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CARBONATE-CLASTIC SYNTHEMS OF THE MIDDLE BEEKMANTOWN GROUP IN THE CENTRAL AND SOUTHERN CHAMPLAIN VALLEY

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INTRODUCTION

The Champlain Valley is the type-localtiy for the Beekmantown Group (Clarke and Schuchert, 1899), originally called the Calciferous Sandrock (Eaton, 1824; Emmons, 1839, 1842, 1855; Brainerd and Seely, 1890a, b). These units are the Lower Ordovician carbonate-clastic sequence of the Appalachian miogeosyncline (Ulrich and Schuchert, 1902; Ulrich, 1911, 1913; Schuchert, 1943). Despite considerable geologic work for more than 150 years, the internal stratigraphy of the Beekmantown group is still in dispute. This field trip will visit some localities where the stratigraphic and temporal relations of the middle Beekmantown can be established (fig. 1).

Although mapped by the early New York and Vermont geologists and their respective surveys, it was not until Augustus Wing, a local schoolteacher and amateur geologist, undertook his studies of the central Champlain Valley that the importance and internal stratigraphy of the Beekmantown strata was recognized (Wing, 1858-75; Dana, 1877a, b; Seely, 1901). Unfortunately, the full results of Wing's investigations were never published; only a summary by Dana (1877a, b) and two sketch maps in Cady (1945) have appeared (the originals of the notebooks disappeared in the early 1940s [Cady, written communication to Washington, 1977]). Brainerd and Seely's (1890a, b) work, the basis for subse-

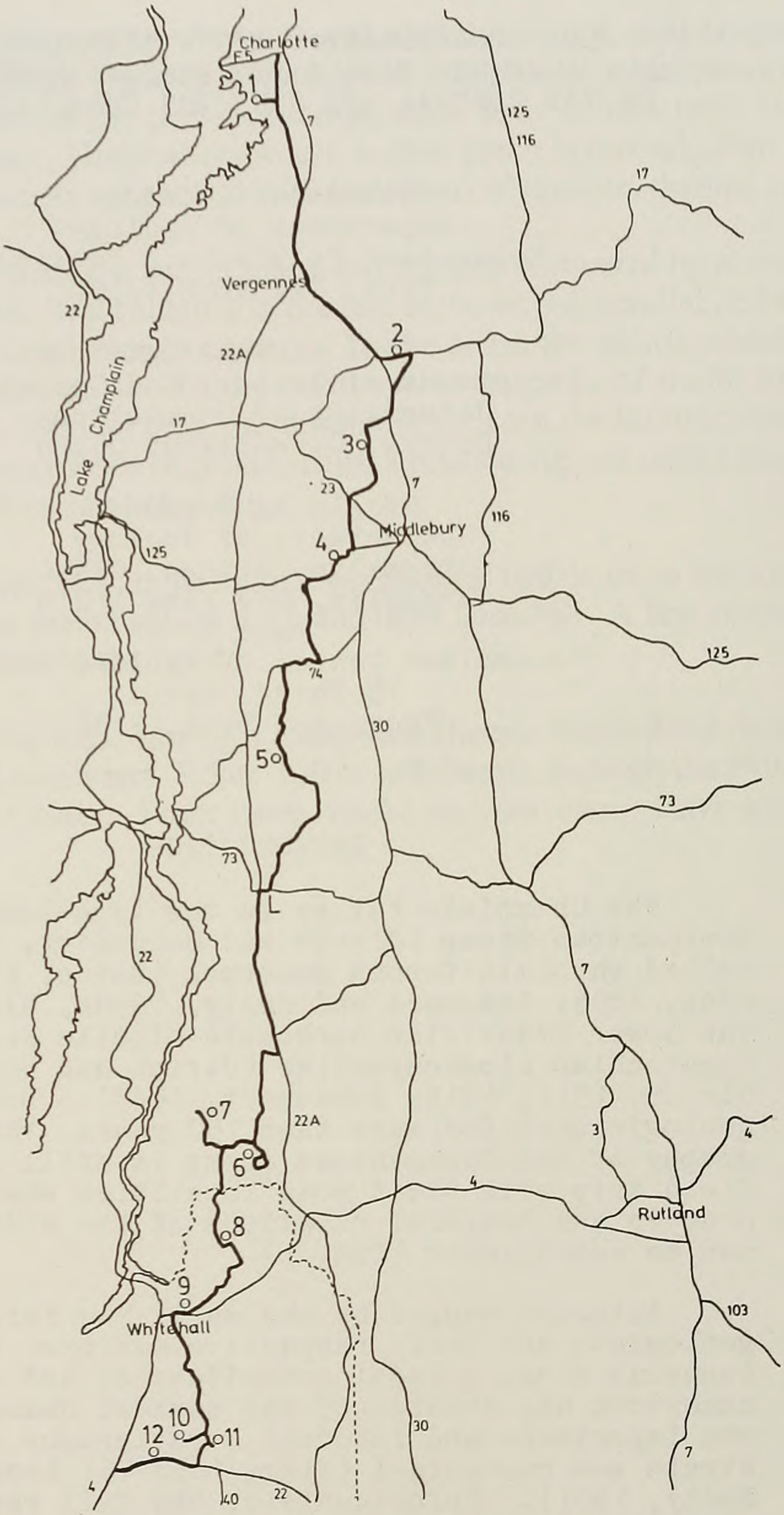

Figure 1 - Route of field trip with locations of stops.

quent Beekmantown stratigraphic systems, was mostly based on Wing's mapping and stratigraphy, although they modified it somewhat. They used Wing's stratigraphic section (after remeasuring and redescribing it) from eastern Shoreham, Vermont, (the Bascom ledges) as their type-section.

Despite the general ignorance of Wing's work, most disagreements over the internal stratigraphy of the Beekmantown Group in the Champlain Valley have revolved around Brainerd and Seely's modifications of Wing's stratigraphic system (Stockwell, 1986). Except for Flower (1964, 1968) who reestablished the paleontolgic foundation for the Beekmantown stratigraphy (unknowingly confirming Wing's work), most Beekmantown studies languished or were reconstituted from Brainerd and Seely (1890a, b) (Seely, 1906, 1910; Foyles, 1924, 1927, 1928a, b; Perkins, 1908). In 1945 Cady presented a general regional synthesis which Welby (1961, 1964), Coney and others (1972), and numerous Senior Theses at Middlebury College have built upon.

Recently, detailed analysis of the Beekmantown strata in the southern Champlain Valley has led back toward Wing's original stratigraphic system (Fisher, 1977, 1984; Fisher and Mazzullo, 1976; Fisher and Wharthen, 1976; Mazzullo, 1975, 1978; Mazzullo and Friedman, 1975, 1977; Chisick and Friedman, 1982a, b; Chisick and Bosworth, 1984). This work has now been extended into the central Champlain Valley (Washington and Chisick, 1987) with minor revisions that bring the stratigraphy even more nearly into alignment with Wing's original work. This field trip will synthesize much of this recent work, especially within the complex middle Beekmantown (i.e. the Bascom Subgroup of Washington and Chisick, 1987).

Stratigraphy

Brainerd and Seely's (1890a, b) stratigraphy included all of the strata between the Potsdam sandstone and the "Trenton" (actually the base of the Chazy) in the Calciferous. Five separate lithologic divisions (the formations of Rodgers, 1937, 1955, and Cady, 1945) were defined and labelled A to E from the base upward. Divisions C and D were further divided into four units each (labelled 1 to 4 from the base upward). No stratigraphic hiatuses were recognized although distinct faunas were known (Wing 1858-1875; Whitfield, 1886, 1887, 1889, 1890a).

