Trip B-4

PALEOENVIRONMENTAL GRADIENTS ALONG A RAMP TO BASIN TRANSITION IN THE MIDDLE DEVONIAN LUDLOWVILLE FORMATION OF CENTRAL NEW YORK STATE

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INTRODUCTION

The richly fossiliferous Middle Devonian Hamilton Group strata of central New York State form a natural laboratory for the study of paleoecology and the relationship of organisms to paleoenvironmental changes during cycles of varying magnitude. Indeed, these rocks have formed the basis for numerous detailed studies about paleoecology (including; Brower, 1987; Bower and Nye, 1991; Brett et al., 1990). These studies have focused largely on vertical gradients of faunal replacement and make a tacit Waltherian assumption that the vertical relationships seen in medium and small-scale cycles within the Hamilton Group reflect lateral changes; however, it is rarely possible to actually test this assumption. Much of this recent work has been framed in the context of sequence stratigraphy and the presence of small-scale sequences and cycles in central New York State this forms part of the basis for our somewhat revised model of siliciclastic-carbonate depositional sequences in foreland basins (see Brett and Baird, 1996).

The Middle Devonian Ludlowville Formation in the eastern Finger Lakes region provides a particularly excellent opportunity for examination of these issues (Brett et al., 1986). The rocks are relatively simple structurally, and are well-exposed in numerous creeks and shoreline bluffs along Owasco, Skaneateles, and Otisco lakes (Owasco, Skaneateles, and Spafford 7.5'quadrangles). These lakes, with relatively northwest-southeast orientation oblique to facies strike, provide natural cross-sections across rapid facies changes particularly within units of the lower Ludlowville Formation. Those units, comprising the Chenango - Centerfield succession and the overlying Otisco Member, are the subject of the present study. In particular, we focus upon the lowest 2-3 cycles of the Ludlowville Formation, consider their sequence stratigraphic context and mode of origin, and describe an unusually steepened gradient within one of these units, the Stag Horn Point submember of the Otisco Member. Together, these units provide insights into both vertical and lateral changes in benthic marine fossil assemblages that are a response to relative water depth as well as variations in sedimentation. We begin with an overview of the physical and sequence stratigraphy of the Chenango to lower Otisco interval and then focus on the details of the Stag Horn submember in the region of Skaneateles and Otisco lakes. The result of this study is a fairly detailed description of lateral as well as vertical gradients of faunal change during the deposition of this interval.

GEOLOGIC SETTING

The rocks under study in this report belong to the Middle Devonian Hamilton group and are of Middle Givetian age (*timorensis* to *rhenanus-varcus* conodont zones). This interval is estimated to be about 383 million years old. The total interval may represent a bit over half a million years based on the inference that it includes the base of one large third-order sequence, the Ludlowville Formation sequence, as well as portions of two smaller fourth- and fifth-order cycles. Hamilton group sediments were deposited in an active foreland basin as debris eroded from the rising Acadian highlands during the pronounced second tectophase (collisional pulse) of the Acadian Orogeny during the latest Eifelian (Fig. 1; Ettensohn 1998; Kaufmann 2006). The foreland was presumably created by thrust loading in the orogenic belt to the east-southeast, and the basin underwent various episodes of movement during this time (Fig. 1). These are viewed as far-field tectonic responses to Acadian thrust loading and probably included reactivation of older basement faults, which was particularly notable during deposition of the upper Hamilton and Tully intervals in New York (Heckel 1973). During deposition of the Ludlowville Formation, progradation of clastics into the foreland basin appears to have been particularly active, resulting in successively more westwardly migrating packages of coarser silts and silty mudstones through the course of deposition of the unit. This is a fact of some consequence to the present interpretations. It appears that major regressive or falling stage intervals triggered progradational pulses, which brought silt to the approximate meridian of present day Otisco and Skaneateles lakes during deposition of the lower Ludlowville sediments, and to the vicinity of Cayuga Lake by the end of Ludlowville deposition. These siliciclastic silts formed relatively shallow, somewhat wave influenced platforms and pass westwardly into the subsiding center of the Appalachian foreland basin, which may have been located in the Cayuga to Seneca valley region during this time (Fig. 1).

In some cases, rapid progradation and/or minor synsedimentary tectonic adjustment on faults may have resulted in over-steepening of prograded clastic wedges, which in turn fostered submarine erosion. Such a case is suggested by the details of the so-called “Stag Horn Platform”, a 10 m-thick, upward-coarsening mudstone to siltstone package that is capped with concretionary, heavily bioturbated silts.

The supply of siliciclastics into the Acadian foreland may have been interrupted periodically by intervals of relative sediment starvation. A plausible explanation for such intervals is rapid rises in sea level, and subsequent flooding of bays and estuaries producing coastal clastic traps and resulting in strong curtailment of siliciclastic sedimentation in offshore settings. Conversely, periods of sea level drop may have triggered more rapid progradation of sediments and led in some cases to unstable conditions.

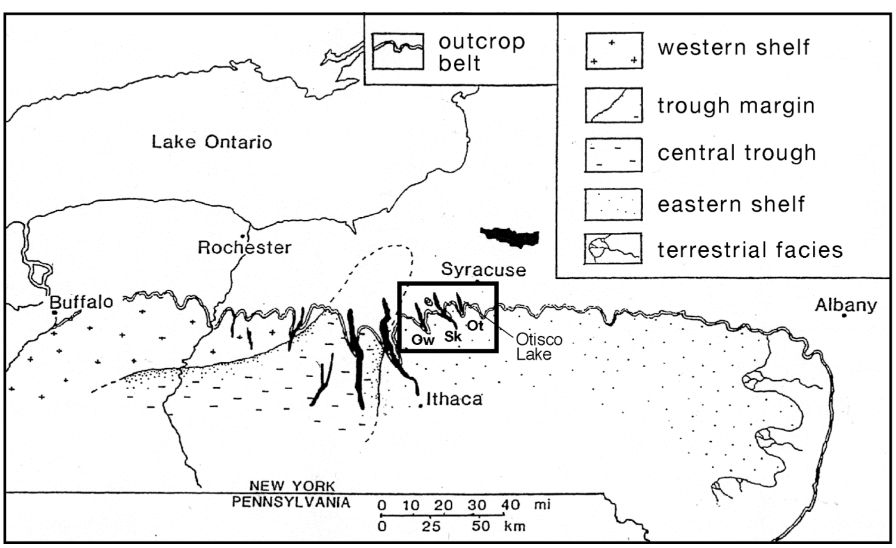

FIGURE 1—Generalized map of New York State showing paleogeography for middle Givetian time, during Ludlowville Formation deposition. Note position of deltaic shoreline and main axis of foreland basin. Study area indicated with box; eastern Finger Lakes initialed: Ow: Owasco Lake; Sk: Skaneateles Lake; Ot: Otisco Lake. Dashed line indicates projected position of Appalachian basin north of the outcrop belt.

Benthic marine communities responded in various ways to changing water depth and sedimentation patterns. Deeper areas of the Acadian foreland basin were occupied much of the time by dysoxic to anoxic water conditions, resulting in deposition of dark, poorly burrowed to laminated shales with monospecific, low diversity assemblages, dominated by the brachiopod *Eumetobolotoechia* and styliolines. Intermediate depth ramp environments, represented by medium to dark gray claystone and mudstone facies, were populated by moderate diversity assemblages of medium to small brachiopods, bivalves, trilobites, small rugose corals and other invertebrates. Shallow shelf areas were populated, during times of low sedimentation, by diverse assemblages of rugose and tabulate corals, bryozoans, brachiopods, and crinoids. Conversely, under higher sedimentation regimes the comparable depth zones favored lower diversity assemblages of brachiopods, such as *Mucrospirifer* and *Tropidoleptus*, and large bivalves. Generally, these biofacies relationships have been inferred from vertical successions of biotic replacement. In the case of the Stag Horn Point submember, however, a faunal gradient is more directly observable because of abrupt lateral facies changes along a rather well-constrained time parallel surface.

PHYSICAL STRATIGRAPHY

The units considered herein are presently assigned to the uppermost portion of the Skaneateles Formation and lower Ludlowville Formation of the Middle Devonian (Givetian) Hamilton Group (Fig. 2).

Butternut and Chenango Members, Skaneateles Formation

The upper Skaneateles Formation is comprised of the Butternut Member, dark gray to nearly black, platy silty shale that carries a sparse to abundant low diversity fauna dominated by the rhynchonellid brachiopod *Eumetabolotoechia multicostum*. The upper portion of the Butternut Member becomes increasingly silty and carries thin beds, typically around 1-2cm, of tabular, laminated siltstone. In some localities east of the study area, thicker siltstone bundles form two minor cycles within the Butternut Member.

The dark, silty upper Butternut Member shales are abruptly and perhaps disconformably overlain by a distinctive shell-rich bed, which was defined as the base of the Centerfield Member by Gray (1986) and subsequently redefined as the base of the Chenango Member of the Skaneateles Formation by Bartholomew et al. (2006). This bed, the Peppermill Gulf Bed (Figs. 2, 3), is somewhat calcareous, blocky mudstone typically about 30-50 cm thick and carries an exceedingly rich fauna of brachiopods, bryozoans, crinoid debris, small- to medium-sized corals, bivalves, and trilobites. This bed shows a marked contrast to the sparsely fossiliferous upper portion of the Butternut Member. The Peppermill Gulf Bed, in turn, is overlain by 4-5m of medium gray slightly silty mudstone that locally carries a moderate fauna of ambocoeliid and chonetid brachiopods, auloporid coral thickets and other faunal elements typical of deeper, slightly dysoxic facies. However, *Eumetabolotoechia* is rare in these beds. Two richer horizons occur near the top of this interval that appear to correspond to the Salt Creek and Browns Creek beds of western New York State (see Savarese et al., 1986). These horizons are calcareous siltstones or silty mudstones that carry a rich fauna typified by atrypid brachiopods and the distinctive pearly brachiopod *Pholidostrophia nacrea*, which also characterizes this interval throughout western New York State. In some areas, abundant proetid trilobites also occur at the level of the Browns Creek horizon as they do in the calcareous facies of the same level in the west. These beds occur at a relatively marked change from mudstone into siltstone that tends to coarsen upward through the remaining 9-10m of the Chenango member. Most of these beds are sparsely fossiliferous and contain a fauna rich in the brachiopod *Tropidoleptus*, along with locally abundant bivalves and the large spiriferid brachiopod *Spinocyrtia* , which occurs in in-situ clusters in some horizons. To the west, this interval also yields rugose and tabulate corals and appears to thin markedly and merge westward into an interval referred to as the Triphammer Falls beds (Saverese et al., 1986) in the Genesee Valley; this is a coral biostrome, generally less than a meter in thickness. The hard upper beds of the Chenango Member, composed of siltstone and sandstone, typically form the caps of waterfalls and a bench in the stream bed.

