UPPER MOSCOW-GENESEE STRATIGRAPHIC RELATIONSHIPS IN WESTERN NEW YORK: EVIDENCE FOR REGIONAL EROSIVE BEVELING IN THE LATE MIDDLE DEVONIAN

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INTRODUCTION

A widespread regressive episode, immediately preceding the late Middle Devonian Taghanic onlap, has long been recognized in eastern North America (Grabau, 1917; Cooper, 1930; Cooper and Williams, 1935; Heckel, 1973; Dennison and Head, 1975; Rickard, 1975). Regional erosive overstep of Hamilton beds by Tully and Genesee strata was documented in the Finger Lakes area (Cooper and Williams, 1935) and was recognized west of Canandaigua Lake (Cooper, 1930), but the nature of pre-Taghanic unconformity in western New York remained obscure due to supposed lack of stratigraphic controls in the upper Moscow (Windom) shales. Indeed certain workers (Stover, 1956; Fulreader, 1957) believed that upper Windom beds were relatively little affected by erosional truncation.

Contacts of the Middle Devonian Windom Shale Member, previously examined and discussed (Brett, 1974a; Brett and Baird, 1975), have received continued study by the present authors; results of new work on the Windom-Genesee paraconformity and adjacent strata in the Erie County region are discussed herein.

Detailed correlation and study of Windom Shale component zones has been undertaken. At least fourteen mappable Windom marker beds and intervals have been correlated across all, or part, of Erie County; these are summarized in the present text. Mapping of Windom units immediately underlying the Genesee Formation permits detailed inference as to the nature of this unconformable contact. These beds also provide insight into the processes of marine mud sedimentation during deposition of the Windom and its influence on fossil community distribution. Particularly notable is the discovery that the thickest Windom sections in the county are the least stratigraphically complete and the thinnest generally display the full complement of marker beds and zones.

Clearly, the regional configuration of Windom Shale units results from the interplay of two processes: westward stratigraphic condensation of the section, and progressive erosive overstep of upper Windom beds. As will be shown here, the magnitude of erosional beveling of Moscow strata increases to the north as the depositional hinge of the Appalachian Basin is approached.

In addition, the Moscow-Genesee discontinuity and associated erosion lag deposits have been reexamined. A newly discovered discontinuity at the base of the Genundewa Limestone (basal Upper Devonian?; see Oliver, et al., 1981) is found to have some similarity to the North Evans Member ("conodont bed") and is probably coeval with it. The sedimentology and mode of origin of the North Evans and Leicester pyrite members is further discussed. Finally, new data are synthesized in a chronological outline of events affecting western New York during Late Middle Devonian time.

DEPOSITIONAL SETTING

Western New York Shelf

The Hamilton Group of New York includes Middle Devonian sediments deposited at or near the northern margin of the Appalachian Basin; they accumulated in the northern arm of an inland sea, the deepest part of which was developed southeast of the study area. The northern and western boundaries of the basin bordered low-relief, cratonic shelf regions; these areas supplied relatively little detrital sediment to the basin as compared with actively rising tectonic source terrains to the southeast of the basin. This accounts for the thin deposits in western New York (Dennison and Head, 1975). A broad, gently south-sloping, muddy shelf existed across most of central and western New York during Hamilton deposition (Cooper, 1957; McCave, 1967, 1973; Grasso, 1970, 1973; Heckel, 1973).

The eastward thickening Hamilton clastic wedge is a result of Acadian tectonic events, including uplift to the east and southeast (Cooper, 1957; Heckel, 1973; Oliver, 1977). It is the initial expression of the Catskill Deltaic Complex which expanded greatly during the Late Devonian. Upper Hamilton formations are composed largely of detrital sediment; in eastern and central New York they record basin filling and general westward migration of the eastern shoreline. In western New York, the Hamilton Group is markedly different, consisting of thin shelf sediments which do not record simple shallowing-upward sequence.

Upper Hamilton sediments are characteristically fossiliferous; the rich biotas of the Ludlowville and Moscow Formations in Erie County have been a source of study for paleontologists for more than a century (Hall, 1843; Grabau, 1989-1899; 1899; Cooper, 1929, 1930, 1957;

Buehler and Tesmer, 1963; Beerbower, et al., 1969; Oliver and Klapper, 1981). The Hamilton sea apparently was relatively shallow and had near-normal salinity, water temperatures, and circulation as evidenced by the presence of diverse stenotopic benthic organisms.

In contrast to the fossilferous Hamilton beds in Erie County, overlying Genesee shales contain relatively low diversity assemblages which are dominated by pelagic taxa. Only in the paraconformity-related Leicester and North Evans Members is the fossil diversity greater, but many of these fossils may have been reworked from the underlying Moscow Formation (see below).

Slope and Basin Environments

The western New York Shelf was bounded to the south by a more actively-subsiding central region of the Appalachian Basin during the Middle Devonian. A southward trending regional slope is recognized for Onondaga (Eifelian) carbonates based on extensive study of subsurface drill cores and well log data (Kissling and Moshier, 1981; Koch, 1981). Brachiopod/coral associations reflect southward increasing depth within the Onondaga and there is major southward thinning of the whole Onondaga carbonate package across the southern tier of western New York (Koch, 1981).

Fossiliferous, gray mudstones and thin limestones of the upper Hamilton Group are correlated southward with the Millboro Member, a thick sequence of dark gray and black shale developed in western Pennsylvania, southeastern Ohio, and West Virginia (Dennison and Hassan, 1976). Similarly, the Tully Formation, which is a compact, laterally extensive carbonate unit in central New York grades southward and westward across Pennsylvania into a thick sequence of calcareous shale and finally into black shale (Burket Member) near the Pennsylvania-Maryland border (Heckel, 1973). The Moscow-Genesee paraconformity of western New York is coextensive with disconformities of decreasing magnitude in the Tully Formation in central New York, this hiatus disappearing southward as the Tully thickens and grades into black shale. Thus, in the region of greater subsidence, the upper Middle Devonian sequence is characterized by deeper water deposits, as indicated by the dysaerobic-anoxic mudstones, and is apparently more complete.

In the present paper, it is argued that apparent eastward erosional truncation of Windom zones and marker beds is really a northward overstep effect, this also reflecting the subtle influence of depositional hinge effects or on differential subsidence to the south. This and other north-south depositional changes are discussed in the text.

During Genesee (latest Givetian to early Frasnian) time general deepening of shelf waters occurred in western New York, as a part of a widespread Taghanic Onlap (Johnson, 1970; Dennison and Head, 1975). The consequent development of dysaerobic and anaerobic basin-type conditions in western New York resulted in deposition of dark gray and black, sparsely fossiliferous muds (Sutton, et al., 1970; Thayer, 1974; Bowen, et al., 1974). Anoxic bottom conditions inhibited development of benthos. However, as will be shown, significant bottom currents were present to the degree that reworked fossils and diagenetic debris were sorted into lenses within the basal Genesee sequence.

General Stratigraphy

The Middle Devonian (Givetian) Hamilton Group and the Middle to Upper Devonian Genesee Formation (U. Givetian-Frasnian) are eastward thickening wedges of terrigenous sediment which are predominantly marine except in east-central and eastern New York. This aggregate sequence, ranging from 88 m (290 ft) at Lake Erie to more than 1220 m (4000 ft) at the Catskill Front, is composed of detrital sediments which coarsen to the east and southeast. In western New York , the Genesee beds are highly condensed stratigraphically, thinning westward from over 305 m (1000 ft) in the Seneca Lake region to as little as 3 m (10 ft) at the Lake Erie Shore, the Erie County region being characterized by particularly slow sedimentation. Hamilton and Genesee marine shales in western New York are displaced eastward by siltstone and sandstone facies in central New York, these to be succeeded, in turn by redbed floodplain deposits and fluvial sandstones in east-central and eastern New York State (Rickard, 1975).

Westward thinning of marine Hamilton and Genesee strata is associated with appearance of widespread discontinuities and condensed sedimentary units. Most significant of these is the regional paraconformity separation Hamilton-Tully beds and the overlying Genesee Formation. This discontinuity, originating in the uppermost Tully Formation in Seneca County (see Huddle, 1981) becomes progressively more significant westward as a stratigraphic gap; several upper Hamilton faunal zones are overstepped progressively to the west beneath the break (Baird and Brett, in press). However, there is corresponding westward depositional onlap of overlying Genesee beds; the basal Geneseo Shale rests on Windom in Genesee County whereas only the upper Penn Yan and finally Genundewa Members rest directly on the Hamilton in western Erie County (deWitt and Colton, 1978). This interpretation is corroborated by conodont (Huddle, 1981; Klapper, 1981) and goniatite biostratigraphy (Kirchgasser, 1973).

STRATIGRAPHY, THICKNESS VARIATION AND EROSIONAL BEVELING OF THE WINDOM SHALE MEMBER (MOSCOW FORMATION)

Detailed Stratigraphy

The Windom Shale Member (Grabau, 1917) comprises the uppermost unit of the Moscow Formation and of the Hamilton Group as a whole. In Erie County localities (Fig. 1), the Windom Member is composed primarily of medium to dark gray, variably calcareous mudstone with several thin persistent argillaceous limestones, concretionary beds, and pyritic horizons (Buehler and Tesmer, 1963; Fig. 2). It is bounded by discontinuities at its base and top (Brett, 1974a; Baird, 1978, 1979) and ranges in thickness from 2.2 m (7 ft) at the south-western section near Pike Creek on the Lake Erie Shore to perhaps as much as 16 m (53 ft) near the Genesee-Erie County boundary. Previous workers (Cooper, 1930) have noted an anomolous area of eastward-thinning of the Windom Shale in Genesee County, to about 10.7 m (35 ft) near Darien. As will be demonstrated, the thickness pattern of the Windom reflects a complex interplay of westward sedimentary thinning and northward regional, erosional truncation.

The most complete and best exposed Windom section is in the abandoned Penn-Dixie cement quarry near Bay View, New York (loc. 7), which provides an excellent reference section (Fig. 2). Component fossil assemblage zones from this locality are described in detail elsewhere (Brett, 1974b; Baird and Brett, in press). The following section summarizes the characteristics of the various Windom fossil zones and marker beds in ascending order.

Unit 1: *Ambocoelia umbonata* Beds. Soft, friable, medium to dark-gray shales at the base of the Windom contain very abundant specimens of the brachiopod *Ambocoelia umbonata*, as well as chonetids (Stover, 1956; Brett, 1974b). This zone is only 16 cm (6 in) thick at the Lake Erie Shore and 20 cm (8 in) at Penn-Dixie Quarry but it thickens abruptly eastward from about 0.5 m (2 ft) at Smoke Creek to 2.6 m (18.5 ft) at Buffalo Creek and over 7.5 m (24 ft) at West Alden near the Erie-Genesee County border.

Unit 2: Bay View Coral Bed (Baird and Brett, in press). This unit, equivalent to the Moscow Coral Bed of Grabau (1899) and *Spinatrypa spinosa* bed of Brett (1974b), consists of soft to somewhat indurated calcareous shale containing a diverse fauna of at least 50 species of fossils including small rugose corals, diverse brachiopods, pelmatozoan debris and trilobites. The Bay View bed thickens eastward from 5 cm (2 in) at Lake Erie to 2 m (7 ft) near Buffalo Creek. Correspondingly, the density of fossils declines strikingly and the single band breaks into an interval of shell-coral rich layers separated by barren, calcareous mudstones. Coincident with this lithologic transition is a slight faunal change. Western sections of the Bay View bed

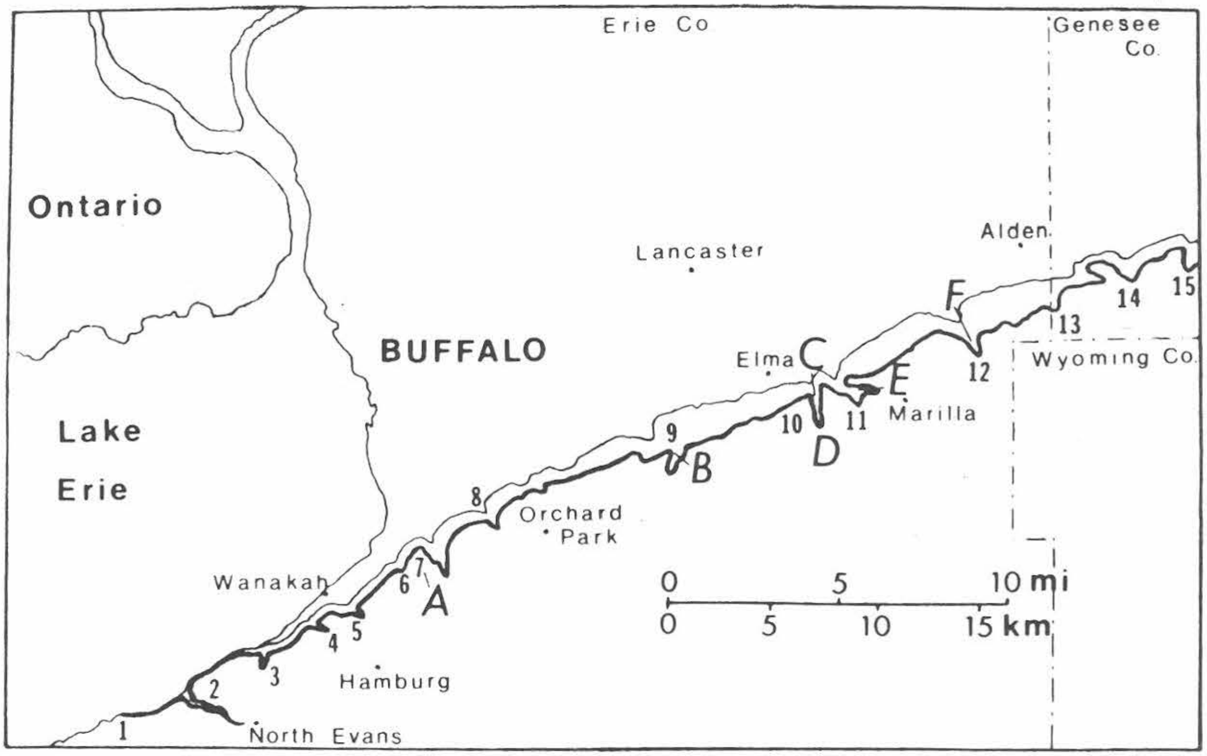

Figure 1. Study area. Outcrop belt of Middle Devonian Windom Shale Member and localities examined; light line denotes base of Windom Member; heavy line denotes base of Genesee Formation. Numbered sections include: 1) Pike Creek; 2) Eighteen Mile Creek; 3) unnamed creek at Weyer; 4) unnamed creek at Amsdell; 5) Cloverbank Shale Pit (Bethlehem Steel Co.); 6) unnamed creek south of Big Tree Road; 7) Bay View Shale Pit (formerly Penn Dixie Co.); 8) South Branch, Smoke Creek; 9) Cazenovia Creek; 10) Buffalo Creek; 11) Little Buffalo Creek; 12) Cayuga Creek; 13) Durkee Creek; 14) Eleven Mile Creek; 15) Murder Creek. Field trip stops, in capital letters, include: A) Bay View Shale Pit; B) Cazenovia Creek; C) Buffalo Creek (lower Windom); D) Buffalo Creek (upper Windom-Genesee Fm.); E) Little Buffalo Creek; F) Cayuga Creek.