Clarke (1903) dropped division A with its obvious Cambrian faunal assemblage, a practice adopted by Cushing (1905), Ruedemann (1906), Ulrich (1911, 1913) and most subsequent workers (Wing considered A to be "Upper Potsdam"). Rodgers (1937), following Ulrich (1911, 1913), suggested that the Cambrian-Ordovician boundary lies within division B; this has now been confirmed by Taylor and Halley's (1974) careful analysis of trilobite assemblages. Detailed work by Chisick (Chisick and Friedman, 1982a, Chisick and Bosworth, 1984) has confirmed Wing's (1858-1875, notebook 5, p. 8-10) conclusion that the top of the Canadian lies within division E. Thus, the type locality of the Beekmantown group shows it extending from Late Cambrian to early Middle Ordovician. Over the last two decades there has been a move to redivide C and D (Washington and Chisick's, 1987, Bascom Subgroup) into two formations comprised of C-1 - D-1 and D-2 - D-4 (Flower, 1964, 1968; Fisher and Mazzullo, 1976; Fisher, 1984). Detailed fossil analysis (Chisick and Friedman, 1982a; Chisick and Bosworth, 1984; Repetski, 1982) shows that the major disconformities and faunal breaks lie within D-1 and D-3; furthermore, the intervening strata are not lithologically divisable on a regional basis. Thus, Washington and Chisick (1987) lumped these enigmatic strata together in a synthem, the Lemon Fair formation.

The stratigraphy of the units seen on this field trip is presented in figure 2. Figure 3 is a partial presentation of the conodont assemblages obtained from these strata in the central and southern Champlain Valley (from Repetski, 1982, Chisick and Bosworth, 1984, and Chisick, unpublished data).

Regional Setting

During most of Cambrian time, the Pre-Cambrian basement (not just the Adirondack region) maintained sufficient relief that it kept the shelf restricted. By the end of the Cambrian, however, the marginal portions of the Pre-Cambrian basement had been peneplained, inundated by shallow seas and capped by an onlapping shelf sequence. From Late Cambrian into Middle Ordovician time, the Champlain Valley was the site of relatively low-energy shelf deposition dominated by carbonate with lesser amounts of generally coarser-grained, well-sorted, bimodal, quartzofeldspathic sands. Generally, the the shelf strata are laminated fine-grained limestones and dolostones, calcareous quartz sands, probably pelloidal limestones, and occassional algal boundstone and oolitic limestone. The sandier sediments spread across the shallow shelf with dominantly dolomitic carbonates concentrated along the high-energy shelf margin edge. As one ascends the Beekmantown stratigraphic sequence, the amount and grain-size of clastics generally decreases. Strikingly sharp stratigraphic contrasts between clastics and carbonate facies suggest juxtaposition of dissimilar sedimentologic regimes.

M. ORDOVICIAN

SNAKE HILL FORMATION

HORTONVILLE FORMATION/
BENSON FORMATION

GLENS FALLS FORMATION — Shoreham Member, Larrabee Member

ISLE LA MOTTE FORMATION — Amsterdam Member, Orwell Member, Lowville Member, Pamelia Member

~~~ disconformity ~~~

CROWN POINT FORMATION

(Glens Falls through Crown Point) — MIDDLEBURY FORMATION: "sandy", "homogeneous", "banded"

~~~ Knox Unconformity ~~~

L. ORDOVICIAN

BEEKMANTOWN GROUP

Bascom Subgroup

PROVIDENCE ISLAND FORMATION
[E - Rhynchonella beds]
— Bridport Member, Beldens Member, Weybridge Member, Burchards Member

FORT CASSIN FORMATION
[D_{3-4} - Conglomerate & upper Trilobite Beds]
— Wing's Conglomerate Member, Emerson Schoolhouse Member, Sciota School Member, Ward Member

~~~ disconformity ~~~

LEMON FAIR FORMATION/
FORT ANN FORMATION
[D_{1-3} - lower Trilobite Beds]

