SUBMARINE DISCONTINUITIES AND SEDIMENTARY CONDENSATION IN THE UPPER HAMILTON GROUP (MIDDLE DEVONIAN): EXAMINATION OF MARINE SHELF AND PALEOSLOPE DEPOSITS IN THE CAYUGA VALLEY

GORDON C. BAIRD
Field Museum of Natural History
Chicago, Illinois 60605

CARLTON E. BRETT
University of Rochester
Rochester, New York 14627

INTRODUCTION

As defined by Jenkyns (1971) condensed sedimentary sequences are differentially thin deposits recording minimum rates of net sediment accumulation. Such sequences are shown through correlation to be greatly condensed equivalents of thicker deposits; these latter typically display convergence of coeval zones or beds along their lateral periphery. It is possible for stratigraphic sequences to thin from hundreds or even thousands of feet to tens of feet or less while preserving or partly preserving the internal sequence of fossil zones or lithologic subunits. Stable depositional settings such as oceanic-rises and seamounts, regions of the open ocean floor, and broad epeiric shelf areas are commonly characterized by condensed sedimentary sequences. Selective winnowing of fines by currents and bioturbation effects, periods of nondeposition, inorganic degradation and biocorrosion of carbonates, exhumation and reburial of concretions and fossils, and juxtaposition or commingling of fossil zones are all variably characteristic of such condensed sedimentary sequences. Association of these sequences with local and regional discontinuities is also common as will be shown for part of the New York Middle Devonian section in this paper.

The upper Hamilton Group (Ludlowville and Moscow Formations) of the Cayuga Valley includes a thick sequence of marine mudstone characterized by widely spaced, thin limestone units and numerous mappable fossil zones. Several of these are associated with a widespread paraconformity and condensed sedimentary sequence at the base of the Moscow Formation; the differentially thin strata include the Portland Point and Kashong Members which are most compressed stratigraphically in the southeast part of the Cayuga Valley. These units thicken northwestward across the Cayuga and Seneca Valleys, 9.5 feet of strata (Portland Point and Kashong Members) at the Portland Point type section expanding to 100-110 feet in the Canandaigua Valley. The Tichenor-Portland Point Members disconformably overlie the King Ferry Shale in the Cayuga Valley, although evidence of erosion is lacking in most outcrops.

The Canandaigua-western Cayuga Valley area was a region of differential subsidence (trough) during the Middle Devonian. This is evidenced at several levels by differentially thickened units (Jaycox, Tichenor,

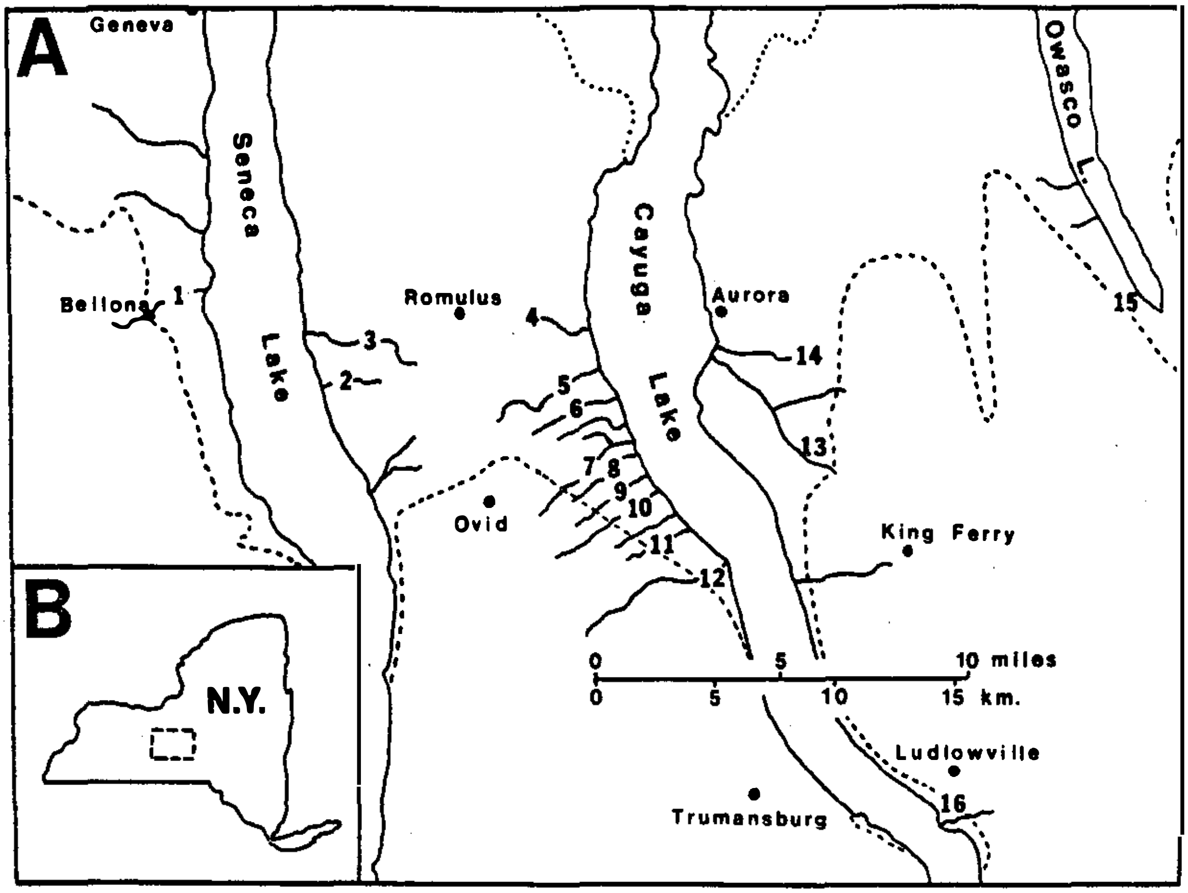


Figure 1. Study area. A is map of Seneca-Owasco Valley region. Figure shows top of Hamilton Group (dashed line) and base of Hamilton (dotted line). Numbered localities are discussed in text. Stops include: 1) Big Hollow Creek (Loc. 5: Stop 1); 2) Bloomer Creek (Loc. 8: Stop 2); 3) Barnum Creek (Loc. 9: Stop 3); 4) Sheldrake Creek (Loc. 12: Stop 4); and 5) Portland Point type section (Loc. 16: optional Stop 5). Inset B shows position of study area in New York State. Modified from Baird (1981).

Deep Run, Kashong Members), transition of calcarenites to argillaceous carbonate facies (Tichenor Member), and local development of black shale facies (Ledyard Member, parts of Wanakah-King Ferry Members 2 levels in Windom Member). Some of this shelf-to-trough facies change will be seen in the 4-mile interval of field trip stops 1-4 west of Cayuga Lake.

The lower (Wanakah-equivalent) part of the King Ferry Shale Member (Ludlowville Formation) displays northwestward facies change from fossil-rich, silty, gray mudstone to dark-gray and black fissile shale across the Cayuga Valley, apparently reflecting lateral paleoenvironmental transition to a poorly oxygenated, deeper water setting. Associated with an area of abrupt, narrow, gray-to-black shale transition west of Cayuga Lake are two diastems; these are characterized by abundant hiatus-concretions which are extensively bored and encrusted by organisms. Submarine erosion which produced the diastems is believed to have been the result of three processes: 1) weak, episodic wave and bottom currents; 2) disturbance and liquifaction of surface muds by infauna; and 3) sediment removal from an inclined sea floor (gentle submarine paleoslope) by current and/or gravity-induced transport. This best explains two closely-spaced, mirror-image discontinuities which display identical regional species-diversity gradients of associated organisms and which cut across a prominent facies change.

The lower Moscow condensed section, the above two diastems, and another discontinuity (phosphatic pebble bed) in the Kashong Shale Member are examined on the field trip. The area of field-trip stops (though small) shows several trends and features associated with the trough margin on the west side of the Cayuga Valley. The Portland Point type section on the east side of Cayuga Lake (Loc. 16), is also included as an optional stop in the road log.

STRATIGRAPHY

The Middle Devonian (Givetian) Hamilton Group is an eastwardly thickening wedge of predominantly terrigenous sediment which is entirely marine except in its easternmost parts. This sequence, ranging from a minimum thickness of 280 feet at Lake Erie to 3,000 feet at the Catskill front, is characterized by detrital sediments which coarsen to the east and southeast. In western New York and through most of the study area (Figure 1) the Hamilton Group is comprised of gray to black marine shale and mudrock with widely spaced thin calcareous intervals. In central and eastern New York shale and limestone are displaced by siltstone and sandstone facies with the appearance of fluvial sandstones and redbed floodplain deposits east of the Schoharie Valley.

The deposits in the study area display marked regional facies change across the Seneca-Owasco Valley region with much of this lateral change occuring in the area of closely spaced numbered localities west of Cayuga Lake (Figure 1). The sedimentary section examined includes the upper one-half of the Ludlowville Formation and the lower 40 feet of the Moscow Formation (Figure 2). These units are moderately to highly fossiliferous and several major units and zones marked by diverse faunas are included. Widespread faunal marker units include: 1) the Tichenor Limestone Member with its diverse and distinct coral, bryozoan, pelmatozoan biota, and 2) the Rhipidomella, Centronella, Spinocyrtia bed (Kashong Member) with its distinctive brachiopod-bryozoan assemblage. Another possibly traceable fossil zone is the Bloomer Creek bed (King Ferry Member) which yields numerous Pleurodictyum americanum and Strophodonta demissa. This diastem, though a local feature, is at the appropriate stratigraphic level (uppermost Wanakah-equivalent King Ferry Member) to be stratigraphically coeval to the S. demissa zone in the upper Wanakah Member of western New York.

