers of deposit feeding genera. In general, species diversity and population density are moderate. Common fossils are: Atrypa, Cryptonella, Pleurotomaria, Leiorhyncus globuliforme, Goniophora and Leptodesma.

V. Grammysia biotope.

Communities characterized by large numbers of the semi-infaunal filter-feeder, Grammysia, and the byssate epifaunal genus, Goniophora, inhabited coarse, unstable sand bottoms in the nearshore delta-front sands. The environment is highly variable in lithology and faunal composition. Strongly developed species dominance and low diversity are characteristic. Brachiopods are typically sharply costate and possess a well-developed fold and sulcus. Locally developed in more sheltered areas are dense colonies of crinoids (Decadocrinus and Acanthocrinus) or hexactinellid sponges (Actinodictya placenta). In these areas, where there is an accumulation of organic debris, gastropods, asteroids, and ophiuroids are abundant.

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ROAD LOG

Leave Manley Fieldhouse parking lot and proceed south on Comstock Avenue, bearing left on Jamesville Road for about .4 mile. Turn right (west) on Ainsley Drive for about .5 mile and turn left (south) on Brighton Avenue. Cross intersection with Route 173 and bear right on Lafayette Road for about 1.7 miles and bear right on Graham Road to Sentinel Heights Road. Turn right and then take first left on Kennedy Road for about 1 mile, turning right on short connecting road to Route 11. Turn right (north) on Route 11 and proceed under the I-81 overpass, turning left into the southbound lane of Route I-81. Travel south on I-81 to Exit 12 at Homer and proceed along entrance road to Route 281. Detailed log from this point below.

	Mileage	Total
Turn right (north) on Route 281.	0.0	0.0
Proceed north along Route 281 to second traffic light, turn left on Route 41.	1.2	1.2
Proceed northwest on Route 41 to junction with Route 41A, turn left.	2.5	3.7
Proceed west on 41A to Homer Gulf, just before rise in road and sharp bend.	1.2	4.9

STOP 1. Outcrop in Homer Gulf on Rte. 41A, 4 miles north of Cortland.

Ponticeras perlatum has been identified from exposures in Homer Gulf. This places the section in the lower portion of the Ithaca formation, probably correlative with the Renwick shale member. The lithology is extremely variable; consisting mainly of gray and reddish shales and siltstones. The fauna contains elements of both the *Warrenella* and Ithaca biotopes. Particularly common are: *Conularia*, *Plumularia*, *Mucrospirifer*, *Hadrorhynchia*, *Cupularostrum eximia*, *Taxocrinus* and linguloid brachiopods.

Turn cars around, proceed back along Route 41A to 41 junction, turn right.	1.2	6.1
Proceed southeast along Route 41 to junction with Route 281, turn right.	2.5	8.6
Proceed south along Route 281 to the fifth traffic light at junction with Route 13.	5.1	13.7
Continue straight through light on Route 13, proceed to large downgrade in road just past the Aquarius Inn and Sweetland Road intersection and the Tompkins County line.	3.6	17.3

STOP 2. Roadcut on Rte. 13, just east of Dryden, Tompkins Co.

This exposure in the lower Triphammer member is one of the most richly fossiliferous outcrops of the Ithaca formation. It contains abundant encrusting epifauna representing an admixture of biotopes, with incursions of the Ithaca biotope from the west and the *Tropidoleptus* from the east. Diversity is at a maximum, with maximum size development of *Leiorhynchus mesacostale*, *Atrypa reticularis* and *Platyrachella mesastralis*. Other common fossils are: *Hadrorhynchia solon*, *Porcellia nias*, *Mucrospirifer posterus* and *Cyrtina hamiltonensis*.

Turn cars around and return to Cortland via Route 13 to Y intersection just past the SCM plant and the Cortlandville shopping mall, bearing right on Route 13.	3.6	20.9
Follow Route 13 to pink house on right (south) side of road just across from Volkswagen dealership on north. Park cars on shoulder and walk to old quarry to rear of empty lot.	0.4	21.3

STOP 3. This locality will be an optional stop, time permitting.

The sequence of shales and siltstones is the source of several of the rarer fossils found in the Ithaca Formation, including the scyphomedusan, *Plectodiscus cortlandensis* and the trace fossil, *Tomaculum problematicum*.

Continue east on Route 13 to third light at Main Street intersection, follow through light onto Port Watson Street.	2.0	23.3
Follow Port Watson Street across Tioughnioga River Bridge and follow Route 11 to Route I-81 interchange 10 and enter I-81 South.	2.7	26.0
Proceed south along I-81 to Marathon Exit 9, leave I-81.	10.6	36.6
Proceed south along Route 11 to center of village of Marathon, taking left turn and follow signs to Rt. I-81 North.	1.3	37.9
Enter Route I-81 northbound and proceed to outcrop on both sides of road past the high bridge over Hoxie's Gorge and just at milepost 47.	9.1	47.0

STOP 4. Road cut on Rte. 81, 3 miles south of Cortland.

This exposure represents the *Grammysia* biotope in nearshore delta-front sands. Lithology is highly *variable* with shales, ripple-marked and cross-laminated siltstones and fine sandstones. Coquinite lenses, especially with *Cupularostrum*, are frequent and usually show distinct size-sorting and *differential* accumulation of valves. Areas of high currents are dominated by the infaunal filter-feeder, *Grammysia*, and the byssally attached bivalve, *Goniophora*. Occasion *vertical burrows* may be seen.

Sheltered areas support an abundant epifauna of crinoids (*Decadocrinus* and *Acanthocrinus*) and occasional brachiopods. This environment is characterized by the accumulation of plant fragments and orthoconic cephalopods, and by the high incidence of carnivores and scavengers--the gastropods, *Pleurotomaria* and *Loxonema*, several asteroids (*Urasterella*, *Lepidasterella*) and ophiuroids.

The orientation of many of the smaller crinoid calices (inverted with free arms outspread) indicates very slight water agitation. However the preservation of fragile specimens such as asteroids and the scyphomedusa, *Plectodiscus cortlandensis*, required periodic rapid sedimentation. Fecal material is occasionally found at this outcrop. It has tentatively been identified as *Tomaculum problematicum*, a form not previously reported in North America.

Continue northbound on Route I-81 to high ledges on right side of road about 1/2 mile north of Interchange 11.	6.0	53.0

STOP 5. Roadcut on Rte. 81 at Homer, Cortland County.

The sequence here consists of alternating dark shales and fine siltstones, occasionally ripple-marked. The sparse fauna, representing the *Leptodesma* or *Grammysia* biotope, consists of rare brachiopods and occasional crinoids (*Acanthocrinus*). At several horizons there are colonies of the hexactinellid sponge, *Actinodictya placenta*. These fragile forms were almost certainly preserved *in situ*.

Small hillside quarries immediately north of this exposure have yielded *Ponticeras perlatum*, indicating a correlation with the lower portion of the Ithaca (Renwick or Six-Mile Creek Members) in the Ithaca meridian.

Continue north on Route I-81 to Interchange 12. At this point, trip ends. Cars traveling north can continue on I-81, or exit to travel south or west for homeward trip.	0.5	53.5

Building Stones Used in the Vicinity of Syracuse

Osborne B. Nye, Jr.
Department of Geology, Syracuse University, Syracuse, NY

Rosario Fazio
Department of Science Teaching, Syracuse University, Syracuse NY

INTRODUCTION

A building provides a visual signpost to the artistic style and the economic framework of the time and culture in which it was built. The materials used in the construction of the building are part of that history and have a story worth telling in their own right. The building stones used in Syracuse are diverse. Many of the classic buildings of central New York are built of Onondaga Limestone or other stone quarried locally, but numerous other buildings were constructed from rocks quarried from distant parts of the United States and Canada. These building stones are representative of nearly every major lithology and geologic age, and therefore are a major geologic resource available to all.

Building stones are selected for appearance, strength, and cost, but other factors may dictate a final selection. For example, architects who build in or around Presidential Plaza in downtown Syracuse must follow the color scheme previously used in the area. Even the road median on Townsend Street was constructed from a commercial granite termed Carnelian Red to conform to this preselected color scheme.

The appearance of a building stone results from a complex of factors. Mineral composition and grain size are prehaps the most obvious and incidentally are the most important characters used by geologists to classify the rock. The red or pink color of many of the granites comes from the presence of numerous pink- or red-colored feldspar crystals. The feldspar is so abundant that it masks the colors of other minerals especially the black micas and hornblende. Feldspar is not always red or pink but may be an off-white to gray to dark purple or blue. In igneous rocks the feldspar generally is by far the dominate mineral in weight percent thus controlling the color of the whole rock, at least when viewed at a distance. Crouse College on the Syracuse University campus is red for another reason. The building blocks are composed of quartz sandstone, a sedimentary rock. Each quartz grain is coated by a thin rind of red iron oxide which binds the sand grains together and imparts a characteristic red color, warmest at sunrise and sunset. Red can be a nuisance however, especially when it results from the chemical breakdown of an unstable mineral producing an unsightly stain. Crystals of pyrite may occur in the Onondaga Limestone. If a facing with pyrite is exposed to the atmosphere, the iron in the pyrite soon oxidizes forming rusty blotches. Other more subtle characteristics add to appearance. Individual grains range in size and shape. Feldspars may occur as long laths whereas quartz occurs as small, glassy, irregular grains seemingly squeezed in between its more regular neighbors. The final arrangement of shapes and sizes presents a characteristic fabric or texture, pleasing to the eye, but not easily described.