~~~ disconformity ~~~

CUTTING HILL FORMATION/
GREAT MEADOWS FORMATION
[C_1-D_1 - Ophileta Beds]
— Smith Basin Member, Fort Edward Member, East Shoreham Member, Kingsbury Member, Winchell Creek Member

~~~ disconformity ~~~

U. CAMBRIAN

Saratoga Springs Subgroup

WHITEHALL FORMATION
[B - Subcrystalline Limestone]
— Skene Member, Rathbunville School Member, Steve's Farm Member, Warner Hill Member, Hoyt Member, Finch Marsh Member, Mosherville Member

TICONDEROGA FORMATION
[A - Upper Potsdam]

POTSDAM FORMATION

Figure 2 - Stratigraphy along the field trip route.
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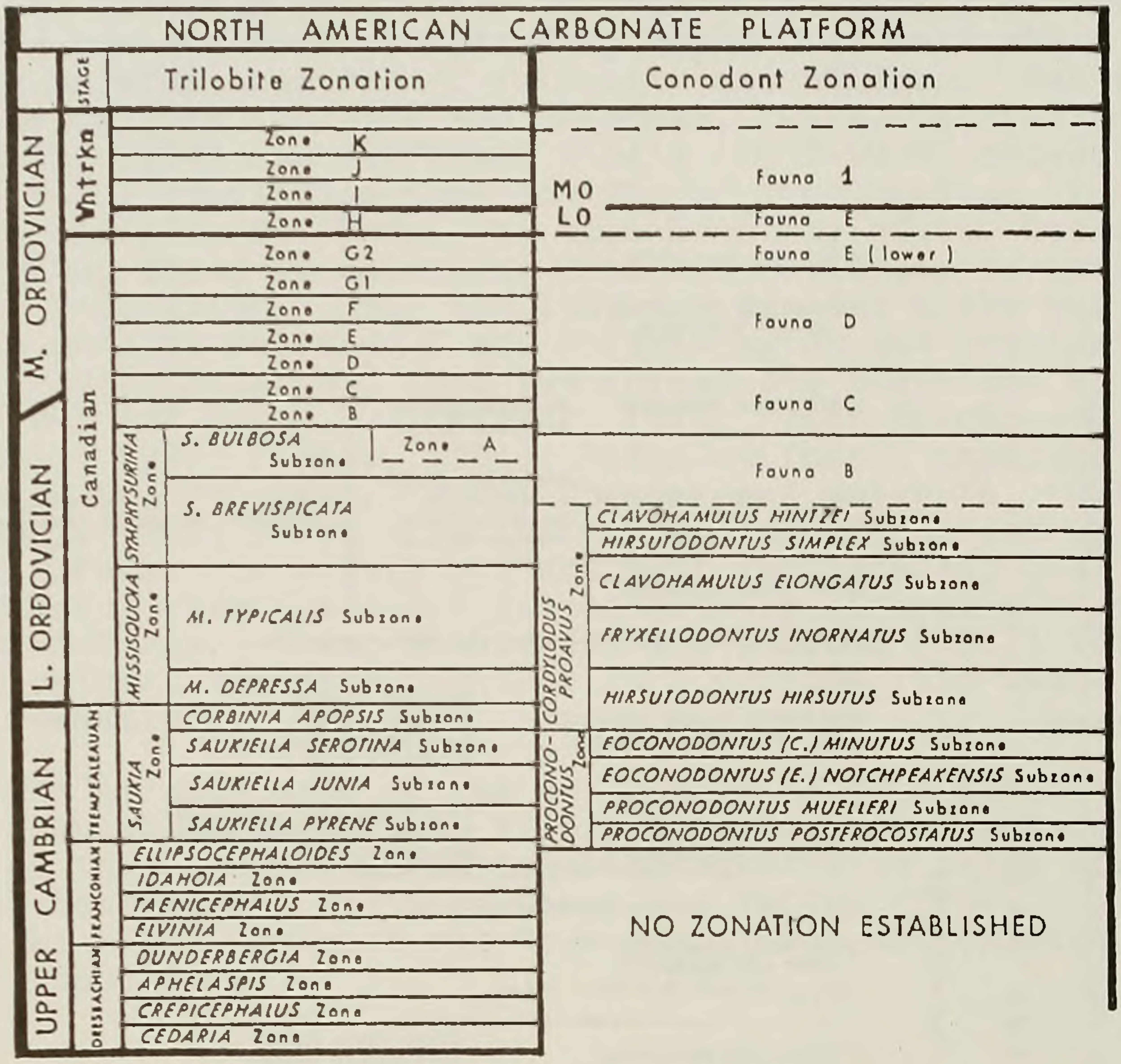

Figure 3 - Conodont Biostratigraphy. Conodont zonation chart for the North American carbonate platform (above) and conodont stratigraphy chart for the middle Beekmantown carbonates in the central and southern Champlain Valley (next page). Samples for conodont processing were collected on an as-needed basis throughout the study area. Primary concerns were: 1) establishing the temporal and faunal relations of the Providence Island formation, 2) clarifying the middle Beekmantown stratigraphy. Most of the conodont elements encountered in these strata in the central and southern Champlain Valley are Midcontinent Province with a secondary North Atlantic Province subset. The majority of mixed Midcontinent/North Atlantic Province samples were obtained from the Rysedorph Hill terrain. Identification of conodonts was by S. Chisick (unpublished data), with assistance by E. Landing (unpublished data) and J. Repetski (1982 and unpublished data).

PROVIDENCE ISLAND FORMATION

Whiterockian (Fauna 1)

Acontiodus coniformis
Eoplacognathus sp.
Gothodus communis = Oepikodus communis
Histiodella altifrons = Histiodella sinuosa
Microzarkodina parva
Multioistodus compressus
Oepikodus quadratus
Oistodus multicorrugatus
?Prioniodus elegans
Protopanderodus asymmetricus
Protopanderodus gradatus
Protoprioniodus aranda
?Pteracontiodus
Reutterodus andinus
Scolopodus paracornuformis
?Tripodus laevis

Whiterockian/Canadian (Fauna 1/E)

Juanognathus jaanussoni
Juanognathus variabilis
Jumudontus gananda
?Oepikodus evae
Oistodus corrugatus
Oistodus longiramis
Rhipidognathus sp.
Scolopodus acontiodiformis

Canadian (Fauna E)

Acodus delicatus
Cristodus loxoides
Drepanodus planus
Juanognathus variabilis
Microzarkodina marathonensis
Oepikodus communis
Oistodus bransoni = Paltodus jeffersonensis
Oistodus pseudoramis
Prioniodus sp.
Protopanderodus rectus
Reutterodus andinus
Walliserodus comptus
Walliserodus ethington

PROVIDENCE ISLAND/FORT CASSIN FORMATIONS

Canadian (Fauna E/uD)

Acodus deltatus (deltatus)
Diaphorodus delicatus
Drepanodus arcuatus
Drepanodus proteus
Oelandodus costatus
Oelandodus elongatus
?Oistodus comptus
?Protopanderodus leonardii
Scandodus pipa
Scolopodus abruptus
?Scolopodus toomeyi
Scolopodus varabilis
?Triangulodus brevibasis
?Tropodus comptus

FORT CASSIN FORMATION

Canadian (Fauna uD)

Drepanodus concavus
Drepanodus conulatus
Drepanodus gracilis
Drepanodus parallelus
Glyptoconus quadraplicatus
?Macerodus diane
Oistodus parallelus
Scandodus flexuous
Scolopodus cornutiformis
Scolopodus emarginatus
Scolopodus parabruptus
Scolopodus triplicatus
Ulrichodina abnormalis
Ulrichodina cristata
?Ulrichodina wisconsinensis

FORT CASSIN/LEMON FAIR FORMATIONS

Canadian (Fauna uD/lD)

Drepanoistodus suberectus
Oistodus inaequalis
?Oistodus gracilis
Oneotodus simplex
?Protopanderodus longibasis
?Scandodus furnishi
Scolopodus gracilis
Ulrichodina sp.

LEMON FAIR FORMATION

Canadian (Fauna lD)

Drepanodus concavus
Drepanoistodus basiovalis
?Drepanoistodus inaequalis
Histodella donnae
?Oistodus lecheguillensis
Scolopodus filosus
?Scolopodus quadraplicatus
Scolopodus rex
Scolopodus rex paltodiformis
Ulrichodina deflexa

LEMON FAIR/CUTTING HILL FORMATIONS

Canadian (Fauna lD/uC)

Drepanodus pseudoconcavus
Drepanoistodus forceps
Oneotodus variabilis
Paracordylodis gracilis = ?Oneotodus gracilis
Protopanderodus elongatus
?Rossodus highgatensis
?Scanodus flexuosus
?Scolopodus bolites

CUTTING HILL FORMATION

Canadian (Fauna C)

Acanthodus lineatus
Acanthodus uncinatus
Acodus oneotensis
Acodus triangularis
Clavohamulis densus
?Cordylodus lindstromi
Iapetognathus preaengensis
Loxodus bransoni
?Paltodus bassleri
Rossodus manitouensis

The slope to base-of-slope complex was dominated by fine-grained terrigenous sediments with occassional interbeds of lime mud that was carried off of the shelf in suspension. Coarse-grained carbonate or clastic sediment was either trapped on the shelf or carried past the slope into deeper water by turbidity flows passing down submarrine canyons transecting the slope and cutting into the shelf. Periodically, carbonates would build out onto the upper slope shales, producing the ragged slope-shelf boundary now represented in the Rysedorph Hill terrain.

Sedimentation

The Beekmantown shelf (Mazzullo and Friedman, 1975, 1977; Mazzullo, 1978) is punctuated by many pure quartzo-feldspathic sands and very arenaceous carbonates formed in littoral zones leading out (eastward) into generally peritidal flats of lime muds with localized siliciclastic accumulation. Algal mat remains (stromatolites) were ubiquitous. Reef-like accumulations (bioherms) of stromatolite heads and thrombolites frequently occurred. Oolitic shoals are encountered near the shelf edges and along the edges of deeper channels.

The peritidal shelf-edge shows abundant features of shallow-water deposition, e.g. dessication cracks, rip-up clasts, flat-pebble conglomerates, cryptalgal-laminites, probable tidal channels, and flaser bedding. Peritidal cycles reflect depth-controlled oscillations in sedimentation rate coupled to long-term gradual subsidence and short-term oscillation in sea-level. The deposits are shallowing-upward cycles (SUCs) (Mazzullo and Friedman, 1975, 1977; Mazzullo, 1978; Chisick and Friedman, 1982a), asymmetric units of very fine calcarenite overlain by a thicker section of coarse calcilutite. Upwards through a SUC, there is a decrease in fossil taxa, grain-size, intraclasts, and pelloids, and an increase in dolomite and fenestrae or a change from current laminates to disrupted planar algal laminates. Subaerial overprints (marked by crusts with wavy shale partings) are common near the top of middle Beekmantown SUCs.

Although dominated by peritidal carbonates, the Beekmantown does contain subtidal sequences formed during repeated drowning of the outer portions of the shelf. Regionally, cyclic peritidal sequences encase subtidal limestones and bioherms which pass landward into cyclic peritidal facies. Basal transgressive sands formed during submergence, followed by ribbon carbonates and intraclastic wave-agitated layers or mixed flats in shallow intertidal settings. Reworking is evident in abundant fining-upward layers, channel-lags, and wave-formed structures. Episodic surges of sediment laden storm currents overwhelmed developing algal-mats with very rapidly deposited silt and sand, temporarily terminating mat growth.

The Beekmantown sediments found in the Champlain Valley attest to mild epierogenic basin deposition. Gradual subsidence during sedimentation maintained the depositional surface, producing subtle switchback regressive-transgressive packets which are time-site specific but not time-basinal correlative. Vertical sequencing of conformable lithologic units reflects lateral juxtaposition of corresponding environments, thereby implying large-scale trends involving regionally significant changes in marine conditions, thus demonstrating Walther's "Law of Facies". The asymmetry of the total vertical section must represent a more complex change in environmental/sedimentological parameters over time.

In the Champlain Valley correlations of immediately adjacent lithologies are difficult, at best, because of facies changes, repetitive lithic sequences, sedimentologic discontinuities, localized and regional diagenetic events (esp. dolomitization and dedolomitization), and structural complexities. In addition, the strata generally have sparse and biostratigraphically nondiagnostic macrofossil assemblages. Thus, the Beekmantown is difficult to unravel in the Champlain Valley.

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ITINERARY

The assembly point is the Williams Old Brick Store in the village of Charlotte (just west of Route 7 on Route F-5). Time: 8:30 a.m.

Mileage