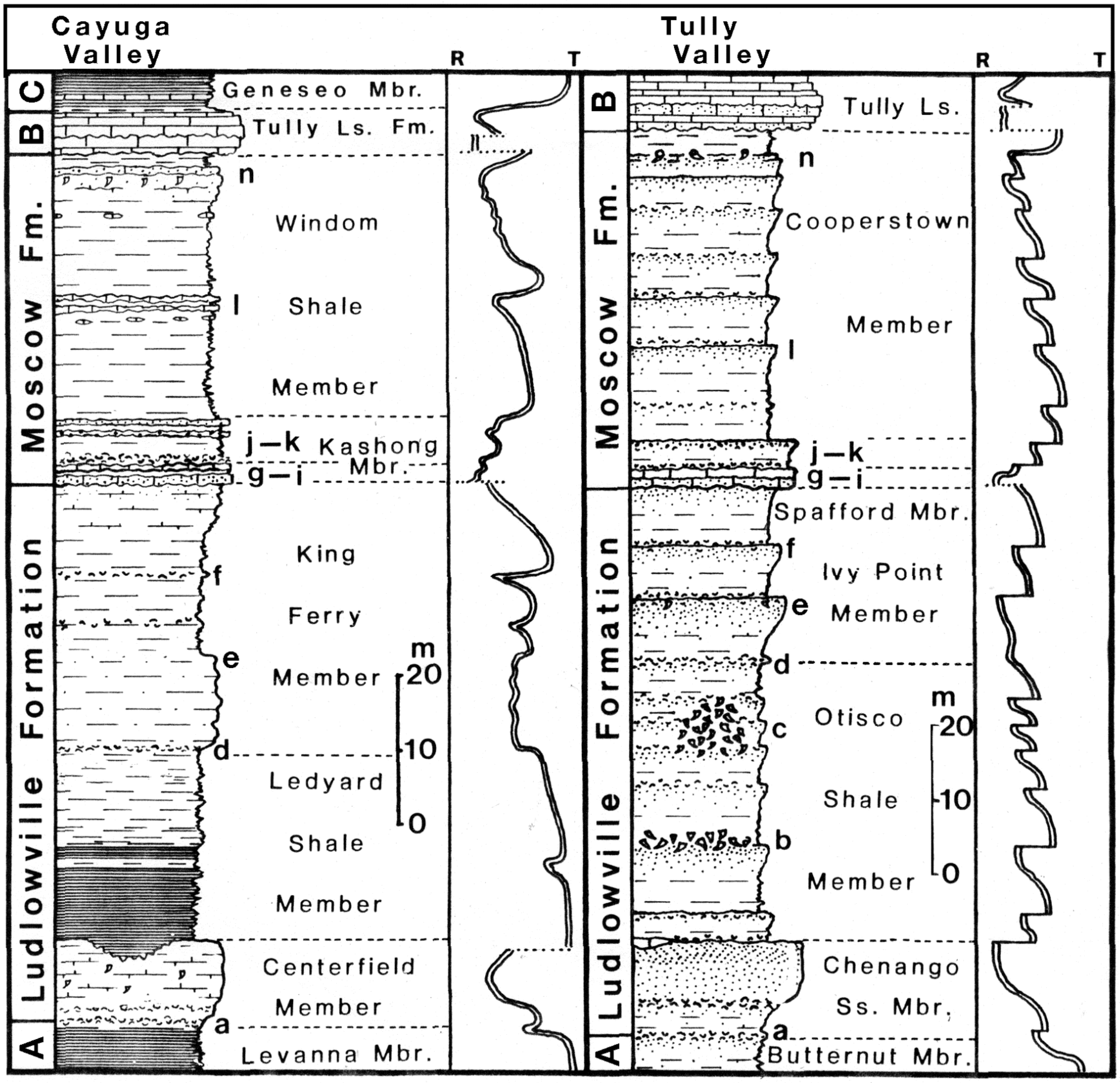

FIGURE 2—Lithostratigraphy and relative sea-level curve for the upper Hamilton Group in the Cayuga Lake and eastern Finger Lakes area. Lettered bed levels are as follows: A) Skaneateles Formation; B) Tully Formation; C) Genesee Formation; a) Peppermill Gulf bed; b) Stag Horn Point coral biostrome; c) Joshua coral biostrome; d) Mt. Vernon (Elmwood Point) bed; e) Ensenore Ravine shell/coral bed; f) Bloomer Creek shell bed; g-i) Portland Point Member= g) Tichenor Ls., h) Deep Run Shale, i) Menteth Ls.; j) RC shell bed; k) Barnes Gully bed; l) Bay View shell bed; n) South Lansing shell bed.

Centerfield Member

The Chenango Member is capped by an interval typically about 0.5 m-thick which is heavily bioturbated and shows exquisite spreite structures of the trace fossil *Zoophycos* (Figs. 2,3) Amidst these burrows are occasional large tabulate corals (i.e.: *Favosites*) up to 1.5 m in diameter. Locally this interval merges into or is overlain by skeletal grainstones containing abundant corals and crinoid debris up to several centimeters in thickness referred to in the Hamilton area as the Stone Mill Limestone Member. The Stone Mill is typically quite thin and discontinuous and this bed (or correlative disconformity surface) marks the base of the Centerfield Member of the Ludlowville Formation. This surface is sharply overlain by soft, highly fossiliferous, slightly silty mudstones presently assigned to the upper, or Halls Landing, submember of the Centerfield Member, named for exposures along the east side of Skaneateles Lake south of Hall Creek. The Halls Landing beds, up to about 3 m-thick, carry a very diverse fauna of brachiopods including large *Pseudoatrypa*, *Athryis*, *Mediospirifer*, *Megakozlowskiella*, *Fimbrispirifer*, *Strophodonta demissa*, *Megastrophia*, *Tropidoleptus*, and many others. These brachiopods are admixed with a rather diverse bivalve fauna characterized by *Actinopteria*, *Cornellites*, *Modiomorpha* spp. *Cypricardinia*, and *Cypricardella*. In some levels corals are relatively common and are particularly characterized by large specimens of the domical tabulate *Pleurodictyum*. Some beds carry scattered large rugosans, (*Heliophyllum*, *Cystiphylloides*, and *Heterophrentis*) as well as tabulates, including large favositids. The crinoid grapnel *Ancyrocrinus* is also abundant and large in the Halls Landing beds. The Halls Landing beds, in turn. are capped by a thin, highly fossiliferous coquina horizon carrying locally large rounded phosphatic pebbles, termed the Moonshine Falls Phosphate Bed for exposures along Paines Creek at Moonshine Falls on the east side of Cayuga Lake. This important bed marks the upper boundary of the Centerfield Member and the base of the Ledyard/Otisco members.

Ledyard Member

In the vicinity of Aurora on the east side of Cayuga Lake (Ledyard Township, Cayuga Co.), is the type section of the Ledyard Shale Member (Fig. 3A;Cooper, 1930). In this area, as typified by the section at Moonshine Falls, the Halls Landing Beds of the Centerfield Member are abruptly (disconformably) overlain by hard, strongly jointed dark platy shales that carry a low diversity fauna including small nuculid bivalves, the brachiopod *Eumetabolotoechia*, and gastropods including *Paleozygopleura*. A few higher beds are more diverse. For example, one horizon, approximately 14 m above the Moonshine Falls Bed, locally yields abundant ambocoeliid brachiopods in a fossil debris (“hash layer”); this horizon may correlate eastward to the Stag Horn Point submember of the Otisco Member (see below). Similar more fossiliferous medium gray mudstone horizons occur at at least two other levels within the Ledyard Member, perhaps corresponding to the Glen Cove and Joshua submembers of the Oticso Member. Ledyard deposits at the Cayuga Valley range from 15 m in thickness near Romulus to the northwest to about 40 meters at Aurora to the southeast; these dark shales pass westward into predominantly gray mudstones in the Genesee Valley-Erie County region. In this area, the Ledyard typically is marked by a horizon of abundant pyrite (Alden Pyrite Bed) within 10 m of its base and a dark gray to black interval near the middle subdividing the Ledyard into the Alden and Elma submembers of McCollum (1982).

Otisco Member

The Ledyard Member passes laterally within a relatively short distance (~20 km) into highly fossiliferous, medium gray, silty mudstones, assigned to the Otisco Member (Figs. 2, 4). The Otisco Member makes its westernmost appearance at Portland Point near the south end of Cayuga Lake where the Fir Tree anticline brings the upper beds of this interval into view; these beds are rich in the brachiopods *Athyris*, *Mucrospirifer*, chonetids and others. These beds have already undergone the transition to Otisco facies although they are only about 35 km due southwest of the type Ledyard Shale.

Exposures in the northern portions of the Owasco and Spafford quadrangles show a dark, more fossiliferous facies characterized by an increased abundance of *Eumetabolotoechia*. However, to the south-southeast, particularly in outcrops along stream gullies and bluff exposures along Owasco, Skaneateles and Otisco Lakes, the Otisco Member becomes increasingly fossiliferous. It was divided into component submembers by Smith (1935).

Owasco Lake exposures show transitional facies between typical Ledyard and Otisco shale. In this area, the lower 30 m and the middle shales are dark, platy, and carry an abundance of the brachiopod *Eumetabolotoechia multicostum*. However, other horizons, particularly 30 m or more above the base, have already passed into gray mudstones with abundant brachiopods, typified by *Athyris*, and bivalves, especially *Modiomorpha subalata* and *Cypricardella bellistriata*. Certain horizons yield an abundance of the small rugose coral, *Stereolasma rectum*.