Sedimentary rocks usually exhibit characteristic fossils or markings from its origin on the shifting bottoms of turbulent seas. Cross sections of ancient corals appear similar to spoked-wheels in the Onondaga Limestone. The highly polished interior walls of the H.B. Crouse Building on the Syracuse University Campus or in the Foyer of the Herald Journal Building at South Salina and Erie are a naturally cemented accumulation of the shells of millions of marine organisms.

Architects and geologists use different terms. Of course this is acceptable and probably necessary because each profession has different requirements. For those of us interested in tracing the origin of a building stone a promising search may end in a morass of names. For this reason we have only dented the surface of building stones used in the Syracuse region.

The pathway from interesting building to useful data generally followed this course: (1) determine the architect; (2) contact the architect for information which usually leads to: (a) an informative individual with a superb memory; (b) original plans calling for a specific building stone, this bonanza may lead to a blank wall because another building stone with similar characteristics was substituted for economic or other reasons; or (c) complete blank, the architect could not be located, or if located no one alive had any knowledge of the building; (3) determine the geographic source of the stone; (4) consult state surveys, state geologic maps, texts on building stones for leads to the geologic name and pertinent geologic references; and (5) return to the building and check the data. The following publications were most helpful for locally derived building stone, Chute (1970), Hopkins, (1914), Luther (1895), and Vanuxem (1842). Sweet's Architectural Catalogue, (1978) provided a general source for firms and geographic locations of building stone.

BUILDING STONES QUARRIED IN NORTHERN ONONDAGA COUNTY

Syracuse, located on the northern edge of the Appalachian Plateau, is underlain by lower to middle Paleozoic sedimentary rocks which dip gently to the south. North of Syracuse the bedrock is dominated by relatively soft shales which were excavated deeply by the great glaciers of the Pleistocene to form a vast lowland. As the ice melted, its load of sediment mantled the lowland with the unconsolidated gravels, tills, sand, and clays termed glacial drift. Today this area is marked by numerous low hills, swamps, and lakes, and the underlying bedrock is seldom exposed. As a result early builders relied upon wood. Foundations were constructed of field stone, usually a conglomeration of glacially transported boulders which littered the lands to be tilled. An exception was the dolomitic layers of the Lockport Formation.

The Lockport Formation is geologically, the oldest rock unit in the County that has been quarried for building stone (Niagaran stage of the Lower Silurian). Although it holds up a low, rather obscure ridge extending from Lysander in the northwestern corner of Onondaga County through Brewerton just southwest of Oneida Lake, the Lockport is everywhere covered by drift. Where the need for foundation stone could not be satisfied by the availability of fieldstones (cobble- to boulder-sized glacial erratics) or the expense was too great for hauling Onondaga limestone to the building site, the glacial deposits were scraped off and the Lockport was quarried. Many of the older buildings in and around Lysander have cellars and foundations constructed of the Lockport. An interesting combination of local building stones can be seen in a house constructed in 1871 on Plainville Road, Lysander, now owned and being renovated by Mr. Wayne Harney. The foundation is dark-gray Lockport Dolomite, the supporting walls are brick but window and door casings are Onondaga Limestone. Lockport also was used locally for culverts and bridge abutments and in the Oswego Canal.

Although Vanuxem (1842, p. 93) referred to the presence of numerous quarries in the Lockport during the early part of the last century, nearly all of these long since have been filled and overgrown, although Zenger (1965) was able to recover rock samples from four of them.

In recent years the Lockport has been considered as a group (Rickard 1975) or as a formation (Zenger, 1965). Either way this unit is continuous with the massive dolomites which cap Niagara Falls and hold up a major escarpment which can be traced from Rochester, New York, into southern Ontario past Hamilton; to the Bruce Peninsula separating Georgian Bay from Lake Huron; hopskotching Lake Huron via the Manitoulin Islands to the upper peninsula of Michigan; wrapping about the western shore of Lake Michigan to die out south of Green Bay, Wisconsin.

The local facies of the Lockport termed the Sconondoa Member by Zenger (1965), is a dark gray or blue, fine-grained limestone west of Baldwinsville which includes interbeds of shaly limestone and coarser grained dolomites. Zenger observed zones rich in interclasts, ripple marks, and small ostracods. East of Baldwinsville the Sconondoa is a brownish gray to gray black, medium-grained dolomite containing a fair number of fossils including stromatolites, corals, one species each of a brachiopod and a clam, and several ostracod species. Zenger also observed edgewise conglomerates and incomplete mudcracks all of which suggests that the more eastern sediments were deposited in shallow, sometimes intertidal waters that were slightly more saline than normal seawater.

BUILDING STONES QUARRIED IN SOUTHERN ONONDAGA COUNTY

South of the lowlands the more resistant dolomites, limestones, and siltstones of Late Silurian to Middle Devonian age hold up a step-wise series of uplands which mark the northern boundary of the Appalachian Province. Locally the boundary between lowland and upland is marked by an irregular escarpment which is breached by streams with spectacular waterfalls at the most resistant beds, or muddled by the complex erosional and depositional overprints of Pleistocene glaciation. Many of the rocks exposed naturally in the escarpment, or by man in the hillside quarries have provided building materials since the area was settled. Canal building and salt-refining stimulated the need for the inexpensive building materials, so abundantly available in Onondaga County.

Much of the local Silurian bedrock is important economically because it contains major deposits of salt which are exploited today exclusively for the Solvay Process. During the last century Syracuse was the major center for salt in the U.S. Large deposits of gypsum also occur locally but these were used mainly in agriculture as "land plaster". Only a small fraction was mined for use in wall plaster.

As noted by Hopkins (1914, p. 26) nearly all of the limestones and dolomites in the Upper Silurian and Devonian have been used to some extent for building purposes. Most however have only been used for rough building purposes along the outcrop. Only two limestones are durable, workable, and attractive enough for wide-spread use. These are the upper "Blue Layers" of the Manlius and the lower most or Edgecliff Member of the Onondaga Limestone.

Manlius Formation

The limestone beds of the Helderberg Group (Lower Devonian) provided both quicklime from the upper blue lime layers of the Manlius Formation and hydraulic cement from the underlying water limes of the Manlius and Rondout Formations. Hydraulic cement was a major product of Onondaga County produced after the rediscovery of its manufacture and first use in the Erie Canal in 1819 until the early 1900's when Portland cement became available. During this period the thin blue lime layers which were stripped off the underlying water limes were used for building stone, principally as cellar or foundation stone. Some blue stone of the Manlius Formation is used today for fireplaces, decorative walls, and paving. The rock was available from numerous small quarries so that most of the homes built in the preconcrete era and located in Manlius, Fayetteville, Jamesville, Syracuse, etc., have foundations constructed of it.

The Helderberg Group has been the subject of several recent studies, the most notable of these are that by Rickard (1962) and LaPorte (1969). References to other important geological studies can be found in these two publications. The rocks of the Helderberg Group largely are limestones with lesser amounts of dolomite and shale. Although when first seen, these rocks seem alike, careful systematic studies of the lithology, the fossils, and the sedimentary structures such as mudcracks reveal several different rock suites or facies. After the geometric relationships of these different facies were determined, Rickard and later LaPorte concluded that the Helderberg Group was deposited in a vast, shallow-marine sea. Each facies or formation reflected a particular set of environmental factors which, at least in part, could be evaluated and described. LaPorte (1967, p. 78-82) compared the dolomitic, poorly fossiliferous, mudcracked layers of the Manlius Formation to the supratidal, limey, mudflats which can be observed today in the Florida Keys and the Bahamas. The upper part of the Manlius contains large, ovoid fossils of stromotoporoids (probably a sponge) and corals. LaPorte interpreted these as sediments accumulating just offshore from the barren mudflats. The same situation can be observed today in subtropic and tropical seas although the organisms have changed somewhat during the intervening 350 million years or so.

