STUDIES IN STRATIGRAPHY AND PALEONTOLOGY IN HONOR OF DONALD W. FISHER

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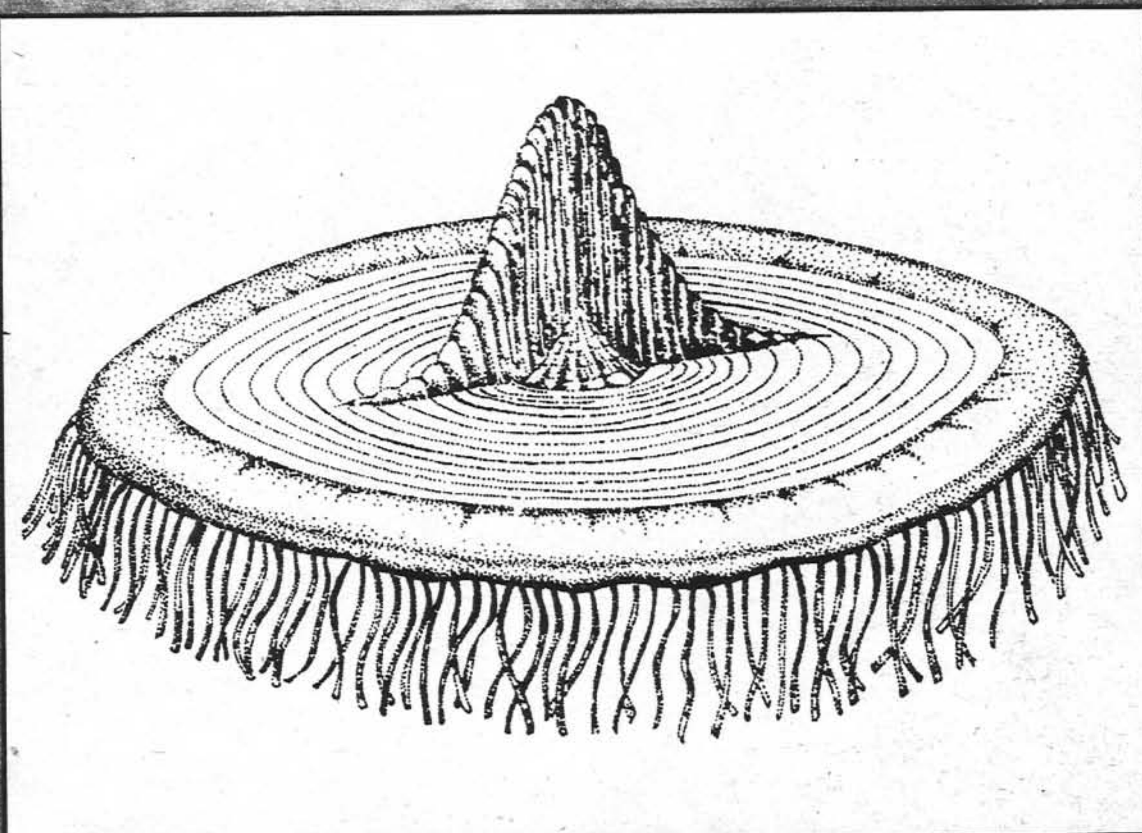

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Revised stratigraphic and facies relationships of the lower part of the Clinton Group (middle Llandoverian) of western New York State

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Abstract

The lower part of the Clinton Group (Lower Silurian, Llandoverian) of western New York State and adjacent Ontario is an unconformity-bounded sequence composed of alternating greenish grey to purplish shale, fossiliferous carbonates, and thin hematites. Successively older Clinton units are beveled in a westward direction beneath a major unconformity at the middle of the Clinton Group (sub-Williamson unconformity). The three lower formations (the Neahga and Maplewood Shales and the Reynales Limestone), which alone persist into Orleans and Niagara Counties, are the subject of this paper. The base of the Clinton Group (emend.) can be drawn unambiguously at a thin phosphatic conglomerate bed (Densmore Creek Bed, new unit) that unconformably overlies pale greenish grey to white (leached) sandstones and shales of the Kodak and Thorold Formations. Although the latter units have formerly been correlated with and included in the Clinton Group, they are herein separated and assigned to the underlying Medina Group (emend.). The Densmore Creek Bed forms the base of both the Neahga (grey) and Maplewood (greenish grey) Shales; this evidence suggests that these units are precisely correlative. These shales accumulated in shallow, partially partitioned basins separated by a local, northeast-trending high area that crops out near Lockport, New York. The Maplewood Shale also pinches out abruptly into a complex, hematitic, multigenerational phosphatic conglomerate bed (herein termed the "Webster Bed") along a line extending southwest from eastern Monroe County.

The base of the overlying Reynales Limestone (Brewer Dock Member) is also marked by a widespread, thin phosphatic bed (Budd Road Bed, new unit); this horizon may represent a significant unconformity. The Brewer Dock Member of the Reynales Limestone is a thin (0.5 to 1.0 m) interval composed of three carbonate packstone-to-green-shale, upward-shallowing cycles. The top of the unit is marked locally in Monroe County by a fossiliferous hematitic limestone, the Seneca Park Bed (new unit). The Brewer Dock Member passes eastward into a hematitic limestone and shale interval (Furnaceville Member, emend. herein) of comparable thickness. The overlying 5.0 to 6.0 m-thick Wallington Member also contains several widely traceable carbonate-to-shale cycles that facilitate very detailed correlations eastward into the coeval Bear Creek Shale.

At least three scales of cyclicity (probably 4th- to 6th-order cycles) occur in the lower part of the Clinton Group. Detailed correlation of facies within the minor cycles indicates a relatively consistent pattern of east to west bio- and lithofacies changes. The easternmost quartzose phosphatic conglomerates represent shoreline facies, and pass westward (offshore) into greenish grey shales with an *Eocoelia*-dominated biofacies (benthic assemblage 2 or BA-2). These shales, in turn, give way to pelletal grainstones and pentamerid- (or *Hyattidina*-) rich crinoidal packstones and grainstones (shoal facies, BA-3), and finally to nodular, bryozoan-rich wackestones (BA-4). Detailed facies transects provided by the microstratigraphy of the lower part of the Clinton Group corroborate models of benthic assemblage distribution and provide insight into Silurian biofacies.

Introduction

The Clinton Group (Lower Silurian) of western New York is a thin but complex interval with numerous lithofacies that includes hematitic oolitic iron ore, green shales, phosphatic beds, and coquinoid limestones (Gillette, 1947). Laterally, this interval exhibits a relatively complete facies spectrum from nearshore conglomerates to deeper-shelf facies. At least three scales of cyclicity are present in this thin interval, and the Clinton Group provides key insights into lithofacies cycles within the Silurian. Gillete (1947) informally subdivided the Clinton Group into Lower, Middle, and Upper portions on the basis of discontinuities in ostracode biostratigraphy. Recent work reinforces the utility of this subdivision. In particular, Gillette's units appear to represent unconformity-bounded sequences sensu Vail et al. (1977; see Brett et al., 1990a, 1990b). This report concerns detailed stratigraphy and facies relationships within the lower part of the Clinton Group, or "Lower Clinton Group" of Gillette (1947).

Although the lower part of the Clinton Group (Lower Silurian, Llandoverian) in the Rochester to Niagara area has been studied intensively for over a century, a number of subtle relationships have remained unresolved. Fisher (1953a) made the last detailed study of the lower part of the Clinton Group, and described several aspects of the regional stratigraphy in the area between the Niagara Gorge and the Genesee Gorge.

In New York State, the "Lower Clinton Group" attains a maximum thickness of approximately 50 m in the Wayne County area. This interval includes, in ascending order, the Maplewood Shale (or equivalent), Reynales Limestone, "Lower" and "Upper" Sodus Shales, and Wolcott Limestone. The lower part of the Clinton Group is represented in central Pennsylvania by over 80 m of purple and greenish shale that composes the lower part of the Rose Hill Formation. This interval of the Rose Hill corresponds to the *Zygobolba emaciata*, *Z. anticostiensis* (=Z.

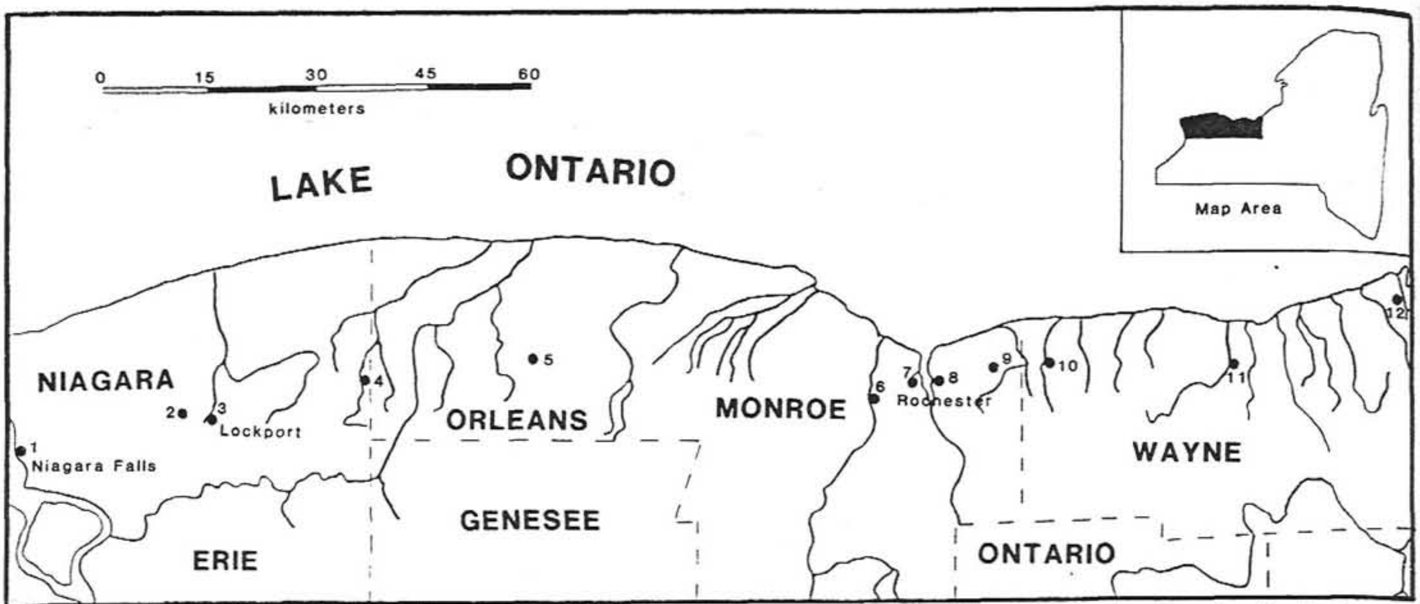


Figure 1. Location map of the study area showing outcrops and drill cores of the lower part of the Clinton Group. Note location of counties referred to in text.

excavata), and *Z. decora* Zones (ostracodes). The lower part of the Clinton Group in western New York represents only part of this sequence, and is equivalent to the lower portion of the *Zygobolba excavata* Zone. Conodont biostratigraphy in this interval remains somewhat uncertain.

This report stems from several new discoveries within the "Lower Clinton Group" that resulted from reexamination of outcrops, extensive drilling in Niagara and Monroe Counties, and test drilling in Orleans and Wayne Counties (Figure 1). These activities provided new data upon which to base the revised correlations.

Fisher (1953a) recognized, as Gillette (1947) had earlier, that the upper portions of the "Lower Clinton Group" ("Lower" and "Upper" Sodus Shales and Wolcott Limestone) were absent in western New York. Recent study (Lin and Brett, 1988) revealed that the upper surface of the "Lower Clinton Group" lies at a distinct regional angular unconformity; moreover, this surface has been proposed (Brett et al., 1990a, 1990b) as a major erosive sequence boundary associated with a late Llandoverian (late C-5 to earliest C-6) sea-level lowstand and coincident with minor tectonism on the Algonquin Arch forebulge. This surface progressively bevels strata in the lower part of the Clinton Group, and actually merges with a sub-Clinton erosion surface that truncates the upper part of the Medina Group in the vicinity of St. Catharine's, Ontario (Figures 2, 3). In western New York and the easternmost Niagara Peninsula of Ontario, only a very small fraction of the "Lower Clinton Group" is available for study. It cannot be proven that higher Clinton strata were ever deposited in this region; however, there is some indication that these units once may have extended at least to Rochester. Gillette (1947) reported the discovery of limestone clasts that closely resemble the Wolcott Limestone on the erosion surface beneath the Williamson Shale at the Genesee Gorge in Rochester. There is no evidence of internal thinning or condensation of units in the lower part of the Clinton Group as they approach their westward erosional terminus. This also points to the probability that these units once extended substantially westward prior to regional uplift in the area that extends from central New York State to Hamilton, Ontario. Furthermore, it recently has been suggested that the western equivalent of much of the lower part of the Clinton Group reappears beneath the C-6 erosion surface in the vicinity of the Bruce Peninsula of Ontario, where the Dyer Bay, Wingfield, and St. Edmund Formations successively appear northward beneath the (Llandoverian C-6) Fossil Hill Formation (Colville and Johnson, 1982; Brett et al., 1990a, 1990b). These units appear to correspond approximately to the Reynales, "Lower" Sodus, "Upper" Sodus, and Wolcott Formations in New York State (Figure 2). Thus the upper surface of the "Lower Clinton Group" appears to be a regional angular unconformity. Unfortunately, the removal of all "Lower Clinton Group" units in southern Ontario precludes complete lateral facies analysis of these formations. However, the lowest beds can be traced west to St. Catharine's, and provide some insights into regional paleogeography and facies distribution.

The base of the Clinton Group also lies at a regional angular, although minor, truncation surface marked by a persistent phosphatic bed (Brett et al., 1990b) that was previously recognized and mapped, in part, by Fisher (1953a; herein designated the "Densmore Creek Bed," Figure 4). Contrary to previous assertions, the sandstone beneath this phosphatic bed is not conformable with overlying strata. Furthermore, the pale greenish grey sandstone that underlies the Clinton Group in western New York and Ontario is not a single, correlative unit. The white to greenish Kodak Sandstone beneath the shales in the lower part of the Clinton Group in the Genesee Gorge area in Rochester does not appear to be correlative with the somewhat similar Thorold Sandstone, that underlies the same shales to the west. Rather, the Kodak Sandstone, and 5.0 to 7.0 m of underlying red and greenish mudstone ("Cambria Shale," designation herein), are beveled beneath the basal Clinton unconformity, and the Thorold itself is truncated west of Grimsby, Ontario. Hence this is another low-angle regional unconformity, and forms a lower sequence boundary.