0.0 Go south from blinker.

0.7 On the right is Barber Hill, an alkaline igneous intrusive complex (syenite) that cuts the Paleozoic sedimentary sequence of the Champlain Valley (Welby, 1961; Laurent and Pierson, 1973), here the Iberville (Clark, 1934) member of the Stoony Point formation (Ulrich, 1911) (Middle Ordovician). To the left is a panorama of the Red Sandrock range, a line of hills capped by Monkton quartzite (Keith, 1923) (Lower Cambrian) of the Champlain thrust sheet. The thrust trace lies at the base of the cliffs near the top of each hill.

1.8 Hill on right contains Burchards member (Cady, 1945) of Providence Island formation (Ulrich and Cooper, 1938) (earliest Middle Ordovician) intruded by a swarm of igneous dikes (Perkins, 1908).

2.0 Turn right onto Thompson's Point Road.

2.1 Railroad crossing.

2.3 Thorp Brook thrust fault. The roadcut is through Bridport member (Cady, 1945) of the Providence Island formation in the footwall.

2.4 Emerson Schoolhouse thrust (Brainerd and Seely, 1890a) separates the Providence Island strata from the Fort Cassin strata of Stop 1.

2.5 STOP 1: Emerson Schoolhouse. The roadcut just west of intersection contains excellent exposures of the Emerson Schoolhouse member (Welby, 1961) of the Fort Cassin formation (Whitfield, 1890a) (the type section is the ledges just south of road). The old Emerson schoolhouse, on northwest corner, has recently been converted into a house. The Emerson Schoolhouse member is a light bluish-grey weathering-enhanced doloargillaceous limestone and silty quartzofeld-spathic calcitic dolostone. Note the abundant dessication and solution-collapse features, indicating episodic emergence. The nodular (?stylonodular) nature of the outcrop suggests syndepositional compaction and stretching that produced sedimentary boudins. The slight overlapping of nodules in the same horizon and folding-contortion of some nodules may indicate minor down-slope movement. Note the basal detachment surfaces, typically planar and parallel with the underlying bedding. Locally the surfaces are undulating and at times truncate underlying units. Occassional black cherty dolostone layers are interspersed within the Emerson Schoolhouse. We feel Welby's (1961) distinction of a Thorp Point member is artificial (Washington and Chisick, 1987) since the type-strata differ from the Emerson Schoolhouse only slightly in amount and character of the constituent lithologies. The top of the Fort Cassin, here at the Emerson Schoolhouse intersection, has been faulted out.

Turn around.

2.9 Railroad crossing.

3.0 Turn right (actually a double right) onto road that parallels railroad.

5.5 Continue straight on Greenbush Road.

7.5 Turn right onto Route 7. Roadcut is Larrabee member (Kay, 1937) of Glens Falls limestone and Orwell (Cady, 1945) member of Isle la Motte formation (Emmons, 1842) (Middle Ordovician).

9.2 Ferrisburg Four Corners. Road to right leads to Fort Cassin headland on Lake Champlain, the type locality of the Fort Cassin formation (Whitfield, 1890a; Cushing, 1905; Ruedemann, 1906) and the fauna of the Cassinian stage (Whitfield, 1886, 1890a,b,c; Foyles, 1923). It is now private property and the landowners are hesitant to allow geologists onto the rocks.

9.8 Outcrops on left are Glens Falls limestone.

10.6 Intersection with Route 22-A. Continue straight on Route 7. Outcrops on right are Crown Point limestone (Cushing, 1905) (Middle Ordovician).

11.4 Railroad crossing. Beldens (Cady, 1945) member of Providence Island formation in fields to left.

13.1 Monkton quartzite along road. This is the north end of the Buck Mountain massif, a tectonically isolated piece of the Champlain thrust sheet (Washington and Chisick, 1987; Washington, 1987c).

15.1 Sciota School (Fisher, 1977) and Emerson Schoolhouse mambers of Fort Cassin formation in field to left.

15.3 White Pigment's New Haven Junction plant. The rock is brought here from quarries in Middlebury and Shelburne. The Middlebury quarry is in Lemon Fair and Fort Cassin strata. The Shelburne quarry is in Shelburne marble (Lower Cambrian [Keith, 1923]). Originally, Lemon Fair strata from nearby quarries supplied the plant.

15.6 Turn left on Route 17.

16.3 STOP 2: New Haven Roadcut. Lemon Fair formation. The outcrops on the north side of the road are exposures of the upper Lemon Fair as it approaches the formational contact with the overlying Fort Cassin (which forms a few outcrops along the crest of this ridge). The Fort Cassin in this area contains Sciota School and Emerson Schoolhouse members, but the Ward siltstone (Fisher, 1977), which lies at the base farther south, is absent.

Lithologically, the upper Lemon Fair approaches the Ward member of the Fort Cassin in its increased dolomitic and sandy nature. However, the conodonts *Histiodella donnae*, *Oneotodus simplex*, *Oneotodus variabilis*, and *Ulrichodina deflexa* peg the Beekmantown D_2-D_3 nature of this exposure. This creates a stratigraphic problem since the Fort Cassin has been defined as D_3-D_4 (Cushing, 1905; Ruedemann, 1906) and is based on a major change in the fauna (Flower, 1964, 1968; Fisher and Mazzullo, 1976; Chisick and Bosworth, 1984) between Cutting Hill (Washington and Chisick, 1987, modified from Cady, 1945) and Fort Cassin. A stratigraphic solution does exist, the synthem (see Chang, 1975; Salvador, 1985).

With synthems, neither the lithologic character of the rocks that compose the unit nor their fossil content nor the time span represented figure into the definition and recognition of the new unit. This avoids excessively inflexible terminology in stratigraphic classification and recognizes the special cases that always exist in the field with unconformity bounded geometric controlled rock bodies.

The Lemon Fair is a classic synthem, bounded above and below by major regional disconformities. Although primarily composed of D_1-D_2 strata, the Lemon Fair does extend nearly to the top of D_3. Despite an internal hiatus that extends for nearly the entire Jeffersonian stage, there is no apparent lithologic boundary within the section. Additionally, D_1 is split between the Smith Basin member (Flower, 1964) of the Cutting Hill formation and the lower Lemon Fair depending on the local position of the regional disconformity. Under ISSC guidelines, the Lemon Fair meets the special requirements of the synthem and helps to resolve a serious impediment to stratigraphic and structural studies in the Champlain Valley.

Sedimentologically, the upper Lemon Fair consists of laminated, cross-laminated, and cross-stratified dolomitic quartzofeldspathic siltstone with thin wisps of fine sandstone on argillaceous siltstone. Ripple-trains/ripple-marks are characteristic features of these beds. This exposure has been structurally deformed. Small chevron folds with associated bedding-plane shear zones and incipient cleavage abound. The dark bands and blebs within and between laminations/bedding planes show dessication and tension cracks filled with anthraxolite (i.e. spent petroleum), indicating that these beds were once excellent source beds for petroleum.

Continue.

17.0 Turn right (first right) by monument onto Town Hill Road. This is New Haven Village.

18.9 Turn left onto Route 7 and continue south.

20.0 Turn right onto Campground Road.

20.4 Railroad Crossing. The outcrops for the next couple miles are Providence Island formation and Middlebury limestone.

21.2 Turn left onto Pearson Road.

58.8 To left is view of Great Ledge and Rattlesnake Mountain. The Taconic Frontal thrust lies about at the base of the cliffs.

59.1 Beldens member of the Providence Island formation on right.

59.7 To the right lies strata ascribed to Forbes Hill conglomerate by Zen (1961), Poughkeepsie melange by Fisher (1977; 1985), and Rysedorph Hill conglomerate by Cushing and Ruedemann (1914) (these are just different names for the same unit).

60.7 To the right on Forbes Hill is an igneous dike-swarm cut by cross-faults in both carbonates and shales.

60.8 Zen's (1959) stop 2.

60.9 Bear left onto Main Road (east).

61.6 Bridge over Hubbarton River.

61.7 Outcrop of Bridport member of the Providence Island formation on left.

62.1 Turn right onto Hackadam Road (dirt).

62.3 Bear right. Outcrops on right are Emerson Schoolhouse member of the Fort Cassin formation and Burchards member of the Providence Island formation.

62.7 To right is upturned Bridport member of Providence Island formation thrust over Hortonville slate.

