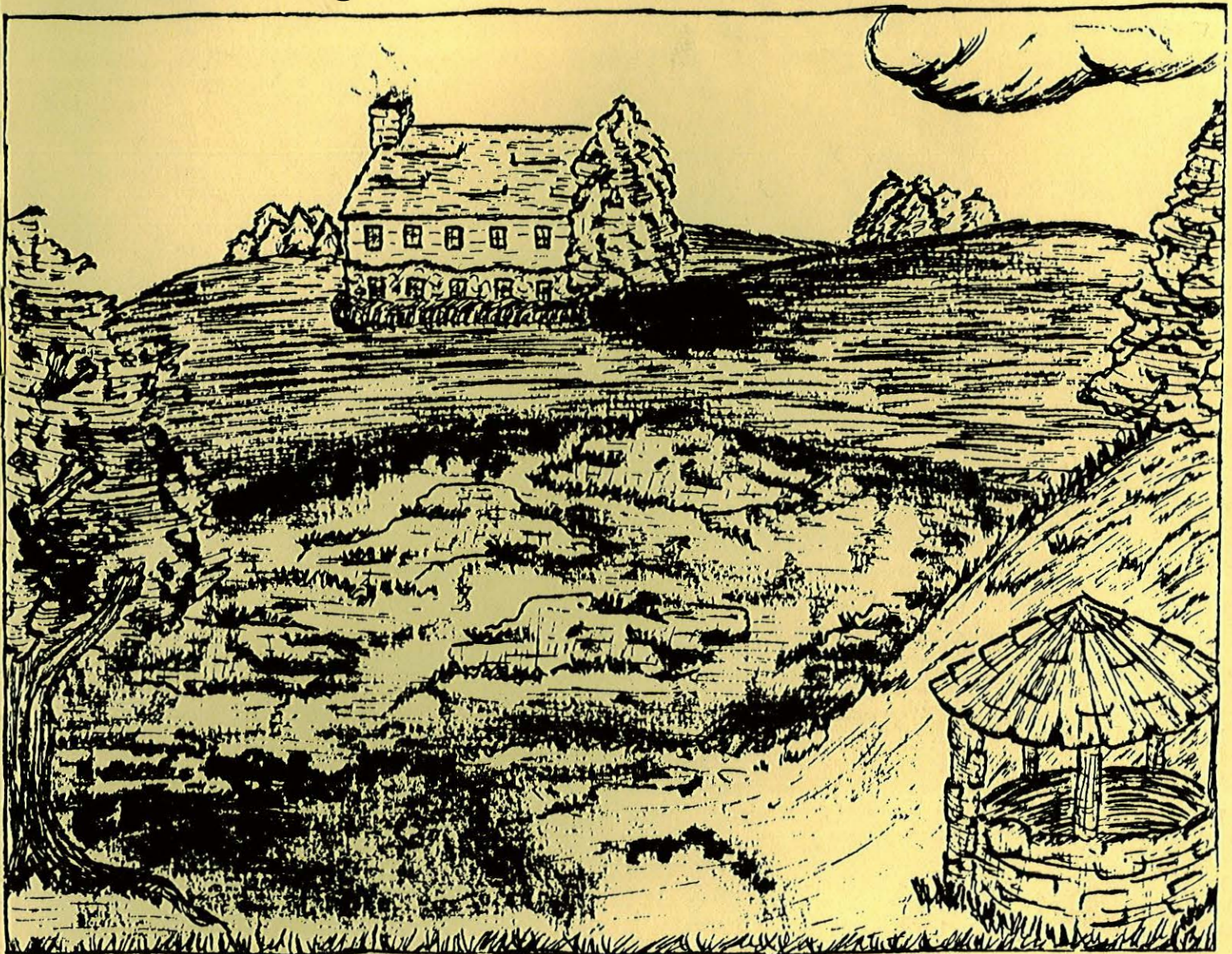


FIELD TRIP GUIDEBOOK

New York State Geological Association



High Rock Park

**57th Annual Meeting
September 27 - 29, 1985**

Department of Geology - Skidmore College

NEW YORK STATE GEOLOGICAL ASSOCIATION

57th Annual Meeting

September 27-29, 1985

FIELD TRIP GUIDEBOOK

Richard H. Lindemann, Editor



Department of Geology

Skidmore College

Saratoga Springs, N.Y. 12866

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PREFACE AND ACKNOWLEDGMENTS

It is a pleasure to welcome all of you to the 57th annual meeting of the New York State Geological Association and to Skidmore College. A program of field trips has been arranged to span the interests of hard rockers, soft rockers, and sand people alike. These trips have been scheduled for September 28 and 29 to visit many of the more outstanding sites in eastern New York State and adjacent New England. In addition to the traditional NYSGA events a program of workshops and field trips has been arranged for Secondary Earth Science teachers. This is scheduled for September 26-29. A separate field trip guidebook has been prepared for the Earth Science program. It is designated as NYSGA Special Publication No. 1 in hopes that this will encourage future host institutions to add to the numbers.

I wish to thank the field trip leaders, particularly those who submitted their manuscripts on time, for their efforts on behalf of the NYSGA. Students of the Skidmore Geology Club and my colleagues of the Skidmore College Department of Geology all contributed a great deal of time and effort in preparing for this meeting. Judy Preston prepared the logo for this year's meeting. Heather Johnson did the cover illustration of High Rock Park and the Old Bryan Inn.