As a result of these two surfaces, the "Lower Clinton Group" is stratigraphically bounded and can be considered as a sequence in the sense of seismic stratigraphers (Figure 3). In a recent report (Brett et al., 1990b), the Medina Group has been designated as sequence I and the lower part

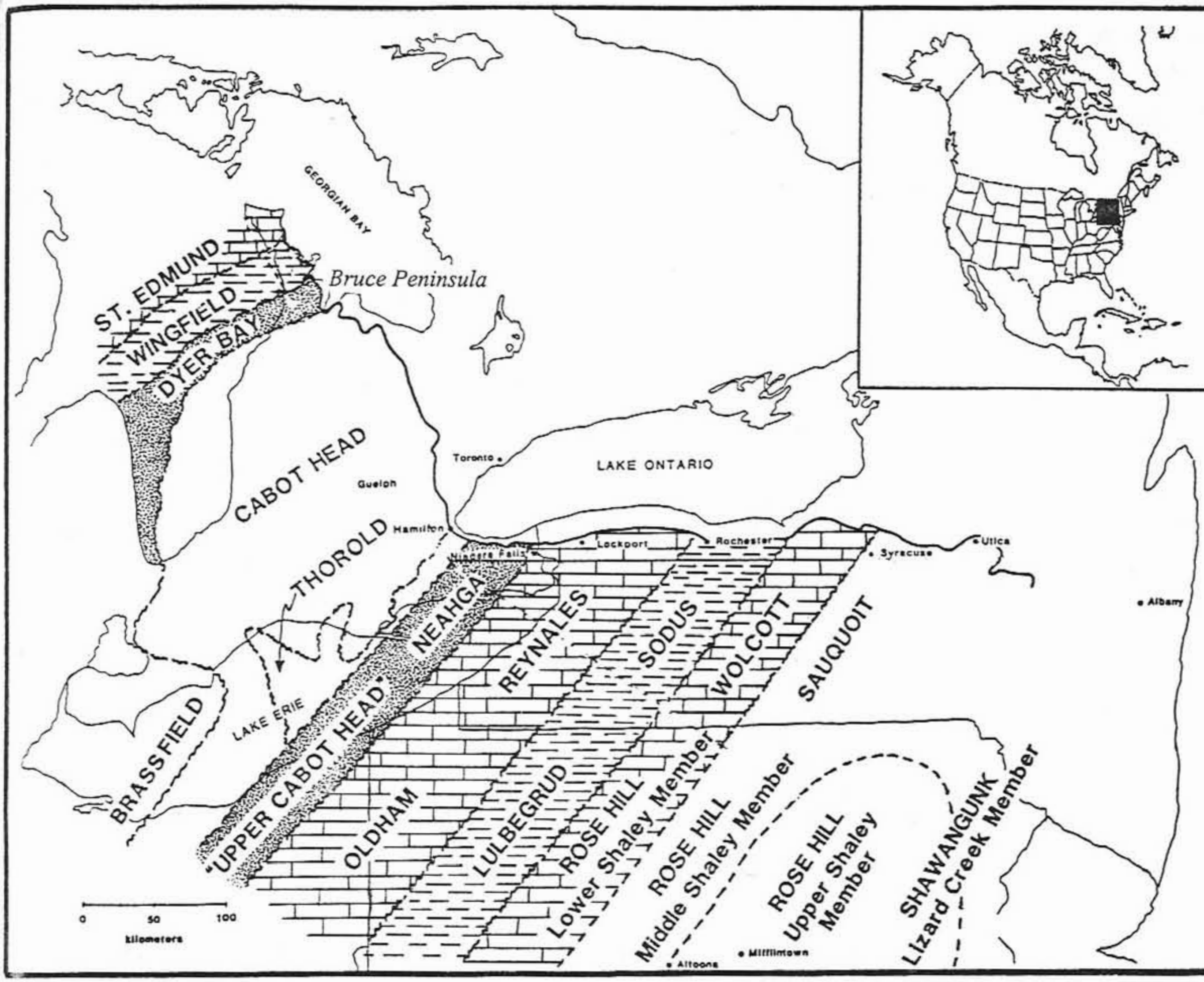


Figure 2. Subcrop map of Silurian units at regional angular unconformity underlying Llandoverian C-6-age strata (Fossil Hill–Merritton Limestones in Canada; Williamson–Willowvale Shales in New York). Note the westward beveling of lower units of the Clinton Group (shaded) in western New York and southern Ontario, and the appearance of possibly coeval strata to the north along the Bruce Peninsula. Area of maximum removal of strata near Hamilton, Ontario, corresponds to the Algonquin Arch (modified from Brett et al., 1990a).

of the Clinton Group as sequence II: the lower part of the Clinton Group is unconformably overlapped by the Sauquoit Formation along a phosphatic conglomeratic bed that marks a third sequence boundary. Westward, the Sauquoit Formation is truncated by the upper erosion surface beneath the Williamson–Willowvale Formations, and the two unconformities merge into one that overlies the "Lower Clinton Group."

Sub-Clinton stratigraphy

Underlying units

Traditionally, the base of the Clinton Group has been drawn at the base of the so-called "Thorold Sandstone." Gillette (1947) and Fisher (1953a) both agreed that the "Thorold" is an extensive, thin (0.7 to 3.0 m), pale grey to greenish sandstone that represents reworked sand cannibalized from the underlying Medina Group. They implied that the "Thorold" was a sheet-like transgressive deposit with a sharp base and was conformable with the overlying Maplewood or Neahga Shale. The so-called "Thorold," or "grayband," was traced from the type area near Thorold, Ontario, eastward at least to western Oswego County, where the unit was believed to merge into the Oneida Conglomerate. Gillette (1947) indicated that this unit belonged to the *Zygobolba excavata* ostracode Zone of the lower part of the Clinton Group. However, the only ostracodes actually found within the so-called "Thorold" interval were nondiagnostic leperditians. Only in some of the eastern localities, where the "Thorold" was said to merge with the Oneida Conglomerate, were zonally significant *Zygobolba* species recovered (see Gillette, 1947, p. 29). Furthermore, the ostracodes were from shale partings in the Oneida, and the latter apparently is separated from the Medina Group by an unconformity.

New observations in the lower part of the Clinton Group and the Medina Group (Brett et al., 1990a, 1990b) indicate that many of the previous assumptions about the so-called "Thorold" are incorrect. First, although a 0.7 m to 3.0 m-thick greenish white mottled sandstone does occur over most of the area from Wayne to Oswego Counties westward into Niagara County, this is not all referable to the Thorold Sandstone. Indeed, the Thorold Sandstone occurs below the Clinton Group only at and near the type section near St. Catharine's, Ontario, and eastward to central Niagara County, New York (Figure 3). West of St. Catharine's, Ontario, "Lower Clinton Group" strata are completely removed by a later erosion surface. In the area west of Grimsby, Ontario, the Merritton Limestone of the upper part of the Clinton Group rests with a sharp contact on light-colored beds that are actually layers of the upper Grimsby Sandstone (W.M. Duke, personal commun., 1989; Figure 3).

In the vicinity of the northern Niagara Gorge, a thin remnant of purple to greenish shale appears between the Thorold Sandstone and the phosphatic sandy carbonate horizon at the base of the Clinton Group. At one section just north of the Robert Moses Power Plant in the vicinity of Lewiston, New York, about 50 cm of this purple to greenish sandy shale is present below the base of the Neahga Shale (lowest Clinton Group unit). Fisher (1953a) recognized this interval in the northern Niagara Gorge and inferred that the green and purple shales should be included as a distinctive basal unit of the Neahga Shale. However, Fisher was apparently unaware that a sandy, brachiopod-bearing, phosphatic limestone or dolostone (Densmore Creek Bed, see below) occurs at the top of the green and purple shales and separates these from the overlying dark grey, fissile, "true" Neahga Shale.

Another critical section is at Lockport Junction Road (New York Rte. 290) near the village of Hickory Corners. Fisher was aware of this outcrop and included this newly discovered section in an addendum in his 1953a paper. The full implications of this cut, however, were not realized until the 1980s, when a fresh exposure was made during road widening (see Brett et al., 1990a). This revealed an excellent section of typical Neahga Shale that has a sharp base at a distinct phosphatic pebble horizon that contains the brachiopod *Hyattidina congesta*. Fisher apparently saw the brachiopods, but he did not recognize that the phosphatic level here was correlative with the phosphatic bed (Densmore Creek Bed, herein) that he observed at Rochester. This phosphatic bed sharply separates the Neahga Shale from the underlying greenish shale with leperditian ostracodes. The latter shale has been termed the "Cambria Shale," with the Lockport Junction roadcut as the type section (Brett et al., 1990a, 1990b).

A distinctive unit lies approximately 1.75 m below the phosphatic marker bed at the base of the Neahga Shale at Lockport Junction Road. This unit forms a mottled pink and white ledge about 1.2 m thick that is composed of fine-grained, moderately well-sorted sandstone with abundant trace fossils (*Daedalus* and *Arthrophycus*). These trace fossils are present in the Thorold Sandstone at Niagara Gorge and westward into Ontario. It is inferred herein that the pinkish sandstone bed 1.75 m below the phosphatic bed is, in fact, the Thorold Sandstone. A compa-

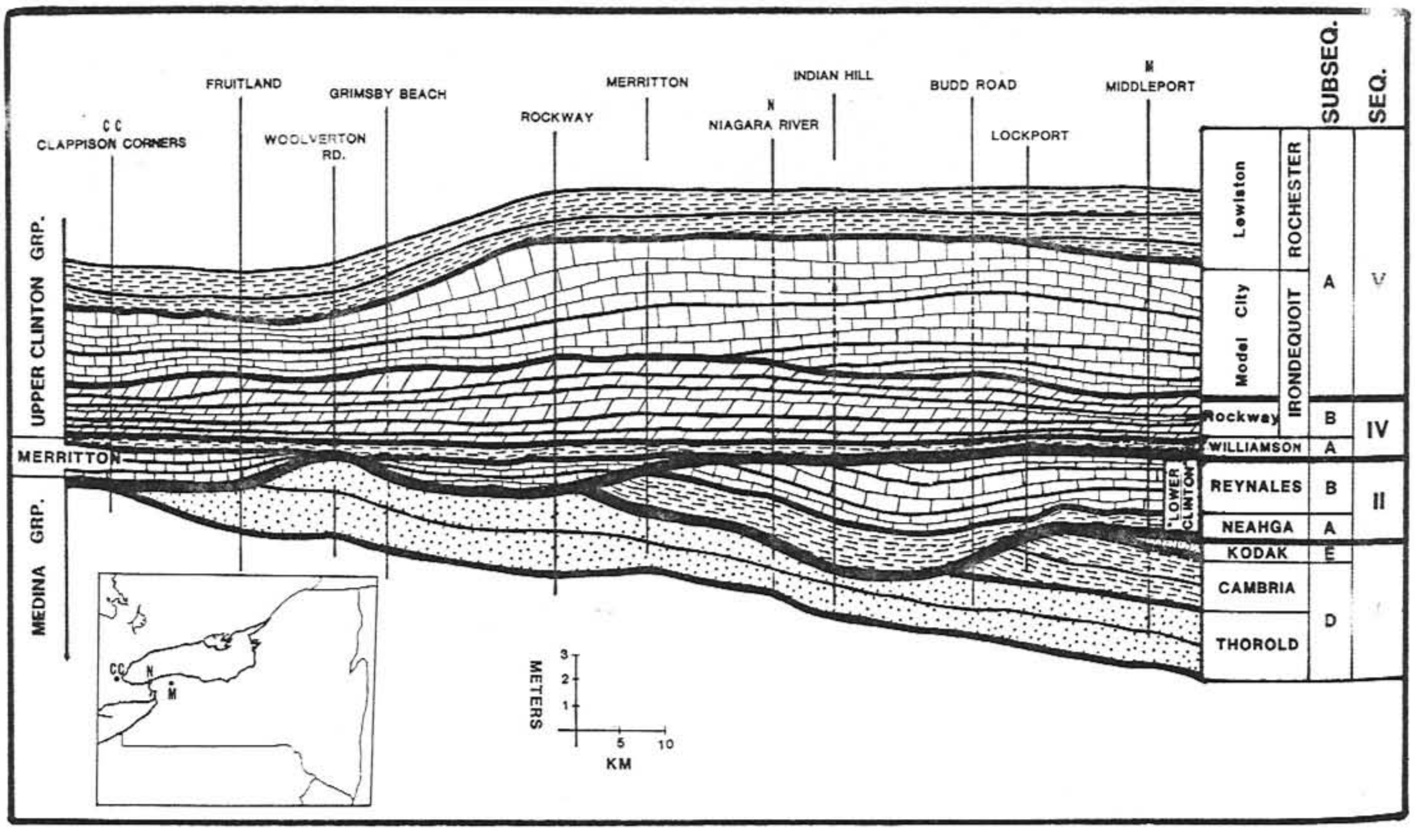


Figure 3. Regional cross-section of upper part of Medina Group (sequence I), lower part of Clinton Group (sequence II), and upper part of Clinton Group (Sequence IV and V) in western New York and southern Ontario (inset map gives location of sections). Note that the lower part of the Clinton Group (Neahga Shale through Reynales Limestone) is an unconformity-bounded sequence preserved as a wedge-like unit because of convergence of bounding unconformities near Merritton, Ontario, where the Merritton Limestone at the base of the Williamson Shale tongue rests on the Neahga Shale. Also, note the westward truncation of upper units of the Medina Group (Kodak, Cambria, Thorold) beneath the base of the Neahga Shale (black line denotes Densmore Creek Bed) (Modified from Kilgour, 1963).

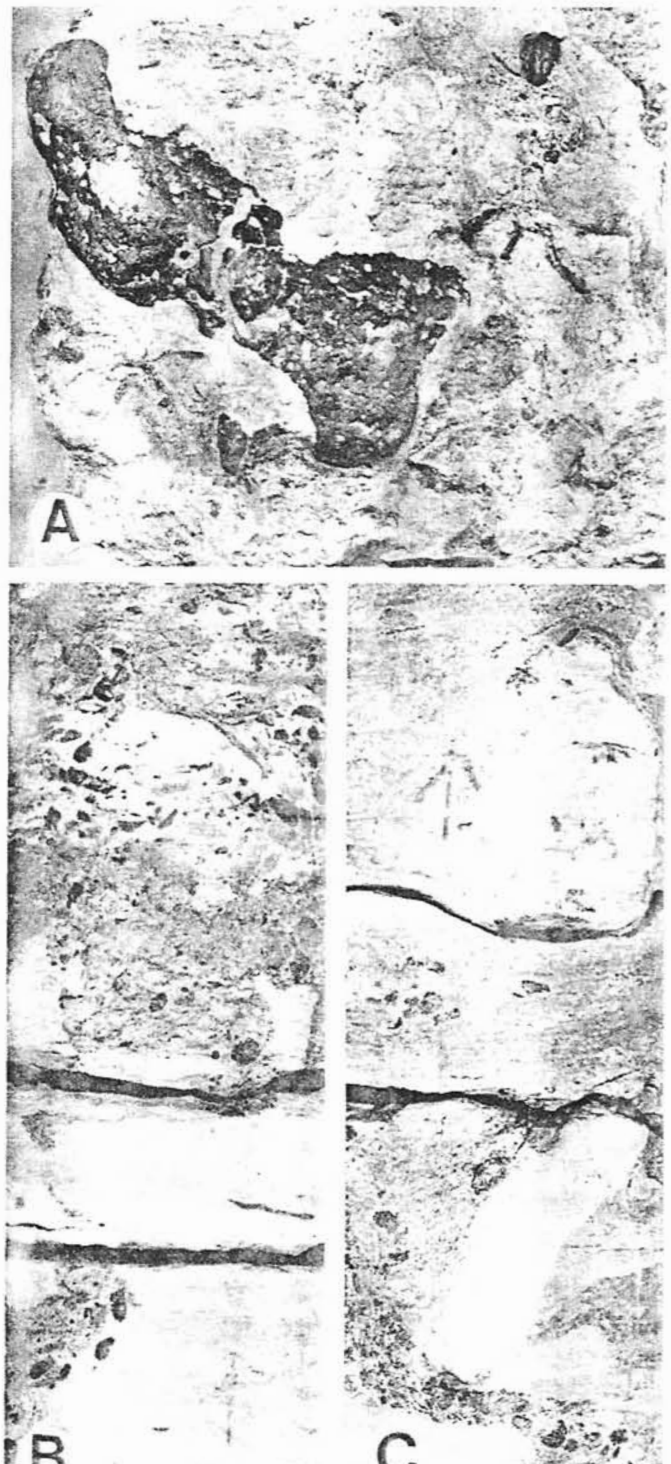


Figure 4. Densmore Creek Bed. *A.* Slab of lower part of Maplewood Shale with abundant bored black phosphatic clasts; Densmore Creek, Rochester, Monroe County, New York. *B.* Drill core through Clinton–Medina Group contact showing piping of phosphatic clasts of Densmore Creek Bed downward into Kodak Sandstone; Albion Landfill site, Albion, Orleans County, New York. *C.* Drill core through Clinton–Medina Group contact showing similar features; Rochester, Monroe County, New York.

rable *Daedalus*-bearing interval has been traced eastward at least to Monroe County.

The 2.0 to 4.0 m-thick Cambria Shale occurs above the Thorold-equivalent interval with *Daedalus* at locations from eastern Niagara County and eastward past Rochester, New York. It underlies a greenish white bioturbated sandstone, referred to as the Kodak Sandstone, at Lockport and eastward.

Still higher green and purple shales occur above the 1.0 to 1.5 m-thick Kodak Sandstone in the Rochester area. Hence the sub-Clinton unconformity truncates, in westward order, first the post-Kodak shale, then the Kodak Sandstone, the Cambria Shale, and finally, in Ontario, the Thorold Sandstone (Figure 3). The strata beneath the Densmore Creek Bed therefore vary from place to place in a regular pattern.

An important observation made by Duke (1987) is that all units that underlie the Neahga–Maplewood Shales are typically light-colored, either white or pale greenish grey sandstone or green shale. These green or pale grey strata appear to grade downward through a transitional mottled zone into pinkish strata at most localities. Duke (1987) inferred that the light, non-red-colored interval underlying the Neahga–Maplewood Shales resulted from a secondary leaching of iron oxide, as reducing pore water derived from the dark green or black Clinton Group muds seeped downward into the older sands and muds. The appearance of a white "Thorold–Kodak" interval everywhere beneath the Clinton Group is therefore believed to be a diagenetic artifact rather than a depositional feature. The bases of the "true" Thorold Sandstone and the Kodak Sandstone are locally sharp, but these do not appear to be major beveling surfaces. Rather, they are simply minor (subsequence) boundaries (see Brett et al., 1990a, 1990b).