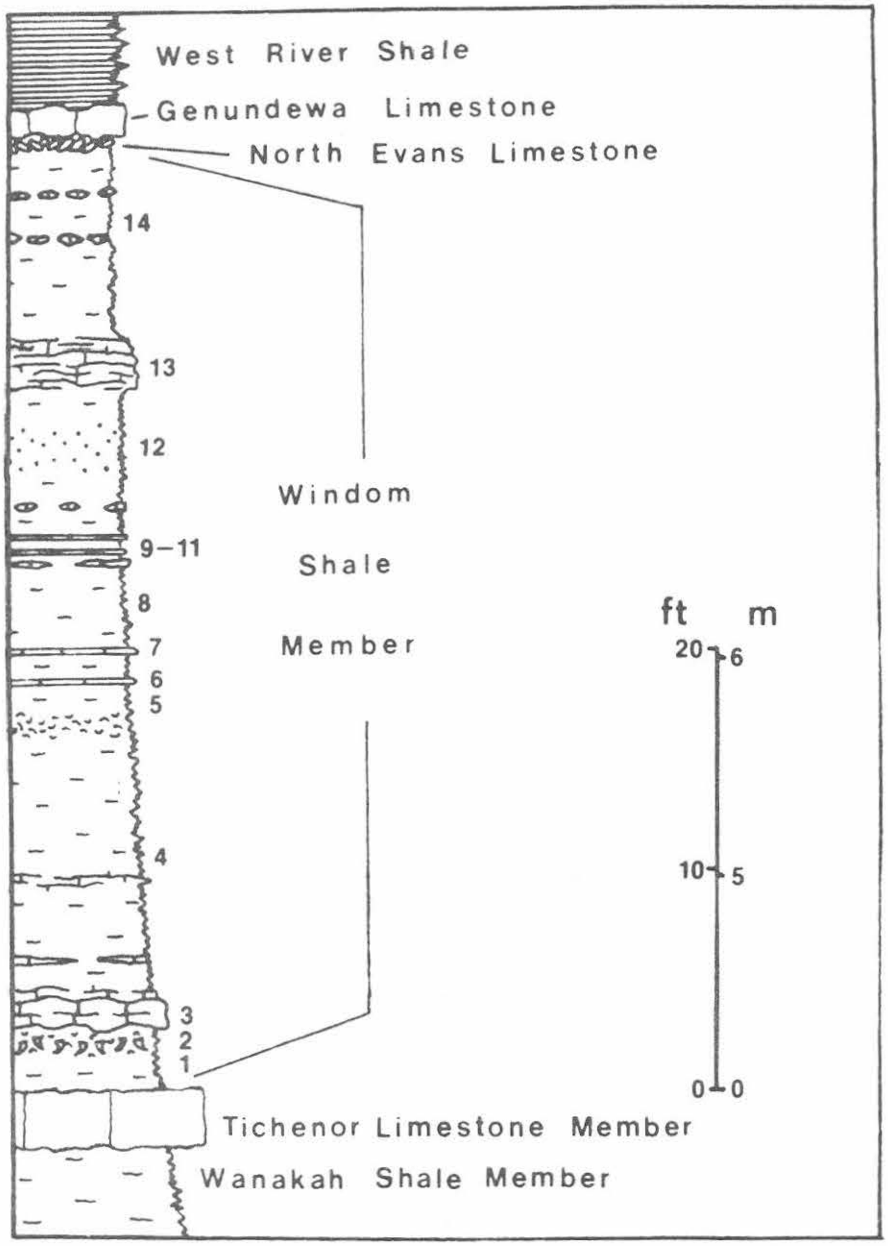

Figure 2. Stratigraphic subdivisions of the Windom Shale Member; standard section Bay View Quarry and unnamed creek near Big Tree; Units include: 1) Ambocoelia umbonata beds; 2) Bay View coral bed; 3) Smoke Creek bed; 4) barren shale interval; 5) Big Tree bed; 6,7) A-B limestones; 8) Buffalo Creek pyritic beds; 9-11) C,D, and E limestones; 12) Penn Dixie pyritic beds; 13) Amsdell bed; 14) upper Ambocoelia? praeumbona-bearing shales.

contain local biostromes of the large rugose corals Cystiphylloides, Heliophyllum and Heterophrentis, east of Smoke Creek. These corals are replaced by a suite of smaller stereolasmatid corals (Amplexiphyllum, Stereolasma), auloporids and Pleurodictyum. Similarly, certain brachiopods such as Spinatrypa spinosa are restricted to the western coral-rich facies whereas bivalves become abundant farther east.

Unit 3: Smoke Creek Bed. Formerly termed the "coral-trilobite" bed (Brett, 1974b), the Smoke Creek bed (Baird and Brett, in press) constitutes a very persistent, ledge-forming calcareous interval. It maintains a relatively uniform thickness of 2-75 cm (8-30 in) in Erie and Genesee Counties, and consists of irregular to blocky fracturing, light-gray calcareous shale and argillaceous limestone. The Smoke Creek bed is one of the most widespread and distinctive markers in the Windom; it is traceable from Lake Erie Shore eastward to Canandaigua Lake (Baird and Brett, in press). This unit typically contains an abundance of small rugose corals, brachiopods including Pseudoatrypa, Mucrospirifer consobrinus and Ambocoelia umbonata. The trilobites Phacops and Greenops may occur as clusters of complete specimens on certain bedding planes.

Unit 4: Shales overlying the Smoke Creek bed are medium to olive gray and are sparsely fossiliferous or completely barren, yielding, at most, scattered trilobites and chonetid brachiopods. From Buffalo Creek (loc. 10) eastward these shales contain two or more calcareous-concretionary horizons which are particularly well displayed at Cayuga Creek (loc 12). This interval ranges from 0.8 m (2.6 ft) at Pike Creek (loc. 1) to over 5.0 m (16 ft) in central Erie County. It appears to correlate with a more fossiliferous zone, containing abundant trilobites (Greenops), pyritized nuculid bivalves and nautiloids, which occurs near the upper contact of the Windom in eastern Erie County (see Stop 5 description).

Unit 5: Big Tree Bed. A thin (5-10 cm) pyrite-rich, fossil horizon occurs at the top of Unit 4. This horizon is characterized by abundance of the brachiopods Pseudoatrypa and Mediospirifer, typically as highly compressed specimens, small rugose corals and crinoid columnals. Weathered exposures of the bed in Penn-Dixie Quarry (loc. 7) have also yielded an abundance of pyritized sponges, blastoids and a variety of molluscan steinkerns. A similar fauna (including the blastoids) has been recognized in Cazenovia and Buffalo Creeks. The Big Tree bed may correlate with the Fall Brook bed, a coral-rich horizon in the Genesee and Wyoming Valleys (Baird and Brett, in press). However, this correlation is tentative due to erosional removal of this sequence in western Genesee and eastern Erie Counties and to apparent regional facies change at this level.

Units 6, 7: A and B Limestones. Immediately overlying the Big Tree bed is an interval containing two thin (3-4 cm), but persistent bands of barren, hard, argillaceous limestone, spaced about 50 cm apart.

These marker bands are simply designated the A and B limestones. Locally, the upper (B bed) may be missing altogether and these beds may break up into a zone of flattened concretions particularly at Buffalo Creek. These bands resemble an overlying set of limestone beds (C, D, and E limestones; see below).

Unit 8: Buffalo Creek Bed. Separating the A or B and C limestones is an interval approximately 1.5-2.4 m (5-8 ft) thick of soft, fissile, medium-gray, pyrite-rich shale. Large (20-30 cm) irregular masses of pyrite occur near the base of this interval at Buffalo Creek (loc. 10). This interval is nearly barren in the westernmost localities (locs. 6-9); however, at Buffalo Creek (loc. 10) it contains Ambocoelia umbonata, chonetids and scattered pyritized burrows, nuculid bivalves, nautiloids and other fossils. At Little Buffalo Creek (loc. 11) Pseudoatrypa, Mediospirifer and Devonochonetes coronatus also occur in these shales suggesting eastward increase in faunal diversity. Because this interval is absent in Genesee County due to erosive overstep, the facies change is inferrential.

Units 9-11: C, D and E Limestones. A series of three, regularly-spaced, hard, argillaceous limestone bands, resembling the A and B beds occur at the top of the Buffalo Creek interval. Each band is uniformly 3-4 cm (1-2 in) thick. Limestone beds D and E are invariably slightly closer together (30-38 cm) than C and D (39-46 cm). As with the A and B limestones one or more of these beds may locally grade laterally to a horizon of tabular concretions. Scattered concretions also occur above or below each of the three beds. These limestones are easily recognizable markers between Penn-Dixie Quarry (loc. 7) and Buffalo Creek (loc. 10). In the vicinity of Eighteen Mile Creek (loc. 2) two or three of the beds appear to merge into a single 20 cm thick calcareous band.

Unit 12: Penn-Dixie Beds (= "small Tropidoleptus" beds, Brett, 1974b). Overlying the E limestone bed is a 1-3 cm (3-10 ft) interval of dark-gray, friable, pyritic shale, closely resembling the Buffalo Creek bed. This shale generally lacks concretionary horizons, but a layer of small oval concretions, many containing pyritic cores is developed at Smoke, Cazenovia and Buffalo Creeks (locs. 8-10). These concretions are associated with scattered large masses of pyrites and, near Lake Erie, thin crusts of pyrite occur at the same level. Unit 12 shalesare characterized by an abundance of small specimens (juveniles?) of Tropidoleptus carinatus and Ambocoelia cf. A. nana; these diminutive brachiopods are not found elsewhere in the Windom of western New York. At Penn-Dixie Quarry, where Unit 8 is best exposed, these beds also yield an abundance of pyritic fossil steinkerns, including nuculoid clams, gastropods, nautiloids, ammonoids and enrolled trilobites. This fauna, reminiscent of the Alden pyrite fauna of the Ledyard Shale (Fisher, 1951), is currently being studied in detail (Dick and Brett, 1982).

Unit 13: Amsdell Beds(= "praeumbona beds", Brett, 1974b). This unit comprises 30-75 cm (12-29 in) of light-gray, slightly concretionary, argillaceous limestone and medium-gray calcareous shale, with abundant specimens of the brachiopods *Ambocoelia*? (*Crurithyris*?) *praeumbona*, *Leiorhynchus*? *quadricostatum*, chonetids and trilobites. In the western most exposures the Amsdell beds are expressed as a series of two or three hard calcareous bands separated by shale. However, at Cazenovia Creek (loc. 9) the Amsdell bed forms a single blocky band of ledge-forming argillaceous limestone. The Amsdell beds are not present in the outcrop belt east of Cazenovia Creek.

Unit 14: From Eighteen Mile Creek northwestward to Smoke Creek the uppermost Windom consists of 1-2.4 m (3-8 ft) of soft, gray shale with three or four horizons of flattened ellipsoidal to bedded concretionary limestone bands. The shale and associated concretions are well exposed in the abandoned Bethlehem Steel quarry near Cloverbank. This interval is generally sparsely fossiliferous, but some concretions contain *Ambocoelia*? *praeumbona*, *Schizobolus truncatus*, *Allanella tullius*, chonetids and trilobites.

Westward Thinning and Condensation

In western New York, the Windom Shale exhibits abrupt southwestward thinning (Figs. 3, 4A). At Cazenovia Creek (loc. 9) the Windom (Units 1-13) is about 14.4 m (47 ft) thick, whereas at Pike Creek on Lake Erie Shore, 30 km to the southwest, the corresponding stratigraphic interval is only 2.2 m (7 ft). Moreover, subsurface data indicate that the Windom pinches out altogether a few kilometers south of this region (Rickard, pers. comm. 1981). Associated with thinning is pronounced stratigraphic condensation; notably, the thin C-E limestone bands (Units 9-11) appear to merge into a single calcareous band at Eighteenmile Creek. Similarly the lower *Ambocoelia*-rich shales (Unit 1) thin dramatically from nearly a meter to 16 cm and, locally, pinch out (Fig. 3).

Various subunits within the Windom exhibit unequal westward thinning. Notably, most of the thickness variation involves shale packages, while thin carbonate units show only minor thickness changes. For example, the Smoke Creek bed maintains a thickness of 70-75 cm from Buffalo Creek eastward through all of Genesee County and only thins to 20 cm in the most condensed section at Pike Creek. The A-E limestones are 3-4 cm thick at all outcrops examined. Similarly, the Amsdell bed only ranges from 30-70 cm. These observations suggest that the carbonate-rich mudstones were generated by processes largely independent of those producing the differentially thickened packages of terrigenous sediment. The fact that all of these limestone bands grade into beds of discrete concretions further suggests that the carbonates are diagenetic, having formed through peculiar geochemical conditions existing in the sediment.

Moreover, westward thinning of shale units is not strictly proportional, but, rather temporally imbricate (Fig. 3). There appears to be a westward progression of the area of maximum thickness in successively higher shale packages within the Windom. Unit 1 is thickest near West Alden (loc. 13) and thins to a feather edge at Lake Erie shore; Unit 4 obtains maximum thickness at Buffalo Creek (loc. 10), Unit 8 at Cazenovia Creek (loc. 9), Unit 12 at Smoke Creek (loc. 8) and Unit 14 near Cloverbank (loc. 5).

Slight variations in lithology accompany thickness changes. Shales are characteristically darker and more pyritic in thicker areas, and more calcareous in the thinner regions. The thickness variations also coincide with subtle changes in the fossil contents of the beds. In every case fossils are the least common and diverse in areas of maximum shale thickness. In fact, Units 4, 8, and 14 are very nearly barren at and near their thickest areas. Marginward from each depocenter, these shales contain increasingly diverse assemblages, typically beginning with Ambocoelia-chonetid associations which give way to those containing larger brachiopods such as Pseudoatrypa, Mediospirifer and Devonochonetes coronatus. As noted above, slightly increased fossil diversity, associated with thinning, is characteristic of the Bay View coral bed.

Association of faunal and lithologic changes with stratigraphic thickening suggests that increased mud deposition was accompanied by other environmental changes such as a decrease in oxygen levels and/or environmental energy. We suggest that the westward progression of thicknesses in the Windom is a reflection of westward migrating diastrophic ridges ("swells") and basins. If so, it appears to mirror on a small scale a trend which has previously been noted for the Ludlowville and Moscow formations as a whole (Baird, 1979; Baird and Brett, 1981). There is an apparent westward shift of the area of greatest thickness in successively higher units in the Ludlowville and Moscow Formations: The King Ferry Shale is thickest near Cayuga Lake, the Jaycox Shale thickest near Seneca Lake, the Deep Run Shale at Canandaigua Lake, and the Kashong Shale in the Genesee Valley. In each case paleontologic and sedimentologic evidence suggest a coincidence of deepest water conditions with the depocenter. We can only speculate that this pattern was generated by a standing wave-type progression of submarine fold axes, these possibly propagating westward from the tectonically active Acadian region in eastern New York.