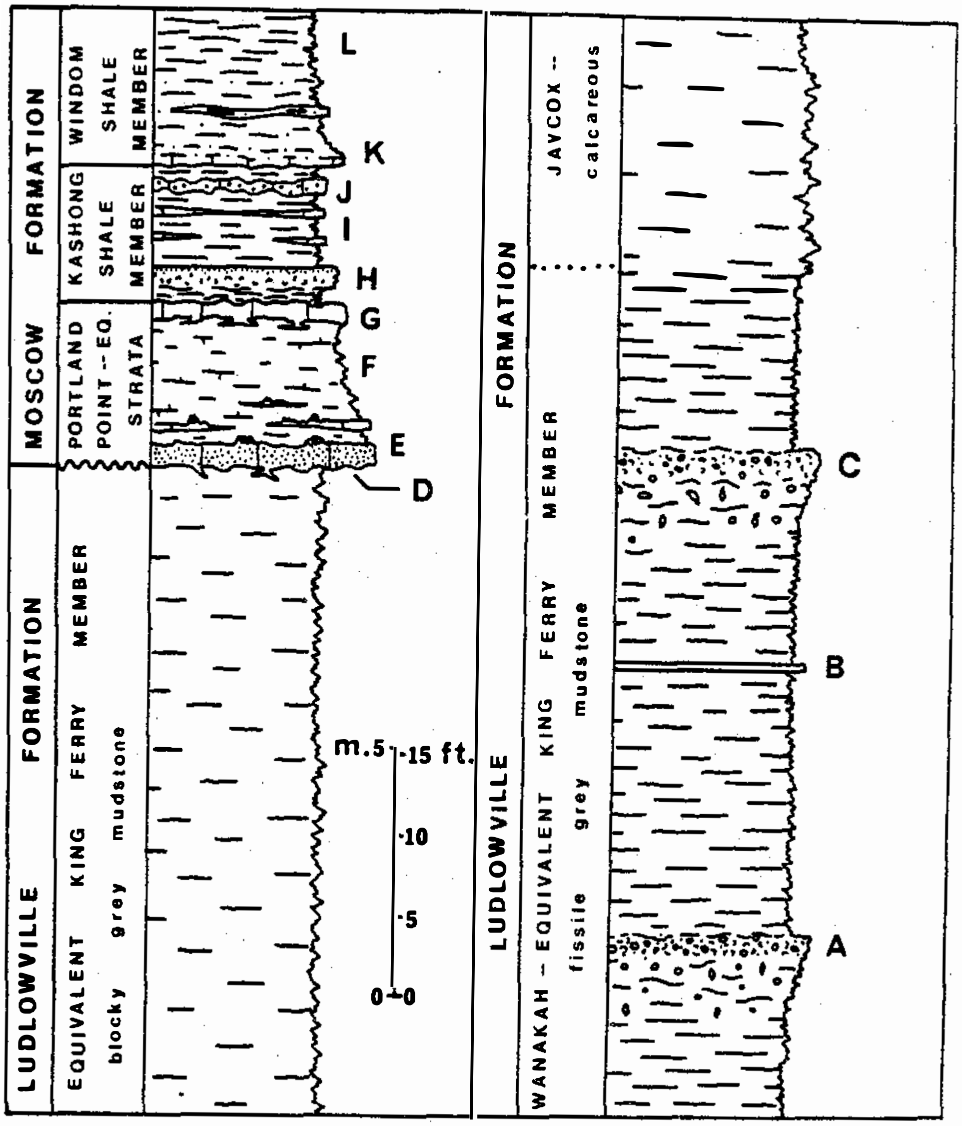


Figure 2. Generalized Upper Ludlowville-Lower Moscow stratigraphic section at Barnum Creek (Loc. 9: Stop 3). Numbered units include: A) Barnum Creek bed; B) Mack Creek turbidite bed; C) Bloomer Creek bed; D) Basal Moscow paraconformity; E) Tichenor Limestone Member; F) Deep Run Shale Member; G) Menteth Limestone Member; H) Kashong Member: Rhipidomella-Centronella bed and basal interval of gray Kashong mudstone; I) Kashong Member: upper Kashong mudstone interval; J) Phosphatic pebble bed (discontinuity); K) Windom Member: basal silty mudstone interval; L) Windom Member: gray, fissile shale of Ambocoelia umbonata-chonetid zone.

DEPOSITIONAL SETTING

Western New York Shelf

The Hamilton sequence of New York includes the northernmost Middle Devonian deposits developed within the Appalachian basin; these sediments accumulated in the northern arm of an inland sea, the deepest part of which was developed south-southwest of the study area in western Pennsylvania, eastern Ohio, and West Virginia (Dennison and Head, 1975; Dennison and Hassan, 1976). The northern and western boundaries of the basin bordered lower relief cratonic shelf regions; these latter areas supplied relatively little detrital sediment to the basin with resultant thin Middle Devonian sections in western New York (Dennison and Head, 1976). A broad,gently-sloping shelf was developed across most of central and western New York during Hamilton deposition (Cooper, 1957; Grasso, 1970, 1973; Heckel, 1973). A shallow sea with a level muddy bottom prevailed over most of this region (Cooper, 1957; McCave, 1967, 1973).

The upper Hamilton formations are composed largely of detrital sediments and include several upward-regressive hemicycles which record basin-filling and general westward migration of the eastern shoreline punctuated by eastward shoreline advance associated with episodic transgressions and/or periods of reduced sediment supply. This westward-thinning detrital sequence is a result of Acadian tectonic events, including uplift and erosion to the east and southeast (Cooper, 1957; Heckel, 1973; Oliver, 1977). It is the initial sedimentary unit of the Catskill delta complex which expanded greatly during the Late Devonian (see Rickard, 1975, for summary of stratigraphy and facies).

Hamilton sediments are characteristically fossiliferous; the rich biotas of the Cayuga Valley section have been described by paleontologists over a period of more than 100 years (Hall, 1843; Cleland, 1903; Cooper, 1929, 1930; Fernow, 1961). The Hamilton sea apparently had near-normal salinity, water temperatures, and circulation as evidenced by presence of diverse stenotopic organisms. However, well-developed faunal endemism in the Hamilton biota suggests partial physical isolation of this sea from "Old World" circum-oceanic waters (Oliver, 1976, 1977).

Inter-Shelf Trough

The western New York shelf was bisected by an actively subsiding trough in the Canandaigua-Cayuga Valley region and particularly at the Seneca Valley meridian. Differential subsidence took place resulting in locally thickened and/or anoxic deposits. This is best illustrated by great local stratigraphic expansion of basal Moscow sediments equivalent to both the Portland Point Member of east-central New York and to the thin Tichenor-Menteth sedimentary sequence in western New York (Figure 3). Nine feet of strata at the Portland Point type section (Figure 4) expand to more than 100 feet of section in the Canandaigua Valley. The Tichenor Limestone Member and lower (Tichenor-equivalent) Portland Point Limestone are thin, widespread calcarenitic units. In central and western New York,respectively,these coeval beds can be

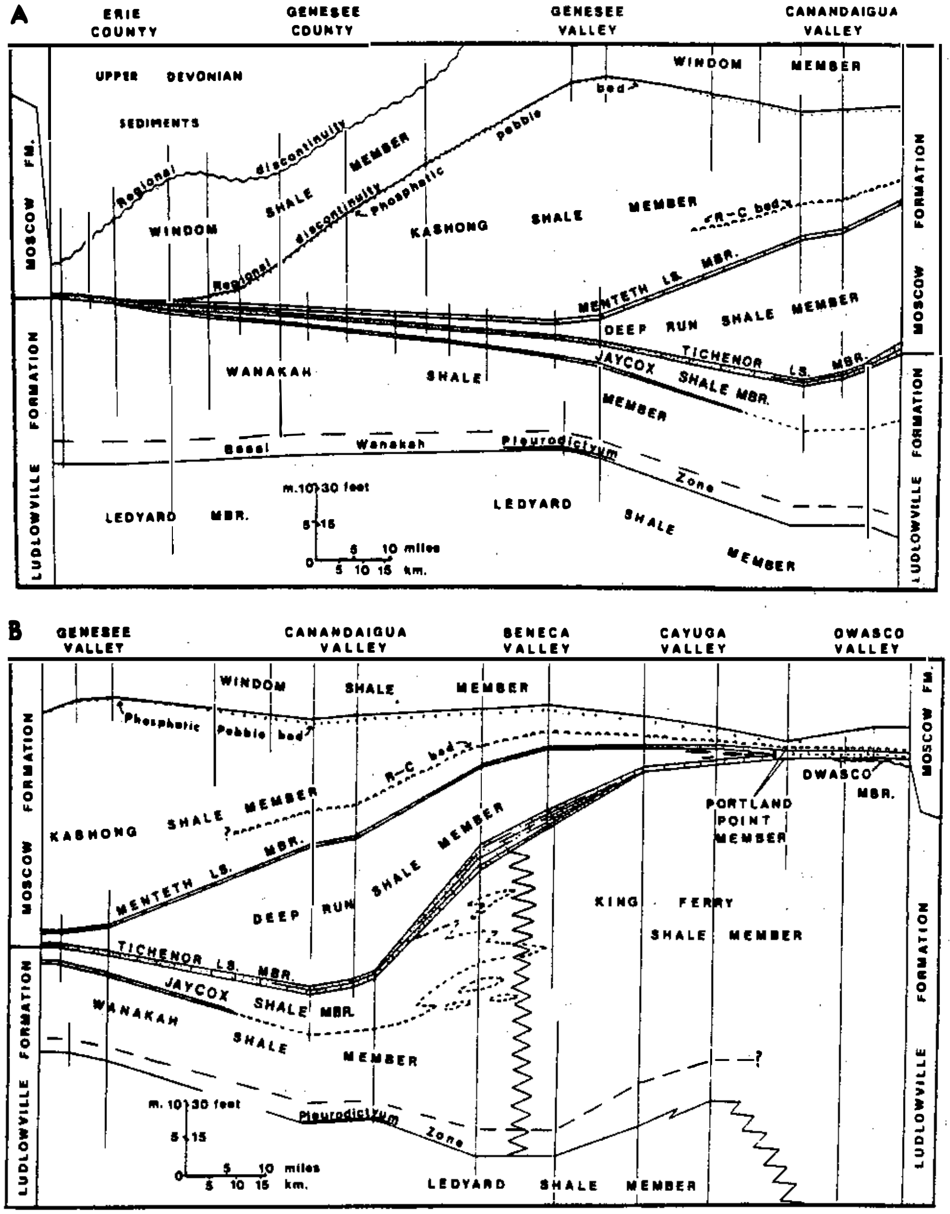


Figure 3. Upper Ludlowville-Lower Moscow stratigraphic relationships observed in present study; A) in western and B) in west-central New York. Vertical lines denote sections. From Baird (1979).

followed from opposing directions into the Seneca Valley where the equivalent sequence is a thicker (10-12 feet) sequence of interbedded calcareous mudstone and fossiliferous argillaceous limestone (Figure 3). The Tichenor and Menteth Members diverge, as the Deep Run Member expands into a thick lentil of calcareous gray mudstone. Moreover, the Jaycox Shale Member thickens eastward from a "feather-edge" carbonate bed in Erie County to 50-60 feet of gray calcareous mudstone in the Seneca-Cayuga Valleys; this sequence apparently thins eastward across the Cayuga Valley (Baird, 1981), but its eastern extremity is not known (Figure 5).

The basal Moscow paraconformity (base of Tichenor Limestone) is visible in all area sections. However, west of Cayuga Lake and in the Seneca Valley, this hiatus is believed to be of lesser magnitude than to the east or west due to differential subsidence and nearly continuous sedimentation in the region. This is suggested by maximum thickness of Jaycox-equivalent strata between Seneca and Cayuga Lakes (Figure 5); this sequence thins both to the east and west with probable erosional loss of beds along the paraconformity.