Fisher (1953a, p. 30) claimed, as did Gillette (1947), that the Thorold Sandstone was gradational into the overlying greenish grey Neahga and Maplewood Shales. He noted, for example, a gradual diminution of quartz content and increase in clay. However, Fisher evidently failed to recognize that these greenish "gradational" shales that locally overlie the Thorold Sandstone are set off from the "true" Neahga Shale by a major and regionally beveling unconformity. The supposedly gradational shales are indeed a part of the Medina Group and comprise different units in the Rochester area than in the Niagara area: post-Thorold shales (Cambria Shale) in Niagara County, and post-Kodak (i.e., younger) shales at Rochester. Hence the interval from above the Kodak Sandstone downward through the Thorold Sandstone (previously simply called "Thorold Formation") is herein removed from the Clinton Group and assigned to the Medina Group.

Neahga and Maplewood Shales

As currently defined, the basal formation of the Clinton Group is the Neahga Shale in western New York and adjacent Ontario, and the Maplewood Shale in the area of Monroe County, New York. The base of both units is drawn at a distinctive marker bed, herein termed the "Densmore Creek Bed". The top is marked by a second phosphatic bed, the "Budd Road Bed" (Figures 4-6: see below).

Densmore Creek Bed

A sandy phosphatic zone up to 15 cm thick with multigenerational calcareous sandstone clasts that contain small, phosphatic nodules is present above the Kodak Sandstone at Densmore Creek, 0.2 km east of Densmore Road, Irondequoit, New York (type section). It also occurs at the Genesee River Gorge, where it forms an excellent basal marker for the Maplewood Shale (Figure 4A). Large, well-defined burrows pipe phosphatic clasts as much as 6.0-7.0 cm downward into the underlying greenish sandy shale that overlies the Kodak Sandstone (Figure 4B, C). These distinctive burrows characterize the basal surface of the bed at Densmore Creek and in some localities in the Niagara County region, and indicate relatively firm (probably overcompacted) but nonlithified sediments on the upper surface of the Medina Group at the time of deposition of the Neahga–Maplewood muds.

Phosphatic nodules and pebbles in the basal Densmore Creek Bed consist of glossy black collophane clasts (Boger and Sutphin, 1984). Small shells of high-spired gastropods and bellerophontids occur abundantly as phosphatic steinkerns. West of the Rochester area, the phosphatic Densmore Creek Bed is readily recognizable to Niagara County, where it becomes a phosphatic sandy dolostone or limestone that ranges from 5 to 10 cm-thick and contains the brachiopod *Hyattidina*. A correlative 20 to 30 cm-thick sandy limestone with abundant brachipods and bryozoans is present above the Thorold Sandstone at St. Catharine's, Ontario. East of the Rochester area, where the Maplewood Shale pinches out, the Densmore Creek Bed grades into the base of the Webster Bed (see below).

Neahga Shale

The Neahga Shale was referred to as the "lower Green Shale" by Hall (1843) and as the "Clinton Shale" by Grabau (1901), and erroneously as the Sodus Shale by Kindle and Taylor (1913) and the Furnaceville Shale by Chadwick (1918) and Williams (1919). Sanford (1935) named the Neahga Shale for its type section along the Niagara Gorge; he used the old Indian name ("Neahga") for the Niagara River. The Neahga Shale is platy, fissile, dark grey to olive greenish grey clay shale with minor amounts of quartz silt. The thickness varies from a feather-edge near Lockport and west of St. Catharine's, Ontario, up to about 2.0 m at the north end of the Niagara Gorge. The Neahga Shale is apparently truncated by a major late Llandoverian unconformity at or near St. Catharine's, Ontario. The shale is absent along the Victoria Avenue roadcut in Jordan, Ontario. Although thin shales referred to as "Neahga" have been reported as far west as Grimsby, Ontario, these appear to be shales within the upper part of the Medina Group. Hence the distribution of the Neahga Shale is limited to the area between St. Catharine's and Lockport. At Lockport, New York, the Neahga Shale thins abruptly from about 1.5 m at the Lockport Junction roadcut to about 25 cm at the new Sommerset railroad cut (see Brett et al., 1990a, for details). It has been inferred, although not demonstrated, that the shale is absent east of Lockport (Fisher, 1953a). Drill cores taken by the U.S. Geological Survey from near the Niagara escarpment southward to Grand Island, New York (about 16 km to the northwest) also display thickness variations in the Neahga Shale. In northern cores, the Neahga Shale ranges up to about 2.0 m thick, as in the northern Niagara Gorge outcrops; however, the Neahga Shale beneath Grand Island is very thin (approximately 30 cm thick).

At all localities, the Neahga Shale bears a sparse *Eocoelia* brachiopod-dominated assemblage. Fisher (1953a, p. 34) provided a faunal list of twenty-three species of brachiopods, bivalves, gastropods, nautiloids, and ostracodes from the Neahga Shale. Gillette (1947, p. 23) reported the zonally diagnostic ostracode *Zygobolba excavata* from the Neahga Shale in Niagara County. Both Gillette (1947) and Fisher (1953a) recognized *Z. curta*, also suggestive of the *Zygobolba excavata* Zone, from Niagara Gorge. Rexroad and Rickard (1965, p. 1219) recorded conodonts of the *Neospathognathodus celloni* Zone (Zone II) from the Neahga Shale at Niagara Gorge. Nicoll and Rexroad (1969) subsequently reassigned the Neahga to the *Icriodina irregularis* Zone (or Zone I). Recently, M. Kleffner (personal commun., 1989) obtained conodonts diagnostic of the *Distamodus kentuckiensis (=Icriodella discretaldeflecta)* Zone; this indicates the Neagha Shale is of Aeronian age. Gillette (1947) noted the presence of *Eocoelia hemispherica* and *E. p-catula* in the Neahga Shale in Niagara County, although he admitted that poor preservation prevented precise species identification. The presence of *E. hemispherica* suggests that the Neahga Shale belongs to the lowest portion of Ziegler's (1966) evolutionary zonation for *Eocoelia*. Together, these lines of evidence indicate a Llandoverian B-2 to C-1 age assignment for the Neahga Shale. This age is corroborated by the discovery of the brachiopod *Hyattidina congesta* at the base of the Neahga Shale at Lockport, (see Fisher, 1953a, p. 35), and subsequently at the Niagara Gorge and St. Catharine's, Ontario.

Figure 5. Bored platter-like clasts of phosphatic sandy limestone from base of Neahga Shale. Merritton railroad cut near Thorold, Ontario.

In terms of lithology, the Neahga Shale is essentially undifferentiated platy green to grey shale, with the thin (1-3 cm-thick), phosphatic, calcareous sandstone of the Densmore Creek Bed everywhere at its base. Fisher (1953a, p. 36) correctly recognized a disconformity between this bed and the underlying sandy green shales with leperditian ostracodes (Cambria Shale of the uppermost Medina Group, herein) at Lockport Junction Road. A thin, bioturbated, brachiopod-bearing sandstone (Densmore Creek Bed, herein) at Niagara Gorge separates the "true" Neahga Shale from 20 to 25 cm of green and purplish shales that overlie the Thorold Sandstone; these shales also apparently belong to the Cambria Shale. The Densmore Creek Bed is present in all sections and is more or less rich in black phosphatic nodules at various loca-

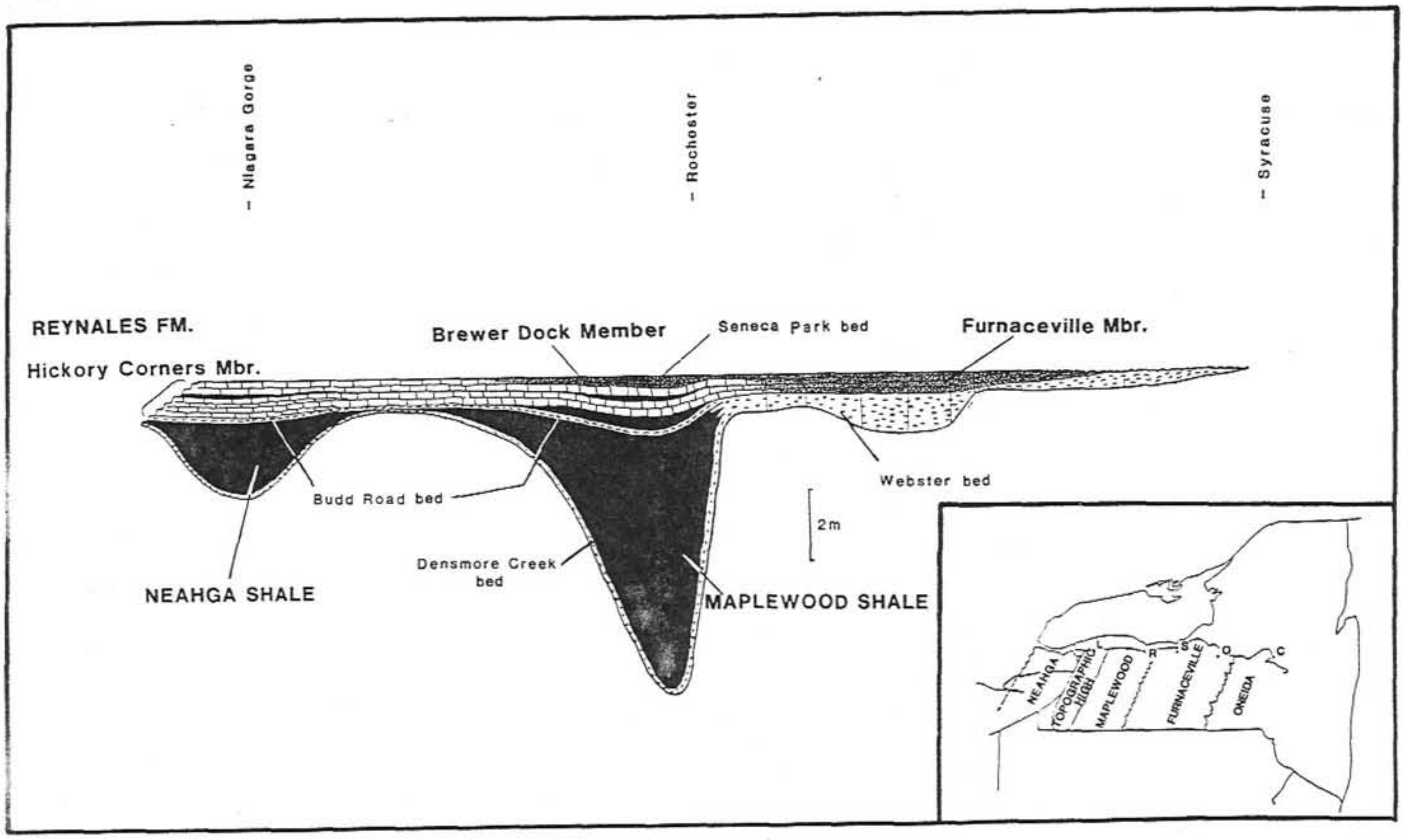


Figure 6. Regional cross-section of the lower part of the Clinton Group between Syracuse, New York, and St. Catharine's, Ontario. Note the presence of two minor depocenters (for Neahga and Maplewood Shales, respectively) separated by a minor arch. Also, note eastward passage of Maplewood Shale into a highly condensed, multigenerational phosphatic conglomerate (Webster Bed). West of Niagara Gorge the Neahga Shale is truncated by the major mid-Clinton Group angular unconformity.

tions. This basal bed is particularly well-developed at the Merritton railroad cut at Thorold, Ontario, where a 15-20 cm-thick, highly fossiliferous, sandy, phosphatic limestone is amalgamated to the top of the Thorold Sandstone. The sand grains within this unit have been reworked from the underlying Thorold Sandstone. Thus although the contact is probably disconformable, it may appear gradational locally due to reworking of the older sands into the younger calcareous, muddy sediments. The base of the Neahga Shale at this locality contains large (up to 20 cm long), flat (up to 1.0 cm thick), black-stained and intensely *Trypanites*-bored clasts of the underlying phosphatic sandy limestone (Figure 5). Multigenerational phosphatic limestone clasts with obvious hardground features are very similar to clasts seen in the basal Maplewood Shale and below the base of the Furnaceville Member eastward in Monroe County. Indeed, the phosphatic calcareous sandstone or sandy limestone unit at the base of the Neahga Shale is correlative with the Densmore Creek Bed of Monroe County.

Maplewood Shale

The Maplewood Shale was named by Chadwick (1918, p. 346) for 6.0 to 7.0 m of distinctly greenish grey, platy, chlorite-rich shale at the Genesee River Gorge in Rochester, Monroe County. It has been referred to earlier as "Sodus Shale" by Hartnagel (1907) and "Lower Green Shale" by Hall (1843). As does the Neahga, the Maplewood shows a substantial variation in thickness, and thins both east and west of the type section. It had previously been recorded only from sections east of the Genesee Gorge, where it thins to 5.3 m at Densmore Creek on the west side of Irondequoit Bay and to 5.0 m at Glen Edith 3.2 km to the east of Irondequoit Bay. As noted by Fisher (1953a), the latter is the most easterly outcrop of the Maplewood Shale. New excavations on the property of the Xerox Corporation in the town of Webster, 10 km northeast of Glen Edith, indicate the absence of Maplewood Shale at this location. Hence the Maplewood Shale pinches out rapidly northeastward, from nearly 7.0 m to a feather-edge within about 10 km (see below).

West of the Genesee River Gorge, there are no outcrops of the Maplewood Shale, with the exception of 0.6 m of green phosphatic shale along Oak Orchard Creek in the town of Medina. However, a drill core from a landfill site at Albion, Orleans County, New York, shows about 60 cm of dark greenish grey shale. This shale is somewhat intermediate in lithology between typical Neagha and Maplewood Shales, and is bounded at its base by a distinctive 10 cm-thick sandy zone packed with black phosphatic nodules, some of which occur in larger clasts of calcareous sandstone (Figure 4B). Large burrows pipe phosphatic material up to 6 cm into the underlying bioturbated green sandstone of the presumed Kodak Formation (Figure 4B).

The Maplewood Shale has an even sparser fossil assemblage than the correlative Neahga Shale in the west. Although Fisher (1953a, p. 34) reported twenty species, most of these were represented by fewer than five specimens and were confined to the basal Densmore Creek Bed. Poorly preserved specimens of *Eocoelia* sp. are relatively common in most of the shale. Recent excavations for the Driving Park Bridge in the Genesee Gorge yielded large blocks of Maplewood Shale, which were split and carefully examined. S.J. Ciurca (personal commun., 1988) obtained several new fossils from this exposure; these include possible phyllocarids, complete camerate crinoids (apparently a new species of a dimerocrinitid), nautiloids, linguloids, acritarchs, and palynomorphs. Fisher (1953b) reported a diverse assemblage of seventeen species of acritarchs now assigned to the genera *Leiosphaera*, *Veryhachium*, and *Micrhystidium* (M. Miller, personal commun., 1985). No zonally significant ostracodes or conodonts have been obtained from the Maplewood Shale, in contrast to the Neagha, but its physical continuity with the latter formation indicates that it is of the same age. Berry and Boucot (1970) tentatively assigned a Llandoverian C-4 age to the Maplewood Shale. This assignment is very doubtful, and in all probability the unit is of Llandoverian B-2 to C-1 age.

Similar to the Neahga Shale, the Maplewood Shale is not lithologically divisible, except for the 5-20 cm-thick phosphatic Densmore Creek Bed at its base. Very thin stringers of phosphatic granules have been found at scattered levels within the Maplewood at the Rochester Gorge, but these are difficult to recognize and do not appear to be traceable. The upper meter of the Maplewood has very thin (<1.0 cm), laminated, calcareous siltstone beds with sharp, slightly grooved soles. Otherwise, there are no interbeds of any sort within the shale. The upper boundary of the unit is drawn at the base of a thin (1-2 cm thick) but distinctive phosphate-rich, calcareous siltstone with *Eocoelia* and rare *Hyattidina* shells. This unit, which is designated the "Budd Road Bed" (see below), marks the base of the Reynales Limestone. This bed is traceable laterally from Monroe County at least to the Niagara Gorge, and therefore marks the top of both the Maplewood and Neagha Shales.