Based on the general eastward thickening of most component zones in the Windom Shale one might predict that the thickest Windom sections should exist east of Erie County. Indeed subsurface data (Rickard, pers. comm., 1981) indicate Windom thicknesses in excess of 18 m (60 ft) south of Darien in Genesee County. However, the Windom is considerably thinner (9.5-11 m; 31-36 ft) in measured sections along the outcrop belt in Genesee County (Figs. 3, 4A). This is a result of a separate process discussed below.

Erosional Beveling of the Windom

Detailed examination of the Moscow-Genesee contact reveals evidence for erosive overstep of the Hamilton in a northeastward direction (Fig. 4). Thus, eastward thickening is partially counteracted by northeastward truncation of upper Windom beds probably due to post-Hamilton erosion.

Although fourteen distinctive marker beds and fossil assemblage zones are present in the thin Windom section of western Erie County (locs. 1-7), only the basal three or four of these are present in thicker sections near the Erie-Genesee County border. Thus, ironically, the stratigraphically most complete sections are generally the thinnest. At Amsdell Creek (loc. 4), 2.8 m (9 ft) of shale containing three distinct concretion horizons overlies the Amsdell bed (Unit 13). At Smoke Creek, only 1.5 m (5 ft) of this shale, including only the lower two concretion horizons, is observed. By Cazenovia Creek, the Amsdell bed is in direct contact with Leicester Pyrite or Penn Yan Shale (Figs. 3-5); locally, northward along the same creek the Amsdell bed is completely truncated (see below). Continued northeastward truncation brings successively lower Windom beds against the Genesee contact: the Penn Dixie beds form the contact at Buffalo Creek, the C or D limestone bed at Little Buffalo Creek and apparently the Big Tree Bed at Cayuga Creek near Clinton Road. Finally, at Eleven Mile Creek (loc. 14) in Genesee County the Smoke Creek bed (Unit 3) is less than 2 m below the Genesee contact (Fig. 3). The Smoke Creek bed is at or near this contact along most of the outcrop belt in Genesee County. Locally, at Bowen Creek, the northernmost outcrop, the

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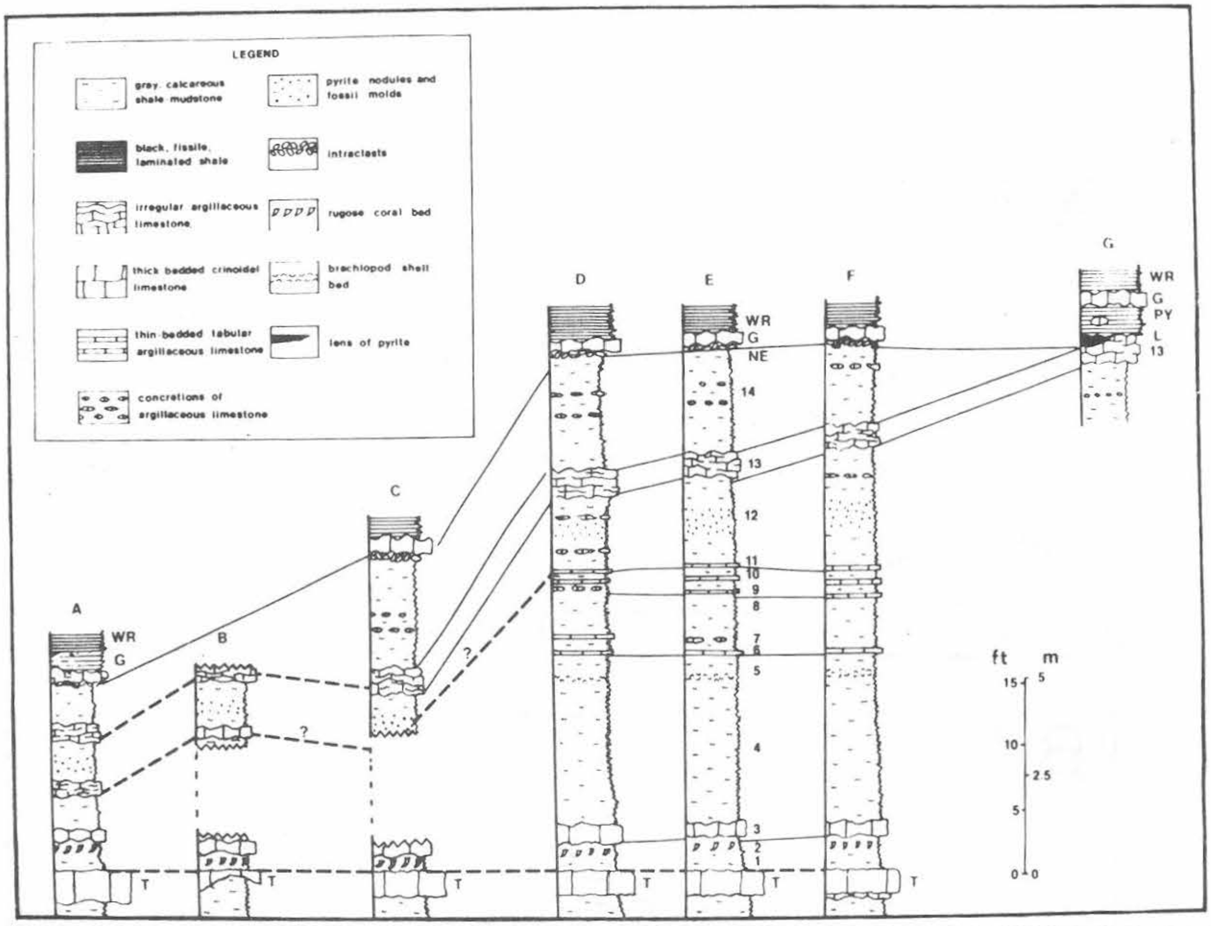
Figure 3. Stratigraphy of the Windom Shale Member in Erie and western Genesee Counties. Columnar sections include: A) Eighteen Mile Creek; B) unnamed creek at Weyer; C) unnamed creek at Amsdell; D) unnamed creek near Big Tree Road; E) Bay View Quarry (shale pit); F) South Branch Smoke Creek; G) Cazenovia Creek (south section); H) Cazenovia Creek (north section); I) Buffalo Creek; J) Little Buffalo Creek; K) Cayuga Creek; L-1, L-2) first west-flowing tributary of Cayuga Creek north of Clinton Road; L-3) second tributary of Cayuga Creek; M) Durkee Creek; N) Eleven Mile Creek. Stratigraphic units include: 1) *Ambocoelia umbonata* beds; 2) Bay View Coral Bed; 3) Smoke Creek bed; 4) lower barren shales; 5) Big Tree pyritic bed; 6,7) A,B limestones; 8) Buffalo Creek pyritic beds; 9,11) C,D and E limestones; 12) Penn Dixie pyritic beds; 13) Amsdell beds; 14) upper shales and concretions. Symbols: T) Tichenor Limestone; M) Menteth Limestone; K) Kashong Shale; L) Leicester pyrite; NE) North Evans Limestone; PY) Penn Yan Shale; G) Genundewa Limestone: WR) West River Shale.


LEGEND
gray, calcareous shale mudstone
black, fissile, laminated shale
irregular argillaceous limestone
thick bedded crinoidal limestone
thin-bedded tabular argillaceous limestone
concretions of argillaceous limestone
pyrite nodules and fossil molds
intraclasts
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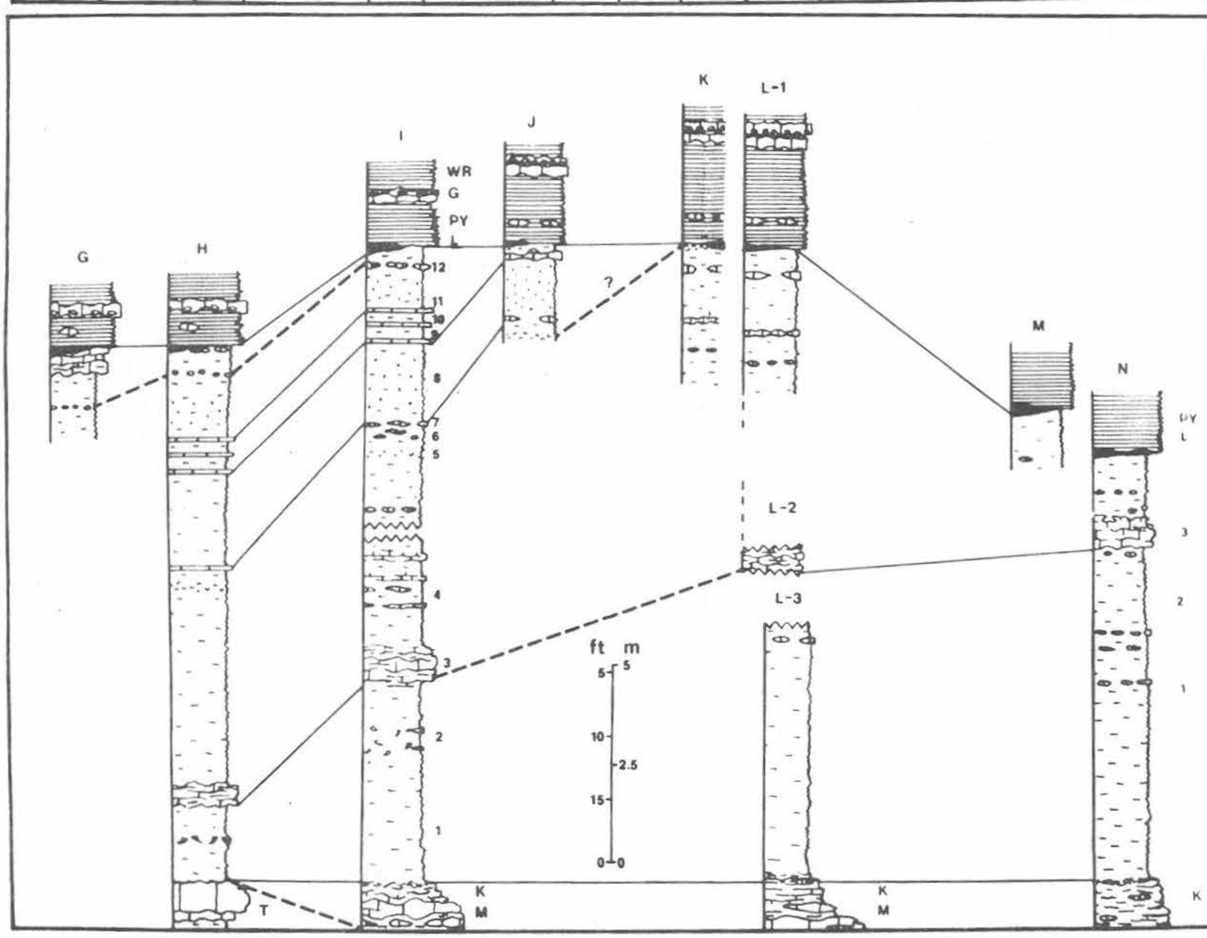
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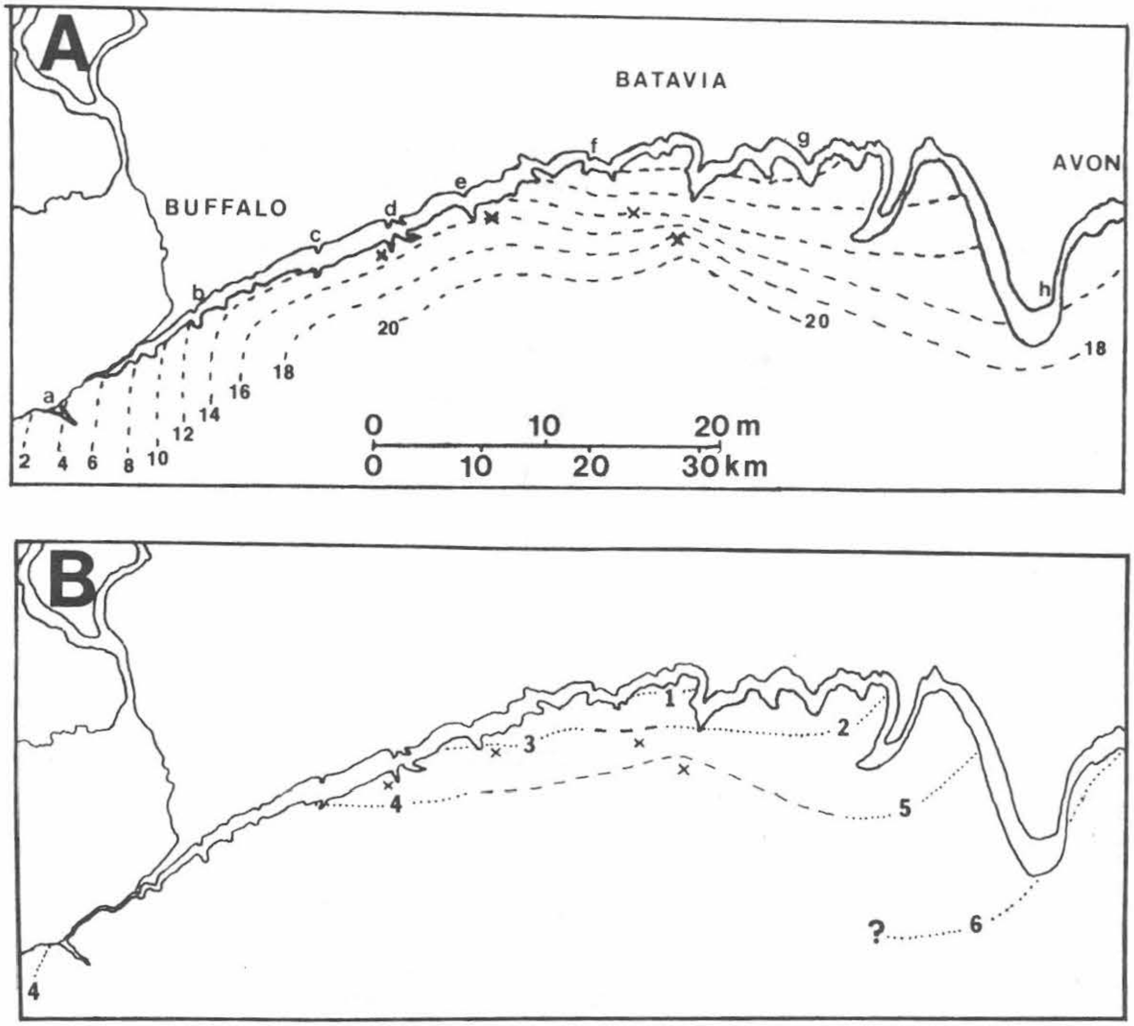

Figure 4. Regional Windom truncation and thickness trends. A) isopach map of Windom based on outcrop and subsurface data; isopleths in meters. B) inferred "paleooutcrop" trends of Windom beds along top Hamilton erosion surface that would be observed if Genesee and younger strata were removed. Localities in A include a) Eighteenmile Creek; b) Bay View shale pit; c) Cazenovia Creek; d) Buffalo Creek; e) Cayuga Creek; f) Elevenmile Creek; g) White Creek; h) Fall Brook. X's denote well sites. In B, strike trends include: 1) Smoke Creek bed; 2) Fall Brook Coral bed; 3) Big Tree bed; 4) Amsdell bed; 5) Ambocoelia? praeumbona beds; 6) uppermost Windom black shales with Alanella tullius.