Black-shale facies displace equivalent gray mudstone and siltstone sequences within parts of the Ludlowville and Moscow Formations mainly in the Seneca Valley. In the Ledyard Member (Ludlowville Fm.), a black-shale facies in the Seneca-Cayuga Valley region grades westward into gray mudstone west of the Canandaigua Valley (McCollum, 1980) and eastward into gray mudstone and siltstone in the Owasco-Skaneateles Valley region (Cooper, 1930; Smith, 1935). In the Wanakah Member and Wanakah-equivalent part of the King Ferry Member, there is a similar lentil of black shale which occupies most of the Wanakah interval at Kashong Glen (Figure 1, Loc.1); this tapers and grades into gray mudstone both to the east and west of the Seneca Valley (Baird, 1979). A lentil of black platy shale (_Crurithyris praeumbona_ Zone) is locally developed in the middle of the Windom Shale Member (Moscow Fm.); this grades westward to gray mudstone between the Seneca and Genesee valleys (Baird and Brett, in prep) and eastward to silty mudstone facies of the Cooperstown Member in central New York. At the top of the Windom, black shale yielding _Allanella_, "_Leiorhynchus_," and _C. praeumbona_ reaches its greatest development in the Seneca-Canandaigua Valley region.

Not all units appear to exhibit differential subsidence in the region. The Mententh Limestone Member, _Rhipidomella-Centronella_ bed (Kashong Member), and Tully Formation extend across the region with little or no evidence of change in sediment character or thickness. Thus, the subsidence is believed to have been gentle and episodic; this was a local trough or "saddle" as opposed to a major basin. Deeper water (black-shale) facies in the trough may be a northward extension of more basinal-type sediments (e.g. Millboro Shale) typical of contemporaneous deposits in the central Appalachian basin. Finally, the axis of maximum subsidence was not entirely stationary; a general westward migration of the trough is apparent in the Jaycox-Kashong interval (Figure 3).

Submarine Paleoslope

Associated with facies change across the Cayuga Valley within the medial King Ferry Member is evidence of a gentle but significant submarine slope. This northwestward facies transition from shallow subtidal, fossil-rich, shelf deposits in the Aurora, King Ferry, and

Ludlowville area to deeper water, dark-gray and black shale in the Romulus-Bellona area (see Figures 1, 5) is characterized by presence of a mappable turbidite bed and evidence of local submarine erosion (Baird, 1981). This erosion, expressed by the presence of two unusual diastems in the area of most abrupt facies change, between localities 5 and 11, occurred through combination of physical and biological processes on a sloping sea bed. These diastems, both commencing in shallow-water facies and terminating within dysaerobic-anaerobic sediments, are key correlative horizons allowing time-controlled study of faunal gradients developed across the shelf-to-trough interval.

SEDIMENTARY CONDENSATION-DISCONTINUITIES:

LOWER MOSCOW FORMATION

Basal Moscow Paraconformity

The Moscow Formation is bounded at the base by a discontinuity below the Tichenor Limestone, which is traceable from Lake Erie to eastern New York (Baird, 1979). This hiatus is considered to be a paraconformity. In outcrop there is no observed angularity of Ludlowville beds beneath the break, but regionally there appears to be evidence of erosional overstep of Jaycox beds, particularly to the west.

In Cayuga Valley sections this discontinuity is conspicuous and can be seen in planar view in overhangs associated with waterfalls. At Bloomer Creek (Loc. 8: Stop 2), Barnum Creek (Loc. 9: Stop 3), Sheldrake Creek (Loc. 12: Stop 4), and at the Portland Point type section (Figure 4, Loc. 9: Stop 5) it can be easily observed; the break occurs beneath calcarenitic facies of the Tichenor Member and of the coeval lower Portland Point Member.

The paraconformity is marked by burrow networks (hypichnia) which locally penetrate into the uppermost King Ferry mudstone. These are somewhat analogous to, though smaller than, burrows observed along the base of the Tully Formation (Heckel, 1973). Reworked shale chips and intraclasts are rare in the basal calcarenite sequence in Cayuga Valley sections. However, further east in the Owasco Valley (Figure 1, Loc. 15), intraclasts occur in cross-bedded lower Portland Point calcarenite; erosional truncation of more coherent sediments in the Owasco Valley and further east probably explains the numerous sediment clasts in the Portland Point, this contrasting with submarine erosion of incompetent mud in Cayuga Valley localities.

Portland Point Member and Coeval Beds

East of the Cayuga Valley basal carbonate beds of the Moscow Formation are represented by the Portland Point Member (Cooper, 1930; Baird, 1978); this member is remarkably widespread, being traceable in outcrop from the Portland Point type section (Figure 4, units 2, 3) almost to the Catskill Front (McCave, 1967, 1973). In marked contrast to this uniformity, the Portland Point stratigraphic interval and that of the overlying Kashong Member expand greatly to the west-northwest across the Cayuga and Seneca Valleys (Figure 3). As the Portland Point

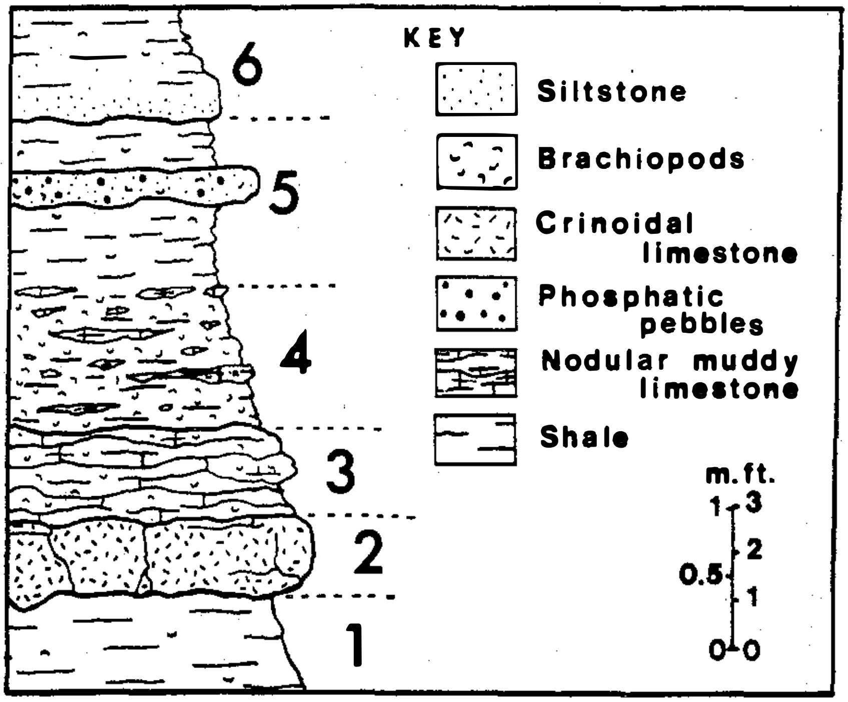


Figure 4. Diagram of Portland Point type section (Loc. 16: optional Stop 5). Units include: 1) Uppermost Ludlowville (King Ferry) shaley mudstone; 2) basal Portland Point (Tichenor-equivalent) calcarenitic bed; 3) Upper Portland Point (Deep Run-Menteth equivalent) muddy limestone; 4) Lower Kashong Rhipidomella-Centronella Bed; 5) Upper Kashong phosphatic pebble bed and synjacent shale; 6) basal siltstone bed and succeeding shales of Windom Member. Units 2 and 3 are Portland Point Member. Units 4 and 5 comprise Kashong Member. From Baird, 1979.

thickens westward from its 4-foot-thick type profile, it becomes differentiable into three distinct members; these are in ascending order: 1) Tichenor Limestone Member; 2) Deep Run Shale Member; and 3) Menteth Limestone Member (see Figure 2, 3). At the Portland Point type section, the Deep Run and Menteth members are undifferentiable, the equivalent interval (Figure 4, unit 3) being expressed as a 2-foot thick, shell-rich argillaceous limestone. At Barnum Creek (Loc. 9, Stop 3), the section shown in Figure 2, Portland Point-equivalent beds include 10 feet of section with the three component members represented. At Localities 7 and 8 (Stop 2), 1.5 miles farther north, this sequence is closer to 15 feet in thickness. The greatest expansion of this interval is between Localities 8 and 1 (see Figures 1, 3), but the basic trend is clearly visible in the field-trip area.

In the Canandaigua Valley the Portland Point-equivalent interval reaches a maximum thickness of 60 feet with the vast bulk of the sequence being composed of Deep Run mudstone. Farther west the Deep Run thins greatly, to a single calcareous mudstone band 1-3-feet-thick, between the Tichenor and Menteth members west of the Genesee Valley (Figure 3A). Thus, a nearly mirror image of sedimentary convergence and condensation is observed with sediments coeval to the Portland Point west of the axis of differential subsidence. The lateral tapering of the Deep Run detrital wedge, both to the east and west, points strongly to the pattern of contemporaneous sedimentary condensation in similar but separate shelf areas.

The Tichenor Member is a conspicuous, though uniformly thin, crinoidal limestone west of the region of differential subsidence. In the Seneca Valley and northwest Cayuga Valley, it is thicker and more argillaceous than in western New York counties. At Kashong Glen (Loc. 1) it consists of interbedded calcareous, gray mudstone and argillaceous biomicritic limestone (Baird, 1979). The fauna is rich and distinctive, being composed of sponges, large rugose corals, fistuliporid and fenestrate bryozoans, diverse brachiopods, and numerous pelmatozoan taxa. Although this diverse fauna is best preserved in the Seneca Lake area, the biota can be followed as a distinct zone both to the east and west. At Bloomer Creek (Loc. 8: Stop 2) the upper part of the Tichenor yields large, characteristic pelmatozoan stems which are massive; these bear pseudocirral protuberances, which apparently acted as attachment structures. These "runners" occur with a rich association of bryozoans, brachiopods, and camerate and inadunate crinoids. Between this locality and Sheldrake Creek (Loc. 12: Stop 4), the Tichenor becomes increasingly calcarenitic and massive, and the distinctive faunal zone at the top of the member largely disappears due to increased condensation and sedimentary disturbance at this level.

The Tichenor calcarenitic band can be followed into central New York as the lower bed of the Portland Point (Baird, 1979). It thins to a discontinuous sheet of calcarenite above the Owasco Sandstone Member east of the Owasco Valley but remains characteristic of the basal Portland Point at least to the Chenango Valley, if not farther east.

The Tichenor-basal Portland Point calcarenite is interpreted as a moderate- to high-energy deposit marking the initial deposit of marine transgression. It overlies the widespread paraconformity which apparently marked even shallower erosive conditions terminating Ludlowville deposition. It is envisioned as a wave-worked, shallow-subtidal sheet-sand facies typical of very shallow conditions on a broad shelf. Pelmatozoan debris comprising the calcarenite is believed to be variably reworked and transported.

The Deep Run Shale Member is a detrital wedge of hard, dark gray, calcareous mudstone, gradational from the distinctive pelmatozoan-coral zone of the upper Tichenor, and at the top, into the Menteth Limestone Member. Although it reaches greatest thickness in the Canandaigua Valley (Figure 3), it is still a prominent unit in the Seneca Valley.