62.8 Turn right onto River Road.

62.9 To right by line of birch trees, note flat lying Providence Island overlying Hortonville. Hortonville has small limestone boulders and cobbles in matrix and along bedding planes.

63.3 STOP 6: Forbes Hill Thrust System. The rock face in the old gravel pit across the Hubbardton River (this is the south end of Forbes Hill) shows highly imbricated Burchards member of the Providence Island formation thrust over Snake Hill shale. The imbricate thrust system exhibits all the characteristics of a duplex (see Fermor and Price, 1976; Elliott and Johnson, 1980; Boyer and Elliott, 1982; Cooper and others, 1983; Washington, 1987a), although the roof thrust sheet has been removed by erosion. As was recognized by Cadell (1888) a century ago, imbrication of this sort necessitates stiff (i.e. lithified) materials. Furthermore, the mechanics of duplex formation (Washington, 1987a) require cohesive overlying strata (for experimental confirmation, see Chamberlin and Miller, 1918). Thus, we interpret the deformation herein to have occurred in lithified materials (Chisick and Washington, in prep.), not soft sediments as Zen (1961, 1967) and Rodgers (1982) have claimed. Further confirmation of our interpretation is provided by the occurrence of fractures, cleavage, and cataclasis in both limestone and shale.

Continue.

63.4 Hortonville slate on right and left.

63.5 Sand pit with varved sand couplets of Fort Ann Stage of Lake Vermont (Chapman, 1942).

63.8 Turn left onto Main Road and cross bridge.

64.5 Bear left.

64.6 Hitchcock Cemetery on left.

64.7 To left is a thrust fault cutting Providence Island strata.

64.8 Thrust fault cutting Providence Island near leading edge of Forbes Hill duplex.

65.0 Continue straight.

65.1 Snake Hill shale.

65.5 West Haven thrust.

66.0 West Haven Village. Continue straight for Stop 7.

66.2 Orwell member of the Isle la Motte limestone (Ulrich and Schuchert, 1902).

66.4 Snake Hill shale on right.

66.6 An unnamed thrust follows the break in slope.

66.8 Turn right onto Burr Road.

66.9 Coggman (aka Codman) Creek.

67.1 Continue straight on Burr Road.

67.3 Lower Lemon Fair strata on left.

locally cherty. In the outcrops at this locality cross-beds and cross-stratification features abound and classic tidal channel features are common. Intermittently, the sand content increases to form dolomitic arenite layers. The chert, black to blue-black, occurs within the more mottled sections. The East Shoreham is a most conspicuous and superb mapping unit, especially when accompanied by the underlying Winchell Creek siltstone member (not exposed here). Ripple marks, desiccation cracks, and (most notably) Scolithus burrows are characteristic features of the Winchell Creek.

Continue.

40.9 Continue straight.

41.0 Richville dam on right, deformed Ticonderoga on left. River valley follows a thrust within the Shoreham duplex.

41.3 Turn left onto Shoreham-Whiting Road.

The type section for the Beekmantown (Brainerd and Seely, 1890a) was measured in the ledges extending north from this road. Although the outcrop is excellent, it would require the rest of the day to show a good composite section in this area.

42.0 East Shoreham Cemetery. This is the south flank of Cutting Hill, the type section for Cady's (1945) Cutting dolostone (see also Fisher and Mazzullo, 1976) and the Cutting Hill formation (Washington and Chisick, 1987). The ledges to the west of the cemetery are the type locality for the East Shoreham member.

42.2 Turn right onto East Shoreham Road (also called Shoreham Depot Road).

42.9 Old Addison Railroad bed. To right is a covered railroad bridge, recently restored.

43.0 Bridge over Richville reservoir (Lemon Fair River). This marks the very southern end of the Pinnacle thrust sheet.

43.8 Turn right onto Royce Hill Road.

45.5 Magnificent view of the Adirondack front. The tectonic cause of this front, which is apparently related to recent uplift of the Adirondacks is not known.

45.6 Ledges of Burchards member of the Providence Island.

46.4 Turn left onto North Orwell Road.

47.1 Old quarries in Orwell member of the Isle la Motte formation and Glens Falls limestone along the side of Deignault Hill to left. These quarries show nice examples of various types of faulting.

47.8 Orwell Cemetery.

48.2 Turn right onto Route 73.

48.3 LUNCH. Park in drive in front of school.

Continue.

48.5 Turn left onto Route 22-A.

Just to the west of this intersection is the Orwell duplex described by Chisick and others (1984).

49.1 Outcrops of Orwell member of the Isle la Motte formation.

49.4 Outcrop on left is Crown Point limestone.

50.0 East Creek Marsh marks the East Creek thrust, the roof thrust of the Orwell duplex.

50.4 Outcrop on left is Glens Falls limestone.

54.6 Cliffs to left are the southwest edge of the Sunset Slice of the Taconics.

54.9 Outcrop on right is Emerson Schoolhouse member of the Fort Cassin thrust atop Hortonville slate (Keith, 1932).

North end of the Rysedorph Hill terrain.

55.8 Turn right onto Benson Landing Road.

56.0 Outcrops of Hortonville slate.

56.6 Benson Corners. Turn left onto Stage Road.

56.9 Snake Hill. Outcrop on right is Benson slate (=Hortonville), not Lower Cambrian "Bull formation" as Zen (1961) claimed.

dant vertical burrows, dessication cracks, intraclasts, fenestrae, and other sedimentological features indicative of deposition in peritidal settings. Salinity varied and circulation was poor. Siliciclastic pulses of fine argillaceous material and minor silt-sized quartz, feldspar, and mica flakes were transported east onto tidal flats and out distal tributary channels. Temporary shut-off of the siliciclastic pulses allowed a more marine and carbonate dominant deposition to occur. The biota diversified and bioturbation (mottling) became more pronounced. Deeper conditions resulted in more limestones and massive bedding. As conditions shallowed, emergent fabrics and dolostones, both primary and dolomitized earlier sediments, formed. Bedding at this stage was controlled by precursor stratification and intensity of dolomitization dynamics.

Continue.

29.3 Cliffs to left are dolostones of the East Shoreham member of the Cutting Hill formation. The trace of the Weybridge thrust follows the base of the cliffs. To the right across the Lemon Fair Valley is the Snake Mountain massif containing Lower Cambrian strata of the Monkton thrust sheet. The Weybridge thrust breached the Champlain thrust sheet and superimposed the Ordovician carbonates onto the trailing edge of the Snake Mountain massif.

30.7 Turn left onto West Street (if you cross the bridge on Route 125, you have gone too far).

As you drive south along West Street, note the hills on the other side of the Lemon Fair Valley (to your right). These hills constitute the type locality for Cady's (1945; Cady and Zen, 1960) Bridport dolostone, now included as a member in the Providence Island formation (Washington and Chisick, 1987; also see Ulrich and Cooper, 1938; Schuchert, 1943).

34.2 Turn right onto Route 74.

34.7 Roadcut through Lemon Fair formation.

35.0 Cliffs of sandy Lemon Fair strata on right; Washington and Chisick's (1987) stop 2. The Pinnacle thrust trace lies at the base of the cliff. For the next 6.5 miles the route lies within the Shoreham duplex (Washington, 1985).

35.1 Lemon Fair River.

35.8 Turn left onto Quiet Valley Road.

36.1 The hills to the left are Ticonderoga (Welby, 1959, 1961, after Rodgers, 1955) (Upper Cambrian) and Whitehall (Rodgers, 1937) (Upper Cambrian - Lower Ordovician) formations; to the right is Lemon Fair formation. A thrust separates them.

37.7 Bascom's Ledge lies across the valley to the east. This is the type locality for the Beekmantown group (Dana, 1877a, b; Brainerd and Seely, 1890a; Clarke and Schuchert, 1899).

38.1 Continue straight onto Shacksboro Road at corner.

38.2 Bridge over Lemon Fair River. The "falls" to the right supported a small village in the 19th century. This village bore the names of Shacksbury and Newell's Mills. The strata exposed in the falls is Lemon Fair formation.

Turn right.

38.6 Crown Point Road marker on the left. This road was built in 1760 (the end of the French and Indian Wars) to connect Fort Crown Point on Lake Champlain with Fort Number Four on the Connecticut River. It crossed this spot because it crossed the Lemon Fair River at the "falls" we just saw, the only feasible ford across the Lemon Fair (the name comes from the French "Limon faire" = "to make mud").