Smoke Creek bed is also partially beveled. However, southeast of Pavilion, New York, higher Windom zones reappear beneath the contact (Fig. 4B). Thus, only the lower three or four units of the Windom (Ambocoelia beds-Smoke Creek bed) can be traced continuously between Erie and Livingston Counties. As noted above, these beds exhibit relatively little change in lithology or fossil content across this region and can be traced readily into the Finger Lakes region. However, correlation of the higher units with upper Windom beds in Erie County is difficult because, unlike the lower beds, these units exhibit pronounced facies changes across this region, and this change is not observable in outcrop.

Initially, we suspected that the trunction of upper Windom beds in Genesee County reflected an area of differential uplift ("Alexander Arch") which ran roughly north-south through the center of Genesee County. In actuality, this pattern is an artifact of the configuration of the outcrop belt, relative to erosional and depositional strike. The outcrop belt forms a northward arc; it trends northeastward across Erie County, then eastward to Pavilion, and finally southeastward into the Genesee Valley (Fig. 4). Most Windom sections in Genesee County exhibit similar levels of truncation (contact lies within 1-2 m above the Smoke Creek bed) and similar thicknesses. Higher beds appear beneath the Genesee contact both east and west of this area at approximately the regions where the outcrop belt begins to curve southward. This suggests that the direction of maximum truncation is not eastward, but northward.

To test this hypothesis we examined long sections of Windom exposed continuously on north-flowing creeks in Erie and Genesee counties, where overstep could be measured in outcrop (see Figs. 5B and D). The Windom/Genesee contact is exposed nearly continuously along a one kilometer north-flowing stretch of Cazenovia Creek (Stop 2). Local northward truncation is observable along this section; at the southernmost exposure (loc. 9b) the complete Amsdell bed and a few centimeters of overlying shale were found to occur beneath the Genesee unconformity, but near Northrup Road bridge, 1 km farther north, the Amsdell bed is largely truncated and fragments of calcareous shale containing Ambocoelia? praeumbona occur in the base of the Leicester Pyrite. A more precise estimate of difference in relative truncation was obtained by measuring the distance between the Windom-Penn Yan unconformity downward to a distinctive concretion zone in the upper part of Unit 12. This concretion band was found to be 84 cm beneath the contact at location 9a and 155 cm below this same contact at 9b, giving a total northward truncation of 71 cm in one kilometer.

Similarly, rapid northward truncation of the Big Tree fossil bed can be observed along a short north-flowing section of Cayuga Creek near Clinton Road (Stop 5A).

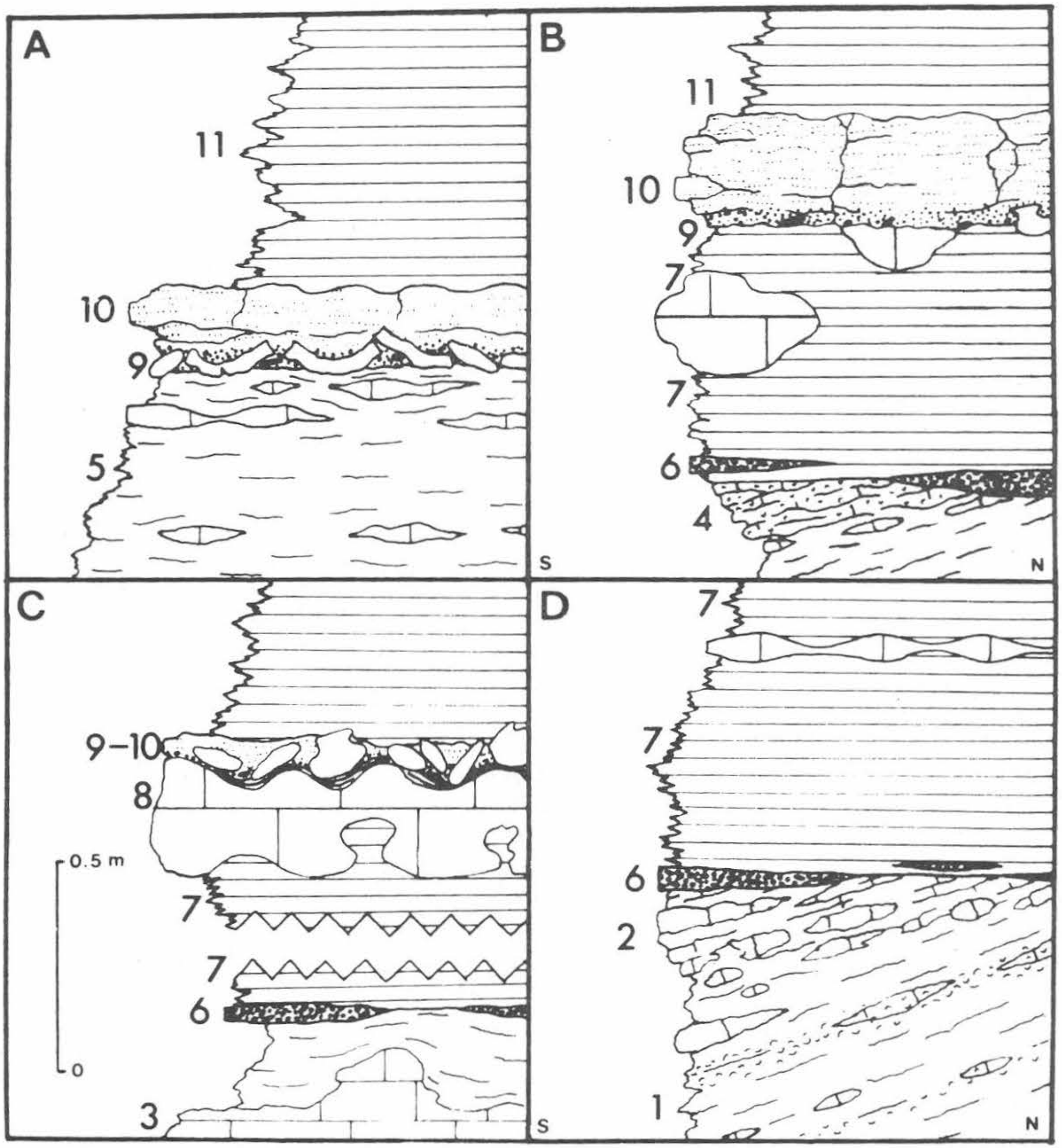

Figure 5. Moscow/Genesee contact and associated beds. Northward erosive overstep of Windom beds is shown schematically in B and D. Localities include: A, Big Tree Creek (Loc. 6); B. Cazenovia Creek (Loc. 9); C. Little Buffalo (Loc. 11); D. Bowen Brook. Units include: 1. Bay View Coral bed; 2. Smoke Creek ed; 3. C-D limestones; 4. Amsdell bed; 5. uppermost Windom Shale (Unit 14); 6. Leicester Pyrite Member; 7. Lower Genesee black shales (Geneseo-Penn Yan members); 8. upper concretionary Penn Yan bed; 9. North Evans Member and eastward equivalent; 10. Genundewa Limestone Member; 11. West River Shale Member.

Such rapid truncations, though suggestive, could result from local undulationsof Windom beds rather than from regional overstep. However, further corroboration of northward truncation is provided by detailed correlation of gamma-ray logs for the Moscow Formation in several wells in Erie and Genesee Counties (Rickard, pers. comm., 1981). Thicker calcareous Windom units, most notably the Smoke Creek bed, were recognized and correlated on these profiles. Wells drilled near Buffalo Creek, Cayuga Creek and Eleven Mile Creek (Fig. 4B) closely match those measured sections and provide outcrop control for gamma-ray patterns. Of particular interest is the Stedman Well south of Darien in Genesee County. It exhibits a combined Moscow Formation thickness substantially greater than that observed at Murder Creek (loc. 15) 5.6 km to the north. Furthermore, in this log profile the peak corresponding to the Smoke Creek bed occurs 8.5 m below the Genesee contact while at Murder Creek this bed is only 1.5 m below the Genesee-Windom contact. This equates to a loss of 1.25 meters per kilometer due to northward truncation. Also, peaks corresponding to the A-E limestones occur below the contact in the well profile; these limestones are missing entirely in the outcrop belt immediately to the north. Hence these subsurface data provide substantial support for the hypothesis of northward truncation of Windom beds.

In summary, Windom zones and beds display not only westward convergence due to sedimentary condensation, but northward-northeastward progressive truncation from the top down. This is best illustrated in Figure 4 where inferred isopach lines for the upper Windom (Units 5-14 interval) trend at nearly right angles to the subsurface erosional strike of several Windom units in western Erie County. Only in eastern Erie and Genesee Counties are these more nearly of coincident strike. The pattern clearly shows that the local condensation of the western Erie County Windom is a process that was largely independent of post-Windom diastrophic events, later erosion having been superimposed on Windom deposits of variable thickness.

STRATIGRAPHY AND CONTACT RELATIONSHIPS OF THE LOWER GENESEE FORMATION

The Genesee Formation in Erie County ranges in thickness from 12 m (40 ft) near the Genesee-Erie County line to 3 m (10 ft) at Lake Erie (Figs. 1, 3). Three component members, Penn Yan, Genundewa, and West River, in ascending order, are traceable across the county. A lower black shale unit, the Geneseo Member, is absent in Erie County (deWitt and Colton, 1978). The Penn Yan and West River Members, composed of dark gray and black bituminous shale, account for the westward thinning, while the Genundewa Member, a pelagic limestone, maintains a nearly constant 15-36 cm (0.5-1.2 ft) thickness range. Two additional Genesee units, Leicester and North Evans Members, are erosional lag concentrations which occur on the Genesee-Windom paraconformity; these have a more restricted distribution in Erie County (see Brett, 1974a; this paper). All Genesee units except the West River will be discussed herein.

Leicester Pyrite

General Character and Stratigraphy. At the base of the Genesee Formation, in most western New York localities, are widely separated lenses of Leicester Pyrite (Sutton, 1951). This distinctive deposit composed of pyritized clasts and fossil steinkerns occurs as a lag concentration both on and immediately above the Windom-Genesee unconformity from central Erie County east to Gage Creek in the Canandaigua Valley. Farther east the Leicester is apparently represented by discontinuous lenses of encrinite in the basal Geneseo Shale. The westernmost locality at which the Leicester can be observed is Cazenovia Creek (loc. 9; Stop 2), where it is well exposed in lenticular pods at the base of the Penn Yan Shale Member (Fig. 5B).

The Leicester Member has previously been interpreted as a condensed lateral equivalent of the Tully Formation (Heckel, 1973; Rickard, 1975). However, lenses of typical Leicester Pyrite overlie the westernmost tongue of the Tully Limestone (Carpenters Falls Bed of Heckel, 1973) at Gage Gully and Leicester-equivalent encrinites occur above the Tully at Seneca Lake (Fulreader, 1957; Huddle, 1981; Klapper, 1981). Conodont studies summarized by Huddle (1981) also indicate a post-Tully age for all Leicester lenses. Moreover, the Leicester is markedly diachronous; westernmost exposures contain conodonts indicative of the lowermost *Polygnathus asymmetricus* subzone, while lenses east of Honeoye Valley belong to the older *Schmidtognathus hermani-Polygnathus cristatus* zone (Huddle, 1981; Klapper, 1981).

The Leicester is composed mainly of granule-to pebble-sized nodular to tubular pyrite with subordinate amounts of pyritized fossil molds, occasional shells, phosphatic nodules, and fish plates. Most of the originally calcareous fossils are preserved as pyritic internal molds; even some pelmatozoan columnals occur as pyritized stereom void-fillings. Most pyrite nodules are irregular but many are distinctly tubular, resembling pyritized burrow fillings which are common in the underlying Hamilton Group (Dick, 1982; Dick and Brett, 1982).

East of the Genesee Valley Leicester pyritic clasts are surrounded by dark gray to black mud matrix. However, western Leicester lenses in Genesee and Erie Counties are characterized by calcite cement. At Cazenovia Creek (loc 9; Stop 2), Little Buffalo Creek (loc. 11), and Cayuga Creek (loc. 12; Stop 5), the Leicester is often a pyrite clast grainstone, nearly lacking intergranular mud.

Sedimentology, Paleontology and Depositional Settings. Evidence of current transport is frequently manifest in Leicester lenses. Tubular clasts may be strongly aligned and foreset beds are present in certain lenses (Fulreader, 1957; this paper). Parallel, linear ridges or furrows also occur on the bases of many Leicester pyrite lenses, although other lenses have smooth, flat bases. Fulreader (1957, p. 37) noted that the long axis alignment of clasts generally parallels the strike of the ridge and groove features. These azimuths trend northeast-southwest in the Canandaigua Valley region, but become more nearly north-south in eastern Erie County. Fulreader interpreted the ridges at the base of the Leicester as casts of ripples on the upper surface of Windom muds. However, bedforms are rarely, if ever, observed in clay-sized sediments (Friedman and Sanders, 1978, p. 86-93). Furthermore, there is evidence that the Windom muds were already lithified or semi-lithified by Geneseo or Penn Yan times and not of a consistency to be rippled; Windom rip-up clasts are common in the Leicester at many localities. Rather, it appears that the ridges are groove casts; indeed, they closely resemble features observed on the soles of turbidites (Sutton, et al., 1970). The grooves thus represent scour features produced in cohesive Windom muds by turbulence and transport of debris by bottom currents (Fig. 6). Parallelism between such sole marks and internal Leicester fabric probably reflects transport and alignment of particles parallel to current direction rather than normal to it as inferred by Fulreader (1957; p. 36).

The Leicester contains a diverse fossil assemblage dominated by brachiopods and mollusks (see Loomis, 1903; Fulreader, 1957, for faunal lists). Loomis (1903) interpreted the fauna as composed of "stunted" or "dwarfed" taxa based on the small size of many forms. Subsequent work by Fulreader (1957) and the present authors shows that a significant size range exists for Leicester fossils and that normal adult individuals are present. Uniformly small size of particular taxa in several lenses is apparently the result of current sorting.