I hope that each of you enjoy the field trips and are enriched by the experience.

Richard H. Lindemann, President
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A CASE OF GEOLOGIC PREDESTINATION

Address of the Retiring President of the
New York State Geological Association

RICHARD H. LINDEMANN
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After a hiatus of several years or geologic periods, depending on your point of view, the New York State Geological Association has found its way to Skidmore College. The site of this meeting is appropriate due to the fact that Skidmore and the City of Saratoga Springs owe their existence to an unusual geologic phenomenon. Certainly any geologist worthy of the title can, with sufficient rumination, devine a geologic explanation for the occurrence and location of any municipality or event in human history. However, in the case of this college and city there is no need to wax creative or stretch the fabric of credibility. We are here as a direct result of the unique occurrence and chemistry of Saratoga's Springs.

Popular histories of this area typically begin with aboriginal tribes of the Iroquois Confederacy, who knew the region as Kayaderossera (land of crooked waters) and the original spring (High Rock) as the Medicine Spring of the Great Spirit (Waller, 1966). The water which babbled and flowed from the spring's tufa cone was salty to the taste and revered as a cure for bodily ailments. In either 1767 or 1771 (Dunn, 1974, p. 541) members of the Mohawk tribe carried their blood brother, Sir William Johnson, the British Crown's Superintendent of Indian Affairs in northern America, to the Medicine Spring to restore his health. At that time, Sir William was suffering from dysentery, gout, and the ill effects of a French musket ball which he had been carrying in one thigh for over a decade (Waller, 1966, p. 8). Following a four day visit, Sir William returned to his duties partly repaired and thoroughly impressed with the Medicine Spring's curative powers. He told some neighbors about the spring and sent for a doctor to analyze its waters. The course was set, there would be no turning back.

In 1783 Philip Schuyler, who owned much of what is now Saratoga County and had heard of the Medicine Spring from Sir William, brought his friends George Clinton, Alexander Hamilton, and George Washington to High Rock for a little relaxation. By that time six additional springs had been discovered in the immediate vicinity. Washington was so impressed that he considered purchasing the area for a summer home, but never did. Following Washington's visit the springs' popularity grew so rapidly that by 1787 it was profitable for Alexander Bryan to open a "public house" on the cliff overlooking the springs to accommodate those who desired beverages other than spring water.

Bryan's public house was a prelude to the area's rapid "development". In 1884 a bath house was constructed for the pleasure and convenience of visitors at the site of Old Red Spring (Dunn, 1974, p. 193). Soon the original springs became too few and too small, so the spade was used to "discover" new ones. Since all known springs flowed in a muck-bottomed valley bounded

on the east by sandy hills and on the west by a prominent "limestone" cliff, early exploration was simple and digging easy. The highly-carbonated, saline, mineral-rich, sulfur-free springs, which flowed in ever increasing abundance, were judged to be on par with the mineral spas of Europe, to which the elite flocked to take "the cure". Not to be outdone, the elite of America required their own watering holes and converged on Saratoga to bathe and drink. Each spring was reputed to possess unique mineral and healthful attributes. Saline springs are cathartic while alkaline springs ease gastric discomfort and improve digestion. Bath and drink houses sprang up like mushrooms after a rain. Entrepreneurs bottled spring water for those unable to visit Saratoga. While a visit to the springs themselves could cure circulatory problems, skin ailments, arthritis, rheumatism, and the like, the bottled waters were advertised as cures for everything from lead poisoning to foul temper. A bottle factory and a village to serve it were built in nearby Greenfield. While plentiful employment in service positions sparked rapid growth of a permanent population, those who came for water and health lingered during the summer season for relaxation and entertainment. Horse racing and casino gambling displaced the more sylvan pleasures of earlier times. Ever increasing demands on the springs eventually exceeded the spade's abilities and the first drilled well penetrated the dolostone aquifer in 1870. A youthful carbonated soda pop industry saw the drilled well as an inexpensive CO₂ source, water became a waste product bound for the ditch. Prior to the end of the 19th century the mineral contents and flow-volumes of most springs were noticeably diminished and some springs had totally ceased to flow.

At the time of Sir William Johnson's visit the Medicine Spring rose within, but did not flow from, its four foot tufa cone. It had flowed freely in earlier times, and aboriginal folk wisdom attributed its decline to the Great Spirit's displeasure with some Mohawk women who had bathed in its waters (Mather, 1843, p. 96). It is not at all unusual for Saratoga's springs to decline, be temporarily interrupted, or cease flowing altogether. In most cases it was found that the spring's vent had become clogged with dirt or boiler scale and that the flow was easily restored. However, by the end of the 19th century there was no doubt that the general decline of free-flowing and pumped springs, as well as the pronounced decline of the mineral concentrations in all springs, were due to excessive pumping and not to boiler scale or the Great Spirit's wrath. In 1909 New York State passed a law enabling it to purchase the springs and mineral rights to them by eminent domain (Dunn, 1974, p. 201). This was an auspicious time as Skidmore was in its formative stages, the Village of Saratoga was about to become a city, and geologists were encouraged to study the springs in hopes of discovering unlimited potential for development.