Oriskany Sandstone

The Oriskany Sandstone was quarried on a small scale in the town of Skaneateles during the last century (Luther, 1895, p. 275). Its most n notable contribution was in the construction of the Erie Canal Lock at Jordan, but it also was used for cellar and foundation stone. Locally the Oriskany was selected for the heat resistant linings in lime kilns. Although the Oriskany generally is thin and sometimes absent it is a sturdy well-cemented sandstone and probably would have been used more widely if the Onondaga Limestone were not so readily available. A similar appearing sandstone occurs locally at the base of the Edgecliff Member of the Onondaga Formation. This sandstone was derived seemingly by the exposure and reworking of the slightly older Oriskany deposits (Oliver, 1954). This sandstone can be seen at Jamesville, New York in the Prison quarry and the Allied Chemical quarry.

Onondaga Limestone

The Onondaga Limestone is sturdy and has a pleasing off-white to gray, locally pink color. It is abundant, forming an almost unbroken escarpment from the eastern side of the county to the western side. The principle quarries have been located at Jamesville, the Onondaga Indian Reservation, and at Split Rock. Only the quarry at Jamesville owned by the Allied Chemical Corporation operates today. In this operation the Onondaga is crushed and used in the manufacture of sodium carbonate at the Solvay plant. Vanuxem (1842, p. 136) noted that a single exposure of the Onondaga Limestone extended for more than a mile at Split Rock (just southwest of Syracuse) and this exposure was "farmed out to contractors, furnishing stone for a considerable portion of the western section of the canal."

The unique combinations of color, workability, and a variety of textures make the Onondaga the most visable of building stones used in the county. It also is the most widely distributed of the building stones quarried in Onondaga County. Not only was it used in the construction of the Erie Canal throughout the State but one slab occurs in the Washington Monument.

The Onondaga Limestone was first recognized in the literature by Amos Eaton in 1824 (noted in Vanuxem, 1842) as the Corniferous Limerock. The <u>nomen</u> corniferous, referred to the presence of Hornstone now known as <u>chert</u>. By the 1830's the first New York State Survey had identified a suprajacent limestone which they termed the Seneca. Today four members are recognized (Edgecliff, Nedrow, Morehouse, and Seneca in ascending order). The most important of these for building stone is the Edgecliff, a massive light gray to pink, crystalline limestone.

Hopkins (1914, p. 27) expressed the major reasons for the popularity of the Edgecliff. "Its durability is shown by its strong relief on all the outcrop and in the buildings in which it has been used. The interlocking crystalline grain has destroyed to a large extent the lamination of the rock, so that under the stone cutter's tools it acts like a marble".

The Edgecliff is richly fossiliferous most noted for its assemblage of corals and of large crinoid columnals up to 1 inch in diameter. The matrix between these larger fossils is composed of shell debris, particularly smaller crinoid columnals. Occasionally a sharp eye will discern the presence of small lacey to net-like bryozoans, bivalved brachiopods or snails, and trilobites. Oliver in 1954 judged that the relatively mud-free, fossil-rich, lime sediments of the Edgecliff were deposited in clear-water fairly constant conditions. Oliver pictured the existence of a shallow, marine sea whose floor was dotted with corals which sometimes became abundant enough to be pictured as forests of corals with crinoids living between the corals. This scene is suggestive of the coral-rich seas of the tropics today, but the differences provide room for future thought.

Hamilton Group

The siltstones of the overlying Hamilton Group which outcrop in the southern part of the county have been used on a local basis for retaining walls, foundation stone, or fences. The rocks usually are brown to dark gray and may have numerous fossils particularly clams or brachiopods. Although these rocks are important and interesting geologically, they have not been used widely in Onondaga County and will not be discussed further here.

IMPORTED BUILDING STONES

In this section we have gathered information on building stones quarried elsewhere in the United States and Canada and then transported to the Syracuse area. Locally derived building stones largely are sedimentary limestones and dolomites, which are nearly uniform in mineralogy (calcium and calcium magnesium carbonate) with subsidiary amounts of quartz sand, silt, and clay. Imported building stones are diverse and have been quarried from igneous, metamorphic, and sedimentary sources, and display considerable variation in composition even with a single variety of building stone.

Milbank Granite

Milbank Granite (carnelian red, mahogany granite), Grant County, South Dakota, quarried by the Cold Spring Granite Co. in Cold Spring, Minnesota. (Cost polished: $20.00 per sq ft, 2 in thick slab.) The granite is pink to dark red with a medium granitoid texture. The Milbank generally is equated with the Ortonville Granite which outcrops in the western most portion of the Minnesota River Valley between Ortonville and Odessa, Minnesota. Lund's (1956, p. 1485) analysis of the Ortonville Granite indicates the following composition by volume percent (40-60% microcline, a potassium felspar; 15-22% oligoclase, a plagioclase feldspar; 16-31% quartz; 3-6% biotite and 1% accessory minerals usually sphene or epidote).

The crushing strength of the granite measured by Rothrock (1944, p. 142) was 15,000 lbs/sq in a rather low figure for granite. The rock failed along cleavage planes in the feldspar. In addition to its use in

Syracuse the Milbank Granite has been used in the large columns in the National Catholic Shrine at Washington, D.C.

The Milbank Granite is dated by the lead-alpha method at a venerable 2470 million years (Goldich, Hedge, and Stern, 1970 p. 3689), the oldest rocks used for building stones known in the Syracuse area. Inclusions of quartz-pyroxene granulite in the Milbank Granite probably are remnants of sedimentary rocks which may have formed the crust of a primitive North American continent existing more than 2,500 my ago.

Texas Pink Granite (Sunset Red)

The Texas Pink is equivalent to the Town Mountain Granite of Stenzel (1932, p. 144). The rock is a coarse-grained, porphyritic granodiorite quarried from an exfoliation dome termed Granite Mountain located near Marble Falls, Texas. This places it in the eastern portion of the Llano Uplift of central Texas. Microcline feldspar, plagioclase feldspar, and quartz are the dominate minerals, subsidiary amounts of biotite, hornblende, rutile, apatite, zircon, and allanite occur locally. Many of the large phenycrysts are microcline rimmed by plagioclass. Tilton and others (1957) dated zircons from the granite at about 1 billion years. Other information on the geology of the Town Mountain Granite can be obtained in Barnes and others (1972) and Goldich (1941).

The following information concerning the history of the quarry is condensed from Barnes (1958, p. 20). The Texas Pink Granite Company took over operation of the quarry in 1893, and in 1895 the owners agreed to donate sufficient granite for construction of the State Capitol Building in Austin. By 1940 approximately 34 million tons of stone had been shipped from the quarry for use in buildings and monuments throughout the country, including two wings of the American Museum of Natural History in New York City, the Times Building in Los Angeles, and surprisingly, the Leif Erickson Memorial in Iceland.

During 1950 the Texas Granite Corporation acquired Granite Mountain. This company is a subsidiary of the Cold Spring Granite Company of Minnesota. Stone from Granite Mountain currently is marketed as "Sunset Red", it was formerly known as "Texas Pink."

Westerly Red Granite

The Westerly Red building stone quarried in the town of Westerly, Washington County, Rhode Island is equivalent to the Narragansett Pier Granite. Exposures of the granite occur near the mouth of Narragansett Bay and westward along the south shores of Rhode Island. Quinn (1971) classifies the rock as a quartz monzonite to granodiorite composed of 30 to 35 percent microcline, 30 to 35 percent oligoclase, 35 to 30 percent quartz, and 3 to 5 percent quartz. The list of minor elements includes zircon, apatite, pyrite, sphene, allanite, and the more exotic minerals, uranoan thorianite, bastnaesite, and monazite (Smith and Cisney, 1956).

The granite was intruded into the Pennsylvanian-age sediments of the Narragansett Basin during the Appalachian revolution in late Permian time. This was based on radiometric dating of zircons yielding a date of 234 million years ± 23 million.

Mount Airy Granite

The Mount Airy Granite is quarried 1 mi north of Mount Airy, Surrey County, North Carolina. The rock is a light gray, nearly white, quartz monzonite. It is composed of orthoclase and plagioclase feldspar, quartz, biotite, and minor amounts of apatite, zircon, muscovite, chlorite, and epidote (Stuckey and Conrad, 1958).

Chelmsford Grey (Oak Hill) Granite

This building stone is known geologically as the Ayer Granite (Emerson, 1917, p. 223). Typically the rock is a muscovite-biotite granite occurring in detached areas along a narrow belt from Hempstead, New Hampshire, through Worcester, Massachusetts, into Connecticut. It has been quarried extensively near Worcester, Westford, and near North Chelmsford. It is used mainly for retaining walls, bridge abutments, curbstones, and paving blocks. Detailed lithologic description of samples from individual quarried are given by Dale (1923, 303-313). Zartman and others (1970, p. 3360) has dated a sample of the Ayer Granite at 372 ± 17 my. This would place the origin of the Ayer in the Early Devonian, perhaps older.