On the basis of physical stratigraphy, the Maplewood and Neahga Shales are laterally equivalent formations (Figure 6). They are also coeval, as indicated by identical acritarch assemblages. The units are bounded at the base by the Densmore Creek Bed, and at the top by the Budd Road Bed of the Reynales Limestone (Figure 6). Fisher (1953a) considered the Neahga and Maplewood Shales to be nearly identical facies of slightly different age. He believed the Maplewood Shale was younger than the Neahga Shale, because he correlated the Densmore Creek Bed at the base of the Maplewood Shale with the Budd Road Bed that occurs at the top of the Neagha Shale. He evidently did not recognize that the Densmore Creek Bed could be traced continuously at

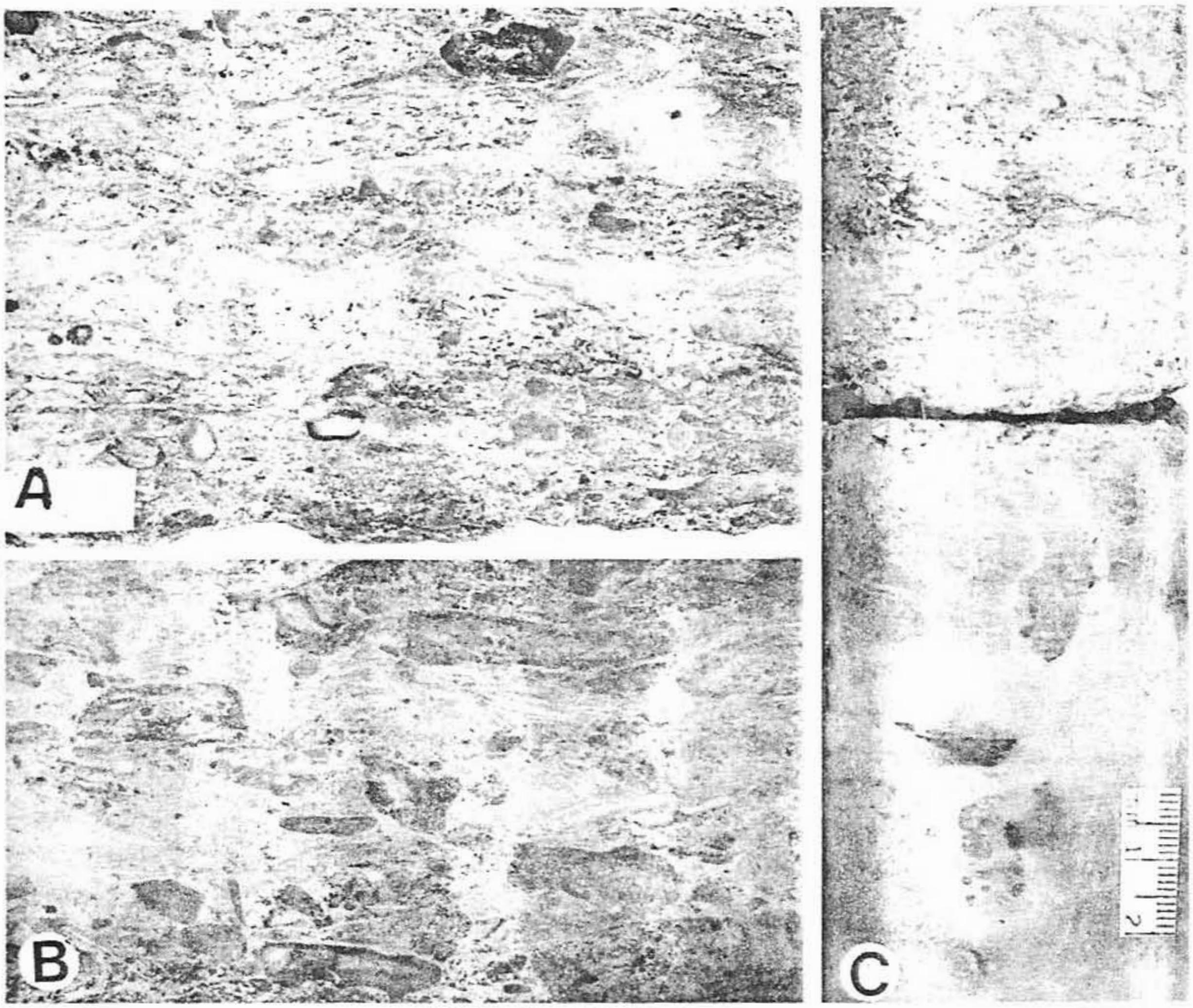


Figure 7. Webster Bed. *A*, Drill core through basal contact of Webster Bed; note piping of phosphatic material downward into underlying Kodak Sandstone. *B, C*, Polished slabs of Webster Bed showing flat, phosphatic, sandy limestone clasts with smaller phosphatic clasts within (multigenerational clasts); block from Xerox Corporation property, Webster, Monroe County, New York.

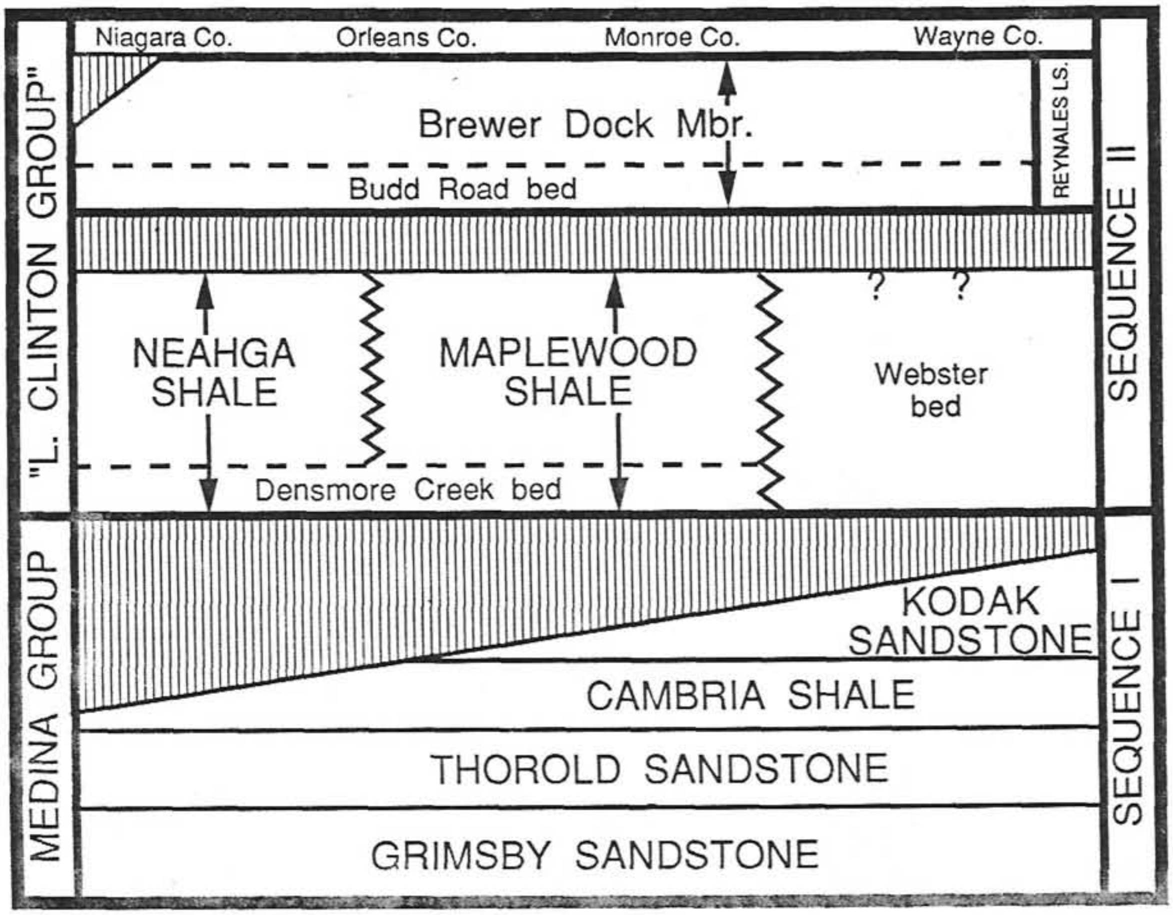


Figure 8. Summary chart of chronostratigraphic relationships of Maplewood–Neahga Shales and boundary phosphatic beds. Note that east of Rochester, New York, the Maplewood Shale interval is represented by a thin (10 to 20 cm) hematitic, phosphatic, limestone conglomerate, the Webster Bed.

the base of the Neahga and Maplewood Shales from Monroe County westward into Ontario. Therefore, he correlated the Maplewood Shale with a portion of the Reynales Limestone in western New York. As indicated below, however, the Reynales Limestone has a distinctive, regionally traceable internal stratigraphy that indicates that the limestones of the Hickory Corners Member of western New York are precisely equivalent to the lower part of the Reynales Limestone in the Monroe County area.

The Neagha and Maplewood Shales are thus time-correlative and extremely similar lithologically. Both are composed of clay shale with an average clay content of 93%, and only minor calcite and quartz. Consequently, the terms "Neahga" and "Maplewood" are essentially synonymous local names for one and the same regionally extensive unit in western New York State and adjacent Ontario, and presumably the subsurface of northwestern Pennsylvania and northeastern Ohio. The term "Maplewood" could probably be applied uniformly to this unit, as was proposed by Chadwick (1918) long before Sanford (1935) proposed the name "Neahga." However, there are very subtle facies differences that could warrant maintaining the separate names. The Maplewood Shale is typically a brighter green-colored shale, whereas the Neagha Shale has a darker grey coloration. The Neagha is also somewhat more fossiliferous, and contains a slightly more diverse fauna than the Maplewood.

Presumably, the Maplewood Shale at Rochester is a more proximal mud facies. The fact that the Maplewood Shale pinches out completely within a short distance to the east of Rochester suggests that a basin margin hinge existed in the area of eastern Monroe County during deposition of the lowest Clinton Group.

No sections have been observed between Monroe County and St. Catharine's, Ontario, in which either the green or dark grey facies are absent. There is a region, centered on Lockport, New York, in which the shale pinches to a feather-edge (5-20 cm). However, despite the thinness of the Neahga Shale at this locality, both the basal Densmore Creek Bed and overlying Budd Road Bed remain distinct and nearly identical in appearance to all other locations. This area of minimum thickness of the Maplewood Shale can be traced in the subsurface to the southwest. Overall, the evidence suggests that there were two weakly differentiated depocenters for the greenish Maplewood Shale and grey Neahga Shale. These two shales are separated by a southwest-trending topographic high, centered at Lockport, New York, that nearly divided the basin during deposition of these muds. This topographic high is oriented approximately along the same strike as the basin hinge, which trends southwestward from immediately east of Rochester to eastern Allegheny County (subsurface data from Van Tyne, 1966).

Webster Bed

As noted above, the Maplewood Shale pinches out abruptly near Webster, New York, in northeastern Monroe County. Drill cores from the Xerox Corporation property at Webster display a 30 cm-thick, red, hematitic, multigenerational phosphatic conglomerate bed interposed between the overlying Reynales Limestone and underlying greenish grey sandstone and mudstone that probably belongs to the Kodak Sandstone or Cambria Shale. Fisher (1953a, p. 31) recorded a thin zone of "phosphate pellets" along the contact between the "Thorold" (=Kodak Sandstone) and the "Furnaceville Iron Ore" along Fish Creek at Wheatland. A similar observation was made by Gillette (1947) at the base of the Fruitland Iron Ore pit at Ontario Center (type section of the Furnaceville). About 45 km to the east of the Genesee River at Salmon Creek, in the town of Wallington, Wayne County, New York, a phosphatic conglomerate intervenes between a few centimeters of green shale, with phosphate pebbles at the base of the Furnaceville Member and the underlying Kodak Sandstone. Fisher's (1953a) conclusion that this phosphatic multigenerational conglomerate is the local, highly attenuated equivalent of the Maplewood Shale is concurred with in this report. This unit is termed the "Webster Bed" herein, for exposures and drill cores taken on the property of the Xerox Corporation near Salt Road in the town of Webster, Monroe County, New York.

The Webster Bed is a thin (10-20 cm) unit of bluish grey to red, hematitic, phosphatic limestone clasts that is laterally equivalent to the Maplewood Shale (Figures 6-8). The base of this bed bears precisely the same depositional relationship to the underlying Kodak Sandstone as does the Densmore Creek Bed to the west (Figure 6). Phosphatic nodules are piped downward 5-10 cm into the underlying bioturbated sediment, which is leached and greenish in color (Figure 7). The Webster Bed is somewhat thicker and more complex lithologically than the Densmore Creek Bed, however. Its top typically contains hematitic ooids and some hematitized clasts and fossil fragments. Particularly noteworthy of this unit are multigenerational clasts of phosphatic limestone (Figure 7). These clasts, which may be up to 10.0 cm across and up to 2.0 cm thick, are sandy limestone with dark rinds and include smaller phosphatic nodules and granules internally. Some of the phosphatic pebbles within the larger clasts have even smaller phosphate grains within them (LoDuca, 1988). Hence in some cases, at least three generations of phosphatization are represented. This strongly suggests that the Webster Bed represents a considerable time interval, and probably is laterally equivalent to the entire 6.0-7.0 m thickness of the Maplewood Shale, including the Densmore Creek Bed a short distance to the west.

At Webster, New York, the Webster Bed directly underlies a limestone assignable to the Wallington Member of the Reynales Limestone. Twenty kilometers farther east in the area of Salmon Creek, Wallington Township, Wayne County, the 10-20 cm-thick phosphatic conglomerate layer occurs either below or as the basal unit of a fossil fragmental and oolitic hematite referred to herein as the "Furnaceville Member." This relationship appears to exist eastward at least to the area of Bear Creek, where the Reynales Limestone changes into the Bear Creek Shale facies (see below). An oolitic hematite, still referable to the Furnaceville Member, underlies the lateral equivalent of the Wallington Member (i.e., Bear Creek Shale) in this area, and a phosphatic conglomerate bed (Webster Bed?) that is a few centimeters thick occurs between this unit and the underlying sandstone. Farther east, at Martville, Cayuga County, New York, Gillette (1947, p. 161) recorded a white conglomeratic sandstone beneath the Furnaceville Member with a layer of quartz pebbles and phosphatic nodules approximately 0.6 m below the contact. This unit may represent the eastward extension of the Webster Bed. At this location, it would appear that the Webster Bed grades laterally into a quartzose conglomeratic sandstone, the Oneida

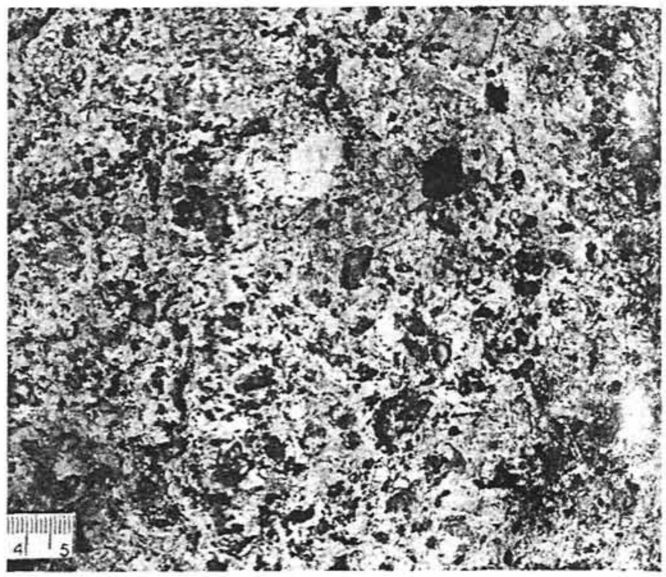


Figure 9. Budd Road Bed of the Reynales Formation. Slab shows closely packed black phosphatic nodules, fossil steinkerns, and bored limestone clasts; Lockport Junction roadcut, Cambria, Niagara County, New York.

Conglomerate, which rests unconformably above the Medina Group farther to the east.

Correlation with equivalent facies

It is possible to trace facies within the Webster–Maplewood interval westward from conglomeratic strandline deposits in Oswego County (Oneida Conglomerate) into a compact, multigenerational phosphatic conglomerate (Webster Bed) that may represent a very shallow, sediment-bypassed environment. Still farther west, an abrupt increase in rate of subsidence has produced a minor trough that has collected fine muds and minor silts (Maplewood Shale) that bypass the eastern gravelly shelf area and accumulate in a relatively quiet, albeit nearshore, shallow-water environment. The presence of pyrite and phosphate likely indicates reducing conditions on or within the seafloor in this area. Highly reducing conditions may have severely restricted the benthic fauna. Westward, this shale unit nearly pinches out on the Lockport high, but an equivalent, slightly darker grey and more fossiliferous shale (Neahga Shale) thickens westward to the Niagara region. A thin limestone bed is present above the Densmore Creek Bed immediately east of the Niagara region. This indicates that the Neahga Shale may pass westward into an argillaceous to arenaceous, fossil-rich carbonate facies.