39.3 Cliffs to left are Lemon Fair formation. This is the west side of the Pinnacle.

40.4 STOP 5: The Euber Ledges. The outcrops to be visited extend down the hill from behind the house just southwest of where we stop. The "canyon" of the Lemon Fair River exposes several ledges of the upper Cutting Hill formation, mainly the Smith Basin and East Shoreham members. The uppermost member, the Smith Basin (Flower, 1964; redefined by Fisher and Mazzullo, 1976) is a massively-bedded medium dark grey limestone with wispy laminae of silt-size feldspar and quartz. Some irregular nodules of black chert are locally present in the rocks, usually replacing macro-fossils (Flower, 1964). In both Vermont and New York the Smith Basin is characterized by large solution cavities. Many of the clasts within these paleokarsts are derived from the overlying Lemon Fair formation. Immediately below the Smith Basin is the East Shoreham dolostone. This medium to thin bedded dolostone is very quartzose and

21.9 The hill to left is Crosby's (1963) station 7 and Coney and others (1972) Stop 1.

22.1 Huntington Falls Bridge.

22.2 STOP 3: Huntington Falls. Weybridge Problem. Since Cady (1945; supplemented by Cady and Zen, 1960) the Weybridge siltstone has been considered the basal member of Providence Island formation (nee Beldens, nee Bridport, nee Chipman). This section has been thought to consist of a "flat-lying" sequence of ribbon-thin limestones separated by equally thick dolofeldspathic silts. Careful observations at Huntington Falls, however, shows that the type section is structurally complex. These observations were confirmed during the recent construction of a new power station at the falls, when fresh, continuous cuts were made through the ledges south of the falls proper.

The strata above the falls are definitive "flat-lying" Beldens member of the Providence Island formation, but the falls themselves coincide with a major thrust. Imbricate thrusts form the steps in falls. The small thrust sheets contain mainly Middlebury limestone (Washington, 1987b), often overlain by Hortonville. As has been noted by prior workers in the Champlain Valley, the striped-bedding commonly observed within the limestones is not stratigraphically definitive. The exposures during construction of the new power plant showed that most of the small thrust sheets are capped with Hortonville slate. Although the stratigraphic position of some of the siltstones is not certain, most lie within the upper Middlebury and can be correlated with Washington's (1982) sandy facies of the Middlebury. Thus, the type-locality for the Weybridge siltstone is mostly not (if at all) within the Providence Island. This creates a terminological problem, as yet unresolved, since there truly is a siltstone member that lies near the base of the Providence Island formation.

Continue.

23.5 Outcrops in the woods are Beldens member of the Providence Island formation and those in the fields are primarily Middlebury limestone (Middle Ordovician) of the Sudbury duplex (Washington, 1981a, b, 1987b). This is the northern end of the duplex.

23.9 Turn right onto Hamilton Road.

24.9 James Pasture to right (Crosby, 1963, station 10; Coney and others, 1972, stop 2; Washington, 1987c, stop 6).

25.4 Turn right onto Route 23 and then immediately bear left around monument onto James Road (south).

27.9 Turn right onto Route 125.

28.1 Bear left.

28.4 Bear right.

28.8 STOP 4: The Ledges. The an excellent exposure of the Bascom subgroup (Washington and Chisick, 1987) except for the lower part of the Cutting Hill formation (Winchell Creek [Fisher and Mazzullo, 1976] and lower East Shoreham [Washington and Chisick, 1987] members), overlain by the lower Providence Island formation (primarily Burchards member). The Providence Island strata (except for a thin veneer of Burchards adjacent to the Lemon Fair contact) are highly deformed, being caught up in the Sudbury duplex. The floor thrust of the duplex lies within the lowermost Providence Island and forms the lower boundary for the major deformation.

The Fort Cassin is well-developed here with Wing's Conglomerate (Seely, 1906), Emerson Schoolhouse, and Sciota School members represented stratigraphic succession as one descends through the section. The conodonts Ulrichodina abnormalis, ?Scolopodus toomeyi, Glyptoconus quadraplicatus, and Drepandodus concavus have been identified from the middle of the section.All are good indicators of Cassinian fauna, hence the Fort Cassin formation.

The Ward member is absent from the base of the Fort Cassin here. Just as at Stop 2, the underlying Lemon Fair transcends the Jeffersonian hiatus and Fort Ann (Flower, 1964, 1968) fauna mixes with Fort Cassin fauna. The Lemon Fair is thin at here, so its contact with the uppermost Cutting Hill (Smith Basin member) can be seen near the downhill end of the roadcuts. Since the expected lithologic and faunal breaks can not be seen, this roadcut presents an excellent case for the application of the stratigraphic term synthem. Here the Jeffersonian stage is at least mostly absent, but the sedimentologic logic sequence does not reflect the break.

The Bascom subgroup deposits of mixed carbonate-siliclastic sediments began on a broad tidal flat composed of supratidal and intertidal flats which were dissected by tidal channels. These fine-grained argillaceous units contain a restricted fauna, abun-

67.9 Gate on right. Access path for Shaw Mountain.

68.3 Turn around in barnyard and proceed back along road.

68.6 Park on right far enough over to allow milk truck by.

Figure 4 - Geology of the Shaw Mountain area. Paleozoic thrusts denoted by closed teeth, active high-angle reverse faults by open teeth. Och - Cutting Hill, Ofa - Fort Ann, Olf - Lemon Fair, Oil - Isle la Motte, Ob - Benson, Osp - Stony Point, O Chazy - Chazy undifferentiated.

68.7 STOP 7 (optional): Shaw Mountain Klippe (fig. 4). The Shaw Mountain klippe consists of Fort Cassin and upper Lemon Fair strata and abuts Cutting Hill and lower Lemon Fair to the west and southe. On the east, the klippe is underlain by Hortonville (called the Benson by Wheeler, 1941) slate, and on the north it is underlain by Trenton and Chazy limestones and an unnamed Chazy shale (proposed Benson Landing shale of Chisick and Friedman, 1982b) which also abuts the Cutting Hill to the west. We interpret the Cutting Hill and lower Lemon Fair block to be a modern (active) east-directed thrust sheet associated with the present uplift of the Adirondacks. The strata within the Shaw Mountain klippe is overturned, dipping about 40° east and younging westward. The underlying strata dips eastward between 5° and 12° and youngs upward. Thus, Shaw Mountain is structurally and stratigraphically discordant with the underlying rocks. The most reasonable explanation for its origin is as the recumbent limb of a fault-bend fold above a hangingwall ramp in a thrust sheet overlying the Rysedorph Hill terrain.

Shaw Mountain is probably the reason that no detailed maps have ever been published of this area. The maps published by Dale, Ruedemann, Walcott, Wheeler, Rodgers, and Zen are so generalized as to be meaningless. Recent detailed mapping by Chisick (see Chisick and Friedman, 1982b) has elucidated the stratigraphic relations, but only recently have we been able to resolve the structure into a workable model. It should be noted that Keith also mapped this area (Washington, 1987d) and correctly identified the stratigraphic relations, but he never published his findings. The Centennial Geologic Map of Vermont (Doll and others, 1961) gives a relatively detailed view of this area, but much of the stratigraphy is misidentified, as fossils found by Chisick and Keith show.

Continue.

69.7 Turn left onto Main Road.

70.4 Turn right onto Book Road.

70.6 East-west normal fault of Rodgers (1937).

70.8 Lemon Fair formation.

70.9 Note thrust at base of roadcut on left. Lemon Fair is thrust over Snake Hill shale. This thrust was not recognized by Rodgers (1937) or Rodgers and Fisher (1969).

71.0 Sugar house on right.

71.7 Bridge over Poultney River; Vermont - New York boundary. Note terminology changes.

72.4 Sciota Cemetery on right. Outcrops of Fort Ann (= Lemon Fair) strata.

72.7 Continue straight.