Saratoga's springs have long been the subject of scientific inquiry. The first report of their existence and medicinal attributes dates to 1535 and the French explorer Jacques Cartier. As we have seen, Sir William Johnson had the minerals of High Rock Spring analyzed in the early 1770's. During the following decade several additional analyses were performed in connection with the springs' curative powers. In his report on the First Geological District, Mather (1843) recognized that the springs rise from a "limestone" and noted their location on the east side of a prominent "limestone" cliff. By the time of his geologic survey thousands of people were annually visiting the handful of then known springs. Perhaps with an eye to the future, Mather suggested that greater mineral concentrations would be had if

the "calciferous sandstone" (Potsdam Formation) beneath the "limestone" (Gailor Formation) was penetrated. Kemp (1912) reported that by the early 1870's it was realized that the springs emanated from the down-dropped side of a long north-south trending fault. In his own work, Kemp regarded this relationship to be critical and concluded that the mineral waters derived from eastward sources. He conducted an extensive review of the springs' chemistry as well as Saratoga's geologic setting, and developed an interpretation of the springs' origins (Kemp, 1912) which presaged some aspects of more recent work.

Kemp's (1912) account of the springs' origin involves several components. Flowing westward through lower Paleozoic sandstones and carbonates from locations near or beyond the Hudson River, meteoric water is influenced by buried volcanics (Stark's Knob is the model) which emit "carbonic gas, the chlorids, bromids, iodids, fluorids, and sodium carbonate" (p. 63-64) and possibly add "juvenile water" to the total volume. On the recommendation of H. P. Cushing and R. Ruedemann (published in 1914), Kemp considered the volcanics to be at least pre-Tertiary and probably Triassic in age. Thus charged with carbonic acid the water dissolves passages within the limestones and dolostones through which it flows. Ultimately the westward-moving mineral-laden water is trapped against the Saratoga-Mc Gregor Fault where it mixes with artesian water from the west (p. 64) and rises through fissures in the rock. Since the time of Kemp's work, aspects of his interpretation have been refined but the essential components remain valid.

Kemp's Stark's Knob model was soon regarded as insufficient and altered to a more general heat-source in the form of deep-seated metamorphism (Cushing and Ruedemann, 1914). Colony (1930) suggested the waning phases of Grenville metamorphism while Haertl (1930) supposed a batholith to be nearer the mark. In opposition to these ancient happenings, Young and Putman (1979) postulated secular thermal upwelling possibly related to local Neogene rifting. They also reported the locations of several brine wells not far to the south and south-west of Saratoga Springs. This report is intriguing in its bearing upon the interpretations of Lester W. Strock (1944), a longtime friend of Skidmore's Geology Department. At one time or another, the springs' saline contents have been attributed to connate sea water, igneous exhalation, dissolution of undiscovered salt deposits, and weathering of the Adirondacks. During a quantitative study of the springs' geochemistry, Strock (1944) found the enrichment of Br and I over Cl to be anomalous relative to lithospheric averages. Unable to account for this through the above mechanisms, he sought a specific proximal lithology as a potential source. He found that Silurian "bittern" shales, such as the Camillus, are geochemically similar to the springs and noted that Silurian strata extend to within about 40 miles south and south west of Saratoga. Noting that in central New York the Cambrian Potsdam Sandstone contains brines, Strock proposed that downward percolating ground waters leach salts from the bittern shales and, entering the Potsdam, flow to the north and east mixing with water bodies from eastern sources and rising as the Saratoga springs. He considered this interpretation to be supported by the fact that the Camillus Shale and the springs have similar K^{39}/K^{41} ratios. In the final (at least current) analysis, Kemp's conclusions that the springs occur due to the interactions of faulting, dissolution of Paleozoic strata, thermal input, and mixing of diverse waters is as viable as ever.

Having followed the connecting threads of the preceding pages you can see that terra infirma has staged a punctuated billion-plus year show pre-determining that Homo sapiens, intrigued by the whence and wherefore of the planet, would eventually gather here on the tropical shores of Cambro-Ordovician North America. No single field trip during this the 57th meeting of the NYSGA specifically concerns itself with Saratoga Springs, but most scrutinize one or more of the acts in terra infirma's show which produced them. While you are here to probe the distant past, why not take an example from the recent past (202 years BP) and follow George Washington to the Great Spirit's Medicine Spring. Perhaps you will find, as he did, that it can make a regular person of you.

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CAMBRO-ORDOVICIAN SHOALING AND TIDAL DEPOSITS
MARGINAL TO IAPETUS OCEAN AND
MIDDLE TO UPPER DEVONIAN PERITIDAL DEPOSITS OF THE
CATSKILL FAN-DELTAIC COMPLEX

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This field trip, in which sedimentary facies deposited in Cambrian, Ordovician, and Middle to Upper Devonian shallow-water marine environments will be examined, has been divided into two parts. The first three stops will be devoted to facies of the Cambro-Ordovician period, and the last three will cover the Middle to Upper Devonian facies.

Cambro-Ordovician Shoaling and Tidal Deposits

The area around the Rensselaer Center of Applied Geology in Troy, N.Y. is known for its diversity of sedimentary geology due to its unique location. From Early Cambrian through Early Ordovician, the Center would have been on a carbonate shelf of the Proto-Atlantic (Iapetus) Ocean. During this time, much of the North American continent was a shallow epeiric shelf sea, analogous to the present-day Bahama Bank. On the eastern edge of this sea, i.e. on the eastern edge of this continent, carbonate sediment moved down a relatively steep slope by slides, slumps, turbidity currents, mud flows, and sandfalls, and came to rest at the deep-water basin margin (rise) depositing a shale facies (Figure 1) (Sanders and Friedman, 1967, p. 240-248; Friedman, 1972, p. 3; Friedman, 1979, Friedman *et al.*, 1982, Keith and Friedman, 1977, 1978; Friedman and Sanders, 1978, p. 389, 392). Shale also formed much of the basinal facies at greater oceanic depths.