In the Cayuga Valley it can be seen to best advantage at Bloomer Creek (Loc. 8: Stop 2), where it is approximately 10 feet thick. At Sheldrake Creek (Stop 4) it is only 4.5 feet thick and distinctly richer in bioclastic hash and shell debris. The Deep Run lacks any particularly distinctive taxa although it is rich in bryozoans, brachiopods, and bivalves, particularly in the thinner, condensed-edge facies.

The Menteth Limestone Member is alimestone bed 1.5 to 2 feet thick which extends from eastern Erie County eastward into the northern part of the Cayuga Valley and to one exposure (Ensenore Ravine) in the Owasco Valley. It thins southeastward across the Cayuga Valley from 1.5 feet at Mack Creek (Loc. 7) to 0.5 feet at Sheldrake Creek (Loc. 12) and 0.4 feet at Paines Creek (Loc. 13); this may be partly due to sedimentary condensation (thinning) or to submarine truncation. It is not recognizable as a discrete part of the type Portland Point but may be correlative with the uppermost part of the member (Figure 4, unit 3). The Menteth similarly disappears southward along the Owasco Valley as the Portland Point thins, and it is not recognizable at the N.Y. Route 38 roadcut section (Loc. 15) at Cascade.

The Menteth is composed of intensely bioturbated argillaceous limestone which weathers to buff-colored irregular ledges in outcrop. It is commonly gradational with the underlying Deep Run Member; elsewhere prod burrows may extend down from the limestone into the underlying mudstone. Unlike the Tichenor Member, this unit is predominently calcisiltite, composed of comminuted skeletal material, variable amounts of terrigenous silt, and larger brachiopod and trilobite debris, rather than pelmatozoan calcarenite. At Mack and Bloomer Creeks (Loc. 7, 8), the Menteth contains large fragments of the trilobites, Phacops and Dipleura, but these are difficult to extract from the matrix. Farther west, in the Genesee Valley, the Menteth has yielded silicified fossils; delicate juvenile stages of several brachiopod genera have been obtained in siliceous residues from this unit (Clarke and Luther, 1904). Siliceous masses occur locally in the Menteth Limestone of the Cayuga Valley and similar small silicified fossils may be plentiful.

The Menteth is characterized by strikingly uniform thickness regionally, and it extends across the intershelf trough with no significant change in character. Clues to its origin include the general similarity of Deep Run and Menteth fossils and the gradational boundary between the members. The Deep Run apparently represents local rapid detrital infilling of a deeper, lower energy trough on the New York shelf. As sediment input exceeded subsidence, the depression was filled to the ambient level of the surrounding shelf such that the seabed had migrated into a slightly higher energy regime. At a critical depth level, sediment input would have equalled sediment removal through winnowing by currents, this winnowing being selectively aided by intense bioturbation and liquification of surface muds by organisms (see Rhoads, 1970; Rhoads and Young, 1970). Fine clay would have been removed leaving behind a thin lag mantle of intensely burrowed silt and shell debris which would later be expressed as the Menteth. This interpretation holds that the Menteth was a terminal depositional phase of the Deep Run, representing condensation following trough infilling. Such an explanation could account for its widespread thin character and uniformity.

Kashong Shale Member

The Kashong Member is best developed in the Genesee Valley-Livonia area where it is more than 80 feet thick; it thins laterally to the east and west in a pattern very similar to that of the Deep Run Member, i.e. it is a lens-shaped unit with tapering margins (Figure 3). This unit reaches maximum thickness well to the west of the region of maximum thickness of the Deep Run, indicating that subsidence and associated fine mud deposition had shifted westward along the New York shelf.

The Kashong consists of gray, calcareous mudstone with numerous shell beds and lenses of concretionary limestone. It is characterized by diverse benthos (about 60-70 genera) of brachiopods, bryozoans, and pelmatozoans. Characteristic taxa include Tropidoleptus carinatus, Pleurodictyum americanum, Orthonota undulata, and Dipleura dekayi. Crinoid colonies occur at several levels with numerous genera represented. In the Cayuga Valley, the Kashong is greatly condensed, and the diverse, delicate fauna typical of sections to the west is somewhat reduced. However, at localities 8 and 12 (Stops 2, 4) many fossil genera including brachiopods, bivalves, and trilobites can be found in this unit. Characteristic Tropidoleptus, Dipleura, and pentagonal crinoid columnals can be collected on the field trip. The Kashong is only 7-9 feet thick at localities 8, 9, and 12 (Figure 2), and it thins further to 3 feet at the Portland Point type section (Figure 4); however, it is particularly fossil-rich and contains both the distinctive Rhipidomella-Centronella bed and the phosphatic pebble (discontinuity) bed (Baird, 1978, 1979; see Figures 2, 3).

The Rhipidomella-Centronella ("R-C") bed is a prominent shell-rich unit which is traceable from at least Menteth Glen in the Canandaigua Valley eastward into central New York where it constitutes a basal thin zone of the Cooperstown Member. From the Canandaigua Valley to the Owasco Valley, this unit is of nearly uniform 1.5- to 3-foot thickness. East of the Owasco Valley it gradually thins to a single smear of characteristic brachiopods and pelmatozoan debris and disappears as a recognizable marker east of the Cazenovia-De Ruyter meridian. At Menteth Glen, the R-C bed is separated from the Menteth Member by 10 feet of Tropidoleptus and bivalve-rich gray mudstone. This mudstone thins eastward as the R-C bed and Menteth converge; it is only 5-7 feet thick in the Seneca Valley and 0-1.5 feet between localities 7 and 12 in the Cayuga Valley. From Sheldrake Creek (Loc. 12) southeastward, the R-C bed rests directly on Menteth-Portland Point carbonates.

The R-C bed contains a distinctive macrofauna of brachiopods, including the terebratulids, (Centronella and Cryptonella), the orthid, Rhipidomella, and the large spirifer, Spinocyrtia, which are all rare to absent in adjacent Kashong beds. The brachiopods are packed in with abundant bivalves and bryozoan debris. Large corals such as Heliophyllum and Favosites occur rarely in the unit, and unusual taxa such as rostroconchs and a flexible crinoid have also been found. Of particular importance is distinctive mechanical abrasion (faceting) of larger brachiopods which often have the shell worn through and surface detail completely removed. The R-C bed is usually capped by a thin bed,1-2 inches thick, of pelmatozoan-ossicle packstone.

The R-C bed apparently represents a regressive episode within the Kashong; in sections to the west of the Cayuga Valley, shell beds of Tropidoleptus and other debris become thicker and more closely spaced immediately below the unit, suggesting a shoaling trend. The presence of large corals and thick-shelled brachiopods indicates further regression and establishment of equitable bottom conditions. Mechanical wear on the brachiopods is strong evidence of wave action and disturbance, the climax phase of this regression is expressed by the thin calcarenitic interval capping the bed.

The phosphatic pebble bed of the uppermost Kashong Member is indicative of a widespread shale-floored discontinuity which is best developed in western New York (Baird, 1978). This discontinuity, marked by a bed 3 to 10 inches thick of phosphatic pebbles and reworked shell debris, is traceable from the Cayuga Valley westward to Lake Erie (Figure 3). West of the Canandaigua Valley the break marks the top of the Kashong Member; it occurs at the boundary of the Tropidoleptus-rich fauna of the upper Kashong and Devonochonetes-Ambocoelia-rich shale of the lower Windom Member. From the Canandaigua Valley east to the Portland Point type section the discontinuity occurs approximately one foot below a calcareous siltstone bed which marks the base of the Windom (Baird, 1978). The intervening mudstone interval is characterized by a mixture of Kashong and Windom-type fossils. Again, this unit contains unusual faunal elements like those of the R-C bed including rare large rugose corals and faceted valves of Spinocyrtia, suggesting a second regressive episode.

From the Canandaigua Valley westward, the bed is rich in phosphatic pebbles and phosphatic fossil steinkerns of Kashong taxa. Some of these are admixed with and encrusted by Windom epizoan taxa (Baird, 1978), indicating that submarine erosion and exposure of the pebbles had continued up to and past the time of initial colonization by Windom organisms. In the Seneca and Cayuga Valleys, the change of faunas is less distinct as the discontinuity becomes less pronounced, but epizoans (Spirorbis, bryozoans) are commonly observed on reworked phosphatic material.

Sediment mixing by infauna characterized the erosion process; burrowing and sediment churning by Zoophycos organisms caused vertical mixing of shells and nodules such that the discontinuity shows up as a bed rather than as a discrete break. Such a bed strongly resembles a condensed sediment interval, the only difference being evidence of erosional overstep of underlying sediments, which is expressed in westward erosional truncation of the Kashong sequence in Genesee and eastern Erie Counties (Baird, 1978). Both at and east of the Cayuga Valley erosion appears to have been minimal or absent, and the phosphatic pebble bed is more truly a condensed sediment interval.

This bed can be seen at Bloomer and Sheldrake Creeks (Stops 2 and 4) and at the Portland Point type section (optional Stop 5). Phosphatic pebbles are present but not very common in Cayuga Valley sections, and they are hard to extract from the silty, calcareous mudstone matrix. Tropidoleptus is common in the bed; these brachiopods should be examined for phosphoritic interior fillings. Some of these brachiopods are worn and disarticulated, and the black phosphorite is clearly visible showing through the shell or adhering to valves (see Baird, 1978). This indicates that phosphatization occurred within near-surface sediment, often within sediment-infilled shells. Steinkerns of aragonitic shells are commonly observed indicating that shell carbonate was not replaced by phosphorite. Interstitial phosphorite formation appears to have been associated with prolonged intervals of nonsedimentation, sediment mixing, and disturbance prior to submarine erosion.

STRATIGRAPHIC SIGNIFICANCE OF BASAL MOSCOW CONDENSATION AND DISCONTINUITIES

The Portland Point-Kashong complex of beds and zones displays the greatest aggregate convergence of strata in the western New York Middle Devonian. Moreover, the nearly mirror-image thinning, convergence, and truncation of the same strata in western New York clearly point to a major, long-lasting geologic event or closely spaced series of events affecting virtually the entire New York shelf.

The pattern of convergence of many different units and juxtaposition of widespread thin limestone and shell beds indicate that the time interval represented by the basal Moscow sequence and the underlying paraconformity is probably very great. The Portland Point interval in both western and eastern New York appears to represent widespread and greatly prolonged periods of nondeposition of terrigenous sediment in the shelf region, allowing for widespread, uniform stacking of thin carbonate units of significantly different ages. As noted above, this apparent "sediment starvation" may have resulted from selective winnowing of fine-grained sediments in the very shallow shelf area. The thin carbonates grade into relatively thick clastic lentils (i.e. Deep Run and Kashong members) which were deposited rapidly in the slightly deeper, lower energy subsiding trough. It is in the inter-shelf trough that the sequence shows its great time significance by the stratigraphic "ballooning" described earlier.

This sequence of condensed beds should recur in equivalent strata elsewhere around the Appalachian basin, but perhaps not in the basin center where subsidence was greatest. It should be a basin-margin feature associated with one or more discontinuities, coral-pelmatozoan rich beds, or unusual fossil zones.