Several Leicester taxa including varcus zone conodonts are clearly derived from the underlying Windom Shale (cf. Huddle, 1981, p. B8-9). As Windom fossil assemblage zones are overstepped regionally from the Canandaigua Valley northwestward into Genesee County, there is corresponding sequential appearance of fossils from these zones in the Leicester. Similarly, northeastward overstep of the Amsdell bed and overlying shales at Cazenovia Creek (loc. 9; Stop 2) is associated with the appearance of calcitic shells of the diagnostic brachiopod *Ambocoelia? praeumbona* in the pyrite lenses.

Other Leicester fossils may be of post-Hamilton age: fish bones, and conodonts, in particular, may be of Late Taghanic age (hermani-cristatus to lowermost asymmetricus conodont subzones; Klapper, 1981). Although many large brachiopods and bivalves are Hamilton forms and appear to have been exhumed from the Windom, it is probable that some

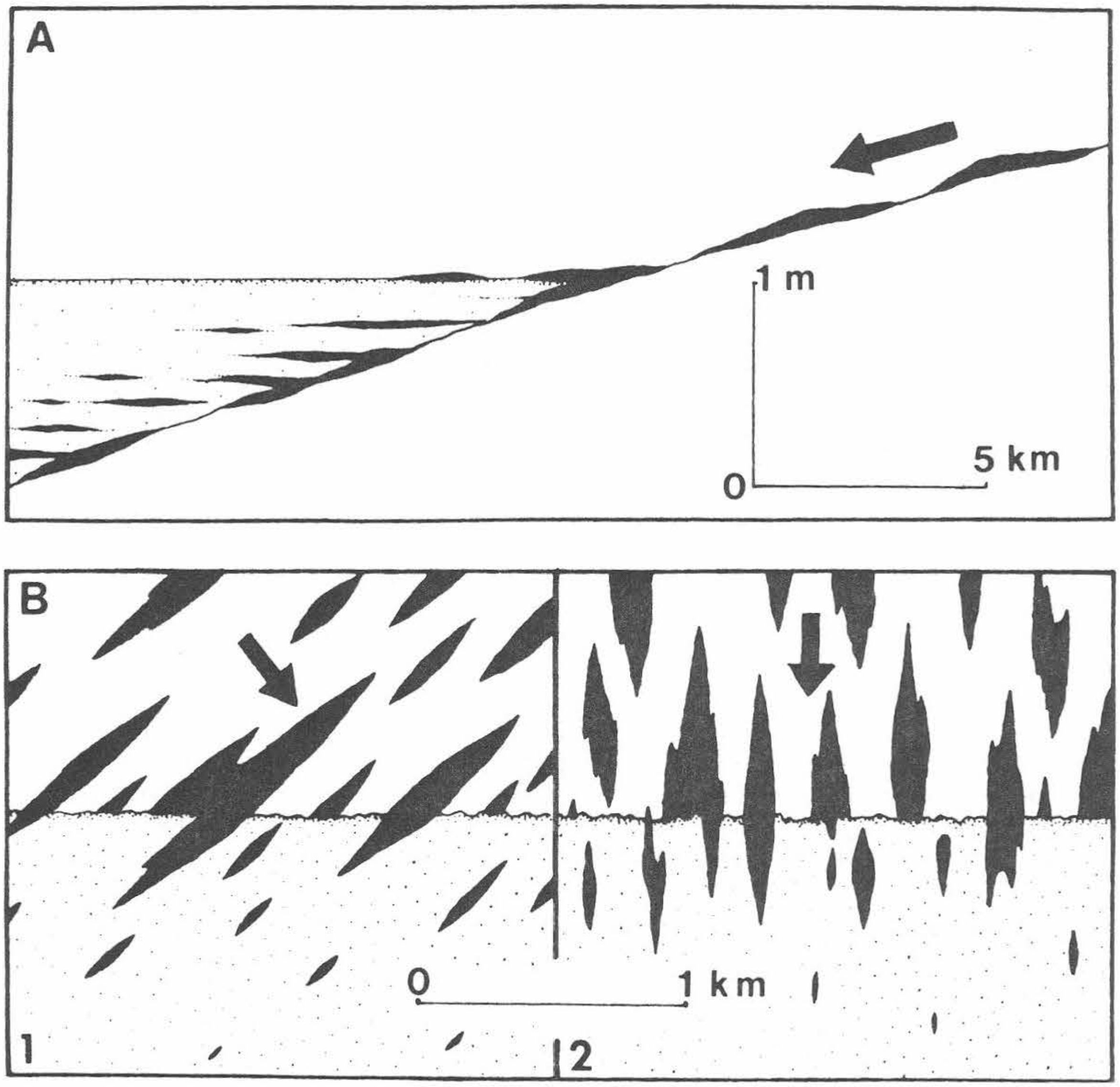

Figure 6. Deposition of Leicester pyrite lenses. A shows hypothetical downslope transport of Leicester reworked debris through current traction. Some lenses migrate out over Genesee mud deposits. Depositional onlap of Genesee muds results in diachronous imbrication of lenses. B shows possible modes of tractive lens migration; in 1, lenses are moved as pyrite granule-sand waves aligned perpendicular to current flow; in 2, lenses are aligned as flutes parallel to current flow.

smaller, easily transported shells may have come from post-Windom habitats ("Tully" shelf or other upslope aerobic settings) at some distance from present Leicester sections.

A key question to be considered is whether the pyritic tubes, nodules and steinkerns were exhumed and reworked as pre-pyritized material or whether the pyritization occurred mainly after lenses were formed and buried (cf. Huddle, 1981, p. B14). It is apparent that much intergranular pyrite formed after Leicester deposition (Park and Weiss, 1972). However, certain pyritic clasts strongly resemble early diagenetic pyrite of the Hamilton Group (Dick, 1982). The interval of time between deposition and submarine re-erosion of Windom muds is clearly of a magnitude such that early diagenetic pyrite would have long been present in this sediment, prior to reworking. Recent studies indicate that much pyrite mold formation may occur within tens to hundreds of years of burial (Berner, 1969, 1970; see Dick, 1982, for review). Moreover, the anaerobic bottom setting suggested by Genesee sediments would favor stability of exhumed pyrite on the sea floor.

Reworking of at least some pre-pyritized material is suggested by the abundance of the aforementioned tubular clasts in the Leicester. These resemble pyritic burrow structures in the Windom, which occasionally protrude slightly above the Windom erosion surface, into the overlying Genesee. Additionally, pyritic fossil steinkerns occur in the Leicester, which display reoriented geopetal and compactional features, clearly indicating an earlier phase of fossil burial and diagenesis.

A more problematical feature of the Leicester is the scarcity of calcareous shells and reworked Windom carbonate debris, even though Windom concretion beds and coral-brachiopod zones are regionally truncated (Baird and Brett, in press). Except for the Leicester-equivalent encrinites in eastern Ontario County (Bellona and Gorham sections) which are largely calcareous, the Leicester rarely contains calcareous fossils. It is probable that much calcareous debris exhumed during post-Windom erosion had already been destroyed by abrasion and bioerosion by the time the Leicester lenses accumulated. Hiatus concretions and large exhumed fossils are similarly scarce along other discontinuities where erosive overstep is indicated such as the base of the Tichenor Member and Tully Formation.

However, the nearly total lack of even calcitic shells and preponderance of pyritic clasts suggests a further mechanism for the destruction of calcareous material. A key to the absence of primary carbonate is the inferred paleoenvironment of the lower Genesee Shales. The Geneseo and, to a lesser extent, the Penn Yan are interpreted as deeper water, anaerobic bottom muds (Thayer, 1974; Bowen, Rhoads and

McAlester, 1974). A highly reducing, low pH environment could have accelerated submarine dissolution of reworked calcareous debris. Thus, the Leicester could, in part, represent a chemical residue of formerly thicker, calcareous-pyritic and phosphatic lag deposits.

Penn Yan and Geneseo Shales

Above the Leicester Pyrite in Erie County is the Penn Yan Shale Member which thins from 3 m (10 ft) at the Genesee-Erie County line to .6 m (2 ft) at Cazenovia Creek (Stop 2). It pinches out southwest of Stop 2 and the overlying Genundewa Limestone Member and subjacent North Evans Member rest directly on the Hamilton from Smoke Creek southwest to Eighteen Mile Creek (Buehler and Tesmer, 1963; Brett, 1974a). At the Lake Erie Shore, southwest of Eighteen Mile Creek, a 25-30 cm (10-20 in) thick black shale reappears below the Genundewa, which may be a black shale wedge within or immediately above the North Evans.

The Penn Yan consists of a dark gray to chocolate-brown, calcareous mudstone with one or more beds of calcareous septarian concretions. Fossils include numerous small Devonochonetes, Styliolina, wood fragments, and both orthoconic and goniatitic cephalopods. The depauperate biota reflects dysaerobic to anaerobic bottom conditions combined with aerobic surface waters capable of supporting planktonic organisms.

The base of the Genesee Formation is diachronous; in western Erie County it is formed by the Genundewa Limestone (Fig. 5A), near Cazenovia Creek by the Penn Yan Shale (Fig. 5A). In Genesee County a still older unit, Geneseo Shale Member (Fig. 5D), appears at the base of the Formation and progressively thickens eastward (Kirchgasser, 1973; Rickard, 1975; deWitt and Colton, 1978).

The Leicester Pyrite must be similarly diachronous as many pyrite lenses occur slightly above the unconformity within the basal Geneseo in the east or the Penn Yan in the west (Fig. 5B). This is corroborated by conodont studies of Huddle (1981) and Klapper (1981), cited above.

Leicester lenses within the black shales reflect lateral current transport during the time of black mud deposition and imply the presence of bottom currents associated with the anaerobic setting. It is suspected that during and following the Taghanic transgression, the deeply submerged relict Hamilton substrate was gently sloped to the east and south; although the surface was progressively covered by onlapping Genesee sediments, first in the deeper basinal areas and later in Erie County, a long period of time persisted when bottom currents scoured the exposed and sloped Windom substrate. The importance of bottom currents is well documented in the deep sea (Heezen and Hollister, 1971), many of these being strong boundary currents which scour large regions of the sea floor. Within the Geneseo black shale there is abundant evidence for bottom currents; Styliolina shells, orthoconic cephalopods, and wood fragments are commonly current aligned. Similar features are likewise known from Mesozoic black and dark gray shale sequences (see Brenner and Seilacher, 1978).

Erosion and transport of Windom fossils and diagenetic structures, accompanied by possible dissolution of shell and nodule carbonate is envisioned to have produced the Leicester lenses (Fig. 6). Transport of some debris across the upslope margin of Genesee sediment accumulation is believed to have produced the secondary, and usually thinner, lenses in the basal Penn Yan and Geneseo; this hypothetical reconstruction is shown in Figure 6.

North Evans Member ("Conodont Bed")

Overlying the Windom Shale from Smoke Creek southwestward to Eighteen Mile Creek is a thin 2-18 cm (1-7 in) lag concentration of hiatus-concretions, bone fragments, pelmatozoan fragments, and conodonts (Figs. 3, 5A) which rests on the Moscow-Genesee unconformity (Hussakoff and Bryant, 1918; Brett, 1974a). Unlike the Leicester, the North Evans is conspicuously carbonate-rich. Pyrite is a variable but minor component, occurring as tubular clasts identical to pyritic burrow tubes in the underlying Windom. The typical crinoid-rich North Evans is present where Penn Yan shale is absent or very thin; southwest of Eighteen Mile Creek where Penn Yan-equivalent black shale reappears beneath the Genundewa, the North Evans changes laterally into a more pyrite dominated "Leicester" type of unit.

The North Evans is a striking deposit which is described in earlier papers (see Grabau, 1898-1899; Hussakoff and Bryant, 1918; Brett, 1974a). It is one of the richest units for conodont yield in the world. Furthermore, the bed contains a mixture of conodonts indicative of three to four distinct subzones (lower asymmetricus, lowermost asymmetricus, upper hermani-cristatus and probably upper varcus subzones) providing evidence for sedimentary condensation (Huddle 1981; Klapper, 1981). Also conspicuous in the North Evans are tabular, glauconite-coated hiatus concretions and limestone fragments derived from the Windom (Fig. 5A). In sections east of Cazenovia Creek, hiatus-concretions are derived from the Penn Yan. Windom limestone fragments commonly contain brachiopods, bryozoans, and trilobites. Mixed throughout the conodont-crinoid calcarenite between the fragments are abundant hybodont and ptyctodont fish teeth, placoderm armor, and unidentifiable bone fragments. The North Evans Member can be sampled at the Penn Dixie (Bay View) Quarry (Stop 1); fish and conodont material can be easily etched from slabs with dilute acid.

From Cazenovia Creek (loc. 9; Stop 2) eastward at least to Eleven Mile Creek (loc. 15), a thin basal portion of the Genundewa Limestone contains some crinoid fragments, large fish bones, conodonts and reworked, glauconite-coated hiatus concretions (Fig. 5B,C). The similarity of this debris with typical North Evans west of Smoke Creek suggests that the two units are coextensive. In turn, this implies that a widespread post-Penn Yan discontinuity exists. This surface may overstep the Moscow/Genesee unconformity in the west.

Any interpretation of the temporal relationships of Leicester Pyrite, Penn Yan Shale, and North Evans Limestone must account for several factors, as follows: First, some reworking of North Evans calcarenites evidently took place contemporaneously with dark mud deposition, as the two facies are locally interfingering (Brett and Baird, 1975). Very probably, the limit of black mud deposition was an upslope boundary (Fig. 6). The region of Genundewa-North Evans-Windom juxtaposition has been referred to as a local structural axis or arch in western Erie County (Brett, 1974a; Brett and Baird, 1975). Shoaling in this area is also indicated by evidence of local high energy (storm?) conditions such as upended rip-up clasts in North Evans calcarenite. Such storm conditions could also have transported North Evans debris layers out over adjacent black muds to produce interfingering. The occurrence of a shale wedge between thin North Evans and Genundewa along Lake Erie Shore also proves that in some places remanié sediments were buried by dark muds.

Second, there are two distinct erosional hiatus surfaces within the Genesee in sections east of Cazenovia Creek (loc. 9): the lower, Windom-Genesee unconformity marked by lenses of Leicester pyrite and an upper, pre-Genundewa discontinuity of lesser magnitude, characterized by a thin North Evans-like calcarenite on eroded Penn Yan Shale. These two discontinuities evidently merge southwest of Cazenovia Creek into the single Windom-North Evans boundary (Fig. 7).