The Cambro-Ordovician shelf to basin transition facies, which would have originally been located east of Rutland, Vermont, has been tectonically displaced across the shelf facies. Today, the exposures on and near the Rensselaer Center of Applied Geology are Cambrian and Early Ordovician rocks of basin margin (rise) and deep basin facies (shales deposited in the Middle Ordovician (Schenectady) west of the Rensselaer Center of Applied Geology are autochthonous basin facies).

To the west, Cambrian and Ordovician carbonate shelf facies are exposed that are analogous to those of the west shore of Andros Island on the Great Bahama Bank, (Friedman, 1972) (Figure 1). This area was probably an active hinge line between the continent to the west and the ocean to the east, similar to the Jurassic hinge line of the eastern Mediterranean between carbonate shelf facies and deep-water shoals (Friedman, Barzel and Derin, 1971). Early in geosynclinal history, such hinge lines in mountain belts are fixed by contemporaneous down-to-basin normal faulting (Rodgers,

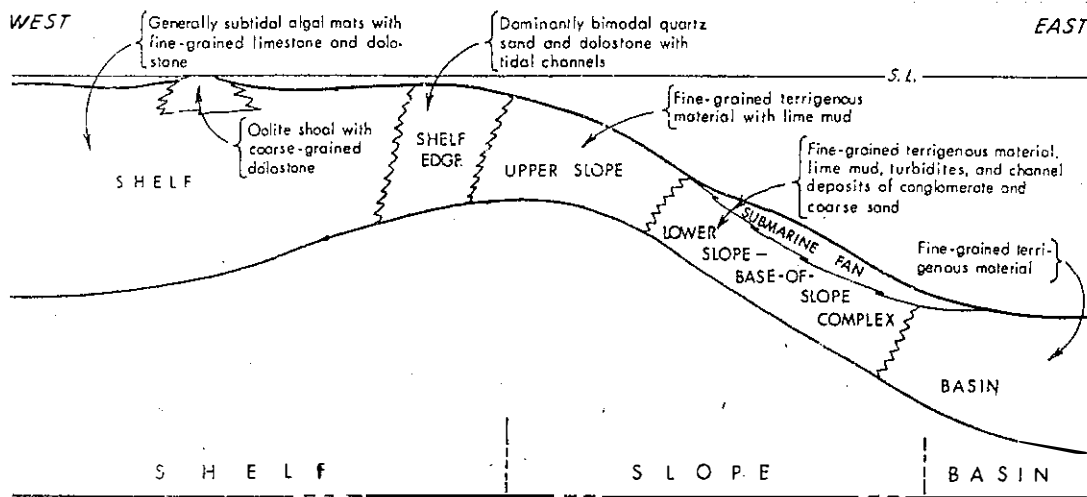


Figure 1. Diagrammatic sketch map showing depositional environments and characteristic sediments of Proto-Atlantic (Iapetus) Ocean for eastern New York and western Vermont during the Early Paleozoic (Keith and Friedman, 1977, Fig. 2, p. 1222, Friedman *et al.*, 1979 (IAS Guidebook), Fig. 1, p. 48).

1968, quoting Truempy, 1960), as probably occurred with the rocks of the area near the Rensselaer Center of Applied Geology. Later thrusting lifted the deep-water facies across the shelf facies along hinge-line faults and resulted in the contiguity of the two facies. This later displacement was so great that the Cambrian and Early Ordovician deep-water sediments were shifted far west of their basin margin.

This occurrence of deep-water basin margin (rise) and basinal facies in the vicinity of the Rensselaer Center and carbonate shelf to the west are partly responsible for the great diversity in sedimentary facies in this area.

During the Cambrian and Ordovician periods shallow-water limestones and dolostones accumulated at the then-eastern edge of this submerged continent. On this field trip we shall study those which are part of the Tribes Hill Formation of lowermost Ordovician age (Fisher, 1954). The steep paleoslope, which marked the transition from the submerged continent to the deep sea, lay about 35 miles east of the present Tribes Hill exposures which we shall visit.

The carbonate rocks of the Tribes Hill Formation show many features such as mud cracks, birdseye textures, undulating stromatolitic structures, mottles, lumpy structures, scour-and-fill structures, flat pebbles, cross-beds, and, as a lithology, syngenetic dolostone (Friedman and Sanders, 1967; Friedman and Braun, 1975). The presence of these features suggests that the rocks were subjected to repeated shoaling and intermittent sub-aerial exposure. Most known Lower Ordovician shallow-water carbonates that underlie much of North America have features identical to these. The site of accumulation of the Tribes Hill carbonates however, is markedly different from that of most other Paleozoic carbonates that stretch across North America. Since the Tribes Hill carbonates were deposited close to

the edge of the continent, diurnal or semi-diurnal fluctuations of the waters of the deep ocean should have left their mark on the Tribes Hill deposits, classifying them as tidal.