The Neahga Shale and age-equivalent strata are absent in a broad region from St. Catharine's northwestward to Owen Sound near the southernmost part of the Bruce Peninsula in Ontario (Figure 2). At Owen Sound, a distinct unit, the Dyer Bay Limestone, occurs above the Medina Group-equivalent Cabot Head Shale. Although the Dyer Bay Limestone is poorly dated at present, limited biostratigraphic evidence, based on the occurrence of *Zygobolba williamsi* in the upper portion of the formation and the presence of the brachiopod *Virgiana* in the lower part of the Dyer Bay Limestone, indicates a Llandoverian B-3 to early C-1 age for this unit. Hence it is the approximate age-equivalent of the Neahga Shale, and perhaps the immediately overlying lower part of the Reynales Limestone. Furthermore, the presence of abundant multigenerational phosphatic clasts near the base of the Dyer Bay Limestone strongly suggests a physical correlation with the basal phosphatic, calcareous unit (Densmore Creek Bed) of the Neahga–Maplewood Shale interval. The Dyer Bay Limestone may represent a lateral equivalent of the Neahga Shale and lower part of the Reynales Limestone that is preserved on the northwestward side of the Algonquin Arch. This region of truncation of "Lower Clinton Group" units between St. Catharine's and Owen Sound presumably coincides with the main axis of the Algonquin Arch. It is interesting that the axis of this arch probably trended northeast-southwest and therefore was subparallel to the minor Lockport high (noted above). Both could be interpreted as units that reflect minor forebulge arching that locally subdivided the Maplewood–Neahga Shale basins.

Reynales Limestone

The Reynales Limestone is a rather heterolithic unit of interbedded brachiopod- and crinoid-rich grain- and packstones, argillaceous and pelletal wacke- and packstones (calcisiltites), nodular wackestones, and greenish to grey shales. Paxson (1985) provided detailed descriptions and interpretations of the petrography of this unit. Originally named the "*Pentamerus* limestone" by Hall (1843) in recognition of the abundance of *Pentamerus oblongus* at Rochester, the unit was mistakenly correlated with the Wolcott Limestone by Hartnagel (1907). The Wolcott is a stratigraphically higher *Pentamerus*-bearing limestone in central New York.

The age of the Reynales Limestone is debatable. The entire unit (Brewer Dock–Wallington Members) apparently belongs to a single ostracode zone (*Zygobolba excavata* Zone) that can be correlated with a relatively thin interval of the lower part of the Rose Hill Shale in Pennsylvania (Ulrich and Bassler, 1923; Gillette, 1947). Nicoll and Rexroad (1969) assigned the Reynales to the *Neospathognathodus celloni* Zone on the basis of conodonts. These conodonts suggest a late Aeronian age. However, Rickard (1975) assigned the Reynales Limestone to the Llandoverian C-2 based on the presence of *Eocoelia intermedia*.

Recent conodont work by M. Kleffner (personal commun., 1990) suggests a possible unconformity near the base of the Reynales. Conodonts indicate that the lowest beds of the Reynales Limestone and the underlying Neahga–Maplewood Shales may be of Llandoverian C-2 age, whereas the overlying Reynales Limestone is of late C-4 to C-5 age. These results are tentative and are not reflected in the correlation charts of this report (Figures 3, 8). The major unconformity, if there is one, may be suggested to lie actually below the Budd Road Bed at the contact between the Reynales Limestone and the underlying Maplewood–Neahga Shales. Conodonts obtained from phosphatic limestones a few centimeters above this contact may well be reworked from the underlying shales. At present, it can be noted that age relationships are only incompletely understood, and require further study.

Western facies: Hickory Corners Member

Chadwick (1918, p. 344-345), who formally named the Reynales

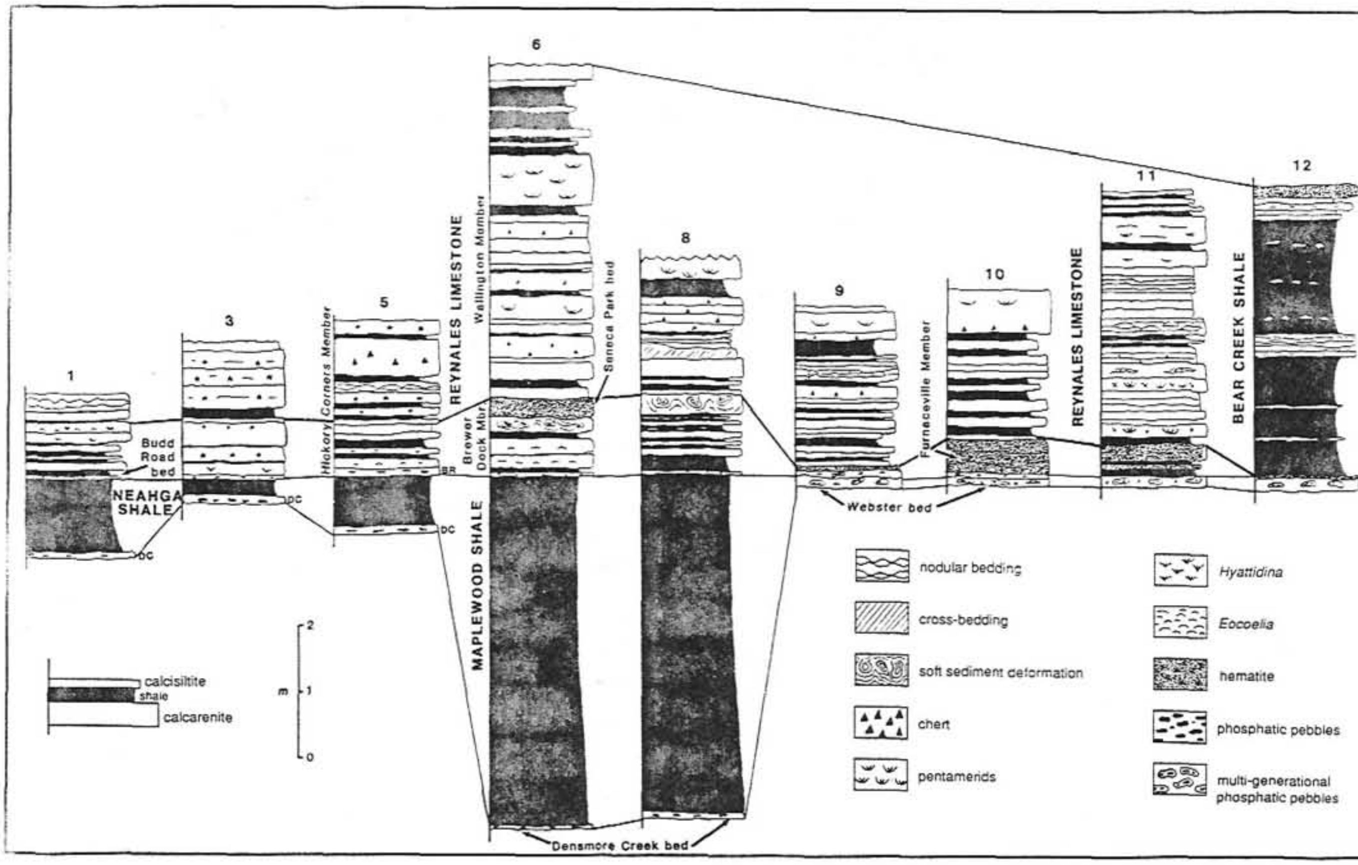
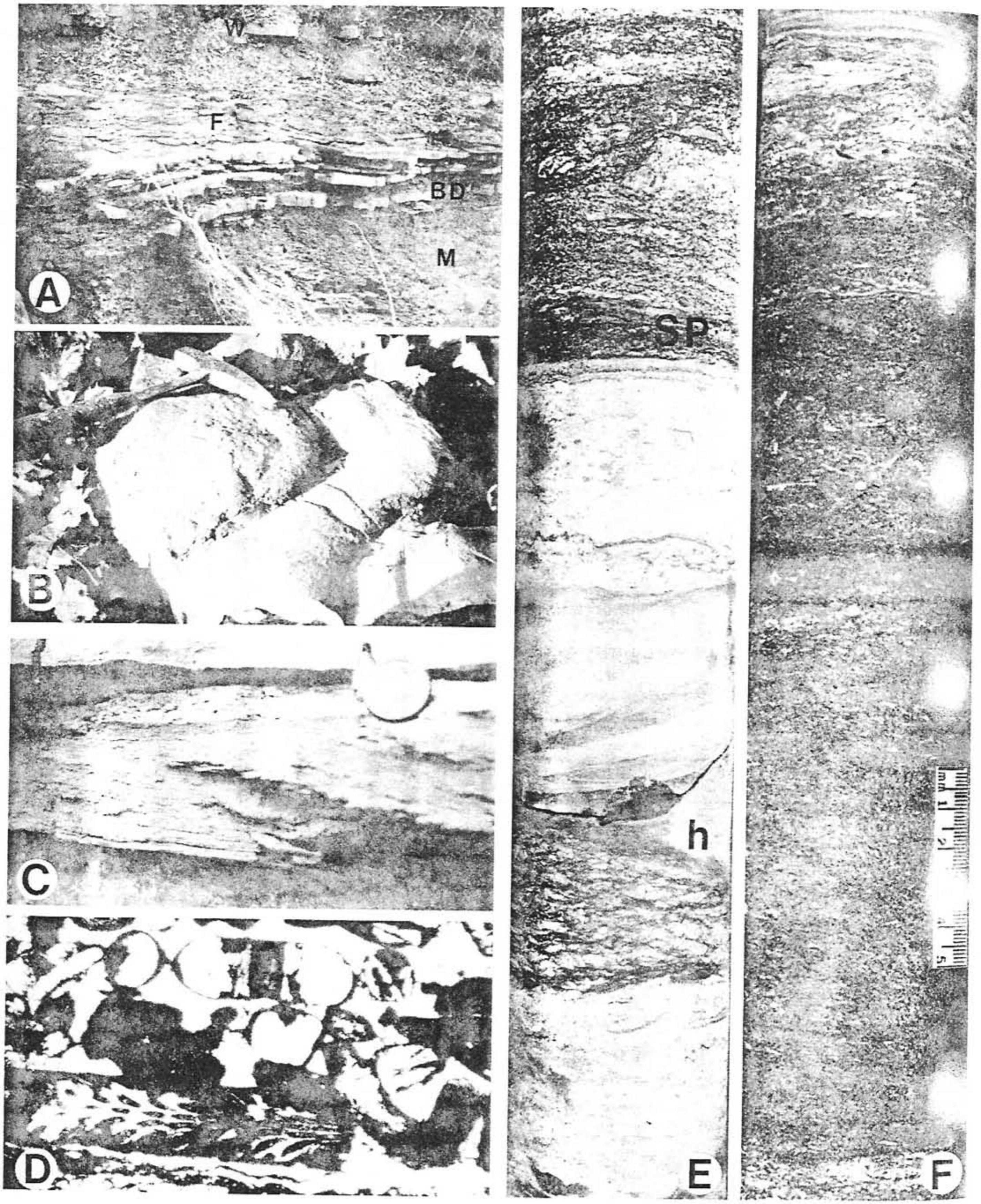


Figure 10. Fence diagram illustrating microstratigraphic relationships of "Lower Clinton Group" (Neahga–Maplewood and Reynales) strata in Ontario and western New York State. Locations of measured sections are shown in Figure 1.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Limestone, chose a rather atypical exposure at Reynale's Basin near Middleport, Niagara County, as the type section. In this area, the Reynales Limestone consists of about 2.5 m of interbedded, medium bluish grey to dark grey, buff-weathering, silty, dolomitic limestone. Much of this is a brachiopod- and crinoid-rich packstone with thin shale interbeds. Small chert nodules occur in a few beds near the top (see Paxson, 1985). This more or less undifferentiated interval is characterized by the brachiopods *Hyattidina congesta, Platystrophia, Dalejina, Coolinia*, and *Eocoelia*; small rugose corals (*Enterolasma*); and the trilobites *Encrinurus, Calymene*, and *Bumastus* (Figures 9-14). Eckert (1989) recently described a new echinoderm fauna from the Reynales Limestone of Niagara County. This consists of a species of disparid inadunate crinoid with pentalobate columns, a calceocrinid, a myelodactylid, two camerates, and two flexible crinoids; all represent new species. Pentamerid brachiopods do not occur in any sections in Niagara County or Ontario.

The Reynales Limestone at the type section is equivalent and essentially identical to the Hickory Corners Member. The latter unit was proposed by Kilgour (1963) for the thin-bedded, argillaceous, crinoidal pack- and grainstones characterized by *Hyattidina* at the Lockport Junction roadcut near the hamlet of Hickory Corners, Niagara County, New York. Kilgour (1963) recognized that Chadwick (1918) and others had incorrectly included 1.2 to 2.5 m of medium to dark grey fine-grained dolostone with rare fossils in the Reynales Limestone at its type section and elsewhere. This unit, which Kilgour (1963) assigned to the Rockway Member of the Irondequoit Formation, is separated from the "true" Reynales by a major sequence-bounding unconformity which, as noted, bevels the "Lower Clinton Group," including the Reynales Limestone, to the west (Figure 3). In contrast, the overlying dark grey dolostone beds of the Rockway Member extend from central New York into Ontario (Lin and Brett, 1988). A distinctive phosphatic bed, the Second Creek Bed (see Lin and Brett, 1988), lies between the Rockway Member and the beveled upper surface of the "true" Reynales Limestone.

The term "Hickory Corners Member" is probably unnecessary, because it is a synonym of an earlier-named unit. The "Hickory Corners Member" is only the western extension of both the Brewer Dock Member and the lower beds of the Wallington Member of the Reynales Limestone (see below).

Eastern facies: Brewer Dock, Furnaceville, and Wallington Members

The type Reynales Limestone of Niagara County is quite unlike the "classic" pentamerid facies characteristic of the Genesee Gorge region and elsewhere east of Monroe County. At the Genesee Gorge in Rochester, the Reynales Limestone is about 6.5 m thick and is differentiable into three units. These are, in ascending order, the Brewer Dock Member, the Seneca Park Bed (new designation), and the Wallington Member.

Budd Road Bed.—The base of the Reynales Limestone is drawn to the lower boundary of a unit termed herein the "Budd Road Bed," a 1.0 to 6.0 cm-thick silty limestone with very small phosphatic nodules and granules (Figure 9). This unit is traceable at least from Monroe County (Glen Edith) westward to the Niagara Gorge; it is present in all outcrops and drill cores in this region, but is best-developed in the area of Lockport. The unit is named for exposures at Budd Road near the hamlet of Hickory Corners, Niagara County, New York.

Brewer Dock Member.—The Brewer Dock Member was named for Brewer's Dock on the Genesee River at the lower falls in Rochester Gorge, Monroe County, New York (Sanford, 1935). The Brewer Dock Member is approximately 0.5 to 1.0 m thick and consists of light grey crinoidal- and bryozoan-rich limestone with considerable shale near the base (see Paxson, 1985, for details of petrology; and Figures 10 and 11 herein). The base of the Brewer Dock Member is drawn at the lower boundary of the Budd Road Bed.

It should be noted that recent conodont sampling of the Reynales Limestone has revealed an abrupt change in conodont assemblages within the Brewer Dock Member (Kleffner, 1990, personal commun.). A diverse assemblage, typical of the *Distamodus kentuckiensis* Zone (≈ *Icriodella discreta–Icriodella deflecta* Zone) occurs in the lower phosphatic limestone beds of the Brewer Dock Member. This assemblage is identical to that of the underlying Neagha–Maplewood Shale interval and suggests an early Aeronian age (Llandoverian B to C-2). A major change in the conodont fauna apparently coincides with the base of the Seneca Park Bed. This faunal change also occurs near the base of the apparently equivalent non-hematitic grainstone bed to the west. Conodonts from the Seneca Park Bed belong to the *Neospathognathodus celloni* Zone according to M. Kleffner (1990, personal commun.). A nearly identical conodont assemblage characterizes the overlying Wallington Limestone and, indeed, all of the overlying units assigned to the "Lower Clinton Group" ("Lower" Sodus, "Upper" Sodus, and Wolcott Formations). On the basis of this evidence, M. Kleffner (1990, personal commun.) is of the opinion that the entire interval above the base of the Seneca Park Bed is conformable and of Llandoverian C-4 to C-5 age. Furthermore, he postulates a major unconformity within the Brewer Dock Member. However, there is seemingly no physical evidence for a major break below the Seneca Park Bed. Furthermore, the *Eocoelia* brachiopod zonation proposed by Zeigler (1966) suggests that these strata range from C-2 to C-4 age. An important ostracode zonal boundary occurs above the "Lower" Sodus Shale, whereas the Neahga–Brewer Dock–Wallington– "Lower" Sodus interval apparently belongs to the *Zygobolba excavata* Zone, a rather thin interval in the classic Pennsylvania succession (Ulrich and Bassler, 1923). This evidence argues against a major unconformity within the Brewer Dock Member. It is suggested herein that an unconformity may exist below the Reynales Limestone, and that the conodonts from the lower part of the Brewer Dock Member are reworked from the underlying Neagha Shale.