DIASTEMS IN KING FERRY SHALE MEMBER

Barnum Creek Bed

Two diastems, characterized by abundant hiatus concretions and fossil shell debris, occur in the Wanakah-equivalent part of the King Ferry Member, these are best developed between Powell Creek (Loc. 11) and Mack Creek (Loc. 7). The lower diastem,represented by the Barnum Creek bed (Baird, 1981), is a subtle hiatus lacking any discrete discontinuity surface (Figure 2, 5B). It can be easily overlooked except for the presence of bored and bioencrusted reworked concretions (Figure 6b). From Powell Creek (Loc. 11) and Short Creek (Loc. 14) southeastward, this bed is characterized only by shell debris which is variably biocorroded (Figure 3b). Abundant fossils including the coral, *Stereolasma*; brachiopods, *Athyris spiriferoides*, *Mediospirifer audaculus*; bryozoans, and bivalves characterize this fauna. The mudstone sequence underlying the Barnum Creek bed yields numerous *in situ* calcareous concretions as well as macrofauna similar to that in the overlying shell bed. Large conulariids, associated with and infilled by concretionary calcareous mudstone, occur within this sequence; these "pre-fossilized" objects appear within the Barnum Creek bed north of locality 11 as the underlying conulariid zone is overstepped.

From Groves Creek (Loc. 10) northward, the Barnum Creek bed is characterized by an interval 5 to 10 inches thick of mixed shells, mud, and hiatus concretions. North of Barnum Creek (Loc. 9, Stop 3) this bed thins, and fossils decrease in abundance and diversity northward to Hicks Gully (Loc. 4) and westward to Sampson State Park (Locs. 2 and 3) in the Seneca Valley. This occurs as synjacent sediments become darker in color and distinctly less fossiliferous, reflecting the regional shelf-to-trough facies transition discussed earlier.

Bioencrusted hiatus concretions and reworked conulariids are characteristic of this unit at Barnum Creek (Stop 3) and Groves Creek (Loc. 10); these objects show a complete spectrum of degradation from minimally or partially exhumed forms to intensely bored and bioencrusted fragments (Figure 5B, 6). Small rugose and auloporid corals (*Stereolasma*, *Cladochonus*), bryozoans (*Ascodictyon*, *Hederella*, encrusting trepostomes), and pelmatozoans are characteristic encrusters (Figure 6). Borings are predominantly a vasiform morphotype of *Trypanites*. Numerous parallel and intersecting sets of grooves on concretions may be scratch marks produced by burrowing infauna impinging against disturbed, but not yet exhumed, concretions. These marks are similar to those produced by infauna on Jurassic nodules (Fürsich, 1979). Pre-fossilized conulariids are characteristic of the reworked sediment interval; these are typically three-dimensional and infilled by concretionary cemented mudstone (Figure 6). These are reworked as evidenced by variable degradation of thecae and bioencrustation of exposed concretionary mudstone. North and west of Mack Creek (Loc. 7), epizoans are still observed on hiatus concretions, but epizoan diversity is low overall. At Sampson State Park Locs. 2, 3) only *Cladochonus* and *Ascodictyon* are observed on concretions. The hiatus concretions themselves tend to be small, flattened objects reflecting diagenesis in darker, underlying mudstone facies; these are sometimes stacked like shingles along the bed. West of Seneca Lake (Loc. 2) the Barnum Creek bed is no longer recognizable, its position is occupied by dark-gray to black platy shale.

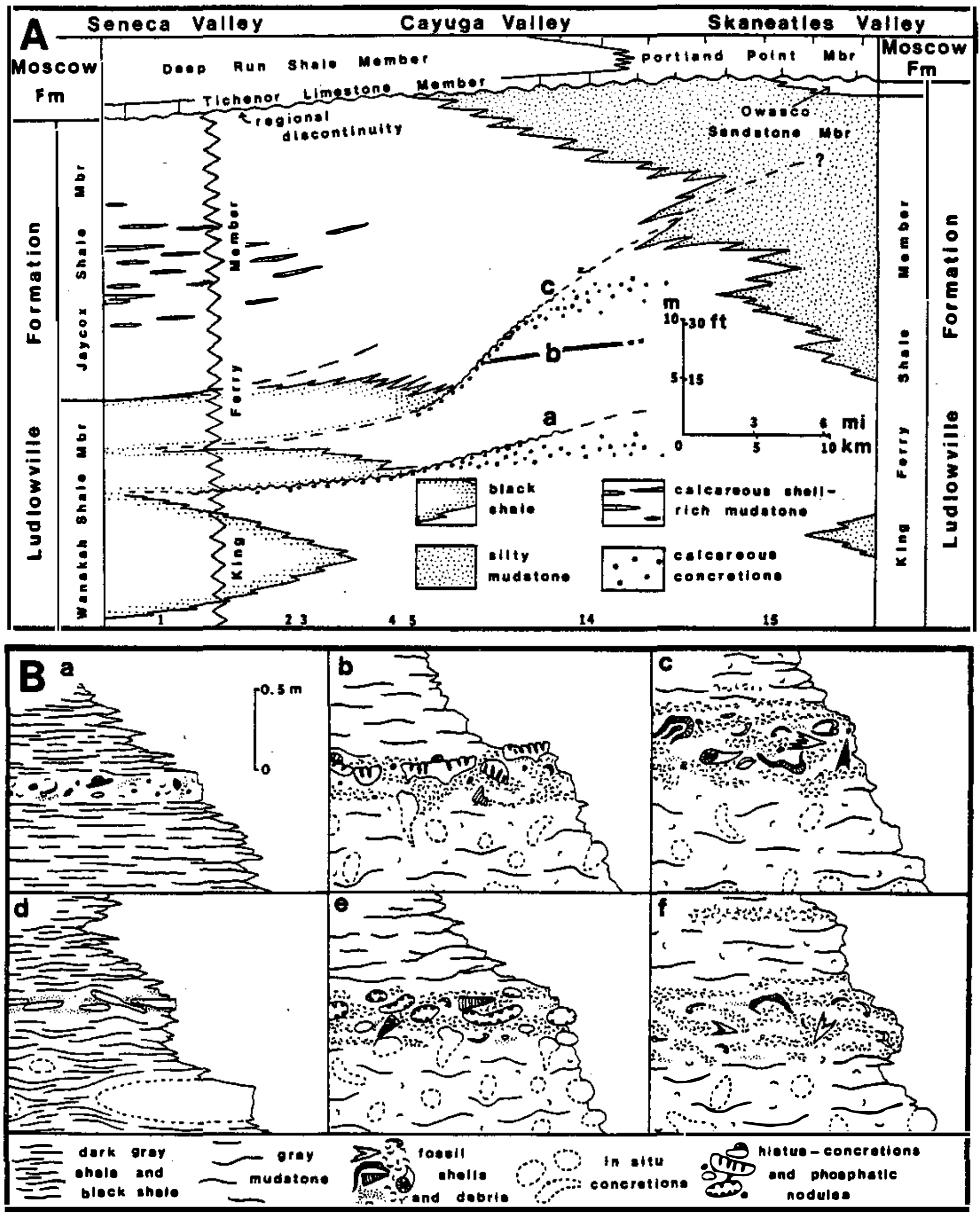


Figure 5. Stratigraphy associated with King Ferry diastems. A shows Barnum Creek bed (a), Mack Creek bed (b), and Bloomer Creek bed (c) relative to regional facies distribution. Note truncation of Mack Creek bed by Bloomer Creek bed. B, schematic vertical profiles of King Ferry diastems. a-c show Bloomer Creek bed at localities 5, 9, and 13 respectively, d-f show Barnum Creek bed at localities 2, 9, and 15. Localities in A correspond to those in Figure 1. From Baird, 1981.

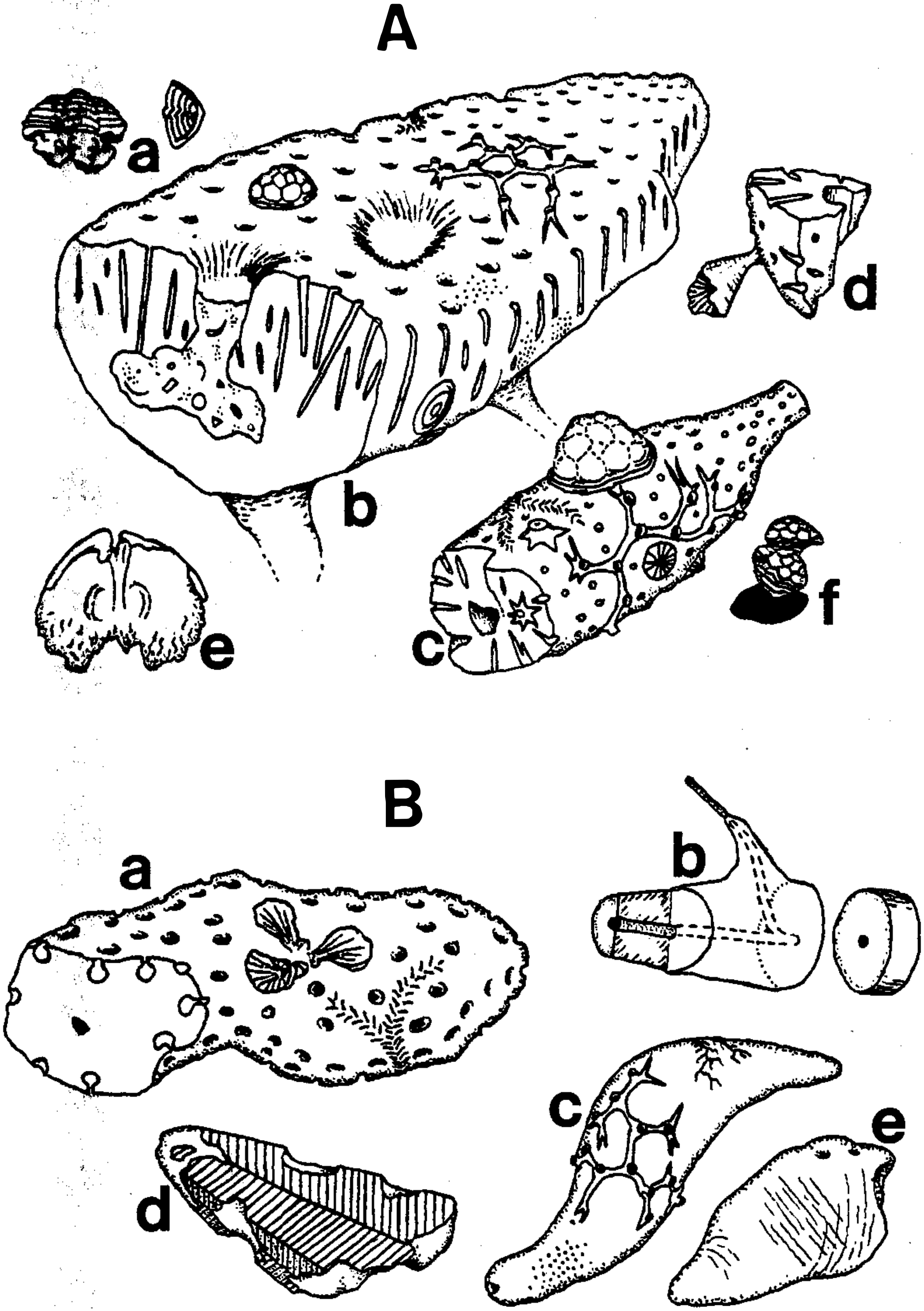
Bloomer Creek Bed

Twelve to thirty feet above the Barnum Creek bed another more pronounced discontinuity is observed; although lacking a discrete erosion surface, the Bloomer Creek bed displays dicontinuity character mainly from Groves Creek (Loc. 10) northward to Big Hollow Creek (Loc. 5; Stop 1). It too, is characterized by vertically-mixed hiatus concretions and shells in the same general area as the Barnum Creek bed. From Powell Creek eastward and southward, the bed generally lacks reworked early-diagenetic material and is characterized by abundant brachiopod and bivalve shells irregularly packed in gray mudstone matrix. In situ concretions are common in the 3-to-6 foot mudstone interval immediately below the bed; these are progressively exhumed north of Powell Creek as the discontinuity oversteps this sequence. North of Mack Creek (Loc. 7) hiatus concretions become less common as the underlying concretion zone is erosionally cut out, and there is a marked drop-off in abundance and diversity of epifauna.