The most obvious of the morphologic features in modern tidal sediments are tidal channels. What may be ancient tidal channels can be observed in the rocks of the Tribes Hill Formation. Such channels have not been reported from the Cambro-Ordovician carbonate-rock sequences in other parts of North America.

The sizes of the channels in the Tribes Hill Formation are comparable to the sizes of modern tidal channels. Sharp basal truncations are typical. The material within the channel consists mostly of carbonate skeletal and intraclastic sand (biosparite and intrasparite), a high-energy facies. These channels cut into a mottled dolomitic micrite and biomicrite, a low-energy facies. Lodged within the channel fill are large blocks of micrite, up to 1 meter in diameter. They are thought to have been derived by undercutting of the banks. To accomplish such undercutting the currents in these channels must have flowed fast. The contrast between the high-energy facies filling the channels and the low-energy facies in the flats adjacent to the channels also suggests that currents in the channels flowed swiftly.

In Paleozoic limestones the products of shoal waters are ubiquitous, but tidal deposits may have been restricted to the margins of the continents where the epeiric shelf faced the deep ocean. The carbonate rocks of the Tribes Hill Formation may be an example of such a tidal sequence.

An essential constituent of the carbonate rocks of the Tribes Hill Formation is authigenic feldspar. Such feldspars are the end products of the zeolite alteration. In rocks older than mid-Paleozoic, any original zeolites probably have changed to feldspars, therefore zeolites are not found in sedimentary rocks as old as Early Ordovician. In volcanoclastic rocks of Cenozoic age, authigenic feldspar is known to be the end product of volcanic glass whose initial alteration product was a zeolite (Sheppard and Gude, 1969; Goodwin, 1973). The high concentration of feldspars caused stromatolitic laminae to weather in positive relief.

The feldspars in the Tribes Hill Formation are interpreted as wind-transported tephra that accumulated at the margin of the Proto-Atlantic (Iapetus) Ocean. The active volcanoes responsible for such tephra may have been parts of ancient island arcs (Braun and Friedman, 1969; Buyce and Friedman, 1975; Friedman and Sanders, 1978).

Middle To Upper Devonian Peritidal Deposits

The Devonian strata of New York State include one of the most complete fossiliferous records of Devonian time almost anywhere in the world. The carbonate strata in the Catskill Mountains are essentially flat-lying. They range from 2.4 to 2.5 km in thickness and decrease to about 1 km thick in the most western part of New York State. Among the Lower Devonian carbonates are the Helderberg Limestones, named after prominent cliffs along the northern and eastern margins of the Helderberg Mountains, a range of hills southwest of Troy and Albany. Carbonate strata of the

Middle Devonian include the Onondaga Limestone which forms a prominent westward escarpment across the State.

Parts of the Middle and Upper Devonian strata in New York State are sometimes referred to as the "Catskill redbeds." Included are various nonmarine, chiefly fluvial conglomerates and coarse sandstones, which were deposited as fans and by braided streams, and sandstones and red and green siltstones, which probably were deposited on flood plains of meandering rivers. These fluvial deposits are part of a vast wedge of sediment that was spread out along the southeast margins of the Appalachian seaway and eventually became so abundant that the shoreline was prograded several hundred kilometers to the west. A wide alluvial plain came to occupy part of the former seaway.

Beginning with the classic work of Joseph Barrell (1912, 1913, 1914) early in the twentieth century, it has been recognized that the thick complex of nonmarine "Catskill redbeds" overlying and interfingering with marine shales and sandstones was the work of ancient deltas. Modern sedimentologic studies have shown that the Devonian of the Catskill area includes sediments that were deposited in point-bar sequences and associated overbank deposits of flood-plain rivers, on fans, in braided streams, on intertidal flats, in lagoons, on barrier beaches, in various parts of marine deltas, and in shallow seas away from shore (Friedman and Sanders, 1978).

Although previous work has outlined and supported the concept that deltas were present in the Catskill region during the Devonian Period, (Barrell, 1914, 1923; Friedman, 1972; Friedman and Johnson, 1966; Humphreys and Friedman, 1975; Johnson and Friedman, 1969; Mazzullo, 1973; McCave, 1969a, 1969b, 1973; Rickard, 1975; Wolff, 1967a, 1967b), the actual strata that were deposited on marine deltas themselves have scarcely been mentioned. The chief emphasis has been placed instead on the marine strata upon which the marine deltas must have prograded; and on the nonmarine alluvial deposits of flood-plain rivers, braided streams, and fans, which aggraded upward above the topsets as supratopset strata. The marine strata, important because they contain fossils and are laterally persistent, are the basis for making stratigraphic subdivisions and correlations. The supratopset nonmarine strata have been studied because they are so well-exposed.