Canadian Black Granite (Peerless Black)

The building stone is sold by National Granite Limited, St. Joseph d'Alma, Quebec. The rock is a coarse-grained anorthosite of dark gray almost black color. Approximately 85 percent of the rock is composed of labradorite, a dark-colored plagioclase feldspar. Where coarsely cleaved this mineral may display a spectacular play of blue and green colors reminiscent of a peacock's tail. The remaining minerals include pyroxene, ilmenite, hornblende, pyrrhotite, calcite, and biotite. The anorthosite probably was quarried in the Lac St. Jean area of Quebec, perhaps at the St. Gedeon quarry.

Anorthosite geologically is an unusual rock in that it is almost entirely composed of plagioclase feldspar. It also is uncommon in occurrence. Most of the anorthosite in North America occurs in Quebec, Labrador, and the Adirondack Mountains of New York State.

Polychrome Granite

This building stone, quarried by National Granite Limited probably is obtained from the vicinity of Bagotville, Quebec. The rock is a hornblende granite which contains 60 percent microperthitic orthoclase feldspar, 30 percent quartz, 4 percent plagioclase, 3 percent hornblende, and minor amounts of biotite, apatite, and zircon.

Longmeadow Sandstone

The Longmeadow is a somewhat feldspthic quartz sandstone, cemented mainly by iron oxides, which outcrops in the vicinity of Longmeadow, Massachusetts and along the Connecticut River. The Longmeadow is famous for its dinosaur tracks, ripplemarks, rain-drop impressions, frost crystal impressions, mudcracks, and plant stems. The sedimentary structures led geologists to believe that the longmeadow sands were deposited in shallow basins which often dried out completely. The dinosaurs seemingly traveled in herds leaving only their footprints behind.

BUILDINGS AND BUILDING STONES IN SYRACUSE

Bird Library, Main Campus, Syracuse University
Coarse Aggregate - Croghan Red Granite, Fine Aggregate - (sand) Croghan Red
Granite, Cement - Alpha, Inside Flooring - Tennessee Marble coarse aggregate in Terrazzo material
Completed in 1972

Bray Hall, Environmental Science & Forestry
Indiana Limestone
Built 1917

Cathedral of the Immaculate Conception, Jefferson St. and Montgomery Sts.
Onondaga Limestone (outside material)

City Hall, 233 E. Washington St.
Onondaga Limestone

Civic Center, 411 Montgomery St.
Red pavers outside building - made of coarse aggregate. Croghan Red Granite.

H.B. Crouse, Main Campus, Syracuse University
The bases, cornices, copings, windowsills, frames, outside walls, and trim are constructed of Indiana Limestone.

Crouse Irving Hospital, 736 Irving Ave.
Coarse Aggregate: North Bay Ontario granite. Cement, White Medusa

Dey Brothers Department Store, 401 South Salina St.
Marble outside - Georgia

Everson Museum, Montgomery St. and Harrison St.
Coarse Aggregate: Croghan Red (outside and inside building) - Cement Alpha

Gridley Building, 103 Water St.
Carved Onondaga Limestone

Hall of Languages, Main Campus, Syracuse University
Onondaga Limestone
Built in 1871. This was the first building used for classes on the Syracuse University Campus. Architect was Horatio White.

Herald-Journal Building, Clinton Square
Marble outside: Vermont, Green Slate outside: Vermont

Heroy Geology Laboratory, Main Campus, Syracuse University
Interior lobby floor - Buckingham Slate
Wood over lobby: Douglas fir
Opened 1971. Architects King & King

Holden Obseravatory, Main Campus, Syracuse University
Onondaga Limestone
Built in 1886. Architect was Archimedes Russell

John Crouse College of Fine Arts, Main Campus, Syracuse University
Longmeadow Sandstone
Built in 1889 by Archimedes Russell. The nine bells hanging in the central tower were cast in Belgium and cost $6,000.00. The sandstone ornaments were carved rather than cast.

Lyman Hall of Natural History, Main Campus, Syracuse University
Indiana Limestone, Gouveneur Marble
Built in 1907. A fire on January 11, 1937 destroyed a great part of the museum.

Marine Midland Bank, Corner of Butternut and Salina Sts.
Outside Building (upper portion) Kasota, Minnesota limestone, Polished red granite (outside) - South Dakota

Marine Midland Bank, Presidential Plaza
Outside Marble panels: Vermont, Polished red granite columns: South Dakota, Red Granite bricks: South Dakota, Curbstone: Massachusetts

Merchant's Bank, 220 Warren St.
Vermont Marble (outside of building)

Mony Plaza. 1 Mony Plaza
Outside flooring - Pink "Polychrome" Granite, Quebec Black Granite inside and out - "Canadian Black", Quebec Granite Aggregate outside: North or South Carolina.
More than one acre of "canadian Black" in this building

North Side Parking Garage, Townsend St. across from Presidential Plaza
Red Granite Bricks - South Dakota
Bricks were used to match darker colors of Presidential Plaza

Onondaga Community College, Main Campus, Onondaga Rd.
Granite Curbing: North Carolina, Granite door sills: North Carolina
Pink Granite window sills: Minnesota

Newhouse II, Corner of University Place and University Ave.
Coarse aggregate in Building: Pink granite from Texas

Public Safety Building, 511 State St.
Polished red granite columns and walls; on outside: Carnelian red, South Dakota

St. Joseph's Hospital, Prospect Ave.
Virginia Sand, Coarse Aggregate, New Jersey Marble, Cement: Medusa

St. Paul's Cathedral, 310 Montgomery St.
Onondaga Limestone (outside material).

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Virginia Sand, Coarse Aggregate, New Jersey Marble, Cement: Medusa

St. Paul's Cathedral, 310 Montgomery St.
Onondaga Limestone (outside material).

Shea Jr. High School, 1607 S. Geddes St.
Curbstone: North Carolina

State Office Bldg., 133 E. Washington St.
Outside Steps on Washington Ave. - Texas Pink Granite; Curbstone - Texas Pink Granite.

Steele Hall, Main Campus, Syracuse University
Rock faced Onondaga Limestone
Built in 1898

Upstate Medical Building, 750 E. Adams St.
Outside marble - Georgia

ACKNOWLEDGMENTS

We would like to thank Mr. Carl Turner of the Barretto Granite Corp., Charles Doerfler of the Clark, Clark, Millis, and Gilson Architect Firm; Don Sherman of King and King Architects; Lou Fauth of the Clark Concrete Co., Inc.; and Mr. John Cuyle of Syracuse University for their exceptional patience and kind assistance.

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DEPOSITIONAL ENVIRONMENTS OF THE OSWEGO SANDSTONE (UPPER ORDOVICIAN), OSWEGO COUNTY, NEW YORK

Douglas G. Patchen, Head, Oil and Gas Section
West Virginia Geological and Economic Survey, Morgantown, WV 26505

ABSTRACT

The relatively unfossiliferous greenish-gray sandstones, siltstones, mudstones, and shales that comprise the Upper Ordovician Oswego Sandstone near the Salmon River Falls type section in Oswego County were deposited in a sequence of adjacent environments ranging from offshore shelf to intertidal. Vertical changes noted in the Oswego include an upward increase in grain size from predominantly shales and siltstones in the lower part to fine-grained sandstones in the upper part, a color change from gray to green and finally red, and a change in faunal content from fossiliferous lower shales to nonfossiliferous upper sandstones. Along with these changes, a change in characteristic sedimentary structures and bedding characteristic was noted from the bottom to the top of the formation. Combining these data suggests that the lowest Oswego beds were deposited in the deepest waters, probably offshore shelf, and that overlying beds were deposited in progressively shallower water, more nearshore environments that included bar, lagoon, tidal channel and tidal flat. The overlying red sandstones and siltstones of the Queenston (Juniata) Formation were deposited under tidal flat to deltaic conditions. Thus, the Oswego represents the transition from underlying marine Pulaski shales to the overlying red deltaic deposits. This change resulted from a northward regression of the sea concomitant with an uplift in the source area that signaled the beginning of the Taconic Orogeny. Paleocurrent data suggest that this source area was located in southeastern Pennsylvania and that Oswego sediments were dispersed outward in a wedge-shaped mass into New York, western Pennsylvania, and northeastern West Virginia. Therefore, depositional environments in the as-yet unstudied Oswego rocks in West Virginia may be analogous to those in the New York type areas.