At Bloomer and Barnum Creeks (Locs. 8, 9; Stops 2, 3), the Bloomer Creek bed carries a rich biota, dominated by brachiopods and bivalves. Key taxa include the brachiopods, Athryis spiriferoides, Pseudoatrypa cf. P. devoniana, Strophodonta demissa, Mediospirifer, and numerous smaller forms; bivalves include Modiomorpha, pterioids, and protobranchs. Scattered bryozoan fragments, gastropods (Mourlonia, bellerophontids) and fragmental cephalopods and trilobites are abundant. Small Pleurodictyum americanum characterize the bed, particularly north of Bloomer Creek where they are common. These corals commonly encrust shells, but they are also observed on hiatus concretions and phosphatic pebbles (Figures 6B, 7). Large corals, including Cystiphylloides, Heliophyllum, and Favosites, are scarce but present in the shell-rich phases of this unit.

Hiatus concretions are locally conspicuous features of this bed, particularly at Barnum Creek (Stop 3). Most of these are tube-, spindle-, and turnip-shaped objects; these typically display a central tube or axis which is pyrite-infilled when the concretion is in situ. These tubes appear to be early diagenetic features associated with lebensspuren in the underlying mudstone (Figure 7A). The calcareous concretions represent a later phase of carbonate diagenesis around tubes. The exhumed conretions are variably encrusted by epizoans and typically intensely bored (Figures 6A, 7A); a long, straight variety of Trypanites is typical of this bed. Hiatus concretions are variably degraded by the boring process and multiple episodes of bioencrustation are seen on nodules (Figures 6A, 7c-e), suggesting prolonged exposure of the concretions on the bottom and/or multiple episodes of exhumation and reburial. Small phosphatic pebbles and phosphatic steinkerns of brachiopods, nautiloids, and trilobites are common in the Bloomer Creek bed (Figure 6A). At Big Hollow Creek (Loc. 5; Stop 1) Pleurodictyum and Stereolasma have been found encrusting pebbles and steinkerns only a fraction of their size (Figure 6A); this strongly suggests synchronous coral growth and burial of the undersized-nodule substrate during sedimentation. Presence of both reworked phosphatic pebbles and hiatus concretions indicates that the period of submarine erosion may have been much longer than for the Barnum Creek bed.

The Bloomer Creek bed displays conspicuous local, northwestward erosional overstep of underlying beds; this unit is observed to overstep a conspicuous turbidite which is mappable between the diastems from Mack


A
a
d
b
e
c
f
B
a
b
c
e
d

Creek (Loc. 7) southeast to Sheldrake and Paines Creeks (Locs. 13, 12). This turbidite, designated the Mack Creek bed, occurs 17 feet below the Bloomer Creek bed and 18 feet above the Barunum Creek bed in southeastern exposures. The Bloomer Creek hiatus concretions are 8 feet above the turbidite bed at Bloomer Creek, and only 4 feet above it on the north branch of Mack Creek. At a small creek (Loc. 6) 1.3 miles north of Mack Creek the diastems are 17 feet apart and the turbidite is missing. At Big Hollow Creek (Loc. 5; Stop 1) 0.75 miles farther north, the diastems are only 12 feet apart. No further convergence is noted to the north and west of this section. Although some of the 20 feet of diastem convergence can be attributed to northward facies change from gray mudstone to dark gray-black shale, the abundant hiatus-concretion material and truncation of the turbidite clearly indicate that much of this change is the result of submarine erosion.

Submarine-Erosion Processes

The King Ferry diastems are termed stratomictic discontinuities (Baird, 1981); these are erosional breaks characterized by beds or zones of mixed and disturbed sediment, fossils, and reworked diagenetic structures rather than discrete erosion surfaces. The sediment mixing is generally the result of interaction of physical sea-floor erosion by currents and disturbance of near-surface muds by infauna. Such beds resemble condensed sedimentary sequences, but the erosional overstep associated with them excludes these units from this category.

Submarine erosion producing the King Ferry diastems occurred through the additive interaction of at least two and probably three processes; these include 1) dissipation-impingement of weak, episodic wave-current

Figure 6. Reworked concretions and fossils from King Ferry diastems. A shows material from Bloomer Creek bed; this includes: a) phosphoritic steinkern of trilobite, Loc. 9 (Stop 3), X 0.75; b) large partially exhumed calcareous concretion showing differential boring-encrustation of its upper surface, Loc. 9, X 0.7; c) tubular hiatus concretion showing hollow central core axis and encrusting *Pleurodictyum*, *Cladochonus*, and *Philhedra*, Loc. 8 (Stop 2), X 0.75; d) biodegraded hiatus-concretion "crumb" with attached *Stereolasma*, Loc. 8, X 1; e) *Athyris* valve showing bioattrition, Loc. 7, X 0.8; f) *Pleurodictyum* encrusting undersized phosphatic pebble, Loc. 5 (Stop 1), X 0.6. B shows material from Barnum Creek bed; this includes: a) bored and bioencrusted hiatus concretion. Note flask-shaped borings and encrusting *Stereolasma* and *Hederella*, Loc. 9, X 0.6; b) schematic cutaway view of *in situ* concretion showing core axis surrounded by diagenetic carbonate, X 0.5; c) bioencrusted tubular concretion with attached *Ascodictyon* (spots), *Cladochonus*, and *Hederella*, Loc. 8, X 0.8; d) reworked prefossilized conulariid, Loc. 9, X 0.8; e) nodule showing scratch marks attributed to infauna, Loc. 9, X 0.4. From Baird (1981).

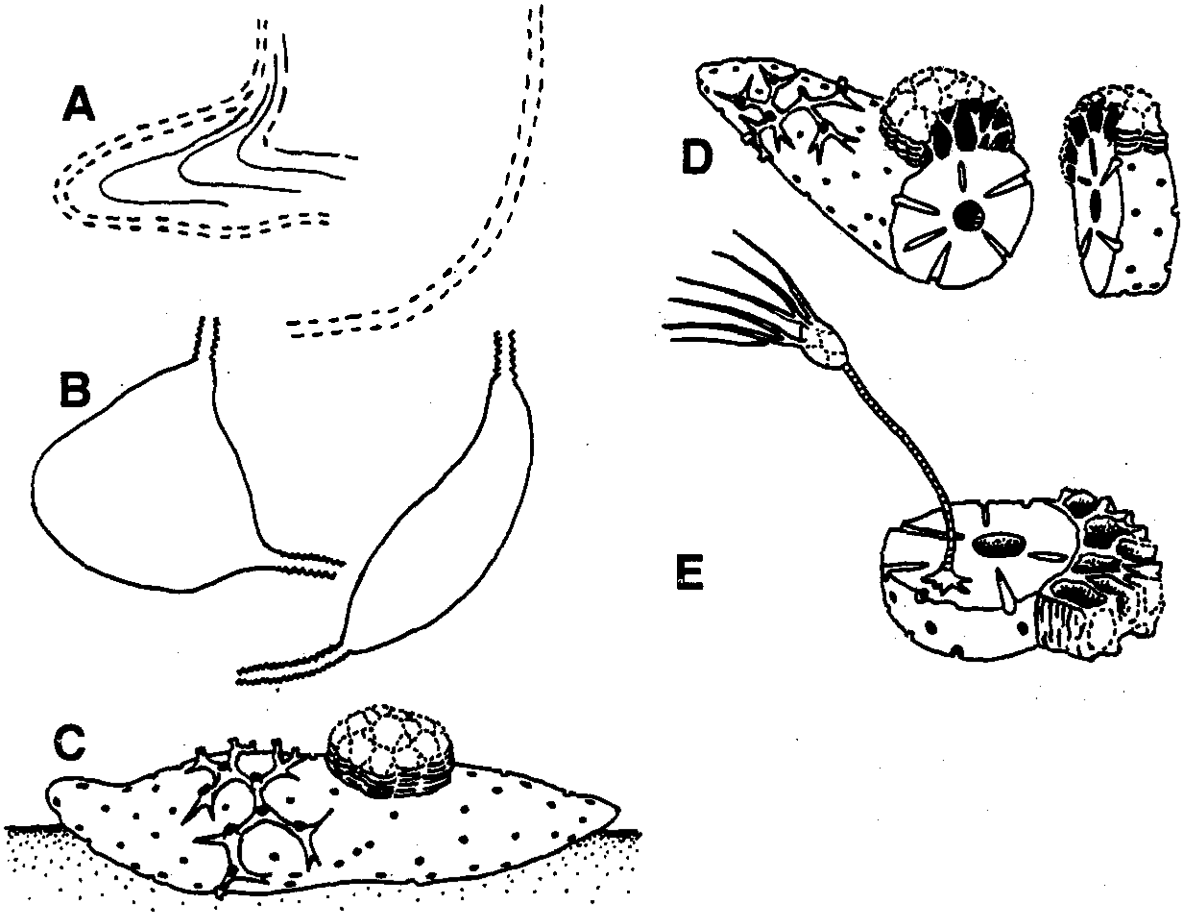


Figure 7. Genesis of "poker chip" hiatus-concretion fragment. A, bioturbation; development of vertical and oblique tubular burrows; B, diagenesic formation of calcareous concretion around burrows and precipitation of pyrite and/or calcite in burrows; C, erosion event; exhumation and bioencrustation-boring of exposed hiatus-concretions; D, hiatus-concretion disintegration; break up of nodule and encrusting coral *Pleurodictyum*; E, post-breakage bioencrustment; pelmatozoan attachment to transverse break surface.

energy on the sea bottom; 2) disturbance and liquefaction of surface muds by infauna; and 3) downslope transport of fines along a storm wave-induced current-energy gradient and/or through gravity effects. The third is less easy to assess but appears reasonable, given the regional character and distribution of the diastems.