It is inferred that on the Devonian marine deltas of the Catskill region were deposited the clay shales, silt shales, and interbedded silt shales and fine-grained sandstones which intervene between the marine limestones or dark-colored marine shales below, and the thick nonmarine strata above. If this concept is correct, then from the generalized restored stratigraphic section it can be inferred that at least 4 episodes of westward progradation by marine deltas must have taken place. It can be concluded that the marine deltas were numerous, and that they prograded seaward very rapidly with respect to the rate of subsidence because the thickness of the inferred marine-deltaic strata is such a small porportion of the total Middle and Upper Devonian succession. Most of the subsidence took place after alluvial plains had become established on the topset parts of the marine deltas. Since the entire succession contains such thick supratopset strata, it is further surmised that the marine deltas must have built

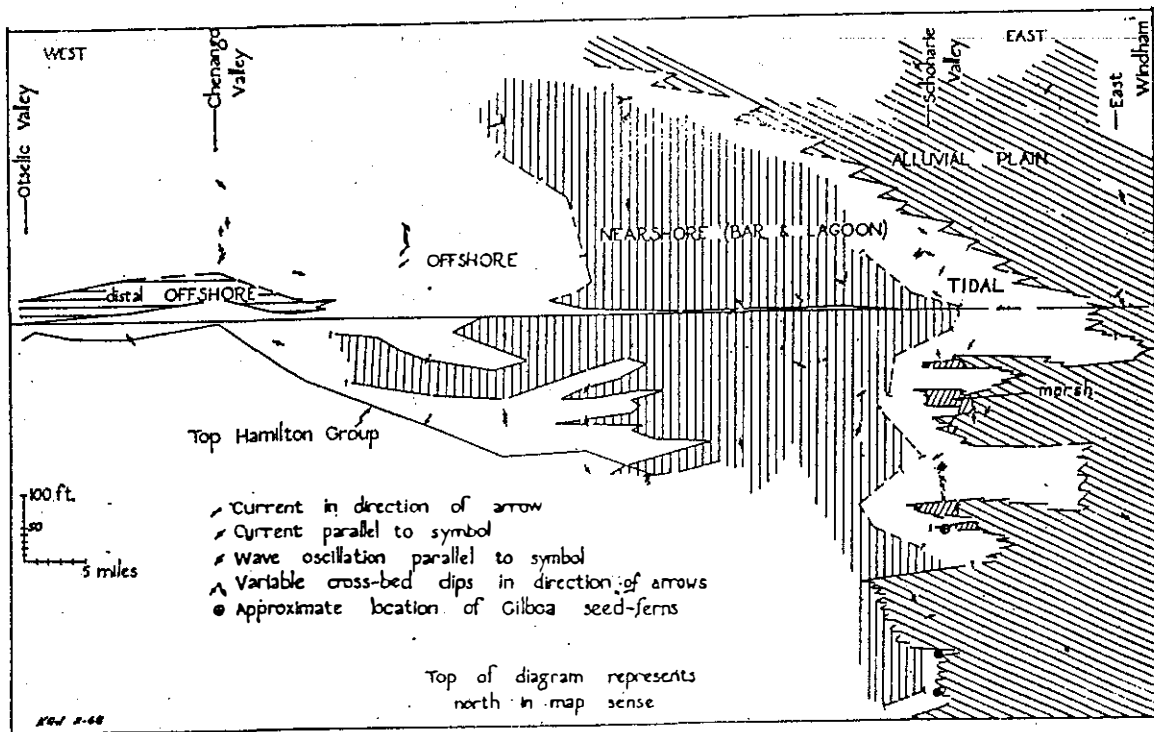


Figure 2. Depositional environments and current indicators, Tully Limestone and associated rocks, east-central New York State (Johnson and Friedman, 1969, p. 480).

westward to the point where the water deepened. The rates of westward growth of the marine delta lobes were checked while the supratopset strata thickened so conspicuously (Friedman and Sanders, 1978).

The absence of bar-finger sand prisms and pods further indicates that the Devonian marine deltas of the Catskill region were of the shoal-water variety. If any such sands are present, they should be located at the western edge of the former shallow platform, an area now covered by younger strata.

If the above conclusions are correct, then the thick, well-exposed supratopset beds of the Devonian marine-delta deposits should be separated from the true deltaic strata. Although both were products of progradation and subsidence, the deltas formed first, and afterwards, as subsidence continued, fans aggraded. To emphasize the inferred presence of both the marine deltas and the supratopset fans it has been suggested that the term "tectonic delta complex" (Friedman and Johnson, 1966) be abandoned and in its place the term "tectonic fan-delta complex" be substituted (Friedman and Sanders, 1978).

Part of the Catskill deltaic complex is represented in the stratigraphic record by the Tully Limestone. The name Tully Limestone applies to a series of beds which are well-exposed in central New York near the town of Tully (Vanuxem, 1838). In an eastward direction the limestone grades into very fine-grained clastic strata. Recognizable in the Tully interval are rocks indicative of various sedimentary environments including alluvial strata of channel and overbank origin, nearshore (bar and lagoon) facies, offshore facies, and sediments of tidal origin (Fig. 2).

Tidal sediments accumulated along the margins of protected coastal water bodies such as lagoons, estuaries, and bays. These sediments may be subdivided into tidal flats and tidal channels. In modern tidal environments, vertical sedimentary processes deposit silt and mud-grade size material on tidal flats. Cutting across these tidal flats is somewhat coarser sediment deposited by lateral sedimentary processes in tidal channels.