The lower (Stag Horn Point) submember comprises about 8-10 m of gray mudstone with scattered small ellipsoidal concretions (Fig. 2, 4). Immediately overlying the Halls Landing Beds, the interval is fossiliferous and contains a great abundance of the small brachiopod *Arcuaminetes scitulus.* Occasional horizons bear large brachiopods, such as atrypids and *Athyris*, and even small rugosans. These shales pass upward into the darkest portion of the interval, which still yields moderately abundant *Eumetabolotoechia*; this interval, in turn, shows a coarsening-upward pattern into silty mudstones and siltstones that typically cap a small bench-forming often referred to as “the Stag Horn platform”. The siltstone, like the upper portion of the underlying Chenango

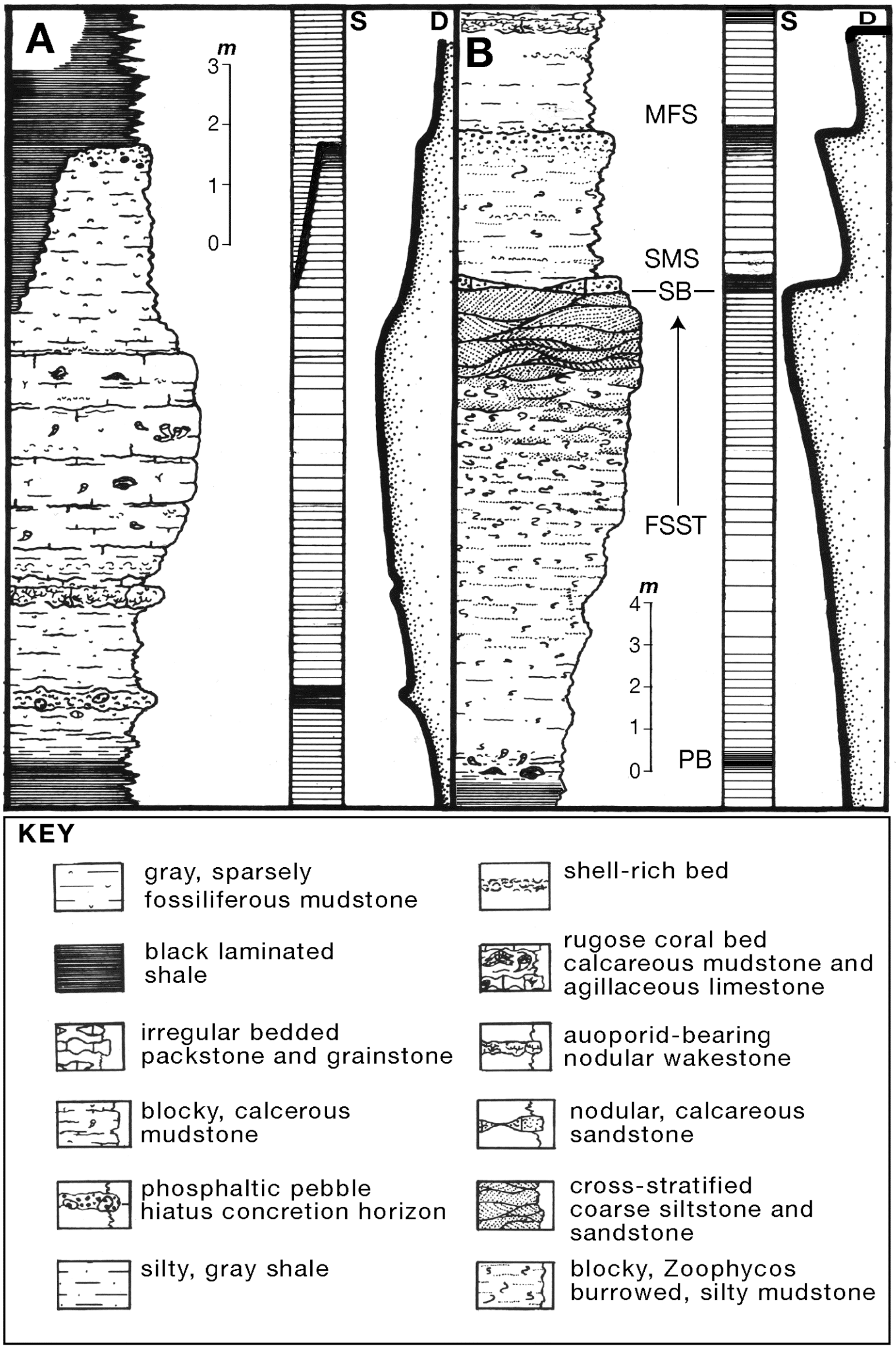

FIGURE 3—Details of the Chenango-Centerfield interval of the upper Skaneateles-Ludlowville Formation boundary in: A) Carbonate rich facies of Seneca-Cayuga Lake area; B) coarser siliciclastics of eastern Finger Lakes area. Bar scales next to columns show spacing of hypothetical equal time units; note condensation shown by tight spacing. PB: precursor bed; FSST: falling stage; SB: sequence boundary; SMS: surface of maximum starvation; MFS: maximum flooding surface. S= shallow; D= deep on relative sea-level curves.

Member, is heavily bioturbated with *Zoophycos* which show excellent spreiten structures. The upper part of the siltstone carries occasional imbedded rugose corals and small phosphatic nodules, and, indeed, a phosphatic nodule and corroded coral layer typically mantles the Stag Horn siltstone bench. The bench in turn is overlain south of Stag Horn Point and in outcrops to the east-northeast to the Oran quadrangle by a biostrome up to 2m thick of densely packed corals dominated by the rugosans *Heliophyllum*, *Cystiphylloides*, and *Siphonophrentis*. This biostrome, the Stag Horn Point Coral Bed (*sensu* Smith, 1935; Oliver, 1951), is well exposed along the eastern shore of Skaneateles Lake from Stag Horn Point south for about a kilometer to Willow Point. To the north of Stag Horn Point, this interval abruptly changes to an interval of individual thin coral beds, separated by mudstone intervals with occasional tabular siltstones. Corals here occur in wedge and pod-shaped accumulations up to a meter thick but thinning laterally over a few 10s of meters into single 5-10 cm coral horizons. The basal horizon typically carries abundant phosphatic pebbles. This succession is described in more detail below. Creek exposures of the lower Otisco Shale to the north-northwest of the Stag Horn Point area show a subtle coarsening-upward pattern. Dark shales, rich in *Eumetabolotoechia* grade upward into *Zoophycos*-churned silty mudstones, which in turn appear to be capped with shell-rich horizons containing a particular abundance of *Athyris* brachiopods and the small rugose coral *Stereolasma*; rare phosphate nodules have been observed in the shales immediately overlying the bioturbated silty mudstones.

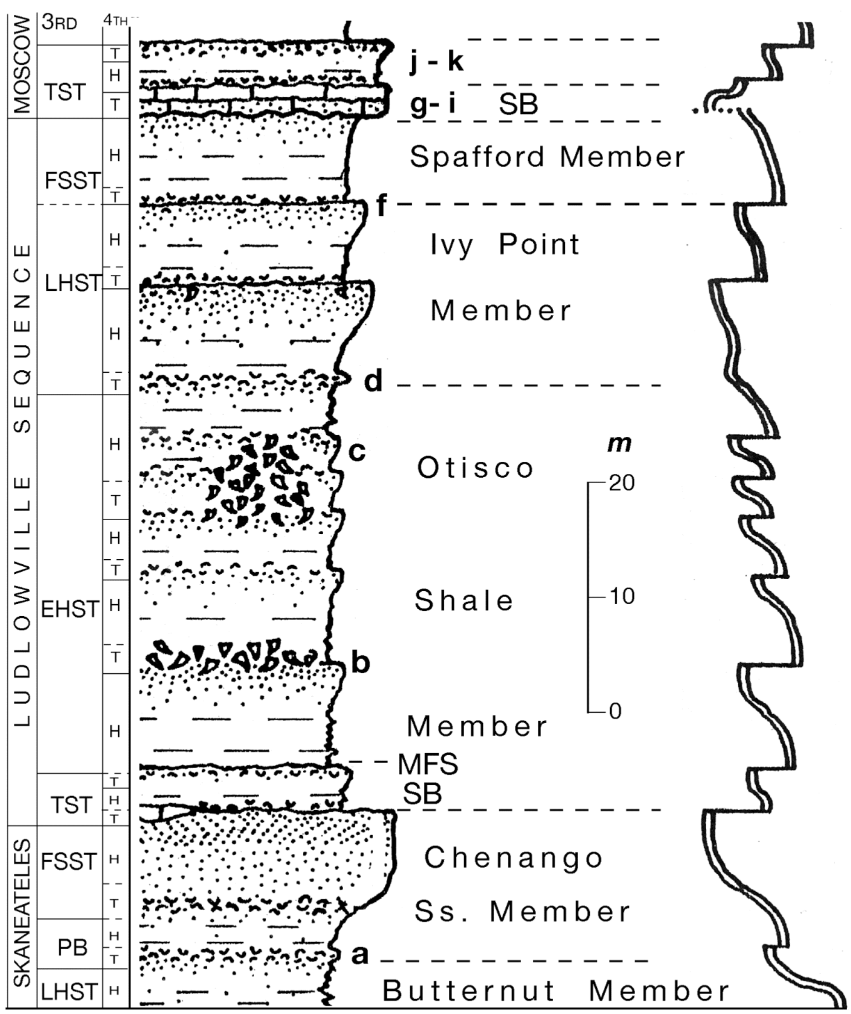

FIGURE 4—Physical and sequence stratigraphic interpretation of Butternut–Chenango-Centerfield –Otisco interval in the study area. Systems tracts for 3rd order (3rd) sequences/formations: TST: transgressive; EHST: early highstand; LHST: late highstand; PB: precursor bed; FSST: falling stage (regressive). Systems tracts for 4th order (4th) sequences; T: transgressive lag; H: highstand-regressive. SB: sequence boundary; MFS: maximum flooding surface.

Approximately 4 meters above the Stag Horn equivalent shell beds in many localities around Skaneateles and Owasco lakes, a second bench-forming silty mudstone interval is overlain by another set of *Athyris* brachiopod- and *Stereolasma* coral-rich horizons. This bed is referred to herein as the Glen Cove shell bed. As with the underlying Stag Horn Point interval, shell horizons may be scattered through approximately one meter of section overlying the silty bench-forming beds. About 3-4 meters higher is yet another subtle bench, that is never associated with a major siltstone (Fig.4). This, is in turn overlain by a variable interval up to 10m thick at Ten Mile Point Ravine at Skaneateles Lake but as little as a few centimeter in thickness in other sections, that carries abundant large rugose corals, as well as *Stereolasma*, *Athyris*, *Pseudoatrypa*, strophomenids, and other diverse brachiopods. This coral-rich division, up to 10m-thick at Ten Mile Point Ravine at Skaneateles Lake but as little as a few centimeter in thickenss in other sections, is referred to as the Joshua submember for exposures along Rte. 80 at Lords Hill near Joshua, in the South Onondaga quadrangle where corals are found in a road-side ditch through approximately 25m of section (Grasso 1970). The uppermost Otisco interval is composed of fossiliferous silty mudstones that carry an abundant shelly fauna including particularly toward the top abundant *Tropidoleptus*, *Athyris*, and atrypid-rich shell beds. The Otisco Member, as does the Ledyard Member, terminates at a silty, blocky mudstone horizon referred to as the Elmwood Point bed. This shell bed has been shown to correlate westward with Grabau's (1898-1899) *Strophalosia* (or *Truncalosia*) bed, referred to as the Mount Vernon bed by Kloc (1983). This forms the base of the Wanakah Member in the west and the Ivy Point Member in the east.