Submarine erosion along the trough margin seems to have started as the result of an outside control such as slight regression, and/or reduction in sediment supply to the region. Such a shift, timed with ongoing bioturbation of shelf-slope muds, would have shifted the sedimentation balance from net accumulation to net loss without radical environmental change. Increased current energy acting on a soft bioturbated substrate would have resulted in resuspension and removal of fines. The activity of bottom organisms is known to contribute greatly to bottom erosion particularly in sloped sea-floor areas (Rowe et al., 1974; Stanley and Freeland, 1978). Animals may cause erosion at current flow velocities much lower than the threshold erosion velocity for a given sediment type by ejecting or scattering clay flocs into suspension, thus causing sediment entrainment in weak currents (Dillon and Zimmerman, 1970; Lonsdale and Southard, 1974). Bioturbation in both the Barnum and Bloomer Creek beds is evidenced by presence of Zoophycos and local abundance of protobranch bivalves (Nuculites, Paleoneilo); although protobranchs left no identifiable lebensspuren, these forms were probably active burrowers and sediment ingesters in the near-surface muds (Bowen, Rhoads and McAlester, 1974; Thayer, 1974). They presumably modified surface sediments, probably pelletizing and liquefying them in a pattern similar to that produced by modern Nucula (Rhoads and Young, 1970; Stanley, 1970).

A thin (2 to 15 inches thick) mantle or flux zone of bioturbated surface mud containing admixed shells and hiatus concretions is believed to have been present during concretion formation (Figure 8). Although reworked concretions were locally abundant within this layer, only a variable proportion of these would have been exposed at the surface at any given time due to vertical mixing of mud by organisms and lateral sediment transport. Because of winnowing of fines by currents, this zone of mixed material would have migrated vertically downward with time, overstepping (cannibalizing) progressively older beds (Figure 8, A-C cycle). Downward probing by infauna would have kept pace with downward advance of the sea bed with continuous incorporation of underlying concretions into the burrowed layer.

A gentle northwestward-dipping submarine paleoslope was associated with diastem formation; this regional slope was probably present through the period of deposition of Wanakah-equivalent King Ferry sediments, the two diastems being in part consequences of it. Important features discussed earlier (Baird, 1981) including: 1) gray-to black-shale facies change in the King Ferry, 2) associated faunal diversity gradients along both diastems, 3) distribution of hiatus concretions, 4) distribution and current-directional indicators of the Mack Creek turbidite, and 5) regional facies patterns in units bordering the King Ferry, constitute evidence for the paleoslope. The facies change from gray to black shale is interpreted as an environmental gradient to deeper water; black shales are usually interpreted as outer-shelf or basinal deposits (Heckel, 1973; Bowen, Rhoads and McAlester, 1974; Rhoads, 1975).

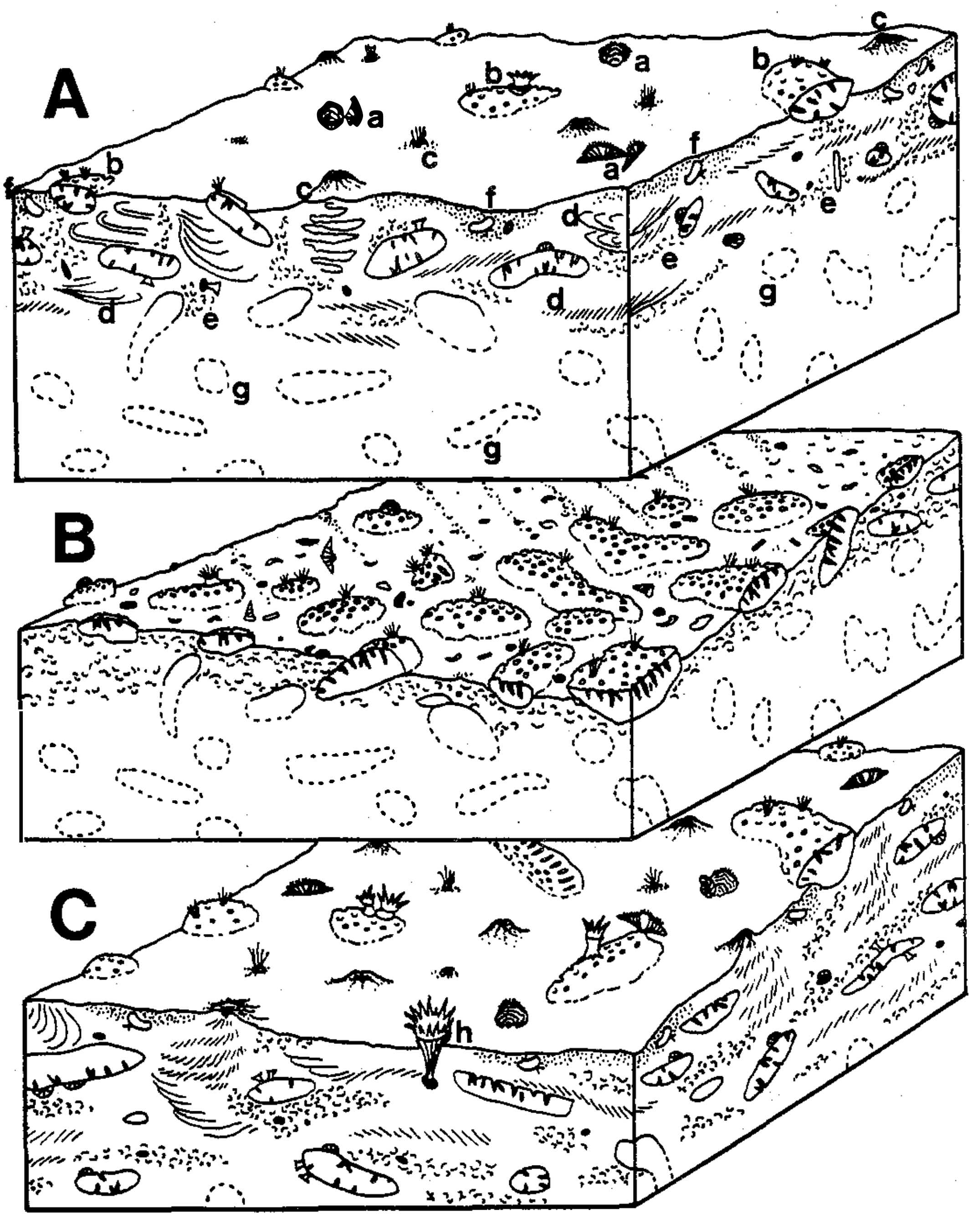
Diastem erosion is believed, in part, to be a result of paleoslope control; both diastems are best developed in the area of maximum facies change and are minimally developed or absent away from the sloped region. Why would these discontinuities be so peculiarly distributed? The answer appears to be related to differential instability of sediments on submarine slopes even including surfaces of less than 1^{o} inclination. The presence of the Mack Creek turbidite with groove casts normal to inferred depositional strike is a strong indication of episodic density-current flow on the paleoslope. Similarly, resuspended fine mud would have been transported downslope (along a gradient of wave-induced current energy); this sediment slowly migrated downslope over time to be deposited as a thin blanket of black mud in deeper, level-bottom trough areas.

ACKNOWLEDGMENTS

The authors are grateful to Drs. Curt Teichert and Robert G. Sutton of the University of Rochester for review and criticism of the paper. Ronald Testa and Robert Eaton prepared the photographs. Elizabeth Moore and Margrit Gardner typed copies of the manuscript during its preparation.

Figure 8. Submarine erosion; schematic reconstruction. A, Biological activity on and within substrate. Development of water-rich burrowed sediment layer. Vertical shell-nodule mixing and loss of fine sediment to currents. B, Increased current scour and accelerated erosion. Concretion exhumation and bioencrustment. Local development of nodule pavements. C, Reduced current scour and erosion. Continued burrowing activity with regeneration of water-rich sediment layer. Downward extension of burrowing activity into undisturbed older muds.

Key: a, brachiopods; b, hiatus-concretion epizoans; c, conjectural surface expression of burrows; d, *Zoophycos* spreiten; e, shell concentrations; f, nuculid bivalves and associated thixotropic (stippled) sediment; g, *in situ* concretions; h, rugose coral displaying growth synchronous with sediment accumulation.


A
a
a
a
b
b
b
c
c
c
d
d
d
e
e
e
f
f
f
g
g
g
B
C
h

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. 48, 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.

______, 1981, Submarine erosion on a gentle paleoslope: a study of two discontinuities in the New York Devonian: Lethaia (in press).

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.

Clarke, J. M. and Luther, D. D., 1904, Stratigraphic and paleontologic map of Canandaigua and Naples quadrangles: New York State Mus. Bull., v. 53, p. 1-67.

Cleland, H. F., 1903, A study of the fauna of Hamilton Formation of the Cayuga Lake section in central New York: U. S. Geol. Surv. Bull. v. 206, 111 p.

Cooper, G. A., 1929, Stratigraphy of the Hamilton Group of New York: Ph.D. dissertation, Yale Univ., New Haven, Conn., 476 p.

______, 1930, Statigraphy 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, v. 2, Paleoecology: Geol. Soc. America Mem. 67, p. 249-278.

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.

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

Dillon, W. P., and Zimmerman, H. B., 1970, Erosion by biological activity in two New England submarine canyons: Jour. Sed. Petrology, v. 40, p. 542-557.

Fernow, L. R., 1961, Paleoecology of the Middle Devonian Hamilton Group in the Cayuga Lake region: Ph.D. dissertation: Cornell Univ., Ithaca, N.Y., 208 p.

Fürsich, F. T., 1979, Genesis, environments, and ecology of Jurassic hardgrounds: Neues Jb. Geol. Paläont. Abh. 158, p. 1-63.

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

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

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. America Spec. Paper 138, 244 p.

Jenkyns, H. C., 1971, The genesis of condensed sequences in the Tethyan Jurassic: Lethaia, v. 4, p. 327-352.

Lonsdale, P., and Southard, J. B., 1974, Experimental erosion of North Pacific red clay: Marine Geol., v. 4, p. M51-M60.

McCave, I. N., 1967, A stratigraphical and sedimentological analysis of a portion of the Hamilton Group (Middle Devonian) of New York State: Ph.D. dissertation, 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.

McCollum, L., 1980, Paleoecology of the Ledyard Shale Member (Middle Devonian: Givetian) of New York: Ph.D. dissertation State Univ. of New York at Binghamton, 143 p.

Oliver, W. A., 1976, Biogeography of Devonian rugose corals: Jour. Paleontology, v. 50, p. 365-373.

———, 1977, Biogeography of Late Silurian and Devonian rugose corals: Palaeogeog., Palaeoclimatol., Palaeoecol., v. 22, p. 85-136.

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.

Rhoads, D. C., Mass properties, stability, and ecology of marine muds related to burrowing activity, in Crimes, T. P., and Harper, J. C., eds., Trace fossils: Geol. Jour. Spec. Issue, v. 3, p. 391-406.