Figure 11. Reynales Limestone at Rochester, Monroe County, New York. *A*, Typical outcrop of Maplewood Shale (M) and lower beds of Reynales Limestone; thin limestone ledges comprise Brewer Dock Member (BD); Seneca Park Bed (S) (hematite) forms bed of creek above falls; ledges of Wallington Member (W) protrude from upper bank; Brewer Dock Member is about 1 m thick; Densmore Creek, Rochester, Monroe County, New York. *B*, Underside of calcisiltite bed beneath Seneca Park hematite bed, Brewer Dock Member, with ball-and-pillow deformation; note hammer for scale. *C*, Seneca Park hematite bed displaying small-scale tabular cross-stratification of hematitic skeletal grainstone; lens cap for scale. *D*, Photomicrograph (x15) of Seneca Park Bed showing hematite-impregnated and -coated skeletal (black) grains, including bryozoan (lower left) and crinoid columnal (top center) surrounded by sparry calcite cement; Genesee Gorge, Rochester, New York. *E, F*, Drill core sections (x0.8) showing upper Brewer Dock interval at Rochester, New York. *E*, Note lower beds rich in the brachiopod *Hyattidina* (h) overlain by laminated calcisiltite and base of hematitic Seneca Park Bed (split between lower and upper sections of core). *F*, Seneca Park Bed hematite with fossil fragments is capped by thin laminated calcisiltite. Core property of Hailey and Aldrich Corporation, Rochester, New York.

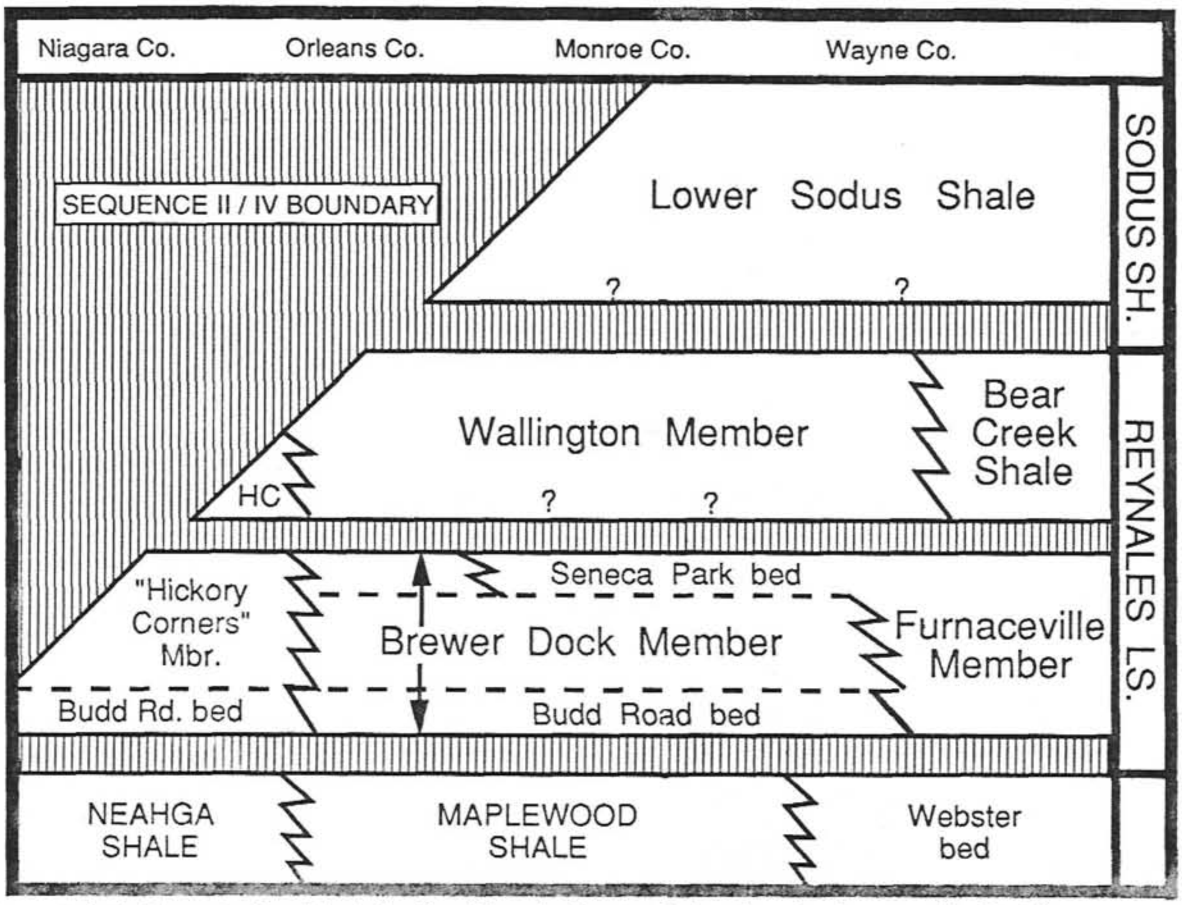


Figure 12. Summary chart of chronostratigraphic relationships of Reynales Limestone beds and members in western New York State.

Seneca Park Bed.—A 20 to 40 cm-thick bed at the top of the Brewer Dock Member has been assigned to the "Furnaceville Hematite" or "Iron Ore" (see Gillette, 1947; and Figures 11E, F, and 12). This hematitic limestone consists of a fossil-rich ore in which fragments of bryozoans, crinoids, and ostracodes, as well as intraclasts, have been replaced by hematite (Figure 11E, F). Restudy indicates that the so-called "Furnaceville Hematite" at Rochester is equivalent only to a part of the Furnaceville Member at the type section in Ontario, Wayne County, New York (LoDuca, 1988). In fact, the hematite at Rochester is equivalent only to the uppermost bed of the "true" Furnaceville Member which, in turn, is laterally equivalent to the entire Brewer Dock Member (see below). Hence this hematitic bed at Rochester is herein treated as a bed of the Brewer Dock Member, and termed the "Seneca Park Bed." It is not known how far this hematitic bed extends westward from the Rochester area. Drill cores from Albion, Orleans County, penetrate this interval and show no hint of a hematitic bed. However, a 20-30 cm-thick crinoidal grainstone bed appears at the appropriate position, about 1.0 m above the base of the Reynales Limestone. This crinoidal grainstone to nodular packstone band can be traced westward to the Niagara Gorge, where it lies immediately below the upper sequence boundary erosion surface (i.e., below the basal Second Creek Bed of the Williamson Shale). This unit always occurs approximately 0.5 to 1.0 m above the base of the Reynales Limestone, and forms a useful marker for the top of the Brewer Dock Member beyond the range of occurrence of the hematitic Seneca Park Bed in western New York (Figure 10). The Seneca Park Bed and its lateral equivalent, therefore, are used herein to define the top of the Brewer Dock Member.

East of Rochester, the hematitic Seneca Park Bed is absent at Glen Edith on the east side of Irondequoit Bay. Detailed study in this region of the overlying Wallington Member indicates that the Wallington Member directly overlies the lower part of the Brewer Dock Member; the Seneca Park Bed is apparently absent because of non-deposition. Slightly farther east, in drill cores from Xerox Corporation property in Webster, New York, the entire Brewer Dock Member appears to be missing, and marker beds of the basal Wallington Member directly overlie the hematitic Webster Bed. At the Fruitland iron ore pit in Ontario Center, Wayne County, New York, the hematitic and phosphatic conglomerates of the Webster Bed are directly overlain by a 0.5 m-thick succession of hematitic limestone and shale that represents the type section of the Furnaceville Member. The upper portion of the type Furnaceville Member corresponds to the Seneca Park Bed of the Rochester Gorge. The thickness and internal stratigraphy of the Furnaceville Member closely match the Brewer Dock Member, and it is concluded that the two units are coeval. A very similar succession is seen eastward at Salmon Creek and in the Wallington and Wolcott drill cores (Gillette, 1947). In the Wolcott drill core, about a meter of hematitic limestone and interbedded shales occurs above the phosphatic Webster Bed (Figure 10). This interval appears to be a nearly complete, although thoroughly hematitized, version of the Brewer Dock Member.

Brewer Dock–Furnaceville Member correlation.—Detailed microstratigraphic analysis of the Brewer Dock and Furnaceville Members permits a virtual bed-for-bed correlation of six or seven units within this meter-thick interval (Figures 10, 12). These six or seven beds can be grouped into three very small-scale cycles, each of which has a basal, thin phosphatic calcarenite horizon that passes gradationally upward into greenish grey shales.

The first minor cycle of the Brewer Dock Member consists of the thin, phosphatic Budd Road Bed that ranges from about 2.0 to 5.0 cm thick. The Budd Road Bed is overlain by thin greenish-grey shale. This cycle is then overlain by a second phosphatic calcarenite horizon, again about 5.0 to 10.0 cm thick, which also passes upward into a greenish grey shale. This green clay shale ranges upward to 70 cm in thickness in one drill core from Monroe County. Elsewhere, it averages from about 20 to 30 cm in thickness. In turn, this shale is overlain by yet another phosphate granule-bearing horizon that passes upward into a brachiopod (*Hyattidina* and *Eocoelia*) pack- or grainstone (Figure 12). A distinctive 10 to 15 cm bed of calcisiltite (laminated pelletal grainstone) with prominent ball-and-pillow structures occurs above the *Hyattidina* bed in Monroe County localities (Figure 11B, E). This horizon forms a useful local marker, and it is present at Glen Edith where the overlying hematite is absent. The ball-and-pillow horizon is overlain by red, hematitic, bryozoan-rich grainstone of the Seneca Park Bed. A cap of silty calcareous green shale (a few cm thick) terminates this cycle (top of Figure 11F).

The three minor cycles of the Brewer Dock Member extend westward to the Niagara Gorge and can be used to differentiate the Brewer Dock Member from the overlying Wallington Member in the absence of the Seneca Park Bed. The lateral equivalent of the Seneca Park Bed, a crinoidal grain- or packstone, is also widely traceable and permits unambiguous recognition of the Brewer Dock–Wallington interval. Thus the so-called "Hickory Corners Member" of the Reynales Limestone (Kilgour, 1963) is simply an amalgam of the Brewer Dock Member and lower beds of the Wallington Member of the Reynales Limestone (Figures 10 and 13).

Each of the three small-scale cycles within the Brewer Dock Member can be viewed as a small-scale PAC or parasequence (see Goodwin and Anderson, 1985; Van Wagoner et al., 1988). These cycles were initiated abruptly by marine flooding that followed a relatively brief interval of sediment starvation recorded by phosphatic lags. Overlying brachiopod-rich pack- or grainstones then pass upward into greenish shales. The green shales appear to represent the shallowest water facies associated with each minor asymmetrical cycle. Presumably, these Maplewood-like shales, with a BA-2 biofacies (see below), represent minor progradational tongues of nearshore mud. The pack- and grainstones at the bases of the cycles contain a somewhat deeper water, BA-3 biofacies. Thus these small-scale cycles appear to be upward-shallowing. Taken collectively, however, the three minor cycles of the Brewer Dock Member seem to define an upward-deepening trend. In successive cycles, the greenish shales become less pronounced and the carbonates more prominent.

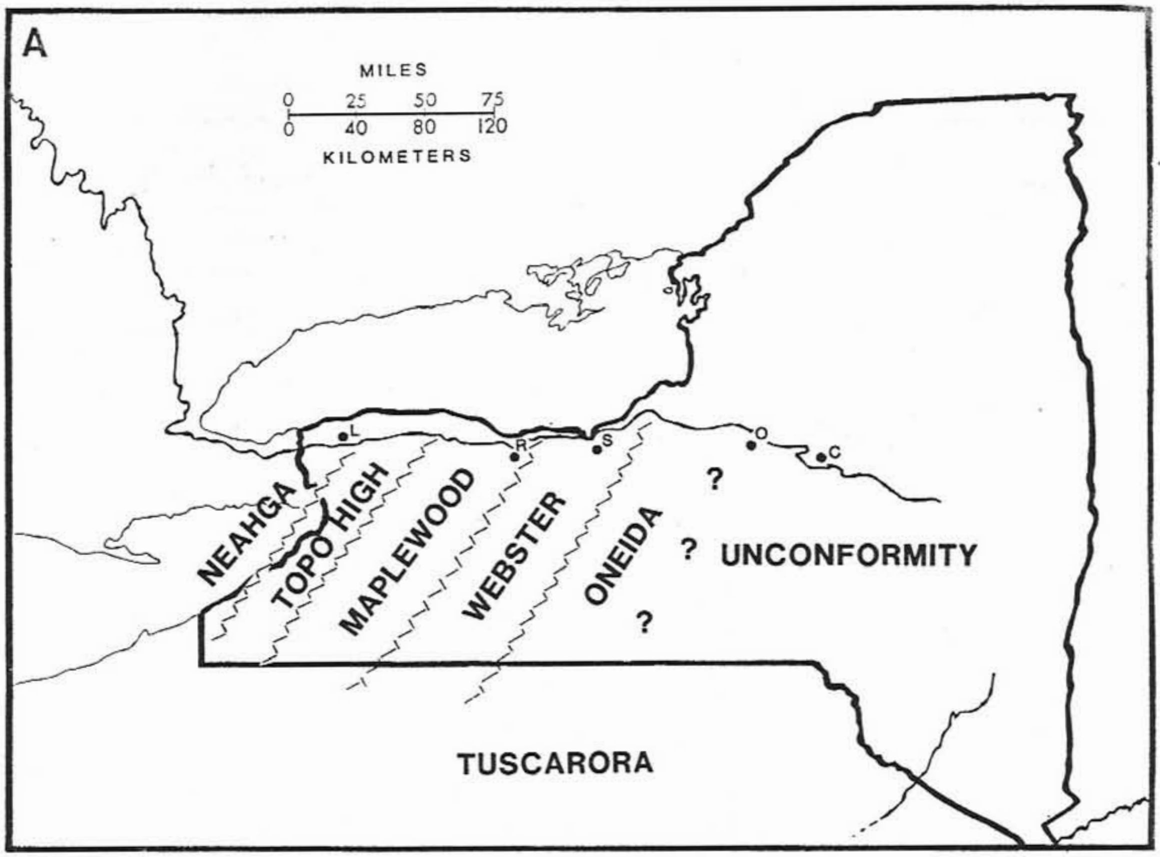
Wallington Member.—The Wallington Member, named for exposures on Salmon Creek at Wallington, Wayne County, New York (Hartnagel, 1907), consists of about 4.0 to 6.0 m of dolostone, commonly cherty brachiopod/crinoid pack- and grainstone, pelletal grainstone (calcisiltite), and greenish grey shale (see Paxson, 1985). The base of the Wallington Member of the Reynales Limestone is defined at the base of a phosphate granule-bearing thin grainstone bed that overlies the Seneca Park Bed. This basal marker bed appears in virtually all sections of the Wallington Member.

The Wallington Member is similar to the Brewer Dock Member and may be subdivided into about six carbonate-to-shale cycles, or PACs, that fine upward; the Wallington Member, as a whole, appears to deepen upward. The base of each cycle can be recognized by a calcarenite bed, in many cases with pentamerid brachiopods (Figure 11A). Six pentamerid-rich grainstone beds recognized in the Genesee Gorge define the bases of minor (PAC-like) asymmetrical carbonate-to-shale cycles (Figure 10). These are positioned at the base (basal Wallington carbonate bed), approximately 1.4 m, 2.0 m, 2.8 m, 3.2 m, and 4.0 m above the base of the formation, respectively. Several of these tend to be cherty, at least at some locations. The most prominent pentamerid-bearing grainstone bed forms the base of the fifth cycle and occurs about 1 m below the contact with the overlying "Lower" Sodus Shale. This unit includes approximately 60 cm of pentamerid-rich crinoidal grainstone with internal, amalgamated, hummocky, normally graded beds with shell-rich calcarenites at the bases that grade upwards into thin calcisiltites. Overlying this bed is 45 cm of greenish grey shale that may represent a somewhat deeper-water environment, as opposed to the more typical greenish shales at the base of the formation. Overall, this cycle appears to represent a strong transgressive episode during deposition of the Reynales Limestone. The uppermost cycle of the Wallington Member at the Genesee Gorge consists of a 15-20 cm bed of dark-stained crinoidal–stromatoporoid–brachiopod-rich limestone. This cycle appears to thin eastward and merge into the 10-20 cm-thick "Sterling Station Hematite" (Gillette, 1947) that marks the top of the Reynales Limestone and the equivalent Bear Creek Shale in Wayne and Oswego Counties.