INTRODUCTION

A comprehensive stratigraphic and petrographic study of the Upper Ordovician and Lower Silurian rocks in Oswego County, New York, was previously carried out by the author (Patchen, 1966). During the course of that study, several vertical trends were noted in the stratigraphic sequence ranging from the Pulaski to the Grimsby Sandstone (Figure 1). These trends included: (1) an upward increase in grain size from predominantly shales in the lower Pulaski to shales and lenticular siltstones in the upper Pulaski and lower Oswego, to shale and very fine-grained sandstone in the middle Oswego, and finally to fine sandstones in the upper Oswego, Queenston, and Grimsby Formations; (2) a color change from dark gray to medium gray from lower Pulaski to lower Oswego, then greenish-gray to green toward the top

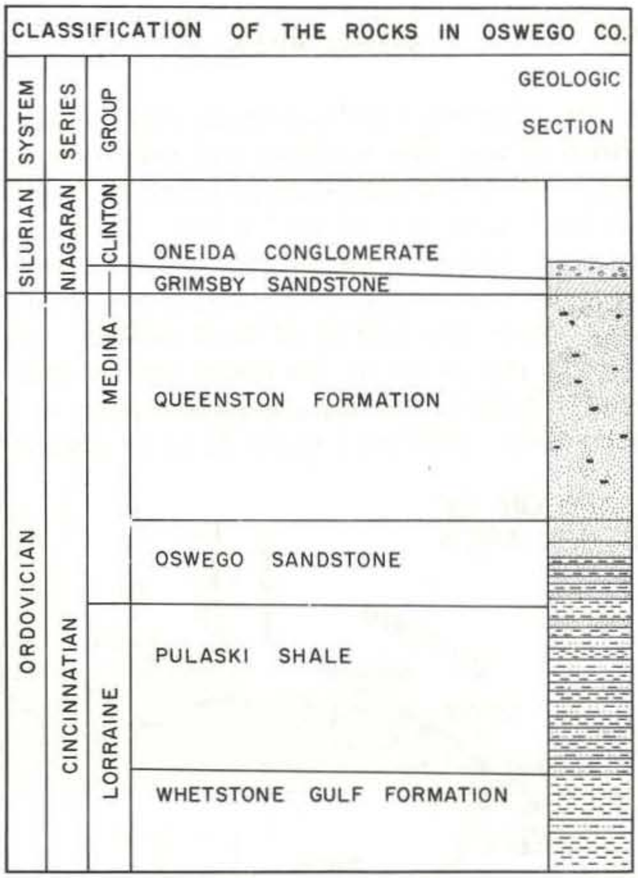


Figure 1. Generalized stratigraphic section and nomenclature for Upper Ordovician and Lower Silurian rocks in Oswego County, New York.

of the Oswego, and (3) a change in the faunal content from the fossiliferous lower Pulaski, to the relatively nonfossiliferous Oswego, to the nonfossiliferous red beds at the top of the sequence. Barren zones increase in thickness in the upper part of the Pulaski (Ulrich, 1913), and fossils are most common in only the lowermost 50 feet of the Oswego. Fossils other than trace fossils (i.e., feeding trails and worm burrows) are relatively rare in most of the Oswego sediments. Thus, the Oswego is the key formation in this transition from dark offshore marine shales to deltaic red beds. Therefore, this paper deals only with the various depositional environments of the Oswego. Most of these have been re-interpreted from data collected in the earlier study and from a recent petrographic study of thin sections made from Oswego core and outcrop samples in the study area. These interpretations are based on: (1) bedding characteristics, (2) associations of sedimentary structures, (3) textural and mineralogic data from thin-section studies, (4) the limited faunal evidence, (5) paleocurrent measurements, and (6) association with adjacent rocks for which an environment has been inferred. This study is preliminary to a similar detailed study of the Oswego rocks in the eastern outcrop areas of West Virginia and the adjacent subsurface areas.

STUDY AREA

The study area included most of Oswego County (Figure 2) although good outcrops were confined to the main streams and river valleys and the southern shore of Lake Ontario. All of the outcrops previously studied are shown, but those emphasized in this paper are all within the area designated by the Oswego outcrop pattern. Those in the vicinity of the Salmon River Falls type section occur in the lower half of the formation, those from Pleasant Point westward to Lakeview are in the middle of the formation, and those from St. Paul's Cemetery to Camp Hollis are in the upper part of the Oswego. Two cores taken by Niagara Mohawk during site preparation for their Ninemile Point nuclear-power facility (APP on Figure 2) were also available for study.

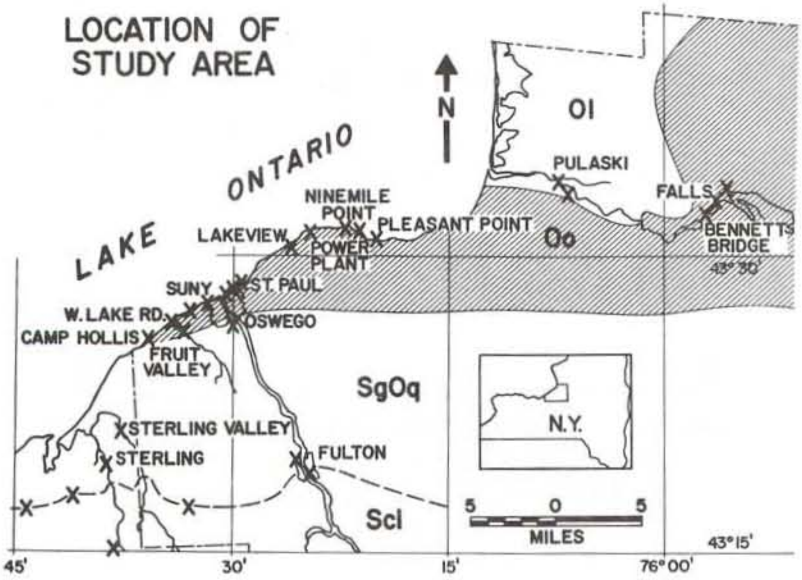


Figure 2. Location of study area in central New York State. Large X's refer to measured sections. Cross-hatched pattern Oo is outcrop area of Oswego Sandstone, Ol outcrop area of Lorraine Group, SgOq combined Grimsby and Queenston outcrop area, and Scl outcrop area of Clinton Group.

STRATIGRAPHY

The regional dip in most of the western part of the study area is approximately 50 feet per mile to the south, whereas farther east the strike is more north-south and the dip is to the west. Using this southward dip of 50 feet per mile, and plotting all outcrops relative to sea level, the stratigraphic relations of most of the outcrops in Figure 2 can be determined. In the central part of the study area, approximately 180 feet of the Oswego are represented by the two cores. The outcrops at Ninemile Point and the atomic-power plant overlap slightly and are the stratigraphic equivalents of the middle part of the cores.

Outcrops at Pleasant Point and Lakeview, although located many miles apart (Figure 2), are the stratigraphic equivalents in this reconstruction.

In the western outcrop area, perhaps 150 feet of Oswego are represented by scattered sections, with 45 to 50 feet of section missing between this western and the central composite sections. This yields a 380-foot thickness for the Oswego from the top down through the uppermost fossil zone, a figure comparable to previous estimates as far back as Prosser (1890). The lowermost beds in these western outcrops are gray and green sandstones, whereas the uppermost beds are red sandstones transitional with the overlying Queenston Formation.

To illustrate the environments of deposition of the Oswego in both a vertical and horizontal reference, several outcrops in Figure 2 will be summarized from the Salmon River Falls type section farther west to outcrops west of the city of Oswego.

Salmon River Falls Section

In the vicinity of the Salmon River Gorge, the lowest outcrops, stratigraphically, are near Bennett Bridge (Figure 3) and consist of fossiliferous (brachiopods and pelecypods) gray shales and mudstones with thin inter-

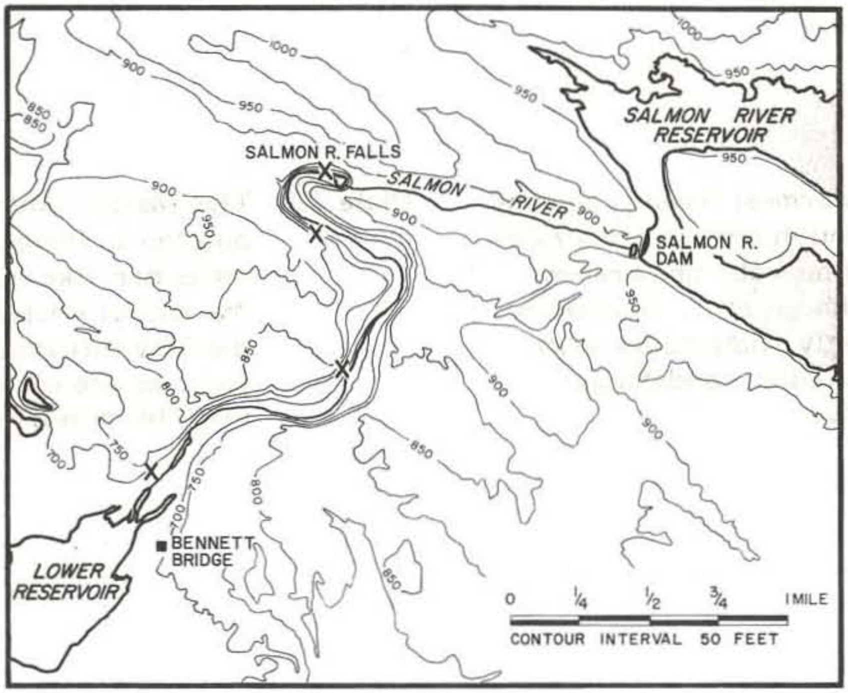


Figure 3. General topography in the vicinity of Salmon River Falls type section. Nearly continuous Oswego outcrops occur in gorge from Bennett Bridge to falls. Plates 1A and 1B are located at second X above Bennett Bridge.