———, 1975, The paleoecological and environmental significance of trace fossils, in Frey, R. W., ed., The study of trace fossils: New York, Springer Verlag, p. 147-160.

Rhoads, D. C. and Young, D. K., 1970, The influence of deposit feeding organisms on sediment stability and community trophic structure: Jour. Marine Research, v. 28, p. 151-178.

Rowe, G. T., Keller, G., Edgerton, H., Starsinich, N., and MacIlvaine, J., 1974, Time-lapse photography of the biological reworking of sediments in a submarine canyon: Jour. Sed. Petrology, v. 44, p. 549-552.

Smith, B., 1935, Geology and mineral resources of the Skaneateles quadrangle: New York State Mus. Bull., v. 300, 120 p.

Stanley, D. J. and Freeland, G. L., 1978, The erosion-deposition boundary in the head of Hudson Submarine Canyon defined on the basis of submarine observations: Marine Geol., v. 26, p. M37-M47.

Stanley, S. M., 1970, Relation of shell form to life habits in the Bivalvia (Mollusca): Geol. Soc. America Mem. 125, 296 p.

ROAD LOG FOR MIDDLE DEVONIAN DISCONFORMITIES AND SEDIMENTARY CONDENSATION IN THE CAYUGA LAKE AREA

TRIP

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0.	0.0	Begin trip at Holiday Inn on Vestal Parkway opposite State University of New York, Binghamton campus. Turn east on parkway, but pull off immediately on northbound exit, Johnson City, Rte. 201.
0.4	0.4	Bridge over Susquehanna River, traffic circle at north end of bridge. Continue north on 201 (Riverside Drive).
1.2	0.8	Junction with N.Y. Route 17, proceed west on 17 to Owego exit.
15.4	14.2	Owego exit. Proceed north across Susquehanna River and through Owego on New York Route 38-96.
17.5	2.1	Junction of New York Routes 38 and 96. Proceed northwest on Route 96.
24.8	7.3	Village of Candor. Junction of New York Routes 96 and 96A. Proceed north on Route 96A.
34.8	10.0	Town of Danby, continue north.

39.7	4.9	Town of Ithaca at base of hill. Proceed west on New York Route 96A to junction of Route 13-14-96 with Route 96A.
40.1	0.4	Junction of Routes 13-34-96 with 96A. Turn north on Route 13-34-96.
40.2	0.1	Junction of Routes 13-34 and 89-96. Turn left (west) on 89-96 and cross Cayuga Inlet.
40.4	0.2	Junction of New York Routes 89 and 96. Turn right (north) on Route 89.
41.2	0.8	Leave town of Ithaca, proceed north along west side of Cayuga Lake.
50.2	9.0	Cross mouth of Taughannock Creek at Taughannock State Park. To the left (upstream) from the road bridge a low waterfall is visible; this section includes the Tully Formation (limestone) overlying the uppermost Hamilton Group (Windom Member). Farther upstream is a splendid gorge-waterfall section exposing sediments of the lower Genesee Group (Upper Devonian: Frasnian Stage).
60.4	10.2	Cross Sheldrake Creek.
62.6	2.2	Cross Barnum Creek.
63.6	1.0	Cross Bloomer Creek.
65.6	2.0	Turn left (west) on Swick Road. Proceed up hill.
66.4	0.8	Slight turn in road. Note deep gully of Big Hollow Creek to right.
66.9	0.5	Junction with north-south blacktop road. Turn right and cross Big Hollow Creek, STOP 1.

STOP 1 (1 hour): BIG HOLLOW CREEK SECTION. At this stop we will examine both the Barnum and Bloomer Creek beds; these can be seen in the creek bed below the small farm north of the creek. The Barnum Creek bed is thin, but characterized by abundant flattish to ovoid hiatus concretions which are encrusted by <u>Cladochonus</u> and small bryozoans. The Bloomer Creek bed occurs about 150 feet upstream from the lower discontinuity and 12 feet higher in the section. This 8-inch-thick mudstone bed has numerous small corals (*Pleurodictyum*, *Stereolasma*) which are commonly attached to phosphatic nodules and hiatus concretions. Above this unit is 25-30 feet of dark-gray and black shale. In a borrow pit upstream from the road crossing, the black shale grades upward to calcareous mudstone marking the base of Jaycox-equivalent King Ferry Member. Return to vehicle.

67.0	0.1	Turn around on blacktop road and turn left (east) on Swick Road.
68.3	1.3	Junction with New York Route 89. Turn right (south).
70.6	2.3	Turn right (west) by sign for vineyard onto gravel farm road.
70.8	0.2	Park by farmhouse at end of road. STOP 2.

STOP 2 (1 hour and 20 minutes): BLOOMER CREEK SECTION. We will walk north for 1500 feet, crossing the main branch of Bloomer Creek to a more accessible section on its northern tributary. At this section we will observe the Mack and Bloomer Creek beds below the small waterfalls and study basal Moscow beds both at and slightly above the falls. This is one of the northernmost sections at which the Mack Creek bed can be observed. The Bloomer Creek bed occurs 8 feet above this unit; it is rich in brachiopod and molluscan debris and hiatus concretions are common; these display abundant epizoans.

The Tichenor Limestone Member occurs in the recess under the falls; it yields abundant pelmatozoan material including articulated crinoids. The Menteth and overlying Kashong Members occur upstream from the falls. Fossils are plentiful in the Kashong sequence, and they can be easily extracted from the *Rhipidomella-Centronella* Bed. The phosphatic pebble bed of the upper Kashong is inconspicuous, but it yields phosphatic pebbles and occasional phosphatic brachiopod and trilobite steinkerns. Return to vehicle and proceed back to main road.

71.0	0.2	Junction with New York Route 89. Turn right and proceed south
71.2	0.2	Park vehicles in open area above high falls on Barnum Creek. STOP 3.

STOP 3 (2 hours, lunch first before examining the rocks): BARNUM CREEK, UPPER LUDLOWVILLE SECTION. We will proceed around the waterfall, which is capped by the Menteth Member, and reach the creek by a safer downstream route. Wading up the creek, we will examine, in order, the Barnum Creek bed, Mack Creek bed, and Bloomer Creek bed. This is a classic complete profile shown schematically in Figure 2. Both the Barnum and Bloomer Creek beds yield a rich, shelly biota and numerous hiatus concretions. The disontinuities overlie intervals of mudstone bearing numerous *in situ* concretions which are the erosional source of hiatus concretions. Of particular interest is the occurrence of reworked, prefossilized conulariids in the Barnum Creek bed. Moreover, large differentially bored hiatus concretions occur in the Bloomer Creek bed; these show intense *Trypanites* borings on their upper surface and no boring underneath (Figure 6A). The nodules have different epizoan assemblages on their upper and lower surfaces, indicating development of microhabitats along their exterior. Return to vehicles.

71.4	0.2	Rejunction with New York Route 89. Turn left (south).
73.3	1.9	Turn left (east) on road to Sheldrake.
73.8	0.5	Turn right (south) and proceed to farm above high falls on Sheldrake Creek.
73.9	0.1	Park vehicle and walk to STOP 4.

STOP 4 (45 minutes): SHELDRAKE CREEK, LOWER MOSCOW CONDENSED STRATIGRAPHIC SECTION. The Tichenor-basal Windom interval is represented by only 17-18 feet of section. The Deep Run Member is only 4.5 feet thick as opposed to 10 feet at Stop 2. The Menteth Limestone is thin and irregular in this section, and the *Rhipidomella-Centronella* bed of the Kashong Member is juxtaposed on it. The Tichenor Member is represented by a massive calcarenitic ledge with a sharp basal contact with the Ludlowville. Medial King Ferry beds will not be examined here, but the Mack Creek bed and the Bloomer Creek bed are both visible in the creek bank below the falls. Return to vehicles.

74.0	0.1	Junction with Sheldrake Road. Turn left (west).
74.5	0.5	Junction with New York Route 89. Turn left (south) and return to Binghamton.
134.6	60.1	Return to Holiday Inn. End of trip.
Return from Locs. 1-4		OPTIONAL STOP 5
94.5	0.0	Start at junction of New York Routes 13-34 and 96 in Ithaca, proceed north on Route 13-34.

96.5	0.2	Junction of New York Routes 13 and 34. Turn left (north) and proceed on Routes 34.
101.1	4.6	Junction of New York Routes 34 and 34B in South Lansing. Turn left (west) on Route 34B.
101.8	0.7	Turn left (southwest) on Portland Point Road.
102.1	0.3	Entrance to Penn Dixie Cement Corp. Portland Point quarry on left. The Tully Formation (limestone) is quarried here, and the uppermost beds of the Moscow Formation (Windom Shale) are exposed. For description of this locality see Grasso (1970) N.Y.S.G.A. field trip D and H, Stop 9. An excellent Tully-Windom exposure is developed to the right of the road in Minnegar Brook.
102.4	0.3	Salt mine to right. The Morton Salt Company is mining salt from the Salina Group (Upper Silurian).
102.8	0.4	Arrival at Portland Point at the mouth of Gulf Creek. Stop vehicles and proceed on foot.

STOP 5a (25 minutes): PORTLAND POINT TYPE SECTION (see Figure 4). It occurs in a railroad cut along Cayuga Lake shore 300 feet south of entrance to Gulf Creek. There is noticeable southward dip to the strata so that 10-15 feet of uppermost King Ferry is visible below the Portland Point; the Portland Point-Kashong interval descends to railroad level over a 100-150 foot distance.

Originally, the Portland Point was described as including 9.0-9.5 feet of calcareous strata with a prominent calcarenite bed at the base and shell-rich limestone at the top (Cooper, 1929, 1930). The Portland Point is now redefined to include only the calcarenitic (Tichenor-equivalent) bed and overlying 2-foot muddy, Deep Run-Menteth equivalent limestone (Baird, 1979). 5.5 feet of succeeding beds are assigned to the Kashong Member. A prominent calcareous siltstone bed believed to be equivalent to the phosphatic pebble bed to the west occurs 8.5-9 feet above the base of the Moscow Formation; this may have been the top marker bed of Cooper's Portland Point section.

This bed occurs about one foot below a calcareous siltstone bed marking the base of the Windom. Above the base of the Windom are numerous Windom brachiopods including *Athyris spiriferoides*, *Ambocoelia umbonata*, and chonetids.

STOP 5b (20 minutes): SHURGER FALLS. We now walk back north to the mouth of Gulf Creek. Proceeding east (upstream) for 100-150 feet we come to Shurger Falls. The Portland Point is now at much higher elevation, capping the 40-50 foot waterfall. We will not climb the falls but will collect fossils from loose blocks which have fallen down.

103.8	1.0	Return to vehicles and proceed back to junction with New York Route 34B.
111.1	7.3	Return to starting point at junction of New York Routes 13-34 and 96 in Ithaca.
150.3	39.2	Return to Holiday Inn, Vestal, New York. END OF TRIP.