SEQUENCE STRATIGRAPHIC INTERPRETATION

Sequence stratigraphy constitutes a predictive framework for interpreting the sea-level and sedimentational history of the the Devonian strata (see Coe, 2004 and Cateneanu, 2002 for recent summaries). The entire Ludlowville Formation, from the upper (post Chenango) portion of the Centerfield Member, upward to the base of the Tichenor Limestone is considered to record a single third-order (~1-2 myr) depositional sequence (Fig. 3B). The underlying Butternut Member is considered to represent the terminal stages of the highstand portion of the Skaneateles third-order sequence, and is the highstand of an internal fourth-order sequence that begins with a stacked set of shell-rich beds termed the Marietta Beds by Baird et al. (2000). The abruptly upward-coarsening succession of the Chenango Member is regarded as a third-order falling stage (regressive) systems tract.

As noted above, in central New York the base of the Chenango is marked by up to 50 cm of highly fossiliferous mudstone (Figs. 2-4), the Peppermill Gulf bed of Gray (1991). Near Cayuga Lake, the Peppermill Gulf Bed locally carries reworked concretions encrusted with auloporid corals and bryozoans that have been exhumed due to erosion of the upper Butternut Member (Gray, 1991). The Peppermill Gulf Bed passes westward into a thin (1-2cm) pavement of ambocoeliid and other brachiopods that lie sharply on black upper Levanna Shale (Butternut equivalent) shales.

The Peppermill Gulf Bed is a "precursor bed" (*sensu* Brett and Baird, 1996; Fig. 4). By this term, Brett and Baird implied a bed showing: a) faunal/ sedimentological evidence of abrupt shallowing, with b) a sharp contact on underlying beds, a facies discontinuity between that bed and underlying strata, and c) significant condensation within the bed. The precursor bed concept suggests that this type of horizon represents the initiation of the falling stage, i.e. first surface of forced regression. As sea level drops abruptly during this phase, the sea floor comes into increased storm wave action, which serves to erode older muds. Interestingly, the initial portion of the forced regression is marked by condensation, whereas later portions are associated with increased progradation of siliciclastic sediments. Brett and Baird (1996) attributed this condensation to the disequilibrium conditions that followed relatively abrupt lowering of sea level. The sharp basal erosion surface may involve storm erosional bypass along a west-facing paleoslope without replacement of sediment during the initial period of drop prior to progradation, possibly coupled with a certain degree of subaerial accommodation associated with re-grading of stream channels during this time. At another scale of process the precursor bed may represent the transgressive lag deposit of a smaller, higher-order sequence and it is clearly overlain by finer grained sediments that signal a return to deeper conditions, though not as deep as those of the underlying succession (Fig. 4). These beds, reflecting the highstand of a fourth-order sequence, show an abrupt upward change into a shallowing- and coarsening-upward succession that marks the later portion of the falling stage or regression. In essence, the falling stage of a fourth-order cycle is superimposed on the falling stage of a third-order cycle to yield a very abrupt and rapid progradation.

Correlation of the Chenango Member into western New York sections shows that it corresponds to a small portion of the "lower Centerfield" cycle (Savarese et al., 1986; Fig. 3). Moreover it is clear that in the western portion of the state, this interval was relatively turbidity-free, allowing for the growth of corals, whereas in central New York State, the large quantity of prograded silty sediments largely overwhelmed bottom communities giving rise to lower diversity assemblages with *Zoophycos*-producing deposit feeders, bivalves, and quasi-infaunal brachiopods as the dominant elements. The sparse, but well-preserved fossils within the Chenango Member suggests rapid sedimentation and an absence of time averaging, as preservation of patchy, in-situ organisms (such as clusters of *Spinocyrtia* in life position), suggests rapid burial of a sea floor mosaic. The shift to more calcareous siltstones with scattered corals in the upper meter or so of the upper Chenango Member suggests turn over of the depositional cycle from falling stage to either lowstand or early transgression (Figs. 3, 4).

In areas where the Stone Mill bed is developed, a condensed trangressive limestone, comparable to that of the Mottville and Tichenor members of the underlying and overlying formations is present. This shell-rich bed records the accumulation of skeletal material during a time of rising sea level (Figs. 3, 4), but still shallow water condition when seas were relatively free of siliciclastics as a result of the sequestering action created by the drowning of river mouths. Hence, the uppermost Chenango and Stone Mill are interpreted as early TST or lowstand deposits. The Halls Landing beds record later phases of transgression to near maximum flooding. During this time in still relatively shallow waters, seas remained rather free of siliciclastics, although an influx of muds had commenced. It is notable that this interval remains more uniform in thickness and facies across a major swath of western and central New York than does the lower Centerfield or Chenango, a consequence of the marked asymmetry in sedimentation rates of transgressive vs.regressive phasaes, in areas proximal to siliciclastic sources as opposed to western areas where siliciclastics failed to have as strong an impact, even during periods of overall regression.

In one sense, the entire upper Ludlowville Formation may be considered the highstand and falling stage of a third-order sequence (Fig. 4), but of course, this is a highly over simplified way of looking at the pattern. In fact, there are a number of fourth-order sequences that feature prominently within the upper Ludlowville Formation. In the Ledyard and Otisco members at least two and perhaps as many as three such sequences are present. The first begins with the upper Centerfield and Halls Landing beds and has a major flooding surface at the phosphatic Moonshine Falls bed. However, actual maximum flooding may occur somewhat higher, above a package of chonetid-brachiopod bearing shales. In the middle portion of the Stag Horn Point submember, dark platy shales with abundant *Eumetabolotoechia* probably signify the deepest and most dysoxic portion of the cycle.These beds grade upward abruptly into silty shales and mudstones and siltstones with *Zoophycos* churning, much like the underlying Chenango Member, and signify the late highstand or falling stage of the Stag Horn Point fourth-order sequence (Fig. 4). Obviously, shallowing triggered progradation of a local siliciclastic wedge well into the foreland basin, but it appears that during the time of the deposition of the "Stag Horn platform", there may have been some active tectonism in the basin which caused local steepening of the prograded wedge and initiated erosion. In a broad sense, the Stag Horn coral biostrome and its lateral equivalent shell beds record sediment starvation associated with initial transgression of the next overlying small-scale depositional cycle. The following succession shows a change upward into sparsely fossiliferous shales and these, in turn, into silty mudstones and siltstones that cap the Glen Cove submember.

THE STAG HORN POINT SUBMEMBER: A CASE STUDY IN SEA FLOOR DEPOSITIONAL PROCESSES AND FAUNAL GRADIENTS

As already noted, the Stag Horn Point cycle represents a probable fourth-order cycle of approximately 100-400 ka duration. It commences with Moonshine Falls, shelly beds formed during sea level rise, deepens upward into mudstones and shallows into siltstones. Where completely developed, bench-forming siltstone, approximately 3m-thick, occurs near the top of the cycle, immediately below the Stag Horn Point coral biostrome (Figs. 6, 7). Large, pyrite-cored concretions are abundant, particularly within its upper portion (0.5-1m below the upper contact). This interval is overlain sharply by the Stag Horn Point coral biostrome in the southern and eastern portion of the study region (Smith 1912, 1935; Oliver, 1951; Brett et al., 1986). As noted above, the biostrome and coeval transported debris are interpreted as having formed during a time of relative sediment starvation associated with sea level rise (Fig. 4).

FIGURE 5—Map of study area in the Owasco-Skaneateles-Otisco Lake region. Inset shows a portion of the Spafford 7.5' Quadrangle with key localities along east side of Skaneateles Lake; arrows denote unnamed coves between Jenney and Stag Horn Points, discussed in the text. Also note Glen Cove on west side of lake.

A remarkable series of outcrops occurs along the shore of Skaneateles Lake northwest from Stag Horn Point (Smith, 1912, 1935; Oliver, 1951; Brett et al., 1986; Figs. 5, 6). At Stag Horn Point, the full development of the siltstone platform with its sharp, concretionary top and overlying coral biostrome is in place. At the contact between the biostrome and the platform, the siltstone is heavily bioturbated by *Zoophycos* and carries corroded corals and phosphatic nodules, an indication of sediment-starvation and time-averaging. The phosphatic nodules include steinkerns of enrolled trilobites, trilobite cephala, conulariids, and other fossil objects, but most are amorphous, black fluorapatite or collophane. The occurrence of corals attached to phosphatic nodules is significant as it indicates that the period of phosphatic nodule growth preceded the development of the coral biostrome. Indeed, the phosphatic nodules formed interstitially within the upper portions of the underlying silts during a period of low sediment input and at a redox boundary; they must have been reworked as many of them are pebbles that have been smoothed, corroded, bored, and encrusted. Pebbles may have provided the initial substrates of the founding corals of the biostrome. However, coral skeletons soon provided a hard substrate for subsequent generations; a classic case for taphonomic feedback (Kidwell and Jablonski 1983). The upper portion of the coral bed appears to be rather abruptly overlain by sparsely fossiliferous gray mudstone. In places, the coral thicket shows horizons of concentrated corals that may represent periods of storm reworking.

Within the ~800m stretch between Stag Horn Point and Jenney Point a remarkable series of outcrops expose what appears to be the edge of the platform with down-draped, onlapping beds that represent locally transported debris shed from the platform edge (Figs. 5, 6). Exposures are poor immediately north of Stag Horn Point but minor outcrops on a bluff between cottages in this stretch along Chase Point show a fairly typically developed platform of siltstone overlain by coral biostrome. However, approaching the north edge of Chase Point, corals overlying the platform occupy a thinner interval. At the north edge of the small cove immediately north of Chase Point, the last portion of the normal platform is exposed with concretionary silts underlying the typical siltstone platform, which is nearly denuded of corals and immediately overlain by dark, middle Otisco Shale Fig. 6). Northward from this area, a gently sloping truncated platform edge occurs toward the middle of the cove with a slope of approximately five degrees representing a truncation surface that cuts down approximately 2-2.5m below the Stag Horn bench elevation. It is particularly notable that the beds in this area appear to dip in a northward direction counter to the regional dip (Fig.6). These beds include a series of packages of coral rich rubble (Fig. 6) of which the lowest, exposed typically below lake level of Skaneateles Lake, carries a corroded coral fragment and phosphatic pebble lag at its base and passes upward into about 2 cm of hummocky-laminated siltstone.