Plate 1A Upper section midway through gorge, overlapping with Plate 1B. Total thickness of the Oswego in these two photos is approximately 100 ft. Thicker sandstones and minor shales dominate upper part.

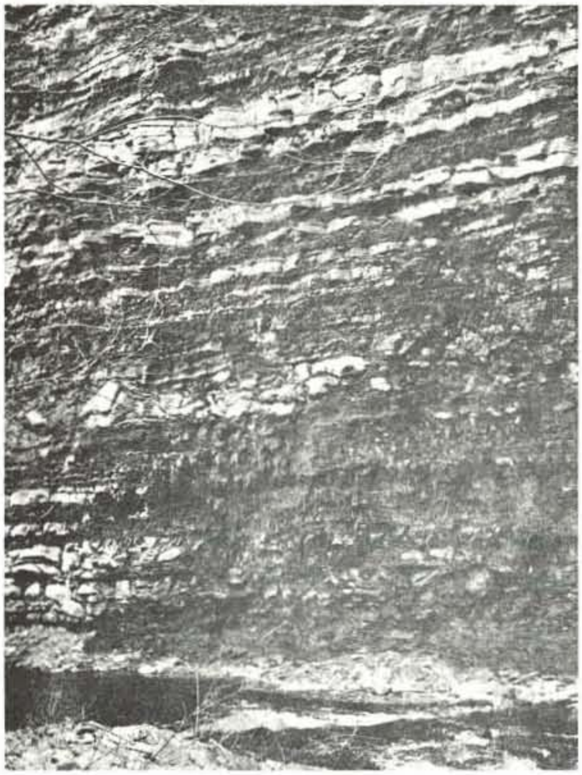
Plate 1B Lowermost Oswego midway through gorge. Two zones of flow rolls are present in lower 20 ft. Section is mostly shale below with lenticular sandstones above.

Plate 1C The Oswego outcrop east of Ninemile Point with thick sandstones at the top, hackly mudstone in the middle, and interbedded sandstones and shale in the lower part. Flow rolls and ripple-marked sandstones occur in the mudstone.

Plate 1D The eastern end of the outcrop in Plate 1C. The large bar-like feature is the lateral equivalent of the flow roll zone. Slump features are associated with this sandstone body.

A

C



B

D

bedded siltstones and very fine-grained sandstones. Sedimentary structures include flow rolls within the thick mudstones, ripple marks on some upper sandstone surfaces, and drag marks on the lower surfaces of other sandstones, trending N_3E to N_3W. The elevation at this point is approximately 650 feet, the level of the lower reservoir, whereas the base of the falls is at 750 feet, the lip is at 850 feet, and the base of the dam at the upper reservoir is at 900 feet. Thus, there are 250 feet of topographic relief in the gorge where the Oswego crops out. Due to the regional dip, however, probably only 200 to 210 feet of Oswego are represented from the lower to the upper reservoir.

The lower part of the Oswego in the gorge near the falls is predominantly gray shale with thin, lenticular gray siltstones and very fine-grained sandstones (Plate 1B). Fossils are found only in the lowermost 8 to 10 feet. Several zones of flow rolls can be observed in the lowermost shales. Other sedimentary structures include ripple marks, flute-, groove-, and load-casts, drag marks, and clay galls. The upper part of this section is more arenaceous and massive (Plate 1A). Sandstones are more prominent relative to shales, and are often cross-bedded. These uppermost beds can be examined in the river bed above the falls and consist of greenish, very fine- and fine-grained sandstone with planar cross-beds, trough cross-beds, sandstone channels, and parting lineation. Paleocurrent directions for these various structures range from $N_{26}E$ to $N_{13}W$.

Thus, there is a change not only in sandstone-shale ratio and faunal content from the lower beds in the gorge to the upper beds, but a change in associated sedimentary structures as well. The lower rocks are interpreted as having been deposited in deeper, more offshore waters than the upper beds, which are nearshore sandstones, probably deposited under the influence of tides in the intertidal zone. These upper rocks resemble those farther west at Lakeview and the atomic-power plant, whereas the lower beds resemble those at the Ninemile Point outcrop, all within the central outcrop area.

Central Area

East of Ninemile Point, thick sandstones are present in the upper 1/3 of the outcrop, with thick mudstone in the middle 1/3, and interbedded thick sandstones and shales in the lower 1/3 as traced along the shoreline of Lake Ontario (Plate 1C). Two flow-roll zones are present in the middle of the mudstone unit (Plate 1C) plus some thin sandstones with ripple-marked upper surfaces and sole marks on the lower bedding surfaces. Farther along the outcrop, the lower flow-roll zone is replaced by a large bar-like feature (Plate 1D). This sandstone body is fine-grained, cross laminated within, and contains large load casts on its lower surfaces. The maximum length is 33 feet and the maximum height is 1.5 feet. The sand body pinches out abruptly not only at each end but backwards into the outcrop. The upper surface descends at a 45-degree angle and the body extends only 2 feet back into the outcrop in the right side of Plate 1D.

The rocks in this outcrop are interpreted as having been deposited in a bar-lagoonal environment. Thin, ripple-marked sandstone lenses were deposited as occasional washover sands into the lagoon that is represented by the hackly mudstone. The thick, interbedded sandstones in the lower part of the outcrop represent the bar sands. Other nearshore sands are represented by the sandstones at the top of the section above the lagoonal muds.

Part of the reason for this interpretation is the close proximity of this outcrop with one less than a mile to the west at Ninemile Point. In that locality, 18 feet of interbedded gray sandstones and shales are present. This is a ripple-mark locality, with 12 of the upper sandstone surfaces exhibiting this sedimentary structure (Plate 2A). The average trend of the ripples is $N_{86}E$. Trace fossils, mainly feeding trails, are present on the lower surfaces of four sandstone beds. Thus, although very close to the section east of Ninemile Point, these rocks are quite different and represent a sandy, muddy, intertidal flat deposit with alternating quiet (mud) and gentle current (rippled sands) deposition. Various organisms fed on the muddy surfaces. This intertidal area would be closely associated with the bar-lagoonal deposits represented in the nearby outcrop.

Above these tidal flat and adjacent bar-lagoonal rocks are sandstone beds resembling those at the top of the type section. These were exposed just west of Ninemile Point during the excavation for Niagara Mohawk's nuclear-power plant (Plate 2B). The 60 feet of vertical section can be divided approximately into three nearly equal parts. The upper 20 feet are very lenticular, cross-bedded, fine-grained gray sandstones. Shales are minor although clay galls are common. The middle 1/3 consists of thinner, darker sandstones and some shales, with sun-crack casts and trace fossils on the lower bedding surfaces. The lower 1/3 consists of thicker, fine-grained gray sandstones with thin shale breaks. These thicker, lower beds formed the pedestal for the nuclear reactor. All of the sandstone beds at this locality probably were deposited as nearshore sands under tidal influence, with muds periodically exposed to form mud-cracks resulting in casts on the overlying sandstone sole (Plate 2C). Raindrop imprints on upper mud surfaces resulted in the formation of raindrop casts on other sandstone soles, again suggesting periodic exposure of the mud layers. Organisms that fed on these muddy surfaces have left their mark as trace fossils on still more sandstone soles.

Adjacent to these rocks just farther to the west at Lakeview, greenish-gray, irregularly bedded, trough cross-bedded sandstones jut out into Lake Ontario at lake level. The long axes of these troughs average N_7W and probably reflect the prevailing direction of the tidal currents that cut and filled them. Thus, the sandstones in the Oswego in the central area represent nearshore sand environments, which include bar, lagoon, tidal channel, and tidal flat.

Plate 2A The upper half of the Oswego outcrop at Ninemile Point. The upper crenulated sandstone surfaces are ripple marked. The entire section contains more shale than shown in this photo.

Plate 2C Sun-crack casts on a sandstone sole from the Oswego at the power plant site. Other sandstone soles in this part of the section contain raindrop imprint casts. Both of these structures suggest periodic exposure of the underlying mud surfaces.

Plate 2B Oswego Sandstone exposed during excavation for the nuclear-power plant at Ninemile Point. Lenticular sandstones are common in the upper, lighter part, with darker shales and sandstones in the middle third. The lowermost sandstones, separated only by thin shales, are more evenly bedded and form the pedestal for the reactor, seen in the lower left.