Westward from the Genesee Gorge area, outcrops of the Wallington Member are infrequent and poorly exposed, although *Pentamerus*-rich limestones are known from scattered, patchy outcrops in the bed of Salmon Creek between Brockport and Spencerport, New York, and drift boulders of *Pentamerus*-rich Reynales Limestone are common in the area around Clarendon. A drill core from the town of Albion shows 1.5-2.0 m of nearly homogeneous crinoidal grainstone. This unit is composed mainly of pentalobate crinoid columnals, although brachiopods, particularly *Hyattidina*, are abundant throughout this portion of the section. This grainstone is the lateral equivalent of the lower greenish shale and carbonate bands found in the basal meter of the Wallington Member at Rochester, and it persists westward at least to Lockport, where about 120 cm of grainstone is present. At Lockport and Middleport, crinoidal pack- and grainstone is the predominant lithology. Neither the Brewer Dock nor the Wallington Member of the Reynales Limestone have previously been recognized in this area, and the term "Hickory Corners Member" has been used to refer to the entire Reynales Limestone in Niagara County.

The Wallington Member maintains a relatively uniform internal stratigraphy east of Rochester (see Figures 10, 12). The shale intervals that form the upper parts of the six minor cycles of the Wallington Member become increasingly pronounced and thicker in the vicinity of the type section of the Wallington Member on Salmon Creek (east) in central Wayne County. The second chert-rich pentamerid-bearing band, about 120-150 cm above the base of the unit, becomes increasingly rich with these brachiopods eastward to the type section. East of the type area, this interval loses the pentamarids but remains cherty at least to the area of Wolcott. The upper two pentamerid beds of the Rochester Gorge, which are the most condensed crinoidal grainstones, also persist for the longest distance to the east.

Bear Creek Shale.—The greenish grey shales of the Wallington Member at Bear Creek in eastern Wayne County have thickened so



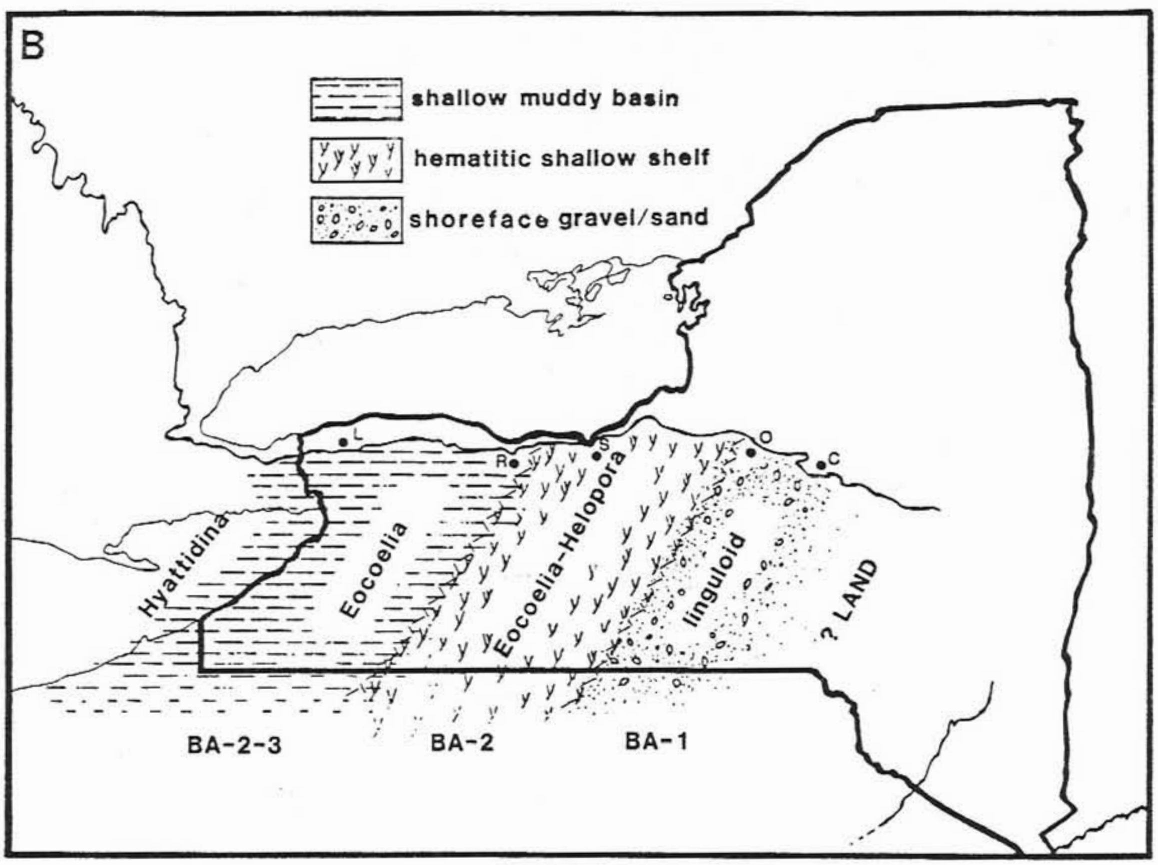


Figure 13. Litho- and biofacies maps of the Neahga–Maplewood interval. *A*, Lithofacies map of Neahga–Maplewood interval; note northeast-southwest strike of facies belts and minor high area separating Neahga and Maplewood facies; wavy lines represent approximate lateral boundaries. *B*, Paleogeographic map showing distribution of biofacies; benthic assemblages (BA) and names of prominent fossils are indicated.

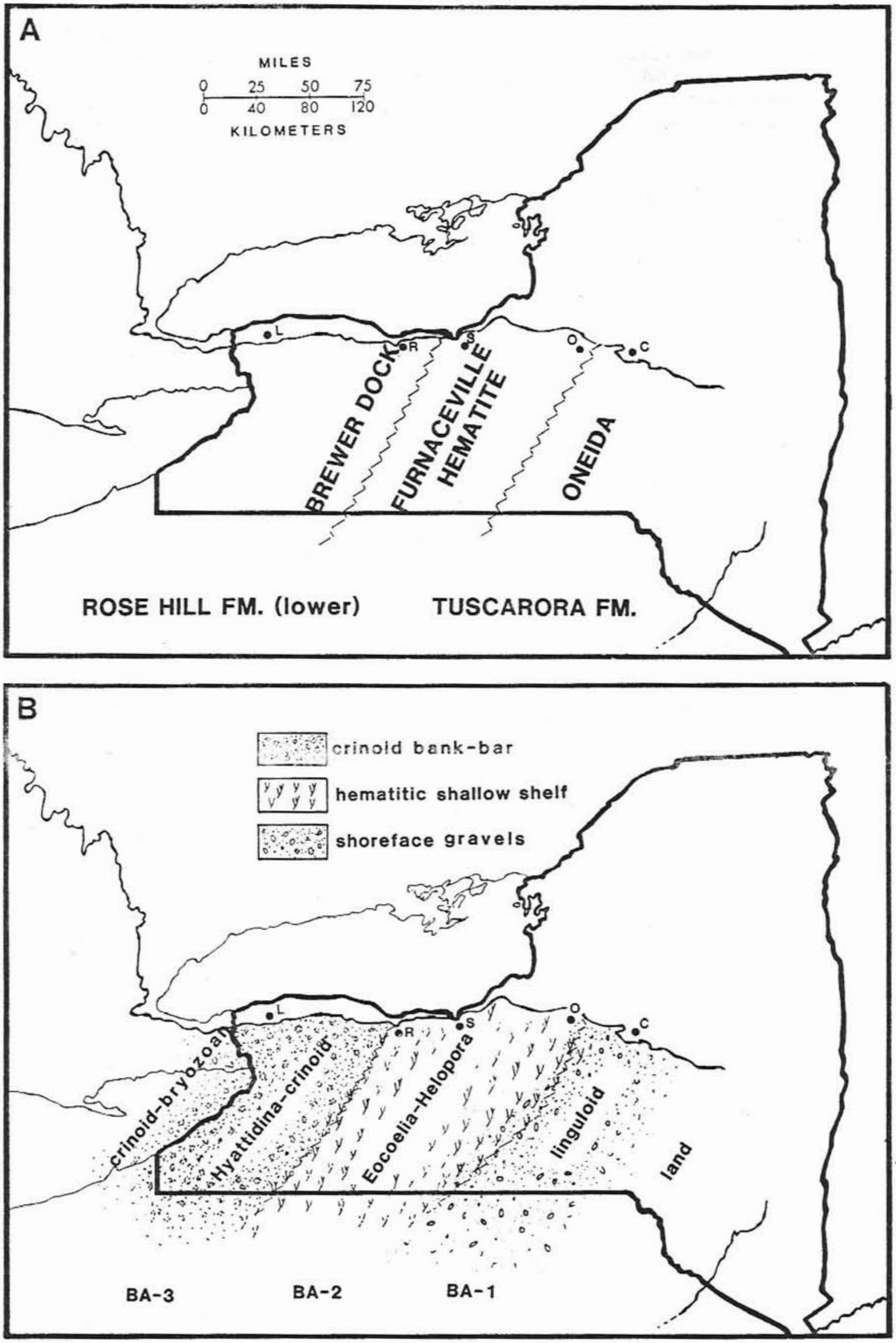


Figure 14. Litho- and biofacies maps of the Reynales Limestone and equivalents. *A*, Lithofacies map for lower part of the Reynales Limestone (Brewer Dock–Furnaceville) interval. Local names of lithostratigraphic units are indicated. *B*, Paleogeographic map showing inferred distribution of biofacies; benthic assemblages (BA) and prominent fossils are indicated.

much that the unit has become more than half shale. This interval was designated the "Bear Creek Shale" by Chadwick (1918). At the type locality, the Bear Creek consists almost entirely of shales with very thin, argillaceous, pyritic limestones. These have an *Eocoelia hemispherica*-dominated fauna.

Lithofacies, biofacies, and lateral changes within the lower part of the Clinton Group of western New York

Only three units in the "Lower Clinton Group" can be traced from west-central New York to the Niagara region. However, these permit some assessment of lateral facies changes (see Figures 12-14).

The first of these is the Maplewood–Neahga Shale interval. At its easternmost margin, the interval appears to merge into the basal bed of the Oneida Conglomerate and is represented by a thin, pale greenish grey sandstone and quartz pebble conglomerate, typically less than 30 cm thick, that sharply overlies sandstones attributed herein to the Kodak Sandstone of the Medina Group (Figure 13). The unit contains some trace fossils, including *Skolithos*-like burrows and body fossils of linguloid brachiopods and scattered ostracodes, among them *Zygobolba*. This interval is traceable from Oneida County near Lakeport at Oneida Lake westward approximately to central Oswego County, where it thins slightly and contains abundant multigenerational phosphatic clasts. In this area and to the west, the interval is referred to as the "Webster Bed." The eastern Oneida Conglomerate represents a relatively sediment-starved, nearshore gravel. Tabular cross-bedding suggests current deposition. The sandy layers perhaps represent slightly lower energy environments between gravel bars. These areas were inhabited by linguloid brachiopods and other burrowing organisms.

The hematitic and phosphatic conglomerate of the Webster Bed is probably equivalent to much or all of the Maplewood Shale (Figure 13A). Quartz pebbles and granules occur commonly within the Webster Bed at least as far west as central Wayne County. Fossils are rare within the conglomerate but include phosphatized gastropods, linguloid and *Eocoelia* brachiopods, and the bryozoans *Phaenopora* and *Helopora*. In contrast to the Oneida Conglomerate, which represents a very nearshore fossil assemblage (benthic assemblage 1; BA-1), the Webster Bed shows elements of an *Eocoelia* or BA-2 biofacies (Figure 13B).

The hematitic and phosphatic conglomerate facies of the Webster Bed seem to represent an extremely condensed, shallow-shelf deposit. During deposition of this facies, relict sediments probably covered a broad tract of shelf that extended at least 50 km perpendicular to the facies strike. Phosphatic coatings and mineralized steinkerns in the upper few centimeters of reworked sediment developed, in part, after cannibalization of the underlying sands of the Medina Group. This gravel and the equivalent lower part of the Oneida Conglomerate represent transgressive lag deposits that were associated with a major relative sea-level rise (basal sequence II) that followed a major sea-level fall, during which quartz pebbles and sand were transported toward the basin center.

In northeastern Monroe County along a line that trends approximately N45°E, the thin phosphatic conglomerate of the Webster Bed is abruptly transitional to the main mass of Maplewood Shale (Figure 13A). Within less than 10 km, the shale expands from a thin parting to over 7.0 m. A thin phosphatic pebble bed (Densmore Creek Bed) still occurs at the base of the Maplewood Shale, and extends westward to form the base of the correlative Neahga Shale. The phosphatic bed contains rare brachiopods, including *Hyattidina*, in the Rochester area. Westward, near Lockport, *Hyattidina* becomes very abundant and, near St. Catharine's, Ontario, the basal bed expands to a 30 cm-thick crinoidal sandy carbonate with some *Hyattidina*, as well as bryozoans and a more diverse brachiopod assemblage typical of the overlying Reynales Limestone. The *Hyattidina* biofacies is believed to be an inner shoal BA-2 to BA-3 fossil assemblage, whereas the more diverse, bryozoan-rich sandy limestone at the westernmost exposures of the Neahga interval near St. Catharine's appears to represent a BA-3 shoal-type environment very similar to that of the overlying Reynales Limestone.

The main mass of the Maplewood and Neahga Shales is more or less undifferentiated green and dark grey clay shale. Near the eastern limit of the outcrop belt, the shale contains a few thin siltstone bands, but these rarely exceed a centimeter in thickness. Thin stringers of phosphatic granules observed at widely scattered levels in Rochester and Glen Edith suggest occasional storm transport of phosphatic material from nearby shoals to the northeast. The lack of any internal cyclicity within the Maplewood and Neahga Shales suggests that the shales represent a relatively brief interval of time. Thus while multigenerational phosphatic conglomerates and coarse pebble gravels were deposited in a sediment-starved shelf area to the northeast, the Maplewood and Neahga muds were rapidly deposited in low-energy traps associated with minor subsiding depocenters to the west. The high clay content of both shales is somewhat enigmatic and suggests a relative paucity of sand-sized material available for deposition. Complete crinoids and possible soft-bodied organisms on certain bedding-planes suggest rapid sedimentation of mud layers within the Maplewood Shale; the evidence of episodically high rates of accumulation is not otherwise apparent from examination of the unit. Dark grey to greenish coloration indicates deposition of the muds under reducing conditions or high accumulation rates, and the absence of coarser storm layers suggests low-energy environments within the Neahga and Maplewood basins. Yet the uniform occurrence of diverse sporomorphs suggests a proximal position, as does the presence of rare eurypterid cuticle within the Maplewood Shale.