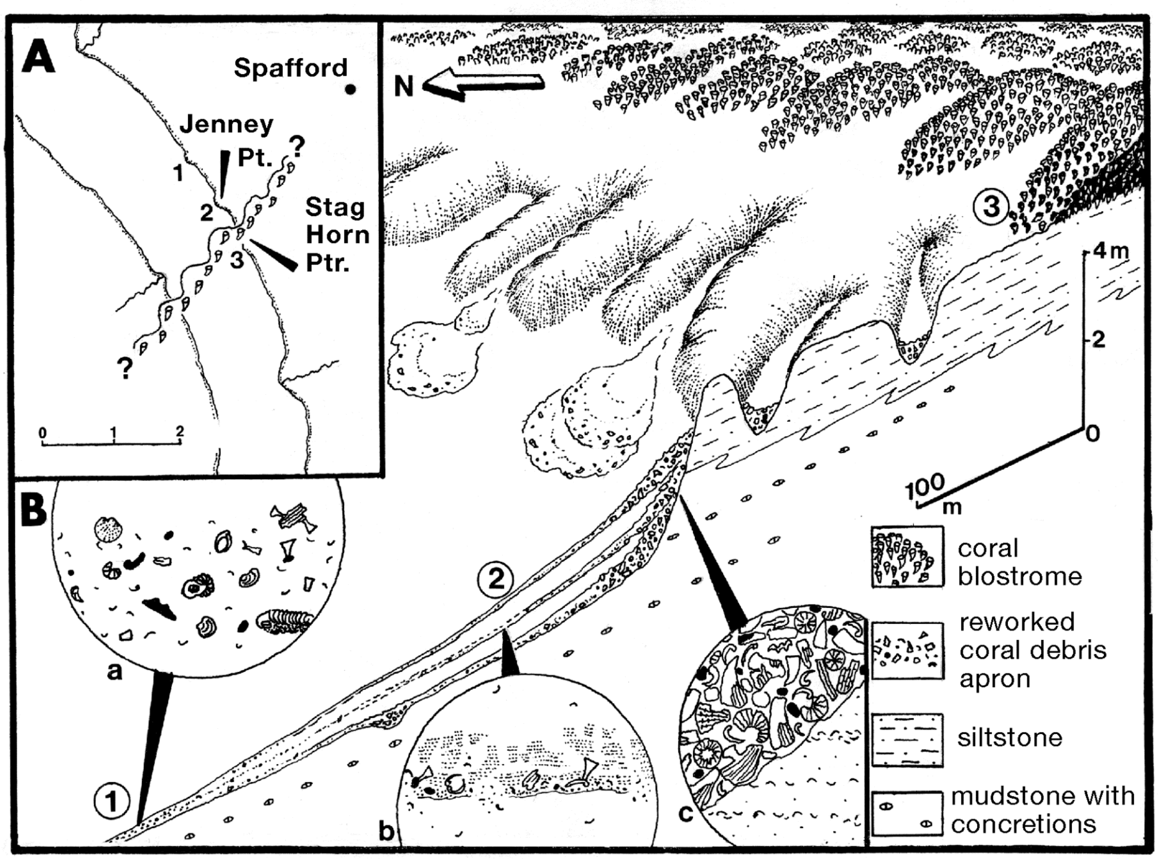

FIGURE 6—Schematic reconstructed cross section of truncated edge of Stag Horn Point siltstone platform as exposed along the east shore of Skaneateles Lake from Stag Horn Point northwestward to north of Jenney Point. Inset circles show details of sedimentary fabric along gradient: a) distal section showing bioturbated sediment with small corals, brachiopods and trilobites; note black phosphatic nodules; b) sharply based bioturbated siltstone bed; note small corals attached to phosphatic nodules; c) sharp contact between lower Otisco mudstone and base of coral debris apron. Modified from Brett et al. (1986).

A series of higher beds of siltstone and coral rubble alternate with more sparsely fossiliferous medium gray mudstone with scattered, transported, rugose corals (Fig. 6), as well as indigenous shelly fauna including athryid and chonetid brachiopods, *Greenops* and *Eldredgeops* trilobites, and others. The intervening beds include four siltstone layers that can be traced laterally along the shore line and appear to thicken toward the platform. Immediately adjacent to the base of the truncated platform is a thick wedge of packed corals. These appear to have been transported off the platform and have accumulated at its margin as a debris apron. The siltstone debris layers appear to finger out from this wedge and become separated by the aforementioned intervening gray mudstones. At the north end of this cove, a reverse pattern is observed where siltstone and coral debris layers rise upward onto the truncated edge of the platform again. It is unlikely that this reappearance of the edge of the platform is a result of the curvature of the cove since this area would, if anything, project outward and should be farther away from the platform edge. Conversely, it is probable that a spur of the platform edge extended out on the opposite side of a large channel-like feature that occupies much of the wall of the cove (Fig. 6). Extending into the next cove that lies to the southeast of Jenney Point, again, the reverse succession is seen. At the south end of this cove, the siltstone platform remains partially truncated; about 30m further to the south, the pyrite-cored concretions, which normally lie below the platform are directly overlain by coral rubble. In places, the coral rubble thickens to about one meter as the truncation surface runs downward from the pyritic concretions to nearly the level of Skaneateles Lake. Once again, a series of graded rubble beds and siltstones emanate from this region and extend out along the cliff in this cove. At the far north end, immediately adjacent to the southern cottage on Jenney Point, the edge of the platform again appears to be in sight and thickened rubble beds thicken out from it and slope gently to the south. Once again there is a suggestion of a large channel that is separating two spurs of an eroded platform edge.

The Staghorn Point interval is exposed in a large cliff, north Jenney Point but with no siltstone platform present (Fig. 6). Rather, a succession of gray mudstones with thin siltstones showing planar to hummocky lamination and coral fragments is present. Near the base of the succession, a horizon yielding abundant coral fragments and phosphatic nodules appears to be correlative with the base of the Stag Horn biostrome further up on the platform; a distinctive hummocky bedded siltstone band occurs slightly about this. From this region northward, the siltstone platform is no longer present and instead, the Stag Horn interval is represented by a 1.5m-thick succession of shell beds. As far north as Ten Mile Point Creek (~2.5 km north), the horizon of the Stag Horn interval still contains abundant phosphatic nodules as well as corroded and non-corroded corals, athyrid brachiopods and other fossils (Figs. 6, 7).

On the west side of Skaneateles Lake, the Stag Horn platform is nowhere visible, having dipped below the surface of Skaneateles Lake southward of the first exposures of the lower Otisco Member in Glen Cove ravine. At this section, the uppermost beds of the Halls Landing submember are exposed in low banks, followed by chonetid-rich shales. Approximately 10 m above this succession there occurs a thin, highly fossiliferous shell bed containing abundant brachiopods including *Athyris*, *Mediospirifer*, as well as small and large coral fragments. This clearly represents the Stag Horn biostrome position, although larger corals are only represented by scattered, corroded “biscuits” and are evidently allochthonous. Another resistant bench capped by abundant stereolasmatid corals occurs approximately 4m above the Stag Horn Point horizon occurs.

Northward to Carpenter Point at Bear Swamp Creek, the Stag Horn-equivalent bed maintains much of its character, with scattered corroded corals, *Athyris*, small stereolasmatid corals, as well as varied bivalves. At Fall Brook, ~ 1.5 km farther northwest, the bed is barely discernable as a thin series of *Athyris*-rich shell horizons with very rare stereolamatid corals. However, there are thin siltstones, possibly emanating from the eroding silty platform to the southeast, and at least one of these showed a small coral at its base as well as an articulated trilobite. Layers rich in columns of *Eutaxocrinus* also provide a link between this succession of the Stag Horn submember and those seen in outcrops along Owasco Lake (Fig. 7).

On Owasco Lake, the interval of the Stag Horn Point submember is present on several creeks, most notably Seward Point ravine on the east side, and Casowasco ravine on the west side; the latter outcrop has been slumped over in recent years and no longer exposes this interval. At both of these sections phosphatic nodules are rare, but shell pavements rich in *Athyris* and *Eumetabolotoechia* brachiopods are associated with abundant *Eutaxocrinus*, some of them preserved as clusters of articulated fossils. Both Casowasco ravine and Seward