A

C

B

Western Area

Rocks in all of the western outcrops, which represent the upper half of the Oswego, are predominantly sandstones characterized by planar cross beds, trough cross beds, sandstone channels, sun-crack casts, parting lineation, some ripple marks, and abundant clay galls. Colors range from gray to green, with red beds common in the outcrops representing the uppermost Oswego beds.

Although many outcrops were studied, they can all be generalized into the following approximate vertical sequence: planar cross beds at the top; sandstone channels (Plate 3A) with parting lineation above the channels; trough cross beds; sun-crack casts; more planar cross beds; and a lower series of trough cross beds. Trace fossils are also common in most outcrops. The complete vertical sequence as outlined above can be observed in outcrops along the beach behind the State University of New York College at Oswego campus. That particular section is near the top of the Oswego and contains abundant red beds although many of the trough cross beds are gray sandstones of fine- to nearly medium-grain size which cut into red very fine-grained sandstones, siltstones, and shales (Plate 3B). These are interpreted as tidal-channel and tidal-flat deposits, respectively. All of the outcrops west of the campus to West Lake Road and Camp Hollis exhibit these same features and are interpreted as tidal-channel and tidal-flat deposits. The main variation is in color, with Oswego sediments at West Lake Road, stratigraphically higher than the red beds at the campus, being green, and those at Camp Hollis, near the Oswego-Queenston contact, being red with green mottles. The rocks at Camp Hollis, however, have an association of sedimentary structures typical of the Oswego including trough cross beds (Plate 3C), sandstone channels, planar cross beds, and parting lineation and are correlated as such. Thus, all of the rocks in the upper Oswego west of St. Paul's Cemetery are interpreted as tidal channel and tidal flat. Alluvial sediments may be interbedded with these intertidal deposits, but evidence of possible alluvial deposits could only be observed in one small area, and is not pursued in this short paper. Furthermore, the outcrop at St. Paul's Cemetery is not described in this paper, but it does contain a very interesting channel deposit previously described (Patchen, 1966). That particular channel is similar to those described by Van Straaten (1954) in the Psammites du Condroz (Devonian) in the Belgian Ardennes, which he interprets as of intertidal origin.

Stratigraphic Summary

Figure 4 illustrates the summary of both stratigraphic and environmental interpretations for the scattered Oswego outcrops in the study area. Three composite sections are shown with the correlation from the east to the central area based on the highest occurrence of fossils and a change in sandstone-shale content. The lowest, fossiliferous, lenticular sandstones, siltstones, and shales are interpreted as offshore shelf deposits, whereas the sandstones

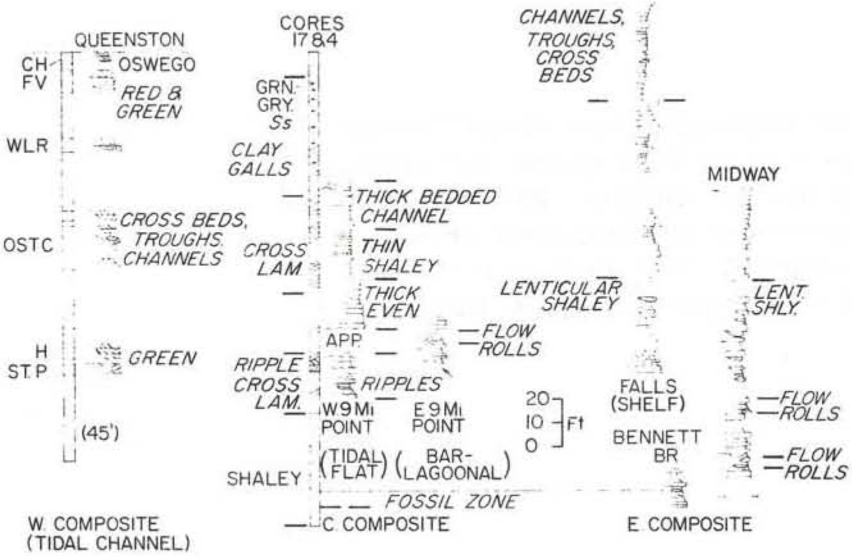


Figure 4. Summary of the sedimentary structures, bedding characteristics, lithologies, and colors for the Oswego Sandstone in the study area. Three composite sections are shown, plus a composite core description adjacent to the central composite. The correlation from that section to the east is on the fossil zone. Interpreted environments are in parentheses. Abbreviations by the western composite correspond to measured sections named in Figure 2.

and mudstones higher in the section east of Ninemile Point are interpreted as bar and lagoon. Ripple-marked intertidal sandstones with interbedded shales at Ninemile Point are interpreted as tidal-flat deposits adjacent to this bar-lagoon complex. These rocks are overlain by a thick sequence dominated by nearshore intertidal sandstones of tidal-channel and tidal-flat origin. In Figure 4 it should be noted that the western composite occurs stratigraphically above the central composite, but is shown in the proper lateral perspective. Red beds are common in the upper Oswego, which is transitional with the overlying Queenston (Juniata facies) red reds.

PETROGRAPHIC SUMMARY

Briefly, some results of the petrographic study can be summarized by referring to Figure 5. Thin-section data from the Oswego samples are shown in the lower part of this figure. Within these samples, collected from a 140-foot vertical interval in Core 17 plus western outcrops in the upper Oswego, grain size gradually increases upward as shown. The sorting and roundness of the quartz grains also increase upward. This relationship of rounded versus angular quartz grains has been emphasized by a pattern in Figure 5 and

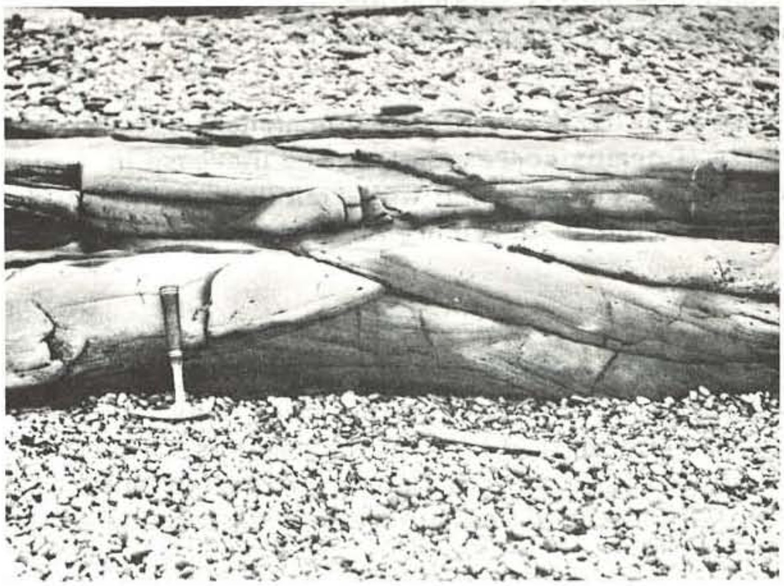
Plate 3A Sandstone channels in red Oswego beds at the State University College at Oswego campus. Parting lineation is common on sandstones above the channels. The average channel is 3-4 ft. wide and 1-1½ ft. high.

Plate 3B Trough cross beds in a gray sandstone at the campus outcrop. This trough cross-bedded zone is generally 3-5 ft. below the channels in Plate 3A. The troughs in this zone average 10-15 ft. in width, 2-3 ft. in thickness, and 25 ft. in length. Bedding conforms to the lower surface and pebble-lag deposits are common.

Plate 3C Overlapping trough cross beds at Camp Hollis in red Oswego beds. Channels, planar cross beds, and sun-crack casts also were observed at this locality. These are the uppermost Oswego beds exposed in the study area.


A


B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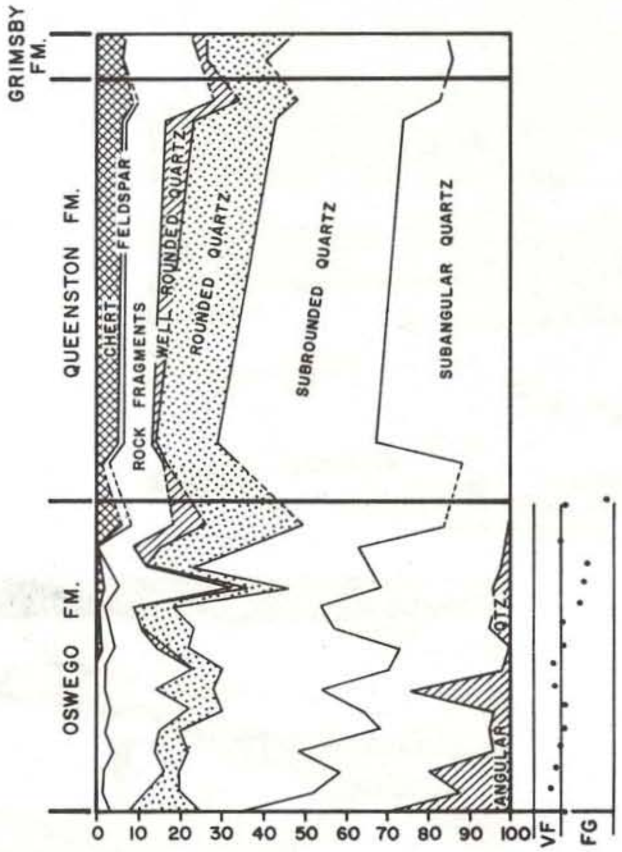

Figure 5. Summary of the thin sections studied from Cores 4 and 17 and uppermost Oswego outcrops. Textural data are emphasized. Grain size increases upwards from very fine (VF) to fine grained (FG). Roundness also increases upward. The overall low roundness, high rock fragment content, and clay matrix suggest low energy levels for Oswego deposition.

may suggest an increase in energy of the depositional environment upward. However, the introduction of chert grains corresponds to the increase in roundness. Therefore, some of these rounded and well-rounded grains could be inherited from a reworked sedimentary source area that also supplied the chert grains.