Third, although the Leicester and North Evans both appear to represent submarine erosion-lag deposits, there are distinct differences between them. The North Evans is a sublenticular to tubular unit, rich in calcareous debris and containing only sparse pyrite clasts; in contrast the Leicester is dominated by pyritic clasts, depicted in carbonate and distinctly lenticular. These distinctions evidently reflect subtle differences in the depositional settings of the two units. An explanation for the difference can be seen in the two different Genesee units which overlie the two discontinuities; the Leicester is overlain by dark gray shale while the North Evans is normally overlain by limestone (cf. Huddle, 1981, p. B14). The Penn Yan Shale clearly appears to be an anaerobic type unit as discussed earlier. The Genundewa Limestone similarly lacks evidence

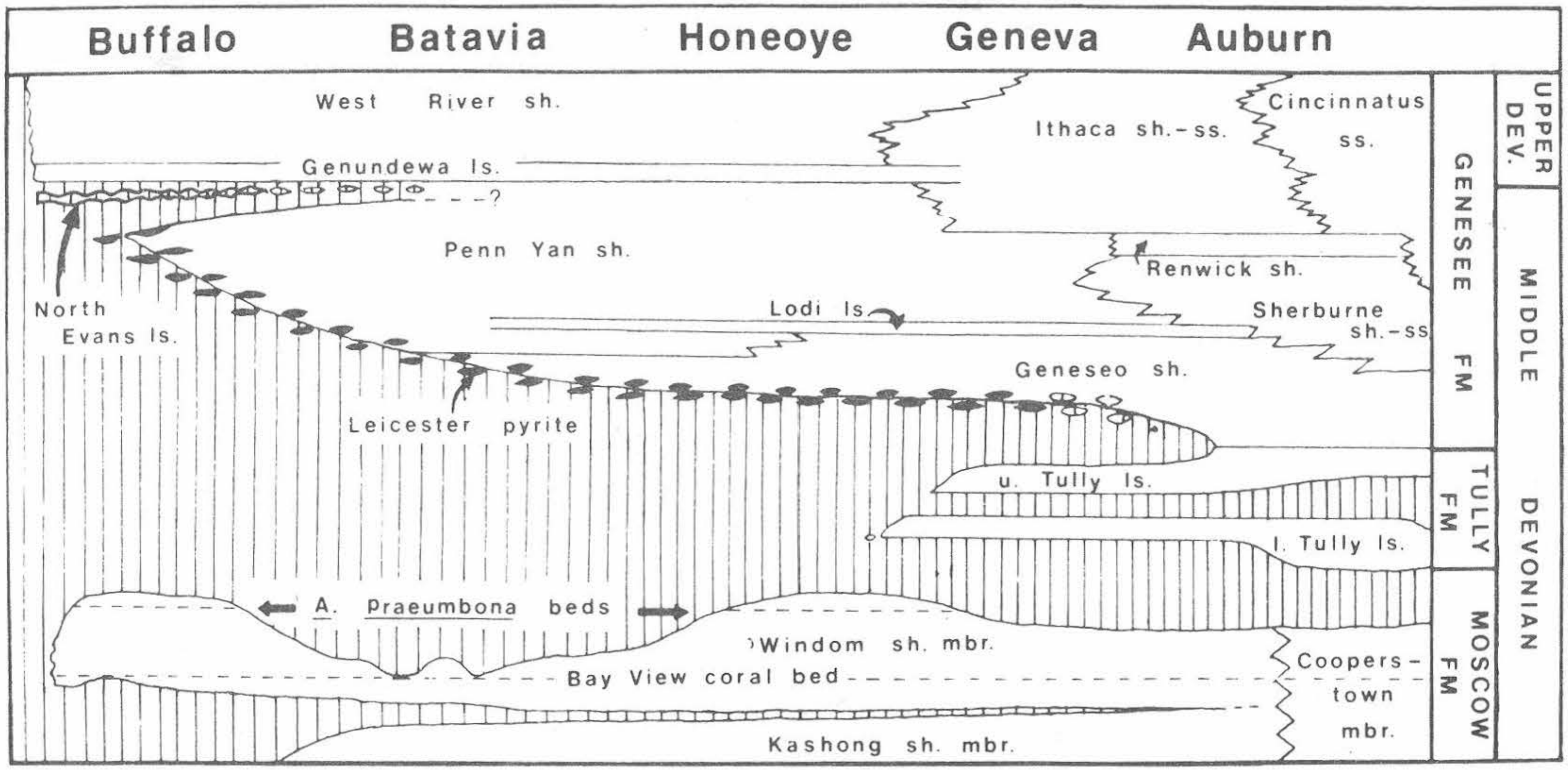

Figure 7. Correlation chart for Moscow Tully, and lower Genesee strata in western New York State. Note proposed revisions. Eastward extent of sub-Genundewa erosion surface is not known at present. Modified from Rickard (1975).

for benthic fauna, but it is calcareous. This suggests somewhat greater oxygen enrichment of the bottom, but still insufficient to support bottom organisms. Such an interpretation is strongly supported by lack of hard surface borers or encrusting organisms on North Evans limestone fragments. It appears that erosion, transport, and burial of the hiatal carbonate material took place within a dysaerobic depositional setting. Both North Evans and Genundewa deposits suggest that the bottom was not so strongly reducing as during deposition of contemporaneous and earlier black muds; a dysaerobic outer shelf and/or slope setting is thus envisioned for the North Evans.

Genundewa Limestone Member

Above the Penn Yan is the thin, but regionally widespread Genundewa Member (Fig. 5a-c); it extends in outcrop from the Lake Erie Shore eastward through the Canandaigua Valley (see Clarke, 1903; Sass, 1952; deWitt and Colton, 1978). In Erie County it is typically a compact 1-50 cm (0.5-1.8 ft) thick resistant bed. In Erie and western Genesee counties, the base of the Genundewa is everywhere abrupt and appears to be erosional.

The Genundewa is composed of a dense concentration of small conoidal shells of the problematic organism Styliolina fissurella with lesser amounts of pelmatozoan columnals, goniatite conchs, wood fragments, and fish fragments. Thin-shelled bivalved organisms Pterochaenia and Buchiola occur in the unit, and, in Ontario County sections, colonies of the crinoid Melocrinites have been found associated with wood fragments by Baird; these last may have attached to floating logs during life (Seilacher, et al., 1968; McIntosh, 1978) or they may have grown on waterlogged wood on the sea floor (Kauffman, 1978).

The Genundewa fits closely in general characteristics with certain Devonian pelagic limestones in Europe (see Tucker, 1973, 1974). These latter, described from tectonic rises in Variscan eugeosynclinal deposits of Germany and France (Tucker, 1974), are similarly characterized by abundant Styliolina, goniatites, wood fragments, and posidoniid bivalves. The physical setting for the Genundewa is markedly different, however, from the eugeosynclinal setting in Europe and it is questionable that the Genundewa is abyssal as is claimed for the Variscan carbonates. Nonetheless, the Genundewa appears to represent slow pelagic sedimentation in a deeper-water intracratonic shelf-basin environment. It could represent a prolonged effect of decreased sediment influx; hence, the rain of planktonic Styliolina and other shelled forms could produce a relatively pure, condensed carbonate blanket instead of the usual black shale.

CHRONOLOGICAL SUMMARY: DEVELOPMENT OF WINDOM/GENESEE DISCONFORMITIES

Figure 7 summarizes the inferred chronological relationships among the several stratigraphic units discussed herein. The following sequence of events is envisaged for the Windom-Genesee unconformity in Erie County, New York. Certain stages are presently hypothetical and the entire sequence is under continuing study.

1) Deposition of Windom Shale sediments includes minor fluctuations of litho- and biofacies (e.g. Ambocoelia-rich dark gray shale to coral dominated, soft gray mudstones). These facies changes are cyclic to some extent and are thought to reflect minor oscillations of depositional environments due to variations in relative sea level. Deeper basinal dark shales record minor transgressions; coral beds reflect minor regressions, coupled with low sediment rates. Facies belts migrated north or south during transgressions and regressions paralleling the northern shoreline.

Largely independent of this cyclic facies variation is a general westward thinning of the Windom, presumably reflecting increasing distance from eastern clastic source areas. Local variation in thickness of particular shale packages within the Windom suggests a migrating axis of differential subsidence perhaps recording diastrophic instability during the late Middle Devonian.

2) Following deposition of the highest Windom unit (Unit 14 and probably higher beds which have subsequently been eroded) a major regression occurred. This was coupled with diastrophic upwarp of the western New York shelf, resulting in gentle, regional southward tilting of Hamilton beds. This event may coincide temporally with upwarp of the Chenango Valley High which, according to Heckel (1975),provided a barrier to clastic sedimentation during Tully deposition.

3) Erosive beveling of Hamilton sediment caused progressive loss of higher units toward the margins of the Appalachian Basin (i.e. toward the northeast in western New York). Overstep of beds probably resulted from submarine erosion and downslope transport of muds. In the process Windom mud was winnowed resulting in a blanket of remanié sediments (fossils, burrow fills, etc.).

The Windom-Genesee unconformity in western New York may actually reflect several periods of submarine erosion. Certainly, a large part of the erosive truncation was accomplished prior to deposition of the late Middle Devonian Tully Limestone, as a Windom truncation surface can be traced beneath the lowest bed of the lower Tully Member (Cooper, 1930; Heckel, 1973). However, Heckel (1973) also recognized a mid-Tully erosion event which destroyed parts of the previously deposited lower Tully (see Fig. 6). Quite probably it further eroded the Windom in areas where the Tully was removed. Finally, a minor post-Tully erosion surface is evidenced by local truncation of upper Tully beds (e.g. Bellona coral bed) west of Cayuga Lake.

Thus, the Windom/Genesee unconformity in western New York (from Canandaigua Lake to Cazenovia Creek) may actually be a composite hiatus surface resulting from the merging of pre-, syn-, and post-Tully disconformities. West of Cazenovia yet another erosion surface merges with these (see below).

4) Following most truncation of the Windom-Tully beds (uppermost varcus subzone time) minor diastrophic upwarp produced a local shoal area (Buffalo Arch) in southwestern Erie County; erosion of upper Windom beds took place here, episodically, during severe storms.

5) During latest Tully (Filmore Glen?) to latest Penn Yan deposition (hermani-cristatus to lowermost asymmetricus subzone) conodonts and fishbones accumulated along with older, erosion-derived relict debris on the truncated Windom surface. This period of prolonged non-deposition and minor erosion coincided with the Taghanic onlap which began with widespread deepening of waters over western New York. These remanié sediments (Leicester lenses) were variably reworked by deep bottom currents, forming starved ripple and/or flute-like lenses. In anaerobic areas, low pH conditions may have resulted in dissolution of carbonates yielding a pyrite-phosphorite enriched residue. In somewhat shallower (upslope), dysaerobic regions (e.g. Buffalo Arch and areas north of the present outcrop belt) calcareous North Evans-type remanié sediments persisted.

6) Input of fine clastics, beginning in latest Givetian time, resulted in deposition of black Geneseo muds in deeper portions of the Appalachian Basin. These laminated muds grade upward into dark gray concretionary Penn Yan sediments; Genesee detrital sediments did not completely onlap the study area until late Penn Yan (lower P. asymmetricus subzone) time. In exposed areas remanié sediments (Penn Yan-age Leicester) continued to be reworked intermittently even after initial deposition of the dark muds nearby. At times fine debris layers were spread out over nearby mud deposits. During this time interval the Buffalo Arch remained an area of extremely slow sedimentation and eposodic erosion. Here younger conodonts (of the lower P. asymmetricus subzone) were ultimately added to the palimpsest deposits. Sediments underwent synsedimentary lithification locally but were then reworked and broken into lithoclasts. Interfingering of black muds with North Evans near shoal margins (e.g. Eighteen Mile Creek) reflect lateral storm transport of the encrinite-lag debris off the Buffalo Arch. From Eighteen-mile Creek southwest to the Lake Erie Shore, intermediate Leicester-NorthEvans-type lenses and encrinites occur beneath a thin black shale which is placed in the Ancyrodella rotundiloba or lower asymmetricus zone (equivalent to upper Penn Yan Shale;

see Huddle, 1981, p. B15). The relationship between this shale and the Penn Yan Shale and Leicester Pyrite east of the Buffalo Arch is uncertain, although the thin shale and true Penn Yan may be continuous south of the outcrop belt.

7) A regressive episode occurring in earliest Frasnian (lower *asymmetricus*) time resulted in a Penn Yan-Genundewa disconformity in western New York. West of Cazenovia Creek this erosion surface merges with the older pre-, syn-, and post-Tully disconformity forming a composite unconformity of considerable magnitude between the Windom Shale and North Evans limestone. During the pre-Genundewa event erosion removed upper Penn Yan muds and possibly western equivalents of the Leicester pyrite. Erosion reworked the blankets of North Evans relict sediments and ripped up calcareous Windom clasts in the area of the Buffalo Arch. The older condensed sediments were thoroughly homogenized forming a "composite lag deposit" (Huddle, 1981, p. B8). In areas farther east the same erosional event disinterred and reworked syngenetic concretions from the upper Penn Yan Shale. A thin layer of encrinite, fish fragments, and conodonts (North Evans eastern correlative unit) was also deposited over the eroded upper surface of the Penn Yan. This material may have been derived from adjacent exposed shoals, including the Buffalo Arch.

8) Rapid transgression with accompanying clastic sediment starvation resulted in deposition of a condensed *Styliolina*-rich, carbonate ooze (Genundewa Limestone) which accumulated as a continuous blanket over the entire erosion surface.

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REFERENCES CITED

Baird, G.C., 1978, Pebbly phosphorites in shale: A key to recognition of a widespread submarine discontinuity in the Middle Devonian of New York. Jour. Sed. Petrology, v. 28, p. 545-555.

__________, 1979, Sedimentary relationships of Portland Point and associated Middle Devonian rocks in central and western New York. New York State Mus. Bull., v. 433, p. 1-23.

________ and Brett, C.E., 1981, Submarine discontinuities and sedimentary condensation in the upper Hamilton Group (Middle Devonian): examination of marine shelf and paleoslope deposits in the Cayuga Valley. In New York State Geol. Assoc. Guidebook, 52nd Ann. Mtg., p. 115-145, Binghamton.

______________________, 1983, (in press), Regional variation and paleontology of two coral beds in the Middle Devonian Hamilton Group of western New York. Jour. Paleontol.

Beerbower, J.R., Buehler, E.J., Bray, R.G., and Jordan, J.W., 1969, A "Paleomicroecologic" study of Mid-Devonian marine assemblages (Hamilton Group) in western New York. North American Paleontol. Conv., Field Trip, n. 5, p. 48-78.

Berner, R.A., 1969, Migration of iron and sulfur within anaerobic sediments during early diagenesis. Am. Jour. Sci., v. 268, p. 19-42.

___________, 1970, Sedimentary pyrite formation. Am. Jour. Sci., v. 269, p. 1-23.

Bowen, Z. P., Rhoads, D.C., and McAlester, A.L., 1974, Marine benthic communities of the Upper Devonian of New York. Lethaia, v. 7, p. 93-120.