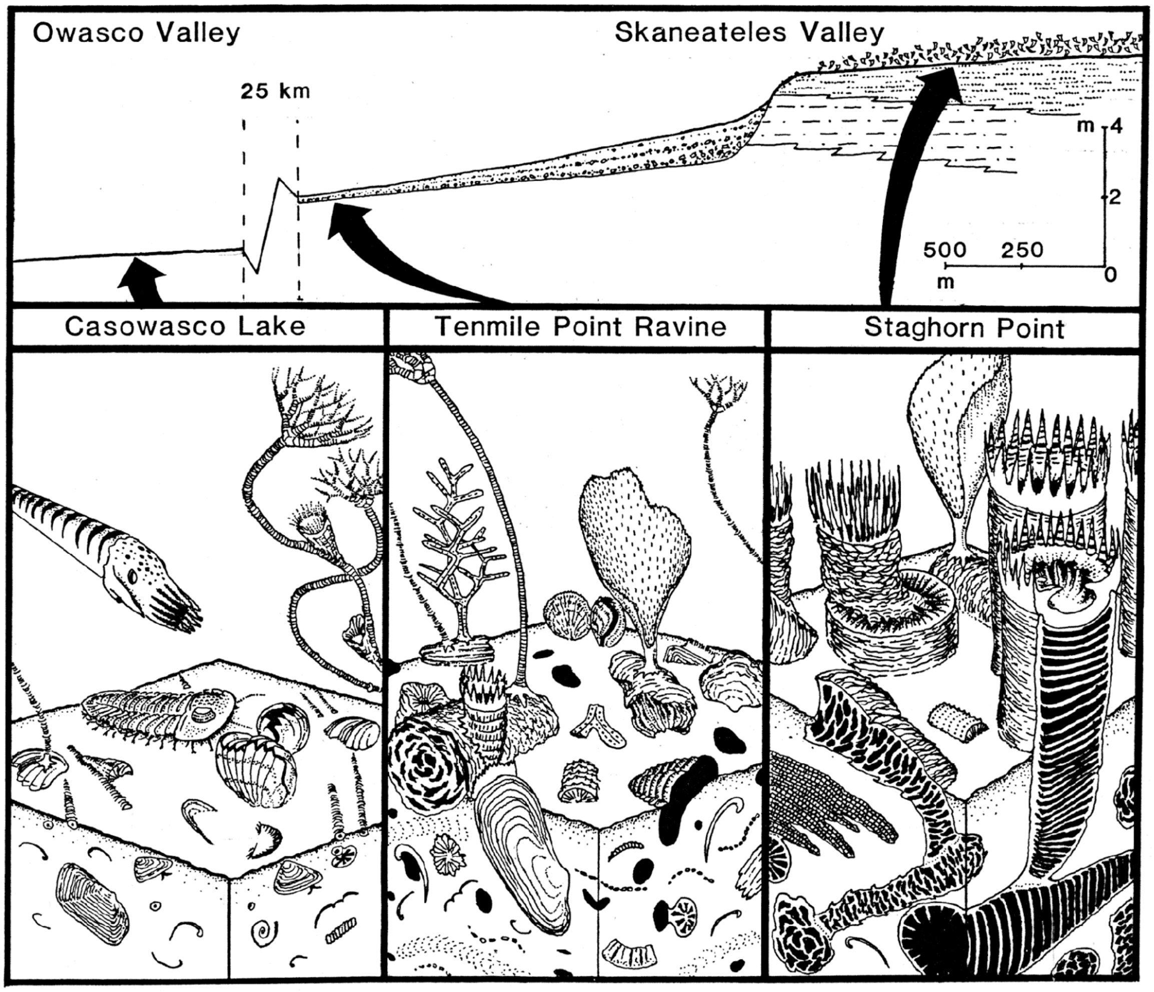

FIGURE 7—Schematic west-east transect of paleoenvironments during Stag Horn coral bed deposition in the Owasco-Skaneateles Lake region, showing reconstructions of seafloor communities at different positions of gradient from bank top coral biostrome (right side) to deeper ramp. **Casowasco Lake**) deeper water assemblage characterized by leiorhynchid brachiopod *Eumetabolotoechia*, phacopid trilobite, burrowing *Cypricardella* and small flexible crinoid*, Eutaxocrinus;* note attachment of small *Stereolasma* corals to crinoid stems; orthoconic nautiloids are common. **Ten Mile Point Ravine**) intermediate depth communities, including brachiopods such as *Rhipidomella*, burrowing bivalve, *Modiomorpha* bivalves, encrusting *Taeniopora* and fenestrate bryozoans and crinoids attached to reworked corals. **Staghorn Point**) Stag Horn Point coral biostrome with large rugose corals *Cystiphylloides* and *Siphonophrentis*. From Brett et al. (1990).

Point ravine have yielded an intriguing occurrence of stereolasmatid corals. The latter are not found commonly attached to benthic shells, but rather occur encrusting along the sides of columns of *Eutaxocrinus* (Fig. 7), which being preserved in an articulated condition evidently were buried very shortly after death. Hence it is clear that these corals attached to the sides of the upright, living crinoid columns. This was possibly a strategy to elevate the corals above a relatively dysoxic, unfavorable sea bottom and allowed them to live in a marginal environment at the outer limit of the Stag Horn coral biostrome. No reworked coral fragments have been found in these sections.

Exposures along Otisco Lake, east of Skaneateles Lake (Fig. 5), provided further information on the orientation of the Stag Horn platform. Oliver (1951) surveyed a series of gullies primarily along the west side of Otisco Lake and in these he was able to map out both the Stag Horn Point and Joshua coral beds. With respect to the Stag Horn submember, he found a siltstone platform and dense overlying coral biostrome in all but the northern-most sections. In the latter, the platform was present, but corals were relatively rare. However, in outcrops to the north in twin-glen tributaries of Willowdale Ravine, the Stag Horn Point coral bed interval is represented only by thin shell horizons with *Athyris* and stereolasmatid corals that overlie a more sparsely fossiliferous silty mudstone. The main body of the Stag Horn cycle, in this area, is occupied by dark gray shales with abundant *Eumetabolotoechia* and *Pustulatia* (*Vitulina*). In a small stream along Coon Hill Road, the Stag Horn level is nearly unrecognizable, although a slightly more fossiliferous zone with some *Athyris* brachiopods occurs between dark, *Eumetabolotoechia*-bearing shales, and seems to mark the position of this interval. Again, in this area, a rapid north-northwest transition from the richly fossiliferous coral platform facies to deeper basin-margin sediments is evident. Together, these outcrops help to constrain the orientation of the Stag Horn silty platform margin and thereby the limit of the coral biostrome to the northwest. Based upon all available information, the line of the front edge of the siltstone escarpment must run north-northeast to south-southwest and cut diagonally across from the north end of Otisco Lake to the east side Skaneateles Lake approximately at the position of Chase Point. From there, it dips out of sight beneath Skaneateles Lake and plunges into the subsurface (see Fig. 6).

The transitional strata northward of the platform provide an excellent transect of faunas from high density, coral-rich beds, to coral rubble beds populated by in-situ stereolasmatid corals, *Athyris*, and *Eutaxocrinus* (Fig. 7). The latter assemblage persists onward into the basin with the addition of *Eumetabolotoechia* in the vicinity of Owasco Lake exposures and the diminution in abundance of *Athyris* and other brachiopods. Corals were able to inhabit these environments only by attaching themselves to the elevated columns of *Eutaxocrinus* (Fig. 7).

SEQUENCE OF EVENTS IN THE STAG HORN POINT SUBMEMBER DEVELOPMENT

Based upon the available evidence enumerated in the previous paragraphs, we visualize the following series of events in the formation of the Stag Horn siltstone platform, coral biostrome, coral rubble beds, and their lateral equivalents (Fig. 8).

Stage I—Initially, a minor fall in sea level initiated progradation of silty muds and silts into the basin at least to the position of the Stag Horn platform line shown on Figure 6. It is possible that very rapid progradation of silts resulted in an unstable, northwest-facing, basinward slope that was somehow subjected to later, transgression-related erosion (Fig. 8A).

Stage II—Reworking and winnowing associated with the lowstand of this cycle may have resulted in the presence of the heavily bioturbated siltstone that caps the platform. During this time and also during the ensuing interval of sediment starvation, carbonate concretions may have begun to nucleate in the sediment about a meter below the top of the platform around pyrite nodules, forming pipe-like to ellipsoidal concretions.

Stage III—Sediment-starvation, probably associated with a sea-level rise of a few meters, resulted both in sediment- stabilization on the top of the platform and reduction of sediment influx owing to transgression-related reduction of delta progradation and the stabilization of the sea floor. During this interval of time, phosphatic nodules apparently developed within the uppermost portion of the silty sediment. In some cases, this phosphate nucleated both within and around the skeletons of various animals, such as trilobites, etc. This interval was followed by a period of minor erosion and reworking, probably the result of further and more extensive sediment-starvation coupled with minor current activity. This resulted in the reworking of phosphate nodules as pebbles on the sea floor. These pebbles were exposed and subsequently bored into by worms that formed *Trypanites* borings, and encrusted by bryozoans and corals. This period of sediment-starvation appears to have been widespread, with the occurrence of phosphatic nodules in silty mudstone northward of the edge of the platform (Fig. 7).

Stage IV—During the next phase, corals grew abundantly and prolifically upon the upper portion of the platform (Fig. 8B). It is likely that at this time, deeper portions of the sea bottom were beginning to be colonized by athyrid brachiopods, stereolasmatid corals, bivalves, and various other organisms. Coral growth on the platform may have been initiated by the presence of pebbly phosphatic substrate that provided areas for settlement of pioneering coral larvae, but as noted, their skeletons would have provided much larger substrates for subsequent generations during the formation of the biostrome. Intermittently during the course of development of the Stag Horn bioherm, the coral thickets were swept by strong, storm-generated currents. These events reworked corals, piling them together, and, in some cases, buried corals in an upright-standing orientation. At other times mud infiltrated into baffles of upright-standing, *in situ* corals. A few brachiopods and bivalves dwelled within this mudstone but the predominant organisms living on the Stag Horn bench were solitary rugosans.

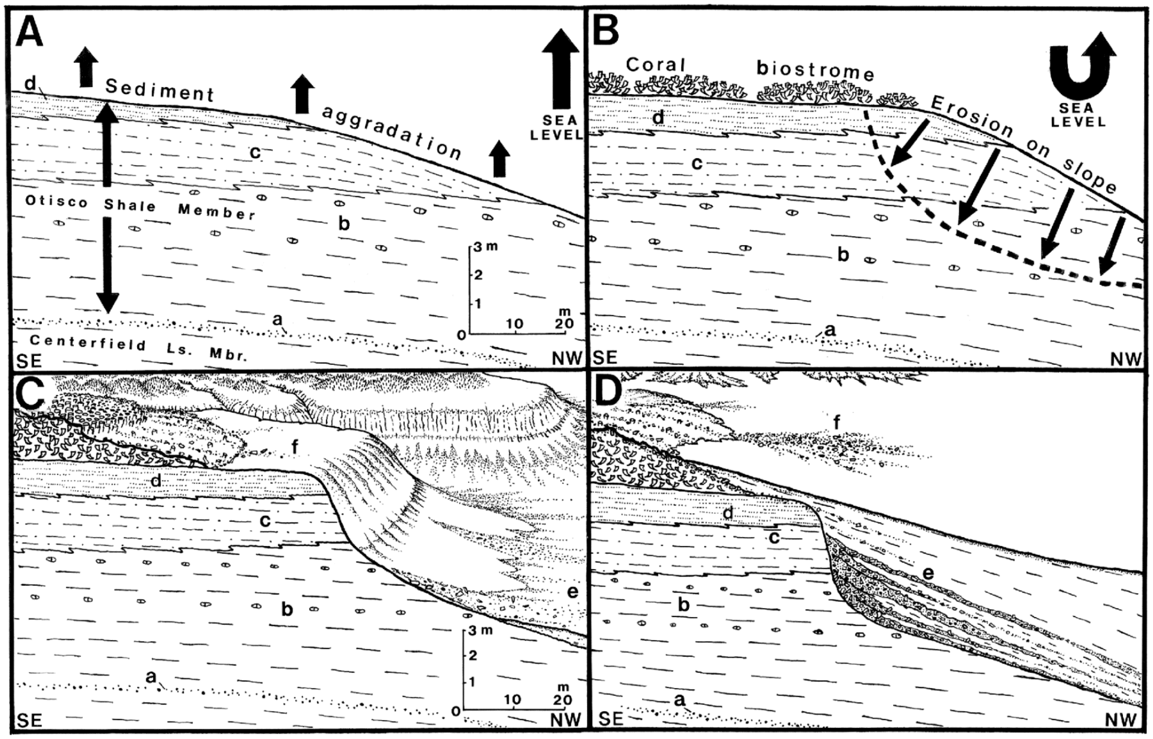

FIGURE 8—Reconstructed series of events in the development and burial of Stag Horn Point siltstone platform and coral biostrome. A) progradation of siltstone tongue into central New York area during regression (falling stage). B) colonization of upper surface of siltstone bench by rugose coral biostrome and storm erosional scouring and steepening of downslope end of submarine siltstone platform. C) development of spur and groove topography of siltstone platform edge, reworking of coral debris from biostrome into surrounding area. D) burial of coral biostrome and debris apron by highstand muds.