73.3 Original site of Sciota School on left. Base of type section for Sciota School limestone member of the Fort Cassin formation.

73.5 Sciota School memberon left, Ward member on right.

73.6 Type locality for Ward siltstone member of the Fort Cassin formation (Fisher, 1977, 1984) named for Ward Road to right. Continue straight.

73.7 Fort Ann on right, Ward member of Fort Cassin on left. Here the Jeffersonian hiatus is the formation boundary so the Lemon Fair name is dropped in favor of Fort Ann (Flower, 1964).

74.3 Turn left onto Washington County Route 11.

74.6 STOP 8: Westcott Corner Thrust Model. This is Bosworth and Kidd's (1985) stop 2. The carbonate blocks within the Rysedorph Hill terrain generally consist of upper Beekmantown strata (Cutting Hill and above), with a few of Crown Point and Isle la Motte strata. All of these blocks contain very limited sections of the carbonate succession and are overlain by Snake Hill slate. Historically, these blocks have been considered olistostromes of a major melange (Cushing and Ruedemann, 1914; Wheeler, 1942; Zen, 1961, 1967, 1972a; Rodgers and Fisher, 1969; Fisher and Wharton, 1976; Fisher, 1977, 1984; Bosworth and Kidd, 1985), but their areal distribution is not random and they are all underlain by thrust surfaces, so we do not accept the old interpretation (see Leonov, 1983). Rather, we feel that their distribution into successive uni-stratigraphic rows of blocks, with the rows lying in proper stratigraphic order, indicates that these blocks are remnants of carbonate stringers built out onto upper rise shales (the Snake Hill) and were deverticulted and deformed during thrusting of this upper rise sequence onto the shelf.

As Bosworth and Kidd (1985, Stop 2) point out, this outcrop shows a block of Burchards member of the

Providence Island formation that has been internally deformed and thrust onto Snake Hill shale. This deformation probably preceded major displacement on the Mettawee River fault (the frontal thrust for the Rysedorph Hill terrain) (see Washington, 1987a, 1987c, for discussions of relative timing of thrusting and deformation). The penetrative structures within the shale and limestone and the cataclastic textures adjacent to the faults indicate that this deformation was definitely post-lithification. Thus, not only is the melange origin of this belt considered unlikely, but the major deformation did not occur in "soft sediments" as so many prior workers have claimed.

Continue.

74.8 Turn right onto Wescott Road.

75.0 Snake Hill shale on left in burrow pit.

75.3 On left, Burchards member of Providence Island thrust over Snake Hill shale. Major thrust in valley to right.

75.4 Larrabee member of Glens Falls limestone on left.

75.7 Isle la Motte limestone thrust over Snake Hill shale.

75.8 To left, Snake Hill shale capped by a klippe of Taconic slates.

75.9 Turn right onto Carlton Road.

76.1 Beldens and Burchards members of Providence Island formation.

76.3 To the south (left) along Mud Brook can be seen a ramp anticline with Burchards member of Providence Island formation overlain by younger limestones. Mud Brook flows along the thrust fault which formed the Mud Brook gulf.

76.5 Cross Bosworth and Kidd's (1985) Taconic Frontal thrust. Although this is indeed a major thrust, it lies within the Rysedorph Hill terrain and is not marked by either a lithologic or metamorphic boundary so we do not feel this should be called the Taconic Frontal thrust.

76.6 Bear left. Snake Hill shale on left after corner. This is Bosworth and Kidd's (1985) stop 3.

76.8 Carlton School on left, Carlton thrust on right.

77.0 Emerson Schoolhouse member of Fort Cassin formation.

77.1 Snake Hill shale.
At this point we pass westward out of Rysedorph Hill terrain onto parautochthonous carbonates.

77.4 Turn right onto Fairhaven Turnpike.
Just west of the corner lies the Carlton thrust, Fisher's (1984) high-angle normal fault boundary separating carbonate autochthon from the allochthonous melange.

77.6 Fort Ann formation on right, Sawmill Pond normal fault on left.

77.9 Turn left onto Buckley Road.

78.2 Emerson Schoolhouse member of Fort Cassin formation on left.

79.6 Park on left by abandoned truck scales.

Stop 9: Tri-County Stone Quarry. Exposed within the abandoned quarry are the Winchell Creek (somewhat more limey than usual) and Kingsbury members of the Great Meadows formation (approximate equivalent of the Cutting Hill formation in Vermont). These units are stereotypical of sabkha-imprinted tidal flats (Mazzullo and Friedman, 1975). Along the northeastern rim of the quarry lies the Sciota School member of the Fort Cassin underlain by a thin layer of Lemon Fair. The limey nature of the Winchell Creek and near absence of the Lemon Fair indicate that this is along stratigraphic strike from Thompsons Point (Stop 1).

During the Lower Ordovician, several withdrawals of marine conditions temporarily exposed broad expanses of continental shelf (Braun and Friedman, 1969). These short-lived exposures are reflected in abrupt changes in types of sedimentation, wavy erosional surfaces, and karstic features. However, one wonders how abrupt is abrupt!

Along the western wall of this quarry, a marked change in sedimentation can be seen. Here the upper Winchell Creek boundary is marked by an iron-stained disconformity separating it from the overlying Kingsbury limestone. The change is abrupt and nicely preserved, but within the realized norm for geology. Along the northeastern rim, wavy erosional surfaces identify major disconformities along the top of the Kingsbury limestone (C_2) of Great Meadows formation and the base of the Sciota School member (D_4) of Fort Cassin formation. Note the rolling nature of the Fort Cassin bedding. This is not thrust fault controlled, rather it is depositional and geometrically expected.

Within the upper Kingsbury and lower Lemon Fair are two sets of enigmatic vertical features. Fisher (1984, from an oral communication by S. Schammel, 1983) interprets these as "Neptunian fissures" caused by undersea earthquakes which "cracked" the limestone and filled these chemically enlarged (i.e. by instantaneous pressure solution) voids with calcarenite. We do not agree.

We interpret these vertical features to be solution-enhanced dessication cracks formed on abruptly emergent intertidal flats. The cracks and subsequent chemical enhancement must have occurred when the material was in a nearly to completely lithified state since no collapse structures have have been found adjacent to these features. The "U-ed" bases of the fissures were definitely created by karstic processes, and the concave layering of the included sediments indicate they were infilled by particulate deposition from above. In addition, the cyclic nature of the fill stratigraphy indicates the material arrived by normal sedimentologic processes.

The fissures are regularly arranged, forming polygons. They reach to relatively constant depths and tend to be bulbous toward the bottom, indicating that depth was controlled by a base water table. They may have been quite deep originally, but erosion of the uplifted material would have decreased the apparent fissure depth. The fissure sets may appear to be quite large, but even larger sets have been observed in West Texas, Arizona, Nevada, and Abu Dhabi in areas where excessive lowering of the water table has occurred in relatively rapid, truly catastrophic events. Thus, we interpret these as recording two catastrophic lowerings of sea-level at some time between lower Cutting Hill and Fort Cassin time. The depth of the fissures indicates the approximate level of the lowered sea-level. From observations elsewhere, we prefer to correlate these with the karst events at the Cutting Hill/Lemon Fair formational boundary and the Jeffersonian hiatus. Finally, the fill bears strong lithologic affinity with the sandier Lemon Fair/Fort Cassin strata, but no fossils have yet been obtained from the fissure fill.

Continue.

79.7 Turn right onto Route 4.

Roadcut on right contains limey Winchell Creek siltstone member.

79.8 Valley marks boundary between Great Meadow formation (east) and Whitehall dolostone (west).

80.0 Quarry in Whitehall formation; both Skene and Steve's Farm members present.

80.1 Skene Mountain on right. Type section of Whitehall formation (Rodgers, 1937).

80.3 Ticonderoga-Whitehall formational contact on right.

80.4 Potsdam-Ticonderoga formational contact on right.