The Maplewood Shale uniformly has a very sparse *Eocoelia* to *Lingula*-bearing (BA-2) assemblage. The Neahga Shale, or western facies of the Maplewood, contains a slightly greater diversity of associated brachipods, although *Eocoelia* still dominates. The occurrence of rare *Eoplectodonta*, *Dalejina*, and other brachiopods at the Niagara Gorge indicates a more distal BA-2 to marginal BA-3 position. The basal sandy limestone bed at the westernmost outcrop of the Neahga Shale suggests that the unit might undergo a lateral facies change from green shale to carbonates. If so, it appears that the lower portions of the Neahga and Maplewood Shales probably represent the deepest water conditions (BA-3), and that these units as a whole display a shallowing-upward trend typical of PAC cycles (Goodwin and Anderson, 1985). The Neahga and Maplewood Shales are abruptly overlain by the thin phosphatic limestone of the Budd Road Bed, which carries an *Eocoelia*-dominated (BA-2) fossil assemblage in the east. In Monroe County, it represents a typical "pearly bed," or dense *Eocoelia* packstone, with mixed *Helopora* bryozoans. Westward in Niagara County, this basal bed has a *Hyattidina* fauna associated with very abundant phosphatic pebbles and granules. Hence the bed comes to resemble closely the Densmore Creek Bed that forms the base of the Maplewood and Neahga Shales. This bed represents an interval of relative sediment starvation, during which authigenic phosphate formed either within fossils or as small nodules in the upper few centimeters of sediment. A microoxidizing zone immediately above the reducing greenish grey muds

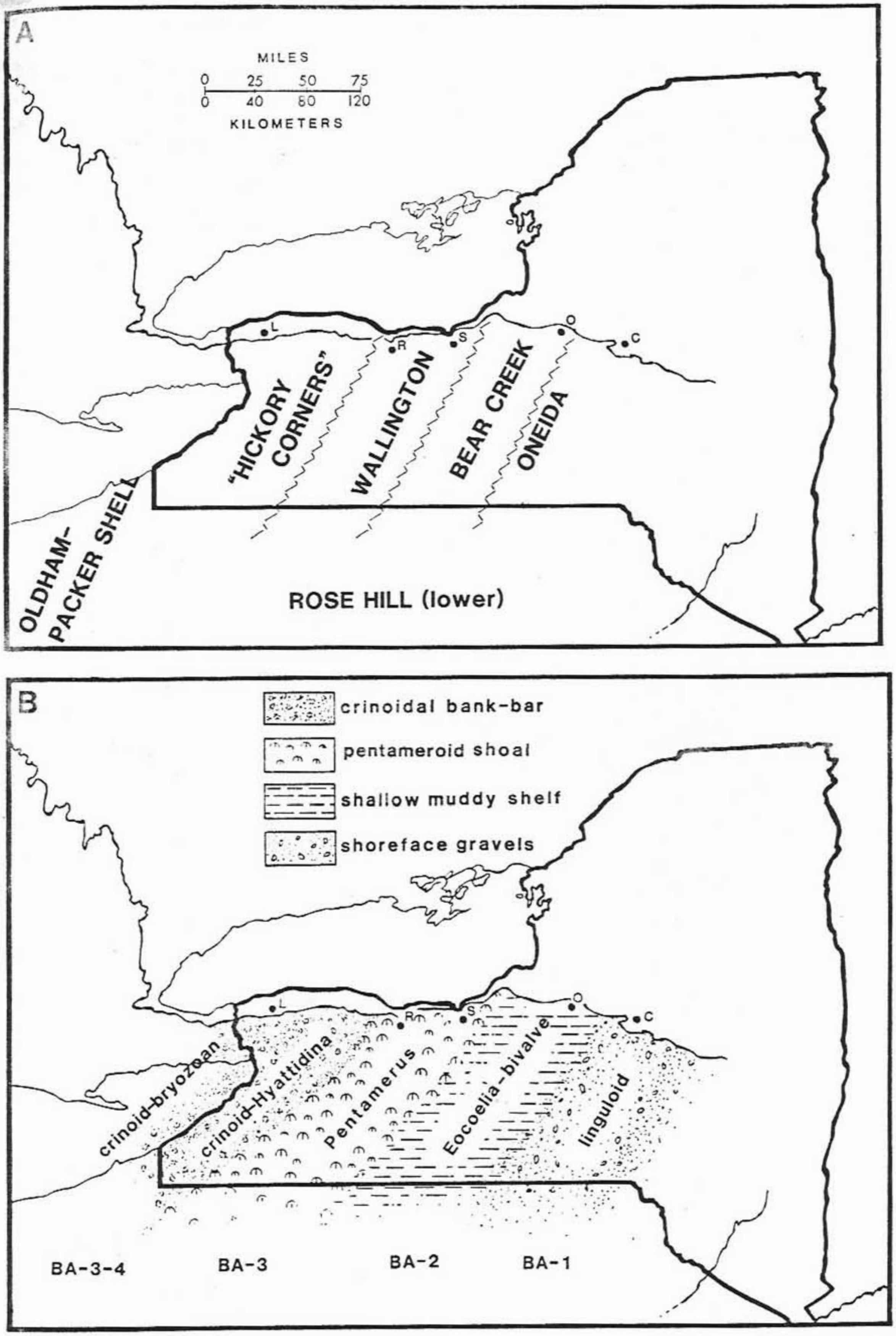


Figure 15. **Litho- and biofacies maps for the upper part of the Reynales Limestone and equivalents.** *A*, Lithofacies map for the upper part of the Reynales Limestone interval (Wallington–Bear Creek). Local names of lithostratigraphic units are indicated. *B*, Paleogeographic map showing inferred distribution of biofacies; benthic assemblages (BA) and names of prominent fossils are indicated.

probably provided a site for nucleation of phosphate nodules. These were reworked on the sea bottom during a period of non-sedimentation and minor erosion.

The Brewer Dock Member provides another facies transect from central to western New York. As the Maplewood–Neahga Shale transects, it suggests a westward change from BA-1 shoreline facies at about Oneida County into BA-3 or even BA-4 offshore deeper-water assemblages westward in Niagara County (Figure 14A, B).

In its eastern outcrop belt, the Brewer Dock Member is equivalent to the Furnaceville Member. The lowest beds of the latter are oolitic, phosphatic hematite beds that directly overlie the somewhat hematitic, phosphatic conglomerate of the Webster Bed. The fauna, where present within these beds, is extremely sparse, but may include the brachiopods *Eocoelia* and *Coolinia*. The upper beds of the Furnaceville Member (equivalent to the third cycle of the Brewer Dock), which typically represent the most hematitic portion of the unit, grade westward into the 20-30 cm-thick thoroughly hematized coquinoid limestone of the Seneca Park Bed. The Seneca Park Bed is composed almost entirely of the brachiopod *Eocoelia*. This coquinoid ledge may give way eastward to a basal shale tongue of the Bear Creek Shale in Oswego County.

Westward in Monroe County, the Furnaceville Member divides into a number of cyclic packages within the Brewer Dock. Only the uppermost cyclic unit remains hematitic as far west as Rochester, where it is referred to as the Seneca Park Bed. The lower portion of the Brewer Dock is approximately 40 to 50 cm thick, and contains two sharp-based phosphatic grainstone beds overlain by green Maplewood-like shale with a sparse *Eocoelia* (BA-2) fossil assemblage. The upper cycle of the Brewer Dock Member has diverse bryozoan- and *Hyattidina*-bearing limestone at its base, and a hematitic grainstone unit (Seneca Park Bed) packed with fragmented *Eocoelia* shells, crinoids, and bryozoans at its top.

The Brewer Dock Member still can be subdivided into its three component cycles in western sections, and the lower half is still the most shaly. In the drill core from the Albion landfill site, *Hyattidina* brachiopods appear with *Eocoelia* in the thin phosphatic limestones and shales of the lower part of the Brewer Dock Member. The upper, more compact limestone loses all traces of hematite and has a crinoidal pack- or grainstone lithology with abundant *Hyattidina* shells scattered throughout. Portions of the Brewer Dock Member that bear *Hyattidina* shells at Rochester rapidly change into crinoid grainstone facies to the west in Orleans County.

Still farther west in the Niagara County region at the type section of the Hickory Corners Member, the lower argillaceous portion of the Brewer Dock Member is dominated by *Hyattidina* with scattered *Eocoelia* (BA-2 to BA-3 boundary fauna), and begins to display a diversity of other brachiopods and some thin ramose bryozoans (Figure 14B). Some of the limestone layers become crinoidal pack- and grainstone. In this area the uppermost cycle has changed into a somewhat nodular crinoidal grain- and packstone with rugose corals; scattered *Hyattidina* and a diversity of other brachipods, such as *Platystrophia* and *Dalejina*; fenestrate bryozoans; nautiloids; and crinoids of various types (Eckert, 1989). The upper portion of this ledge may be capped by a 5-10 cm crinoidal grainstone that corresponds to the hematite of the Seneca Park Bed. At the westernmost localities at Niagara Gorge, the lower portions of the Brewer Dock Member become *Hyattidina*-rich, crinoidal pack- and grainstones, whereas the upper portions become argillaceous and nodular pack- and wackestones that probably represent relatively offshore (BA-3) conditions. Hence, in the Brewer Dock Member, there is a westward shift from BA-2 or even BA-1 assemblages at Oneida County into BA-3 grainstones with dominant *Hyattidina*, and finally into more diverse, offshore, nodular wacke- and packstones with relatively diverse coral, bryozoan, crinoid, and brachiopod assemblages.

The only other "Lower Clinton Group" unit that can be traced over an extensive distance is the lower part of the Wallington Member (Figure 15A). Its lateral correlative can be traced approximately from Lakeport on Oneida Lake, where the entire Wallington equivalent is represented by about 50 cm of very hematitic, *Eocoelia*-bearing limestones and shales assigned to the Bear Creek Shale. In eastern Wayne and Oswego Counties, outcrops of the Bear Creek Shale average about 3 to 4 m in thickness and consist of dark grey to greenish grey, slightly silty shale with a few thin limestone beds notably at the base, near the middle, and near the top of the unit. The dominant fauna consists of *Eocoelia intermedia* and a variety of small bivalves such as *Ctenodonta, Pyrenomoeous*, and *Modiolopsis*. The limestones contain extremely rare pentamerids, as well as *Dalejina, Coolinia*, and various bryozoans and crinoids. Complete articulated specimens of crinoids belonging to three new camerate species and *Dendrocrinus* were obtained at Bear Creek from the upper half-meter of shale (see Eckert, 1989).

The percentage of shale partings within the Wallington Member decreases westward. At the type section on Salmon Creek, the unit consists of a thin green shale overlain by about 30 cm of *Eocoelia*- and pentamerid-bearing hematitic limestone. This is followed by a highly shaly section with thin nodular calcisiltite beds that are overlain by the main pentamerid-bearing beds of cherty, blocky limestones. The uppermost beds again are shaly, except for the top hematitic limestone. The *Pentamerus*-bearing beds at Rochester appear to correlate with shaly portions of the Wallington Member farther east, and this indicates a general progression from *Eocoelia*-rich shales and mudstones of Oneida and eastern Wayne Counties to pentamerid-rich limestones of western Wayne and Monroe Counties. These lateral biofacies trends appear to corroborate the typical BA-2 to BA-3 onshore-offshore gradation observed in many Silurian successions (Figure 15B).

The westernmost exposures of the Wallington Member are equivalent to the upper units of the Hickory Corners Member. These are mostly compact crinoidal pack- and grainstones with some cross-bedding. Minor chert nodules appear near the middle parts of the section and probably correspond to the cherty layers seen at Wallington and Rochester. Pentamerids are notably rare or absent west of Monroe County, where the main mass of the Wallington Member is strictly crinoidal grainstones with relatively abundant *Hyattidina* brachiopods. This phenomenon suggests that pentamerids may be associated with the inner shoal margins adjacent to BA-2, *Eocoelia*-bearing mudstones. These, then, grade offshore into crinoidal facies containing the *Hyattidina* fauna. Observation of further westward facies progression within the Wallington Member is impossible because of regional beveling of the unit by the overlying unconformity that forms the base of the "Upper Clinton Group."

Conclusions

Detailed regional study of the "Lower Clinton Group" in western New York and Ontario supports the following conclusions:

1. The "Lower Clinton Group" is an unconformity-bounded sequence with a basal, regionally beveled surface and a major overlying

angular unconformity that forms the base of the Llandoverian (C-6) Williamson Shale of the "Upper Clinton Group."

2. The Thorold Sandstone should not be included as the basal unit of the Clinton Group. The Thorold Sandstone *sensu stricto* is found beneath the basal Clinton unconformity westward from Niagara County, New York, to St. Catharine's, Ontario. Eastward from Niagara County, the units that overlie the Thorold Sandstone include the 2.0 to 3.0 m, reddish, ostracode-bearing Cambria Shale and the 2.0 to 5.0 m of greenish to slightly reddish grey Kodak Sandstone. These units intervene between the Thorold Sandstone and the basal part of the Clinton Group. The Thorold Sandstone, overlying Cambria Shale, and Kodak Sandstone all appear to be relatively conformable with one another, and therefore are herein included in the uppermost Medina Group and removed from the Clinton Group. These sandstones and shales below the Clinton Group are everywhere white to pale greenish as a result of post-depositional leaching apparently associated with the overlying basal unconformity of the Clinton Group.

3. The Clinton Group is bounded at its base by a phosphatic or quartzose conglomeratic layer. In the east, this constitutes a phosphate-bearing quartz pebble bed of the Oneida Conglomerate; in Wayne County, it consists of a slightly hematitic, phosphatic conglomerate termed the "Webster Bed." In Monroe to Niagara County, it is a thin (10-20 cm-thick) phosphatic unit (Densmore Creek Bed). From Lockport in Niagara County westward to its erosional truncation near St. Catharine's, Ontario, the base of the Clinton Group is a thin (5-30 cm), sandy, dark-stained calcareous sandstone with abundant *Hyattidina* and other fossils, and is considered to be a local facies of the Densmore Creek Bed.

4. The Maplewood and Neahga Shales are laterally coextensive and do not appear to be differentiable at any location. They were, however, deposited in different minor troughs that trended approximately northeast to southwest, and were separated by a central high that extended approximately southwest from the area of Lockport, New York, to Grand Island, New York. These trends are also subparallel to the eastward feather-edge of the Maplewood Shale that strikes southwest through western Monroe to Allegany County.

5. The Maplewood Shale pinches out abruptly along the aforementioned line and passes laterally into the slightly hematitic, phosphatic, multigenerational Webster Bed. This transition appears to represent a change from a very shallow, sediment-starved shelf to nearshore gravel. The Maplewood and Neahga Shales were deposited in relatively shallow, although poorly oxygenated, basins as inner-shelf muds. These units and their lateral equivalents range from BA-1 (linguloid–trace fossil) to outer BA-2 *Eocoelia* community biofacies.

6. The Maplewood–Neahga Shales are everywhere separated from the overlying Reynales Limestone by a thin phosphatic horizon, herein designated the "Budd Road Bed". This unit forms the base of the Reynales Limestone, and therefore constitutes the basal unit of the Hickory Corners Member, as previously designated by Kilgour (1963) in Niagara County, and the base of the Brewer Dock Member in Monroe County. East of Monroe County, the phosphatic Budd Road Bed appears to merge with the underlying phosphatic conglomerate of the Webster Bed, becomes hematitic, and forms the base of the Furnaceville Member. The lower part of the Brewer Dock Member contains three minor (20-100 cm) shallowing-upward cycles that typically have phosphatic, fossiliferous, and locally hematitic limestones at their base and grade upward to green shale. The three cycles can be traced regionally, and each shows an internal westward progression from a shallow-water, nearshore biofacies and lithofacies in Oneida to Wayne Counties to a more offshore biofacies (BA-3 to BA-4) with diverse brachiopod, bryozoan, and coral assemblages in western Niagara County.

7. Although the details are not as firmly established for the overlying Wallington Member of the Reynales Limestone, it too can be traced west from nearshore hematitic sandy limestone beds through slightly offshore greenish grey shales into shell-rich carbonates. In general, both the Brewer Dock and Wallington Members show a biofacies progression from BA-2 (*Eocoelia*-bearing shales and sandy limestones) through BA-3 (pentamerid or *Hyattidina*-bearing crinoidal pack- and wackestone beds); and finally, in the case of the Brewer Dock Member, into nodular argillaceous limestone with a diverse marginal BA-4 bryozoan-dominated, brachiopod–coral assemblage. These lateral facies shifts appear to corroborate the models of earlier workers such as Ziegler et al. (1968).

8. Finally, the "Lower Clinton Group" appears to display a general upward-deepening trend. In terms of sequence stratigraphy, the basal part of the Maplewood and Neahga Shale appears to represent a relatively shallow–water interval during the initial transgression. Overlying phosphatic limestones of the Hickory Corners or the Brewer Dock Members appear to represent sediment-starved conditions associated with the increased rate of sea-level rise. Overlying limestone and shales may represent relative highstand conditions.

The Maplewood–Neahga Shale through Reynales Limestone succession represents one fourth-order subsequence within the "Lower Clinton Group" (sequence II). This subsequence is capped by a thin oolitic hematite, the Sterling Station Bed. A second subsequence, composed of the "Lower" and "Upper" Sodus Shales and overlying Wolcott Limestone, was removed by late Llandoverian erosion in western New York. It is not considered in detail in this report. This subsequence in many ways resembles the lower one, as it is a shale-dominated cycle that passes upward into fossil-rich carbonates. Superimposed on these two subsequences are minor shallowing-upward cycles that consist of basal carbonates that pass upward into greenish grey shales. In western New York, nodular, shaly limestone passes upward into grainstones. These thin (< 1.0 m) parasequences fundamentally appear to be upward-shallowing cycles, and are widely correlative. These minor cycles resemble the PACs of Goodwin and Anderson (1985) and form groupings that seem to constitute fifth-order cycles, such as those represented by the Brewer Dock and Wallington Members.

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