Brenner, K., and Seilacher, A., 1978, New aspects about the origin of the Toarcian Posidonia Shales. Neues Jb. Geol. Paläont. Abh., v. 157, p. 11-17.

Brett, C.E., 1974a, Contacts of the Windom Member (Moscow Formation) in western Erie County, New York. In New York State Geol. Assoc. Guidebook, 46th Ann. Mtg., p. C1-C22, Fredonia.

__________, 1974b, Biostratigraphy and paleoecology of the Windom Shale Member (Moscow Formation) in Erie County, New York. In New York State Geol. Assoc. Guidebook, 52nd Ann. Mtg., p. G1-G-15, Fredonia.

__________ and Baird, G.C., 1975, Description and explanation or erosional features associated with the Middle/Upper Devonian paraconformity in Erie County, New York. Geol. Soc. Am. Abstracts with Programs, v. 7, n. 1, p. 30.

Buehler, E.J. and Tesmer, I.H., 1963, Geology of Erie County. Buffalo Soc. Nat. Sci. Bull., v. 21, n. 3, p. 1-118.

Clarke, J.M., 1903, Classification of New York series of geologic formations. New York State Mus. Handbook 19, 28 p.

Cooper, G.A., 1929. Stratigraphy of the Hamilton Group of New York. Unpubl. Ph.D. Dissert., Yale Univ., 476 p.

__________, 1930, Stratigraphy of the Hamilton Group of New York. Am. Jour. Sci., 5th Ser., v. 19, p. 116-134, 214-236.

__________, 1957, Paleoecology of the Middle Devonian of eastern and central United States. In Ladd, H. S. (ed.) Treatise on Marine Ecology and Paleoecology, 2, Paleoecology, Geol. Soc. America Mem. 67, p. 249-278.

__________ and Williams, J.S., 1935, Tully Formation of New York. Geol. Soc. Am., v. 46, p. 781-868.

Dennison, J.M. and Hasson, K.O., 1976, Stratigraphic cross-section of Hamilton Group (Devonian) and adjacent strata along the south region of Pennsylvania. Am. Assoc. Petroleum Geologists Bull., v. 60, p. 278-287.

__________ and Head, J.W., 1975, Sea level variations interpreted from the Appalachian Basin Silurian and Devonian. Am. Jour. Sci., v. 275, p. 1089-1120.

deWitt, W. and Colton, G.W., 1978, Physical stratigraphy of the Genesee Formation (Devonian) in western and central New York. U.S. Geol. Surv. Prof. Pap. 1032-A, iii+A22 pp.

Dick, V.B., 1982, Taphonomy and depositional environments of Middle Devonian (Hamilton Group) pyritic fossil beds in western New York. Unpubl. M.S. thesis, University of Rochester, 118 p.

__________ and Brett, C.E., 1982, Taphonomy and depositional environments of Middle Devonian (Hamilton Group) pyritic fossil horizons in western New York. Geol. Soc. Am. Abstracts with Programs, v. 14, n. 1, 2, p. 15.

Fisher, D.W., 1951, Marcasite fauna in the Ludlowville Formation of western New York. Jour. Paleontol., v. 15, p. 61-72.

Friedman, G.M. and Sanders, J.E., 1978, Principles of sedimentology. John Wiley & Sons, New York, 792 p.

Fulreader, R., 1957, Geologic studies of the Leicester Pyrite. Unpubl. M.S. Thesis, University of Rochester, 112 p.

Grabau, A.W., 1898-1899, Geology and paleontology of Eighteen Mile Creek and the lake shore sections of Erie County, New York. Buffalo Soc. Nat. Sci. Bull., v. 6, p. 1-403.

__________, 1899, The faunas of the Hamilton Group of Eighteen Mile Creek and vicinity in western New York. N.Y. State Mus. Ann. Rept. 50, v. 2, p. 227-339.

__________, 1917, Stratigraphic relationships of the Tully limestone and Genesee in eastern North America. Geol. Soc. Am. Bull., v. 28, p. 945-958.

Grasso, T.X., 1970, Paleontology, stratigraphy, and paleoecology of the Ludlowville and Moscow Formations (Upper Hamilton Group) in central New York. In Guidebook, New York State Geol. Assoc., 42nd Ann. Mtg., p. D1-D22, Cortland.

__________, 1973, A comparison of environments: The Middle Devonian Hamilton Group in the Genesee Valley: faunal analysis, Jaycox Run. In Guidebook, New York State Geol. Assoc., 45th Ann. Mtg., p. B1-B24, Brockport.

Hall, J., 1843, Geology of New York. Part 4, comprising the Survey of the Fourth geological district, Albany, N.Y., 525 p.

Heckel, P.H., 1973, Nature, origin, and significance of the Tully Limestone. Geol. Soc. Am. Spec. Pap. 138, 244 p.

Heezen, B.C., and Hollister, C.D., 1971, The Face of the Deep. Oxford University Press, New York, 659 p.

Huddle, J.W., 1981, Conodonts from the Genesee Formation in western New York. U.S. Geol. Surv. Prof. Pap. 1032-B: 66 p.

Hussakoff, L. and Bryant, W.L., 1918, Catalog of the fossil fishes in the museum of the Buffalo Society of Natural Sciences. Buffalo Soc. Nat. Sci. Bull.,v. 12.

Johnson, J.G., 1970, Taghanic onlap and the end of North American Devonian provinciality. Geol. Soc. Am. Bull., v. 81, p. 2077-2106.

Kauffman, E.G., 1978, Benthic environments and paleoecology of the Posidonienschiefer. Neues Jb. Geol., Paläont. Abh., v. 157, p. 18-36.

Kirchgasser, W.T., 1973, Lower Upper Devonian stratigraphy from the Batavia-Warsaw meridian to the Genesee Valley: goniatite sequence and correlation. In New York State Geol. Assoc. Guidebook, 45th Ann. Mtg., p. C1-C21, Brockport.

Kissling, D.L. and Moshier, S.O., 1981, The subsurface Onondaga Limestone: Stratigraphy, facies and paleogeography (abstract). In New York State Geol. Soc. Assoc. Guidebook, 53rd Ann. Mtg., p. 277-280, Binghamton.

Klapper, G., 1981, Review of New York Devonian conodont biostratigraphy. In Oliver, W.A. and Klapper, G., eds., Devonian Biostratigraphy of New York, Part 1, Text, p. 57-66, International Union of Geol. Sci., Subcommission on Devonian Stratigraphy, Washington, D.C.

Koch, W.F. III, 1981, Brachiopod community paleoecology, paleobiogeography and depositional topography of the Devonian Onondaga Limestone and correlative strata in eastern North America. Lethaia, v. 14, p. 83-103.

Loomis, F.B., 1903, The dwarf fauna of the pyrite layer at the horizon of the Tully Limestone in western New York. N.Y. State Mus. Bull., v. 69, p. 890-920

McCave, I.N., 1967, A stratigraphical and sedimentological analysis of a portion of the Hamilton Group (Middle Devonian) of New York State. Unpubl. Ph.D. diss., Brown Univ., Providence, R.I., 381 p.

___________, 1973, The sedimentology of a transgression: Portland Point and Cooksburg Members (Middle Devonian); New York State Jour. Sed. Petrology, v. 43, p. 484-504.

McIntosh, G.C., 1978, Pseudoplanktonic crinoid colonies attached to Upper Devonian logs. Geol. Soc. Am., Abstracts with Programs, v. 10, n. 7, p. 453.

Oliver, W.A., Jr., 1977, Late Silurian and Devonian biogeography of rugose corals. Palaeogeography, Palaeoclimatology, Palaeoecology, v. 22, p. 85-135.

___________ and Klapper, G.W. (eds.), 1981, Devonian Biostratigraphy of New York, Part 1, Text, 106 p. International Union of Geol. Sci., Subcommission on an Devonian Stratigraphy, Washington, D.C.

Park, W.C. and Weiss, A.J., 1972, Diagenetic sulfides in fossiliferous marcasite (upper Hamilton Group) from Devonian of New York. Geol. Soc. Am. Abstracts with Programs, v. 4, no. 1, p. 38.

Rickard, L.V., 1975, Correlation of the Silurian and Devonian rocks of New York State. New York State Mus. and Sci. Serv., Map and Chart Ser., 24, 16 p., 4 charts.

Sass, D.B., 1951, Paleoecology and stratigraphy of the Genundewa Limestone of western New York. Unpubl. M.S. thesis, University of Rochester, 113 p.

Seilacher, A., Drozdewski, G., and Haude, R., 1968, Form and function of the stem in a pseudoplanktonic crinoid (Seirocrinus), Palaeontology, v. 11, p. 275-282.

Stover, L.E., 1956, Stratigraphy and paleontology of the Moscow Formation (Hamilton) in central and western New York. (Pt. 1). Unpubl. Ph.D. diss., University of Rochester, 160 p.

Sutton, R.G., 1951, Stratigraphy and structure of the Batavia Quadrangle [New York]. Rochester Acad. Sci. Proc., v. 9, nos. 5-6, p. 348-408.

___________, Bowen, Z.P., and McAlester, A.L., 1970, Marine shelf environments of the upper Devonian Sonyea Group of New York, Geol. Soc. Am. Bull., v. 81, p. 2975-2992.

Thayer, C.W., 1974, Marine paleoecology in the Upper Devonian of New York. Lethaia, v. 7, p. 121-155.

Tucker, M.E., 1973a, Sedimentology and diagenesis of Devonian pelagic limestones (Cephalopoden Kalk) and associated sediments of the Rhenohercynian Geosyncline, West Germany. Neues Jahrb. Geol. Paläont. Abh., v. 142, p. 320-350.

___________, 1974, Sedimentology of Palaeozoic pelagic limestones: the Devonian Griotte (Southern France) and Cephalopoden Kalk (Germany). Spec. Publs. Int. Assoc. Sediment., v. 1, p. 71-92.

ROAD LOG FOR DEVONIAN MOSCOW/GENESEE UNCONFORMITY
IN ERIE COUNTY, NEW YORK

TRIP

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
00.0	00.0	Begin trip at Buffalo Marriott Inn. Turn right (south) onto Millersport Highway and proceed to entrance for Youngmann Highway (I-290).
00.4	00.4	Take entrance ramp for I-290 eastbound, and proceed eastward on Youngmann Highway.
2.9	2.5	Roadcuts in cherty limestone of the Clarence Member, Onondaga Limestone (Middle Devonian). This is the site of the Vogelsanger Quarry; prior to construction of the highway, this quarry exposed a well developed reef in the Edgecliff Member (now covered).
3.4	0.5	Junction Route I-90, New York State Thruway; keep right and merge onto westbound (actually southbound) lane, toward Erie, Pennsylvania.
4.9	1.5	Overpass of Route 33, Kensington Expressway (Interchange 51).
6.5	1.6	Overpass of Walden Ave. (Interchange 52).
6.9	0.4	Overpass of New York Central Railroad tracks
7.6	0.6-0.7	Overpass of I-90 over combined Erie-Lackawanna and Lehigh Valley Railroad tracks
9.3	1.7	Interchange 53; I-190; continue on I-90 west.
10.1	0.8	Cross Buffalo River; 0.3 mile west of junction of Cayuga and Buffalo Creeks.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
11.0	0.9	Interchange 54 for Routes 16 and 400.
11.9	0.9	Cross Cazenovia Creek.
12.8	0.9	Overpass of Route 16, Seneca Street, Interchange 55.
13.1	0.3	Cross North Fork of Smoke Creek.
13.3	0.2	Overpass over Pennsylvania Railroad tracks.
13.6	0.3	Toll Booth, receive ticket; proceed to first exit after booth.
14.5	0.9	Take exit 56 for Mile Strip Road (Blasdell); bear right around ramp.
14.85	0.35	Toll Booth, pay $.15; then proceed straight ahead to intersection of Mile Strip Road.
14.9	0.05	Junction of Mile Strip Road. Go straight across onto Route 299.
15.1	0.2	Junction of South Park Road (Route US 62). Turn left (south).
16.2	1.1	Junction of Big Tree Road. Turn right (west).
16.6	0.4	Junction of first road on left, after West Avenue, which cuts across intersection of Big Tree and Bay View Roads. Turn left onto the cutoff road and park vehicles. Walk north across Big Tree Road and proceed into entrance to Penn Dixie Quarry; continue on foot for about 0.3 mile and turn into shale pit on the east side of quarry road.

STOP 1 (1 1/2 hours): BAY VIEW (PENN DIXIE) QUARRY. This abandoned shale pit, previously described in detail (Brett, 1974b), provides an excellent reference section for the Windom Shale and its upper contact with the Genesee Formation. Here the Windom Member is approximately 13 m (42 ft) thick; 14 units described in the text can be recognized at this location. The disconformable basal contact with the Tichenor Limestone is excellently exposed in a low domal outcrop in the northeast corner of the shale pit.

The basal Ambocoelia umbonata beds, Bay View Coral bed (type section) and Smoke Creek bed are accessible in this area. Barren shales of unit 4 occupy much of the flat floor in the center of the shale pit. Near the top of this interval is a narrow zone containing abundant fossils including highly compressed brachiopods (Pseudoatrypa, Mediospirifer, Mucrospirifer consobrinus) and rare pyritized sponges and blastoids; this unit is termed the Big Tree bed (unit 5). The A-E limestones (units 6-11) crop out as uniform, white-weathering bands which trend roughly east-west across the quarry. Soft shales above the highest limestone band (unit 12) yield abundant pyritized burrow fillings and fossil steinkerns including nuculid clams, gastropods and cephalopods. This interval of approximately 2 m (6 ft) thickness, termed the Penn-Dixie pyritic beds, is characterized by small specimens of the brachiopods Tropidoleptus carinatus and Ambocoelia cf. A. nana. The calcareous Amsdell bed (unit 13; = "Praeumbona bed") caps a low bench near the southern end of the quarry. Beyond this the Penn-Dixie shale pit terminates in a low (2-3 m high) bank which exposes uppermost Windom beds (unit 13) and the contact with the overlying Genesee Formation. The upper beds of the Windom comprise soft,gray shales with concretionary beds near the top; the top of the Windom is marked by a concretionary layer of 20-30 cm (8-12 in) thick containing Ambocoelia? praeumbona, followed by a thin band of argillaceous limestone which has been partially torn up and incorporated in the overlying North Evans Member.

The North Evans Limestone of the basal Genesee Formation comprises 3-10 cm (1.5-4 in) of buff-weathering, dark-gray crinoidal, calcarenitic limestone, which contains very abundant conodonts of mixed zones (lower asymmetricus subzones). Angular intraclasts, up to 10 cm (4 in) across, derived from the upper Windom occur abundantly in the North Evans. Black shales (Geneseo and Penn Yan) are absent from the lower part of the Genesee Formation and the Genundewa Member, a thin Styliolina-rich limestone rests directly on the North Evans.