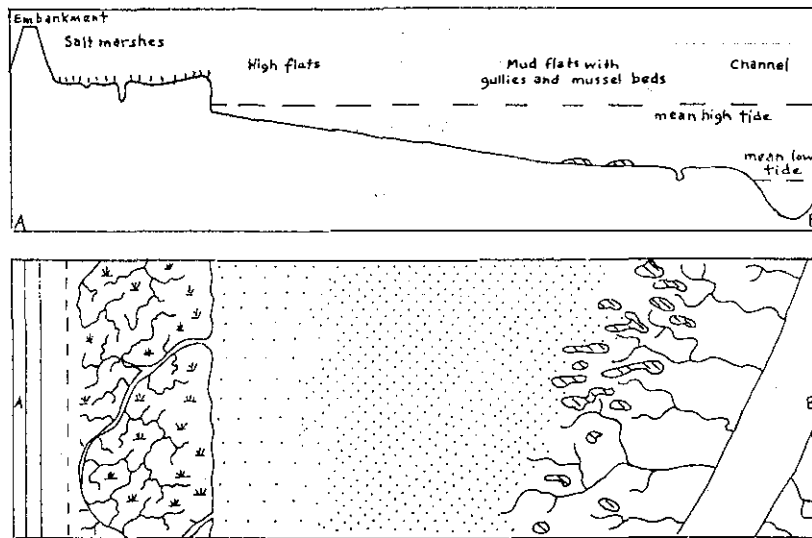
In the Catskill deltaic complex the tidal-flat sedimentation was of the Wadden-type, named after the intertidal sediments of the Wadden Sea, a part of the Rhine-Ems-Scheldt delta complex of northwestern Europe. Van Straaten (1950, 1954) subdivided the Wadden Sea tidal flats into (1) a lower seaward part, where tidal channels cut across and into mud and muddy-sand deposits, and (2) a higher landward part composed dominantly of sand.

In the lower tidal flats sedimentation proceeds at a relatively fast rate and there is little bioturbation, therefore fine cross-lamination and flaser bedding are preserved. Also characteristic of the lower tidal flats are well-developed incised tidal channels. These channels as well as the flaser bedding are lacking in the high tidal flats due to a lower rate of sedimentation and destruction of sedimentary features by organisms.

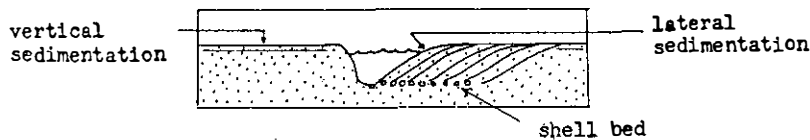
In modern tidal channels, a combination of eroded meander banks and deposition of sediment in slack water along the inner banks of meanders produces cross-bedded channel deposits both laterally and vertically. As flow slackens, fine sediment is deposited as parallel laminae. These sedimentary structures are also found in meandering alluvial channels. Two diagnostic characteristics of tidal channel sand facies however are (1) a close association with stata of marine origin and (2) the unique character of the basal channel lag concentrate. The basal lag concentrates of the Tully interval tidal channel facies consist of a polymictic pebble assemblage and abundant large spiriferid brachiopods of subtidal derivation. Often the calcium carbonate shell material is abundant enough to constitute a coquinite lithology (Johnson and Friedman, 1969). This type of allochthonous organic sedimentary accumulation has been noted in modern tidal flats and channels of the Wadden Sea, Easter Scheldt (Netherlands), and Bay of Arcachon (France) where the shells are typical open sea species that are washed into the tidal flat areas by flood tides (Van Straaten, 1956).

At the base of the clastics lies the Hamilton Group which is a 2500' interval of fossiliferous sandstone and shale thinning toward the west and southwest. The Gilboa Forest of Goldring (1924, 1927) can be found in the uppermost part of the Hamilton Group. Within the Gilboa Formation are fossils of giant seed ferns which grew in a swamp that was located near the strandline of the Catskill deltaic complex toward the end of the Middle Devonian.

The peritidal clastic correlatives of the Tully Limestone evolved during a transgressive phase within the general progradational framework of the Catskill deltaic complex. The growth of a submarine topographic high, the Chenango Valley high (Heckel, 1966), about 60 miles offshore while deposi-



Wadden Sea Tidal Flat Environments



Vertical and Lateral
Sedimentary Processes

Figure 3. Sedimentary environments of the Wadden Sea intertidal zone (after Van Straaten, 1954, p. 27; Johnson and Friedman, 1969, p. 472).

tion was occurring was a primary structural control. This structure formed a barrier to terrigenous material that was moving westward from the source area into the marine basin, making it possible for carbonate sediment to accumulate. The clastic material accumulated in a basin-margin trough or depression which subsided intermittently as deposition continued. During the transgressive phase landward migration of the strandline caused river mouth drowning and resulted in more widespread estuarine (tidal) conditions as the Tully interval was accumulating.

ITINERARY

Figure 4 is the road log.

Cambro-Ordovician Shoaling and Tidal Deposits

Depart from the parking lot of the Performing Arts Center and turn north on NY 50.

MILES FROM LAST POINT	CUMULATIVE MILEAGE	ROUTE DESCRIPTION
0.6	0.6	Bear left following sign to NY 29.