80.5 Turn left onto South Williams Street (by Armory).

80.7 Cross railroad tracks.

81.0 Bridge over Mud Brook.

81.4 Continue Straight.

On left, Greenmount Road; Greenmount Cemetery on hill of Whitehall (Skene member). On right, Adirondack front.

Note the topography - numerous right angle bends in streams, square hills. This is an area of modern block faulting associated with the active uplift of the Adirondacks.

82.0 Old cupolas from destroyed barns on right. Bear right onto Upper Turnpike Road at corner.

82.3 Mettawee River - following Tub Mountain fault here.

82.5 Upper Turnpike Road follows spur of Tub Mountain fault. On right is Fort Edward dolostone and Winchell Creek siltstone members of the Great Meadows formation. On left is Beldens member of Providence Island formation. Hill in distance is Tub Mountain, mostly Whitehall with a cap of Great Meadows.

83.0 Bear left on Upper Turnpike Road (paved).

83.2 Contact between Bridport member of Providence Island formation and Orwell member of Isle la Motte limestone. The Isle la Motte lies in core of a small syncline.

83.3 Bridport member of Providence Island formation.

33.4 Thrust fault placing Potsdam sandstone onto Providence Island formation.

33.8 Bear left. Dick Hyatt Road to right lies along Potsdam-Ticonderoga formational contact.

34.3 Mettawee River thrust, the frontal boundary of the Rysedorph Hill terrain.

34.7 Farmhouse on left served as C. D. Walcott's field station in 1886. On right is Whitehall underlain by Snake Hill shale.

35.6 Rodgers' (1952) suggested stop for private vehicles (road was unfit for buses at time).

35.9 Mettawee River to left follows frontal thrust of the Rysedorph Hill terrain. In this vicinity, Rodgers (1952), Sellick and Bosworth (1933), and Bosworth and Kidd (1985) have called this thrust the Taconic Frontal thrust. Sciota School and Emerson Schoolouse members of Fort Cassin on right.

36.3 Intersection of Comstock Cemetery normal fault with Mettawee River thrust fault. Hill on right contains Providence Island strata; south and to left is Fort Cassin strata.

36.5 Turn right onto Rathbunville Road.

As we proceed along this road, we pass strata equivalent to those at Stop 4, i.e. Providence Island, Fort Cassin, and Fort Ann.

37.4 Turn around and park.

STOP 10: Rathbunville Road. While driving down Rathbunville Road, you have passed down section from the Providence Island and are now stopped alongside the Skene member of the Whitehall formation. Two short walks will be taken:

Walk A: Reef in the Sciota School member of the Fort Cassin formation. On the crest of the hill north of the parking area. This is an in situ domal stromatolite-thrombolite reef with various cephalopods (Cassinoceras, Tarphyceras, and Eurystomites), trilobites, and ostracods (Isochilina) can be seen in a "life-assemblage" along with an excellent paleokarst. Please look but do not hammer!

Walk B: Tidal Flat Sedimentology. A walk west along the ledges next to the abandoned road leading through the Steve's Farm, Rathbunville School, and Skene members of the Whitehall formation will show several sedimentological features common to all tidal-flat environments. Tempesites with flaser-bedding (very rarely preserved) can be seen. Other features seen are horsetail stylolites, laminated crusts, herring-bone cross-beds, sinusoidal ripples, and general supratidal-intertidal environments.

Proceed back to Upper Turnpike Road.

88.3 Turn right onto Upper Turnpike Road.

88.7 Bear left.

88.8 Turn left and park in lot.

STOP 11: Mettawee Falls. This stop illustrates both tidal flat sedimentation/diagenesis and thrust structures of the Rysedorph Hill front. Along the west side of the river lies a thrust sheet containing Burchard's and "Weybridge" members of the Providence Island formation. The riverbank is bedding-plane surfaces of these strata with some of the best examples of tidal-flat features found anywhere. Among the features to be seen are:

a. mega-ripple trains;
b. several other types of ripple marks;
c. Liesegang-banding dessication cracks;
d. animal trails;
e. teepee structures;
f. rip-up clast conglomerates;
g. vanished evaporite nodules;
h. sabkha chertification;
i. paleokarsts.

Structural features present here include:

a. very small ramp anticlines above very small thrusts (some may be doubly blind);
b. tension-gash jointing;
c. incipient cleavage;
d. tectonokarst;
e. the Rysedorph Hill front separating multiply deformed deep-sea shales from the upper rise on the east bank from only slightly deformed, platform carbonates on the west bank.

Some of the structural and sedimentological features (e.g. small ramp anticlines and teepee structures) look very similar. Generally, however, the deformation in the carbonates is so minor that the sedimentary features are undisturbed and spectacularly exposed.

Turn right (west) onto Upper Turnpike Road when leaving parking lot.

88.9 Turn left onto Thomas Road.

Thomas Road follows the Providence Island-Fort Cassin formational contact; Fort Cassin on right, Providence Island on left.

90.0 In woods on right is another reef. This one is in the Fort Cassin formation.

90.5 Turn right onto Route 22.

For the next three miles we follow Emmons (1842) transect through the Beekmantown strata. Rodgers (1952) and Rodgers and Fisher (1969) followed this same route (from west to east) and this served as the type locality for the definition of the Canadian of Flower (1964).

91.2 Fort Ann behind Dot and At's Tavern.

STOP 12: Comstock Traverse. This is the "Calciferous" section described by Emmons (1842). Historically, the Beekmantown units have played an important part in the development of North American geologic thought, especially in the development of American stratigraphic nomenclature. This historic traverse still presents new data that leads to new insights and interpretations.

STOP 12a: Winchell Creek siltstone member of the Great Meadows formation. This outcrop, although somewhat disturbed by thrust deformation, shows the typical Winchell Creek lithology as defined by Fisher and Mazzullo (1976). The weather-enhanced cross-bedding, herring-bone cross-stratification, and soft-sediment deformation (slumps and folds) attest to the unstable depositional and diagenetic conditions of this section of Winchell Creek. Note the flame structures and bubble-escape (blow-out) features. Disc-structures can also be seen. Does this deformation indicate that these strata are from a portion of the Winchell Creek that had built out to the edge of the carbonate platform, or did it result shock-waves from syn-depositional seismic activity? We favor the former interpretation.

Continue.

91.9 Cross Comstock Cemetery normal fault.

92.0 Start of relatively complete Beekmantown section on right side of road. First is Burchards member of Providence Island formation followed by "Weybridge" member, which is underlain by Wing's Conglomerate member of Fort Cassin.

92.4 Boundary between Fort Cassin (east) and Fort Ann (west) on right. On left are dolostones of the Ticonderoga and Whitehall formations.

92.7 Park in space on left of road.

STOP 12b: Comstock Traverse (continued).

1) Skene member of the Whitehall formation.
An excellent example of a solution-collapse breccia. Note its deceptive appearance as a massive dolostone.

2) Skene member of the Whitehall formation.
A thrombolite mound with a highly dolomitized channel to the east. From across the road, one can see the ghosts of rounded gravels that made up the channel-lag. Note the power of the dolomitizing fluids as they moved through these rocks.

3) Winchell Creek member of the Great Meadows formation. Here are carbonate sand dunes dolomitized to look like massive dolostone. Only frosted quartz grains escaped the dolomitization and outline the original sedimentary layering.

Continue.

92.8 Whitehall behind prison guard homes on right.

92.9 On right, Comstock school. On left, Comstock Prison Quarry Road (quarry still active). Boundary between Whitehall and Ticonderoga formations.

93.2 Potsdam outcrops on right. Great Meadows Prison on left.

"Little boys who pick up rocks either go to prison or become geologists." (Ambrose Bearse)

93.5 Warden's House on left sits on Precambrian gneiss.

93.6 Bridge over the Champlain Canal.

94.0 Intersection of Route 22 and Route 4. We are sitting in the Precambrian of the Adirondacks.

End of Field Trip.