At Penn Dixie Quarry as at most localities in western Erie County, the Windom is thin, but stratigraphically quite complete. However, ironically, in these sections unlike those farther east, the upper contact exhibits evidence for erosional scouring. Presumably the scouring of the upper Windom beds and presence of pebble imbrication within the North Evans remanié sediments reflect a late episode of erosion, associated with the pre-Genundewa erosion surface. This event post dates the development of a south dipping truncation surface, prior to Tully deposition, which had left upper Windom beds relatively intact in southwestern Erie County sections.

16.6		Leave Penn Dixie Quarry and return to transportation. Proceed across cutoff road to the intersection of Bay View Road.
16.65	0.05	Intersection of Bay View Road. Turn left (southeast).
17.45	0.8	Junction Route U.S. 62. Proceed straight across on Bay View Road.
17.55	0.1	Junction Route U.S. 20, Southwestern Blvd. Turn left (northeast).
17.85	0.3	Overpass over New York State Thruway (I-90) and Rush Creek.
18.25	0.4	Junction Route 20A, at 6-way intersection. Proceed straight on Route 20.
19.55	1.3	Junction Abbott Road. Proceed on US 20.
19.95	0.4	Entrance to Rich Stadium.
20.15	0.2	Cross south branch of Smoke Creek.
20.25	0.1	Junction California Road. Continue on US 20.
20.7	0.5	Overpass of Route 219 (Southern Tier Expressway).
22.15	1.45	Cross north branch of Smoke Creek.
22.3	0.15	Junction Route 277 (Union Road).
23.15	0.85	Junction Michael Road.
24.0	0.85	Junction Reserve Road.
24.1	0.10	Junction Angle Road

24.9	0.8	Junction Leydecker Road
25.2	0.3	Curve in Route 20 to Junction with Route 78 (Transit Road); prepare to turn right.
25.45	0.25	Junction Kingsley Road. Turn right (east).
25.95	0.5	Junction Northrup Road. Turn right (south).
26.55	0.6	Park near location where power lines cross Northrup Road. At utility poles on east side of road turn right and walk down dirt path to the base of cliff on the flood plain of Cazenovia Creek. At bottom of path turn left and walk north for about 600 ft, following the base of cliff (swampy ground), to exposures along the west bank of Cazenovia Creek.

STOP 2 (1 1/2 hours): CAZENOVIA CREEK SECTION. This east facing cliff provides an excellent, long section of the Windom/Genesee contact. The Genundewa Limestone is nearly at water level at the southern (upstream) end of this section; however, downstream about 1/10 mile some 2 m (7 ft) of Penn Yan and upper Windom shales are exposed beneath the Genundewa. Lowest beds, exposed in the creek floor, are the Penn Dixie pyritic beds of the upper Windom. Diagnostic small specimens of Tropidoleptus carinatus can be obtained in abundance at this location. Overlying beds contain a zone of distinctive ellipsoidal concretions, typically with pyritic cores. The Amsdell bed (unit 12) forms a prominent, light-gray weathering calcareous band about 1 m thick near the top of the Windom. Near the southern end of the section this bed forms a small waterfall in Cazenovia Creek. Note the absence of upper shales (unit 13) in contrast to Penn Dixie Quarry (Stop 1).

The contact between the Windom and the overlying Genesee is sharp and planar with little evidence for erosive scour. Four or five lenses of the Leicester Pyrite, ranging from 1-15 cm thick and up to 2 m across, occur along the Windom/Penn Yan contact at widely spaced intervals. The pyrite contains abundant, reworked?, pyritic burrows, diminutive brachiopods, mollusks, fish bones and wood. One lens along this section exhibits interfingering with the black Penn Yan shale. Lower surfaces of the pyrite lenses exhibit parallel ridge and furrow marks suggestive of current scour of the underlying Windom muds. At this locality about 0.5 m (1.6 ft) of barren, black, laminated Penn Yan Shale overlies the Windom; the upper portion of this shale contains large septarian concretions that locally protrude up into the overlying Genundewa. The Genundewa forms a prominent overhanging ledge about 40 cm (15 in) thick. The lower surface of this ledge is undulatory and is marked by a veneer of encrinite, conodonts, carbonized wood, and abundant fish bones and rare hiatus concretions. This unit probably is correlative in part with the typical North Evans a few miles west of this locality. The upper contact of the Genundewa with the silty, dark-gray West River Shale is gradational. Lower West River beds here yield abundant Pterochaenia, wood, chonetids, pyritized goniatites and rare crinoid columns. Higher units exposed in the upper cliff face include the black Middlesex Shale and gray, concretionary Cashaqua Shale, members of the Sonyea Formation.

26.55		Return to vehicles and reverse direction, proceeding north along Northrup Road.
27.45	0.9	Northrup Road bridge over Cazenovia Creek. Note falls in creek over the Tichenor Limestone of the basal Moscow Formation, just upstream (east) of the bridge. High cliffs visible in the distance, upstream from the falls, expose about 12 m (40 ft) of Windom shale, capped by the Genesee Formation. The Smoke Creek bed is near the base of the cliff. At the upper contact, the Amsdell bed has been largely eroded away.
28.35	0.9	Junction Route 16 (Seneca Street). Turn right (southeast).
28.95	0.6	Junction Rice Road. Turn left (east).
29.45	0.5	Overpass for Route 400 (Aurora Expressway). Note exposures of black Rhinestreet Shale (upper Devonian).
30.95	1.5	Junction Bowen Road. Turn left (north).
32.05	1.1	Junction Bullis Road. Turn right (east).
33.65	1.6	Junction Girdle Road. Continue on Bullis Road.

33.85	0.2	Intersection with old Bullis Road (loops to south over old bridge). Turn right onto old road.
34.10	0.25	Park near old bridge over Buffalo Creek. Walk out onto bridge.

STOP 3A (1/4 hour): BUFFALO CREEK AT OLD BULLIS ROAD BRIDGE. From bridge, view exposures along Buffalo Creek. Downstream (north) and just south of new bridge a series of ledges crop out in the creek floor, representing a condensed upper Ludlowville/lower Moscow section; the lowest ledge is a basal bed of the Jaycox Member, followed by Tichenor Limestone, and calcareous ledges of condensed Deep Run, and basal remnant of Menteth Members followed by highly calcareous Kashong Shale Member. The Windom/Kashong contact, marked by scattered phosphatic nodules is exposed in the floor of the creek directly beneath the old bridge. Looking upstream (south), note high bank exposures of gray, lower Windom Shale. A light-weathering calcareous band about 4 m (13 ft) about the creek floor represents the Smoke Creek bed; concretionary shales beneath this level for about 1 m (3 ft) comprise a local manifestation of the Bay View Coral bed. Note the thickening of the lower *Ambocoelia*-rich shales, here about 3 m thick, compared to about 15 cm (6 in) at Penn Dixie Quarry (Stop 1). At the next stop we will see higher beds of the Windom Member, the lowest of which are slightly higher than the top of this cliff section.

34.10		Return to vehicles and retrace route to new section of Bullis Road over Buffalo Creek
34.35	0.25	Turn right and proceed east on Bullis Road.
34.7	0.35	Intersection Stolle Road. Turn right (south).
35.1	0.4	Turn left on small road leading down into gravel pit; drive to its end and park. Continue on foot for about 1200 ft, downhill and through the woods to bank of Buffalo Creek. Walk south along northeast side of creek to high bank of Windom Shale.

STOP 3B (1 hour): BUFFALO CREEK, UPPER WINDOM SHALE SECTION. This bank exposes about 5 m of upper Windom overlain by Genesee Formation. The lowest shales exposed in the creek bed contain abundant *Zoophycos* spreiten and thin layers rich in the chonetids, *Pseudoatrypa*, *Mediospirifer*, and other brachiopods. Pyritized fossils including nautiloids and one cluster of blastoid *Hyperoblastus* have been discovered at this level. These shales appear to represent the Big Tree fossil bed (unit 5). They are overlain by two or three horizons of large, flattened ellipsoidal concretions probably equivalent to the A and B limestone bands farther west. Large irregular masses of pyrite occur associated with these concretions. Above the concretions is an interval of friable, dark gray shales, with abundant pyritic burrow tubes and scattered pyritized nautiloids, nuculid clams, wood and other fossils, herein designated the Buffalo Creek pyritic beds (unit 8). The C,D and E limestone beds (units 9-11) are clearly visible in the upper part of the bank. At the far south end of the section it is possible to examine the upper contact of the Windom with the overlying Genesee. The last meter of soft shale immediately beneath the contact contains abundant, small Tropidoleptus diagnostic of the Penn Dixie beds (unit 12). Small ellipsoidal concretions just beneath the contact may correlate with those in the upper Penn Dixie beds at Cazenovia Creek. Note the absence of Amsdell and upper shale beds (units 13 and 14) in contrast to Cazenovia Creek and localities farther west. These upper units have been truncated prior to deposition of the overlying Penn Yan Member. Lenses of Leicester Pyrite are present at the contact in several locations, but are not readily accessible, although the Leicester can be observed in fallen blocks. The Genundewa Limestone ranges from 0 to 10 cm in thickness; Styliolina limestone and glausonite coated hiatus-concretions occur in depressions on an undulatory erosion surface at the top of a ledge-forming concretionary band 1.6 m above the base of the Penn Yan.

35.1		Return to vehicles and drive from gravel road back to Stolle Road.
35.2	0.1	Turn left (north on Stolle Road and retrace route to Bullis Road.
35.6	0.4	Junction Bullis Road. Turn right (east).
37.6	2.0	Junction Two Rod Road (Route 358). Turn left (north).
37.7	0.1	Cross Little Buffalo Creek.
37.8	0.1	Park along roadside opposite the home of V.I. Boldt, who has kindly provided access to this creek. Walk eastward through field behind house and barn about 1000 ft to creek bank.

STOP 4 (1 hour): LITTLE BUFFALO CREEK, UPPER WINDOM SECTION. This small creek exposes an excellent section of the Upper Windom, Leicester, Penn Yan Shale (here about 1.8 m thick) and Genundewa Limestone. Lowest exposures include the richly fossiliferous Big Tree bed in the Windom, slightly below a layer of flat concretions. This fossil bed yielded atrypids, Spinocyrtia and other species. The Buffalo Creek pyritic beds (unit 8) are well exposed in the floor of the creek upstream and here contain Devonochonestes coronatus and rare Pseudoatrypa in addition to pyritic tubes and nautiloids characteristic of the bed farther west. The uppermost beds of the Windom include a band of argillaceous limestone followed by shale and irregular large septarian concretions. These units comprise the C and D limestone beds respectively. The upper E unit as well as the Penn Dixie beds are missing at this locality. In places, the septaria of unit D protrude upward and deform the basal Penn Yan Shale: lenses of Leicester Pyrite lap directly onto these concretions. Upstream from the Windom/Penn Yan contact a spectacular bed of grotesquely shaped concretions occurs in the upper Penn Yan Shale immediately below thin Genundewa Limestone. Here the Genundewa contains a basal veneer of North Evans lithology, including glauconite and pyrite-coated hiatus concretions. These concretions, characterized by internal lamination, have been completely disinterred from the Penn Yan and rolled into new orientations. This pre-Genundewa disconformity is believed to correlate westward with the North Evans limestone.

37.8		Return to vehicles and proceed northward along Two Rod Road.
38.75	0.95	Junction Route 354 (Clinton Road). Turn right (east).
39.75	1.0	Intersection of Four Rod Road. Continue straight on Route 354.
40.75	1.0	Intersection of Three Rod Road. Continue straight on Route 354.
41.3	0.55	Turn left into driveway just before intersection with Eastwood Road on right. Park at end of the drive and proceed on foot to lower section of Cayuga Creek. Walk back upstream toward Clinton Road bridge.

STOP 5A (1/2 hour): CAYUGA CREEK, UPPER WINDOM SECTION. The upper 3.5-4 m (11-13 ft) of the Windom Shale are exposed beneath the bridge. There are two zones of ellipsoidal calcareous concretions, separated by about 2 m (6.5 ft) of nearly barren pyritic fissile dark gray shale. The lower concretion band is well exposed in the creek floor north of Clinton Road; surrounding shales contain abundant small brachiopods and a pyritic fauna with large masses of pyrite. This interval resembles superficially the Buffalo Creek pyritic bed (unit 8) but is apparently coextensive with lower barren shales of unit 4 seen farther west.

An upper concretionary band occurs 15-30 cm (6-12 in) below the upper contact of the Windom. Shales immediately above this concretion level are highly fossiliferous and contain abundant chonetids, Mediospirifer, Spinocyrtia, Athyris and Pseudoatrypa. This band appears to be coextensive with the Big Tree bed (unit 5) and it may also represent a western remnant of the Fall Brook Coral bed seen in Genesee County and farther east.

The upper contact of the Windom is sharply defined and exhibits local truncation; the Big Tree bed is observed to approach the contact as it is traced northward along this section of Cayuga Creek. The Windom is abruptly overlain by black fissile shale (possible westward limit of the Renwick Member); it contains oriented Styliolina and patches of chonetid brachiopods. Large lenses of rusty-weathered Leicester pyrite occur at the contact near the Clinton Road bridge. These have yielded well-preserved pyritized wood, fish bones, and other fossils.

41.3		Return to vehicles. Turn left from driveway and proceed eastward along Clinton Road.
41.5	0.2	Cross Cayuga Creek and prepare to turn right.
41.55	0.05	Turn right into driveway on east side of bridge and park at end of drive. Walk to falls and remains of concrete dam across Cayuga Creek.

STOP 5B (1/4 hour): CAYUGA CREEK, LOWER GENESEE SECTION. This section has been thoroughly described in previous field trip guidebooks (see Kirchgasser and Brett, 1981, p. 18). The Genesee Formation here includes 1.3 m (4.3 ft) of black and dark gray (Renwick?) Shale, followed by 1.8 m (6 ft) of gray, concretionary Penn Yan Shale. A prominent line of concretions occurs near the top of the section and is probably correlative with that seen in Little Buffalo Creek. A ledge of Genundewa Limestone about 20 cm (8 in) thick caps a low waterfall near the remains of an old concrete dam. The base of this ledge, again, contains encrinite and black hiatus concretions indicating an eastward extension of the North Evans type lithology associated with a pre-Genundewa erosional unconformity.

41.55		Return to vehicles. Turn left (west) onto Clinton Road and proceed westward.

42.6	1.05	Junction Three Rod Road. Turn left (south).
43.7	1.10	Junction Bullis Road. Turn right (west).
52.9	9.2	Junction Route 28, Transit Road. Turn left (south).
53.4	0.5	Junction 400, Aurora Expressway. Take entrance ramp for Route 400 north (=west).
58.4	5.0	Junction I-90 (NY State Thruway). Take exit for I-90 eastbound (actually northbound in this section).
66.5	8.1	Junction I-290, Youngmann Highway (Exit 50). Exit onto I-290 west.
69.	2.5	Junction Millersport Highway (Route 263). Take exit for Millersport Highway, north.
69.4	0.4	Return to Marriott Hotel.