Stage V—It is possible that, at approximately this time, a minor “down-to-the-northwest” faulting event may have taken place, producing a northwest-facing submarine scarp (Fig. 8B). Following such an event, the scarp would have retreated due to differential erosion and associated sediment-starvation and bypass on the up-thrown side. Such erosion, controlled by deep-storm action and tide-generated currents, may explain the formation of the aforementioned channel-like features along the platform edge. It seems likely that this only would have occurred if the platform already had a steep gradient, but once started, this erosional furrowing could propagate by headward erosion cutting into the front edge of the platform to form a series of spur and groove like features (Figs. 6, 8C). Channels several tens of meters across developed between ridge/pinnacle-like elevated remnants along the platform edge.

During the interval of luxuriant coral growth on the platform, large storms intermittently battered this surface, knocking corals over and burying some and also producing a flow of rubble off the truncated platform margin; this produced accumulations of abundant reworked coral skeletons particularly in the channel-like areas between platform spurs. More distally, coral rubble layers graded laterally (downslope) into graded coral and siltstone beds up to 3-4 cm thick. The presence of hummocky cross-stratification and escape burrows indicates rapid deposition as single graded units during bottom impinging storm events. The occurrence of reworked silt in the higher beds of coral rubble suggests that siltstone flooring the escarpment lip was being actively dissected (Fig. 8C). These tabular siltstones extend hundreds of meters, if not over a kilometer out into the basin as suggested by the occurrence of similar silts in the section at Fall Brook on the west side of Skaneateles Lake.

All of this growth and reworking of corals occurred within the context of relative sediment-starvation probably produced by a rise of base level by a few meters which flooded coastal areas of the Catskill Delta complex and produced estuaries and bays that sequestered sediment temporarily. Biostrome growth may have continued for several millennia before being exterminated and buried by muddy sediments. Intermittent mud influx was ongoing as evidenced by the sparsely fossiliferous mudstone layers that lie between coral and siltstone event beds that lie adjacent to the Stag Horn platform (Fig. 8C, D). Distal ends of the same events may have been responsible for the mass mortality and burial of the thickets of *Eutaxocrinus* farther to the northwest.

Stage VI. Ultimately, the growth of the Stag Horn Point coral bed was terminated (Fig. 8D). This change was probably brought about by a combination of increased water depth, decreasing turbulence and oxygen levels, and increasing turbidity as rates of base level rise slowed, allowing increasing amounts of muddy sediment to prograde offshore. This change was marked by a return to moderate diversity assemblages of small brachiopods and bivalves.

CONCLUSIONS

The middle portion of the Hamilton Group in the eastern Finger Lakes area provides an excellent case study in the interactions of relative sea level fluctuation, related changing patterns of sedimentation, and concurrent biotic responses. Decameter and smaller scale sedimentary cycles are superimposed on a larger scale pattern of sea-level rise and fall, represented by the upper Skaneateles Formation and the Centerfield and Ledyard/Otisco members of the Ludlowville Formation.

Sea-level highstands in this area of the foreland basin were characterized by low diversity assemblages of brachiopods and small mollusks, adapted to dysoxic mud substrates. Falls in relative sea level not only led to shallowing of the seafloor but also increased progradation of muds and silts into the basin. Faunas changed upward to moderate diversity assemblages of larger semi-infaunal brachiopods and bivalves, as well as the deposit feeding organisms responsible for the complex spreiten trace *Zoophycos*.

Conversely, rises in relative sea level were associated with abrupt reduction in sediment supply. Concretions and phosphatic nodules may have developed in older sediments during an interval of sediment starvation representing rapid sea level rise. Highly diverse assemblages including, but not limited to, abundant rugose and some tabulate corals, occupied the shallowest water settings during relatively clean siliciclastic free intervals. In the case of the lower Otisco Stag Horn cycle, a thriving coral biostrome was developed on a shallow prograded siltstone platform during this phase. This example also shows that during times of relatively low sediment input, normal submarine processes such as storm-generated waves and currents may be effective in eroding previously deposited sediments and transporting them further basinward, particularly along the sloping edge of a prograded platform.

The rapid lateral facies changes and constrained stratigraphy of the lower Ludlowville Formation in central New York provide excellent opportunities to examine lateral-, depth- and sedimentation-related gradients of environmental and biofacies change. This is an area wherein exceptional preservation and exposure can be used to test general hypotheses about the connection between physical environmental factors and biotic change on the scale of millennia to hundreds of thousands of years.

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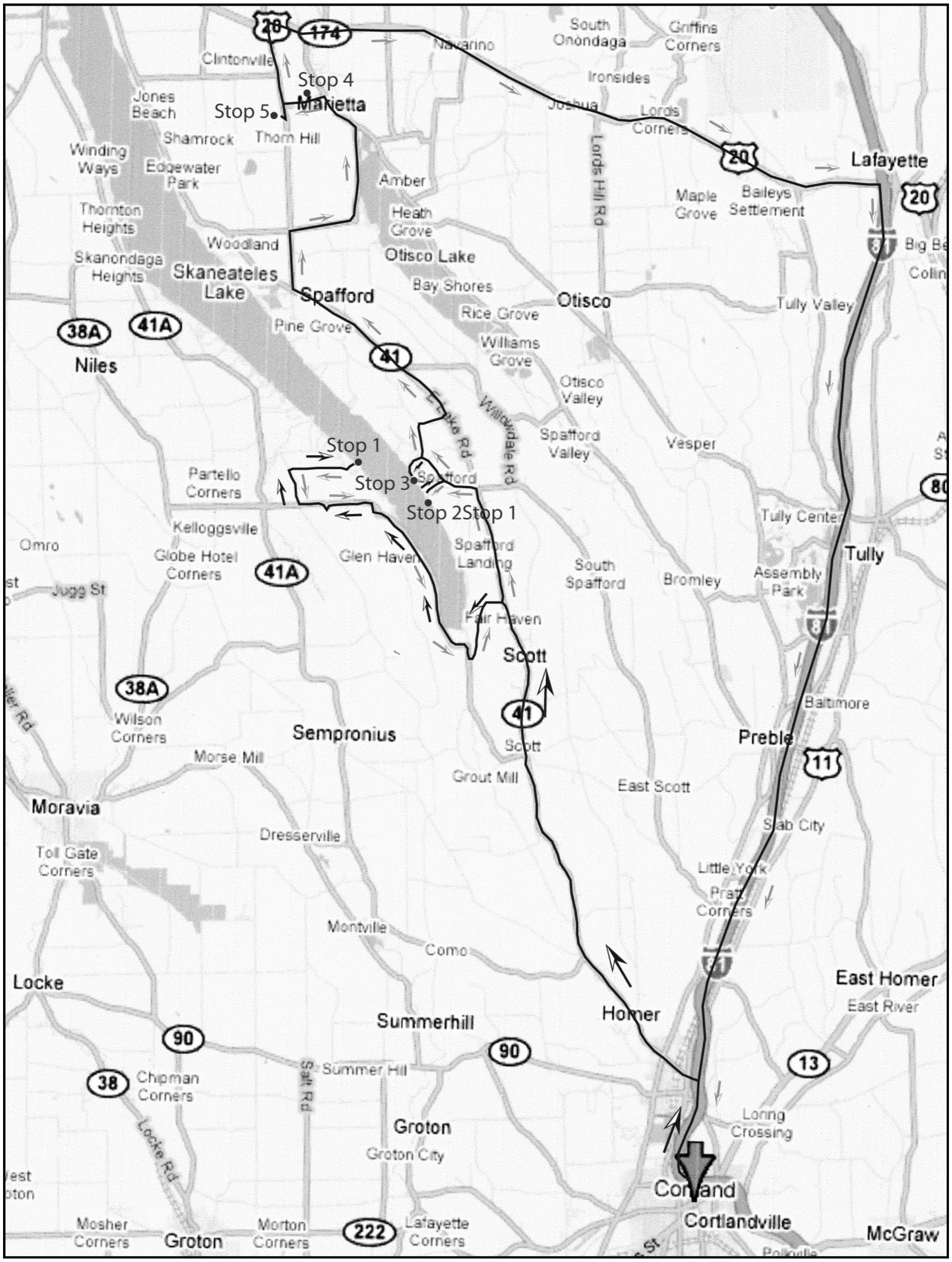

FIGURE 9--Map of study area showing field trip route; numbers correspond to stops on field trip, indicated in road log.

ROAD LOG FOR FIELD TRIP B-4

RECONSTRUCTING A MIDDLE DEVONIAN SUBMARINE ESCARPMENT: CORALS, PALEOSLOPES, AND DISCONTINUITIES WITHIN THE OTISCO SHALE, EASTERN FINGER LAKES REGION

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.00	Jct. Rte. 13 and I-81N
0.4-0.8	0.4-0.8	Outcrops of Ithaca Fm.
1.15	0.7	Homer Exit off I-81N
2.2	1.05	Jct. I-81 and Rte. 11 & 41 – take a left at end of exit loop
2.6	0.4	Jct. Rte. 90, stay straight
2.9	0.6	Jct. Rte. 41 and 11, bear left at fork on Rte. 41
3.5	0.6	Jct. Rte. 281, stay on Rte. 41
4.8	1.3	View of bedded kame gravels to left
5.0	0.2	Jct. Rte. 41A
7.3	2.3	View of bedded kame(?) gravels to left
11.85	4.55	Jct. Ripley Hill Rd., stay on Rte. 41
13.3	1.45	Onondaga Co. line. Turn LEFT onto Vincent Hill Rd.
13.7	0.5	High vista of Skaneateles Lake ahead
14.4	0.7	Old quarry to left in Tully Limestone
14.55	0.15	Contact of Fall Brook and Fisher Gully submembers of the Windom Member of the Moscow Fm. in ditch
14.8	0.25	T-Jct. at Fairhaven Rd. Turn RIGHT (north)
15.0	0.2	Glen Haven Road. Turn LEFT.Town of Scott
15.4	0.4	Cayuga Co. line
15.7	0.3	View of Skaneateles Lake
15.85	0.15	Glenhaven
16.2	0.35	Outcrop of Ivy Point Member siltstone
16.65	0.45	Cross gully. View of Spafford Landing cliffs to east across lake
17.2	0.55	Outcrop of Ivy Point Member siltstone
17.55	0.35	Contact between the Owasco Member of the Ludlowville Fm. and the Tichenor Member of the Moscow Fm.
17.7	0.25	Roadside shale pit in lower Windom Shale rich in *Ambocoelia* roadside shale pit in middle Windom Shale; Bay View bed rich in brachiopods and small corals is exposed in floor adjacent to road; higher banks are in the Bear Swamp submember of the Windom.
18.0	0.3	Three Mile Point ravine; exposures of middle and upper Windom to west of road
19.2	1.2	Upper end of Glen Cove ravine

19.6	0.4	Turn RIGHT onto Carver Road.
20.3	0.7	Glen Cove Road. Turn RIGHT and proceed slowly to bottom of hill and marina at Skaneateles Lake shore
21.7	1.4	Sevy's Boatyard; park vehicles.