Although not shown in Figure 5, clay matrix increases with depth to a slight degree, and calcite cement increases with depth relative to quartz overgrowths. Hematite coatings are abundant in the uppermost red beds. Metamorphic rock fragments are common in most of the Oswego samples. These are well rounded and are considered to be indicators of a low-energy environment. Thus, the sum total of the textural and mineralogic data yields an overall picture of low-energy environments in the Oswego, compatible with those previously described.

SOURCE AREA AND PALEOCURRENTS

More than 250 paleocurrent measurements were made at the various outcrops and are plotted in Figure 6. The rose diagram indicates a strong northward trend with minor lobes just to the east and west. The bimodal nearly east-to-west direction is due to the many ripple marks measured. The axes of these ripples should parallel the shorelines and be perpendicular to tidal

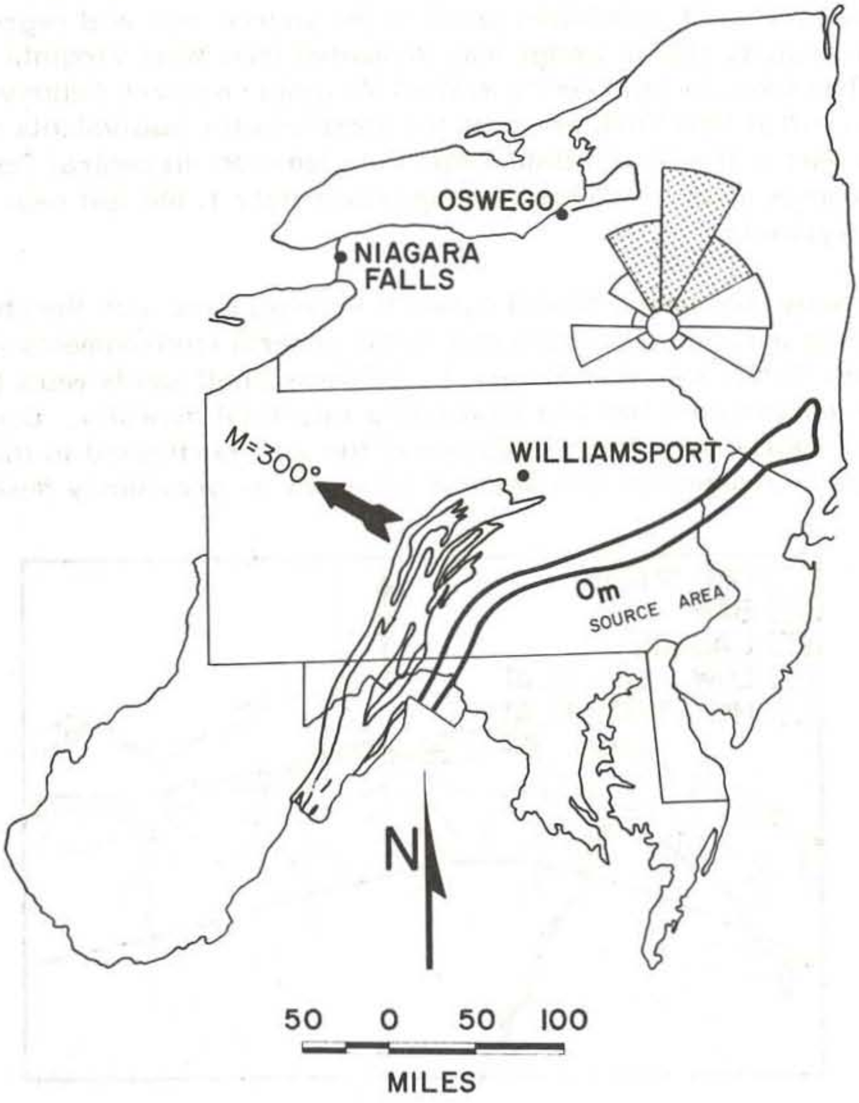

Figure 6. Rose diagram of Oswego paleocurrents in Oswego County outcrops, plus an arrow showing Yeakel's (1962) average trend for the Bald Eagle in central Pennsylvania. Bold line near Om is the Martinsburg Shale outcrop just northwestward from the suggested source area. Oswego outcrops are also shown in West Virginia.

currents that cut and filled sandstone channels and trough cross beds. All of these data are tabulated and illustrated by individual outcrops in the previous study (Patchen, 1966). This general paleocurrent direction can be projected back to the south until it intersects a similar projection made from Yeakel's (1962) Bald Eagle (Oswego) measurements in central Pennsylvania. This pinpoints the source area in southeastern Pennsylvania eastward of the present Martinsburg Shale outcrop area. As the Taconic Orogeny began, sediments from this source area moved southwestward toward West Virginia, westward into central Pennsylvania, and northward toward Oswego County, New York. Initially, clastic material was concentrated in central Pennsylvania (Bald Eagle); however, with continued uplift in the source area and regression of the sea, an arcuate clastic wedge was deposited from West Virginia to Lake Ontario. The Oswego sandstones in West Virginia, western Pennsylvania, and north-central New York are thus the stratigraphic equivalents of the uppermost part of the fluvial Bald Eagle Conglomerate in central Pennsylvania. Those sediments attain a thickness of approximately 1,300 feet near Williamsport, Pennsylvania.

The Oswego sediments moved outward keeping pace with the shoreline of the retreating sea and were deposited in the general environments in Oswego County, New York, shown in Figure 7. Offshore shelf sands were laterally equivalent to nearshore bar and lagoon and intertidal deposits. Continued uplift in the source area and regression of the sea, northward in this area, placed these environments in a vertical sequence as previously described,

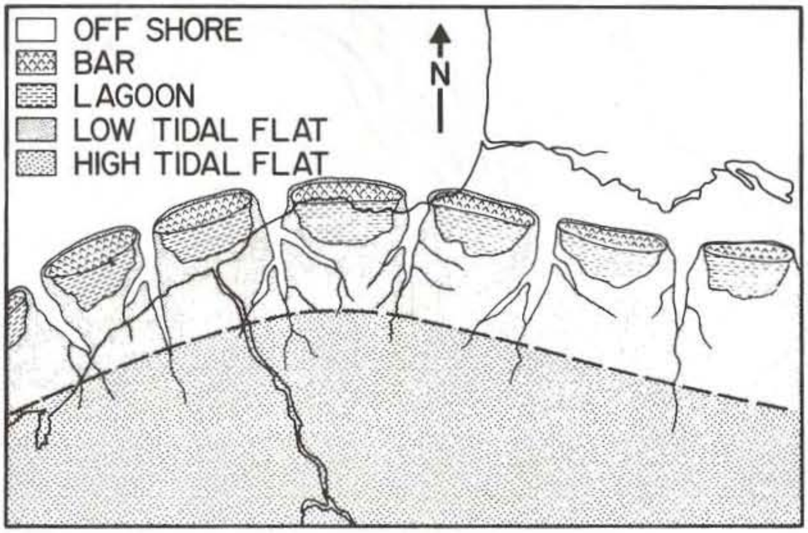

Figure 7. Generalized depositional environments for the Oswego in the study area, ranging from offshore to tidal flat. Large tidal channels cut through these tidal flats. The present shoreline of Lake Ontario and the Salmon and Oswego Rivers are shown for geographic reference.

yielding the coarsening-upward, offshore-to-nearshore sands with faunal and color changes typical of the Oswego vertical sequence. With continued regression, these uppermost Oswego tidal-channel and tidal-flat sediments were overlain, in turn, by red fluvial-deltaic deposits of the Queenston Delta.

ACKNOWLEDGMENTS

Illustrations and photographs in this paper were drafted and printed by Dan Barker and Ray Strawser, both staff members of the West Virginia Geological Survey Publications and Graphics Section. James Carte, former Head of that section, edited the manuscript, and Susan Burkhammer typed the manuscript. All of their efforts are greatly appreciated.

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NOTES