OPTIONAL STOP 1. GLEN COVE CREEK

If water levels in the creek are not too high we may proceed on foot to the mouth of Glen Cove Creek behind the marina. Beds exposed near the creek mouth are in the lower Otisco slightly above Moonshine Falls phosphate bed; these shales are rich in the small brachiopod *Arcuaminetes scitulus* and carry small concretions and pyritic nodules. Upstream a few hundred feet the Stag Horn Coral horizon is exposed near the base of a small falls. The bed here yields primarily *Athyris* and other brachiopods and small corals. Occasional corroded fragments of larger rugose corals may be obtained.

Hiking upstream and climbing the relatively gentle small waterfall provides access the Glen Cove shell bed (type section). Here the bed is rich in *Athyris*, the small rugosan *Stereolasma*, the bivalve *Cypricardella* and *Modiomorpha* among others. These exposures provide a view of relatively fossiliferous down ramp facies of Otisco shelly horizons.

NOTE: if weather permits we will take a boat trip from Sevy's Marina across Skaneateles Lake to the vicinity of Stag Horn Point and Jenney Point; see descriptions under driving directions for STOPS 1 and 2. If so, we will be on the boat for approximately an hour.

23.3	1.6	Return to Carver Rd., Turn LEFT
24.0	0.7	Turn RIGHT onto Glen Haven Rd.
24.6	0.6	Cross upper end of Glen Cove ravine
25.75	1.15	Cross Three Mile Point ravine
26.15	0.4	Large roadside quarry in lower Windom Shale rich in *Ambocoelia*
26.25	0.2	Contact between the Owasco Member of the Ludlowville Fm. and the Tichenor Member of the Moscow Formation
28.8	2.55	Cortland County Line
29.15	0.35	Fair Haven Rd., turn RIGHT
29.35	0.2	Vincent Hill Rd., turn LEFT
29.6	0.25	Contact of Fall Brook and Fisher Gully submembers of the Windom in ditch
29.75	0.15	Old quarry to right in Tully Limestone
30.9	1.15	Jct. Rte. 41, turn LEFT; Onondaga Co. line
33.2	2.3	Jct. Bacon Hill-Cold Brook Rd., turn LEFT on Bacon Hill Rd.
33.5	0.3	Turn RIGHT on Morris Run Rd. (Road to Stag Horn Point)
34.05	0.55	Holzworth Rd., stay RIGHT
34.5	0.45	Park in pull-off to left at bend; remainder of road is too steep for most non-four wheel drive vehicles; so proceed down to shore of Skaneateles Lake (~0.25 mi.), passing by exposures of upper Ivy Point Member, Spafford, and Portland Point members in Chase Point Ravine; note exposures of Otisco Shale on steep road down to shore; past the mouth of Barber Creek proceed past the first cottage (permission for access from homeowners is required); bear left

		(southeast) and onto bench formed by Stag Horn siltstone. (Alternatively, this section may be accessed by boat).

STOP 2. STAG HORN POINT

Here the upper beds of the siltstone are exposed and show excellent spreiten of *Zoophycos*; occasional phosphatic nodules and corroded corals are present in the top of the silt. The bench is abruptly overlain by about 1.5 m of the Stag Horn Point coral biostrome; densely packed solitary rugosans, including *Heliophyllum*, *Cystiphylloides*, and *Siphonophrentis*, the latter up to about 50 cm long. Corals range from corroded flattened fragments to complete and in situ uncorroded skeletons; they are packed in a mudstone matrix; upper part of the bank shows normal middle Otisco Shale. The coral biostrome continues to the south for nearly a kilometer before dipping below lake level.

34.9	0.4	Jct. Bacon Hill Rd., turn LEFT
35.4	0.5	Booth Rd., turn LEFT (Road to Jenney Point)
35.5	0.1	Fork, stay LEFT; proceed cautiously (steep road)
36.1	0.6	Jenney Point, find parking (permission for access from homeowners is required); proceed, if possible, southwestward along shoreline. (Alternatively, this section may be accessed by boat).

STOP 3. COVES SE OF JENNEY POINT: EDGE OF STAG HORN PLATFORM

The first cove southeast of Jenney Point displays the lower Otisco Shale at about the level of the Staghorn biostrome. Depending upon lake level it may be possible to walk along the shore to the next point and into the next cove to examine features of the transition of the platform edge into ramp sediments. Corals are present here in lenticular, wedge-shaped masses and layers that abut the truncated edge of the siltstone platform. Adjacent to the first cottage a large mass of rugose coral corals dips to the south about 8-10° along an apparent erosional surface. At the south end of this cove, the siltstone platform remains partially truncated; about 30m further to the north, near the middle of the cove, the pyrite- cored concretions, which normally lie below the platform are directly overlain by coral rubble. In places, the coral rubble thickens to about one meter as the truncation surface runs downward from the pyritic concretions to nearly the level of Skaneateles Lake.

The next cove to the south between an unnamed point and Chase Point, north of Stag Horn Point exposes a similarly intriguing series of beds including a series of thin graded beds of siltstone, locally with corals in their bases that appear to be storm event beds of silt eroded from the truncated platform margin (see text and Figures 6-8 for details). Together, these two cove sections provide a view of an eroded platform edge that was shedding coral debris and silt layers into the surrounding ramp area.

Return to vehicles and reverse directions back to Bacon Hill Road

36.85		Jct. Bacon Hill Rd., turn LEFT
38.2		Jct. Rte. 41, turn LEFT
40.95		Borodino mud mound (micritic bioherm) in Tully Formation
41.7		Upper Windom Shale outcrops
42.2		Village of Borodino, turn RIGHT onto Rte. 174 North
43.3		Turn RIGHT, follow Rte. 174 North
44.3		Chenango Siltstone outcrop

44.6	0.3	Sharp bend, view of Otisco Lake
46.1	1.5	Road follows along Otisco Lake shore
46.5	0.4	North end of Otisco Lake
46.6	0.1	Turn LEFT following Rte. 174 North; Village of Marietta
47.35	0.75	Coon Hill Rd., turn LEFT
47.7–47.95	0.35-06	Disembark near base of roadcut and walk upward to top along the road; vehicles will park at upper end of exposure

STOP 4. ROAD CUT ALONG COON HILL ROAD, MARIETTA, NY

This long cut exposes the complete transition from the upper Skaneateles Formation to the base of the Ludlowville Formation. Lower portions of the roadcut expose black, silty Butternut Shale. These shales yield a low diversity assemblage of *Eumetabolotoechia*. Its basal contact is exposed in a stream on the south side of the road. The upper 10 meters of the unit contains thin 1 to 2 cm tabular, laminated siltstone beds. The Butternut Shale is abruptly overlain by the Peppermill Gulf Bed, a 30 cm interval of medium gray calcareous and highly fossiliferous mudstone at the base of the Chenango Member.

From this point the Chenango Member, ~10 meters thick, shows an upward-coarsening succession from shale and silty mudstone to *Zoophycos*-churned siltstone. Fossils are generally scattered but the brachiopod *Tropidoleptus* is common at many levels and an *in situ* cluster of the large brachiopod *Spinocyrtia* was found about midway through the succession.

Near the upper end of the roadcut the upper Chenango weathers as a distinct bench. Large favositid and rugose corals present in the upper calcareous sands and overlying thin, silty limestones. These beds signify the basal transgressive systems tract of the Ludlowville Formation. The Halls Landing beds (upper Centerfield Member), mudstones with thin shell rich horizons form the uppermost unit of the cut.

Uppermost exposures in the adjacent stream bank opposite the upper part of Coon Hill Road show the lower Otisco Shale. The Stag Horn siltstone bench is absent at this section and its position is only suggested by beds of silty shale rich in *Athyris* brachiopods.

Return to vehicles and proceed west on Coon Hill Road to junction with Rose Hill Road

48.2	0.25	Bear LEFT at Y onto Rose Hill Rd.
48.4	0.2	Turn RIGHT onto hidden dirt drive into quarry in village of Rose Hill; drive in to parking area at east side of shale pit
48.5	0.1	

OPTIONAL STOP 5. SHALE PIT AT ROSE HILL

This shale pit exposes richly fossiliferous beds of the middle-upper portion of the Otisco Member. Shales contain diverse brachiopods, bivalves and other fossils and a horizon with scattered rugose corals toward the upper part of the pit appears to record the Joshua Coral Biostrome level, although it is poorly developed compared with exposures to the east on Otisco Lake. This section provides an excellent opportunity to collect fossils from the Otisco beds.

48.6	0.1	Turn LEFT on Rose Hill Rd.
50.4	1.8	Jct. U.S. Rte. 20, turn RIGHT; Village of Clintonville; red clay banks
55.9	5.4	Hogsback Rd. and Peppermill Gulf, stay on Rte. 20; type locality of

		Peppermill Gulf Bed at base of Chenango Siltstone
59.0	3.1	Lords Corners, Jct. Rte. 80, stay on Rte. 20
59.1	0.1	Case Hill Rd., stay on Rte. 20
60.6	0.7	Tully Valley, Village of Cardiff, site of famous Cardiff Giant hoax
63.1	2.5	McDonald's on left, turn RIGHT onto ramp to I-81 South, large cut of Butternut Member of the Skaneateles Fm.
69.3	6.2	Windom Shale outcrops
69.7	0.4	Exit for Tully, stay on I-81 South, note large exposure of uppermost Windom Shale behind Best Western Inn to east of highway
71.1	1.4	Cortland Co. line
81.4 – 82.4	10.3-11.3	Roadcuts in Ithaca Formation
84.4	2.0	Exit #11 to Rte. 13 at Cortland

END OF FIELD TRIP