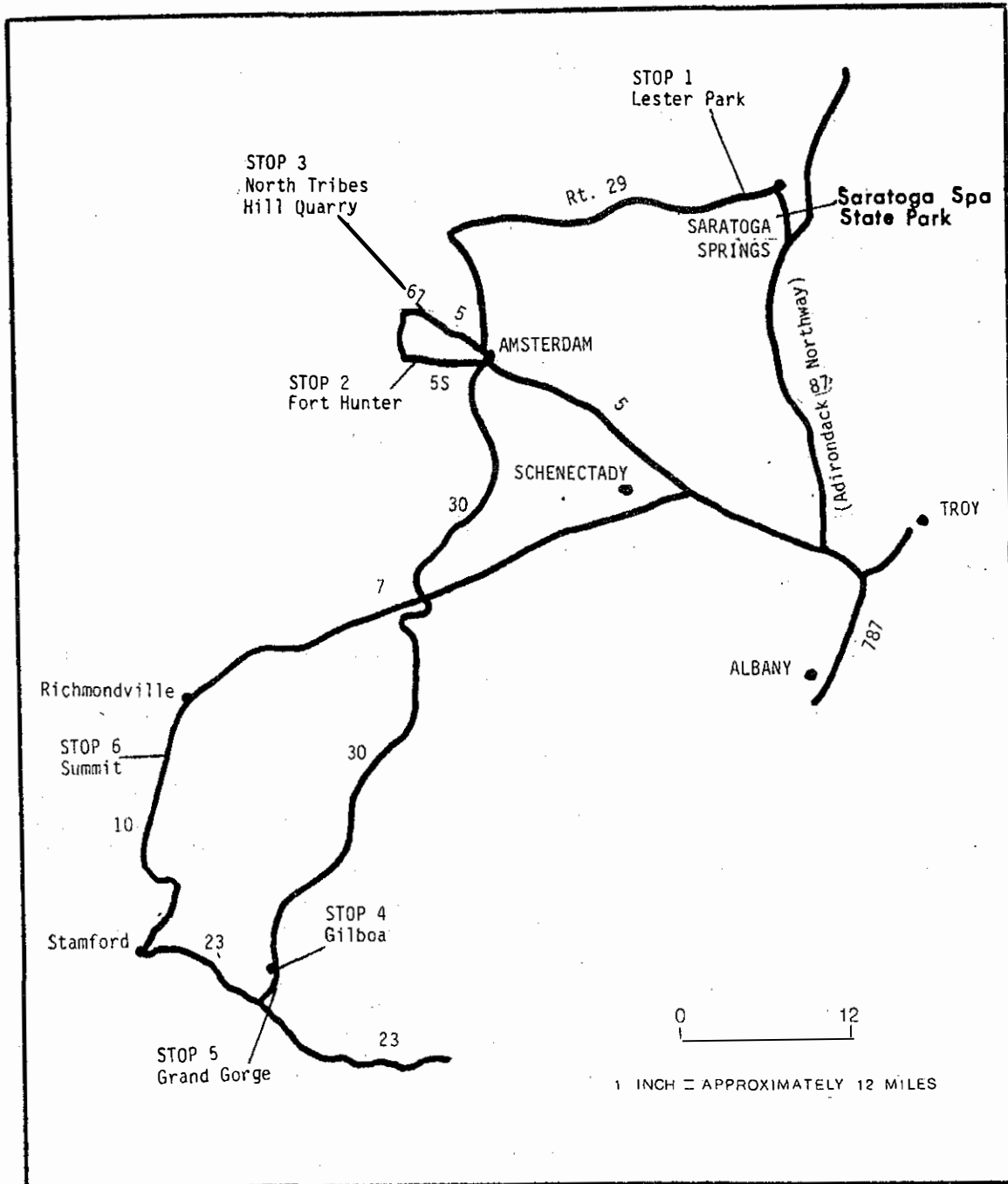


Figure 4. Road log for field trip.

- | | | |
|-----|-----|--|
| 1.2 | 1.8 | Drive to traffic light and turn left (west) on NY 29. |
| 2.1 | 3.9 | Turn right (north) on Petrified Gardens Road; drive past "Petrified Gardens" to Lester Park. |
| 1.2 | 5.1 | Alight at Lester Park. |

STOP 1. PRODUCTS OF INTERTIDAL ENVIRONMENT: DOMED ALGAL MATS
(CABBAGE HEADS)

This locality is the site of one of the finest domed algal mats to be seen anywhere preserved in ancient rocks. On the east side of the road in Lester Park a glaciated surface exposes horizontal sections of the cabbage-shaped heads composed of vertically stacked, hemispherical stromatolites (Figure 5). These structures, known as Cryptozoons, have been classically described by James Hall (1847, 1883), Cushing and Ruedemann (1914), and Goldring (1938); an even earlier study drew attention to the presence of ooids as the first reported ooid occurrence in North America (Steele, 1825). Interest in these rocks has been revived as they are useful environmental indicators (Logan, 1961, Fisher, 1965; Halley, 1971). The algal heads are composed of discrete club-shaped or columnar structures built of hemispheroidal stromatolites expanding upward from a base, although continued expansion may result in the fusion of neighboring colonies into a *Collenia*-type structure (Logan, Rezak, Ginsburg, 1964). The stromatolites are part of the Hoyt Limestone of Late Cambrian (Trempealeauan) age. An intertidal origin has been inferred for these stromatolites (Fig. 6, 7 and 8).



Figure 5. Top view of algal stromatolites showing domed laminae known as cabbage-head structures, Hoyt Limestone (Upper Cambrian), Lester Park, New York (Stop 1).

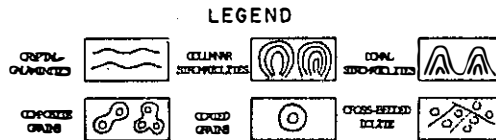
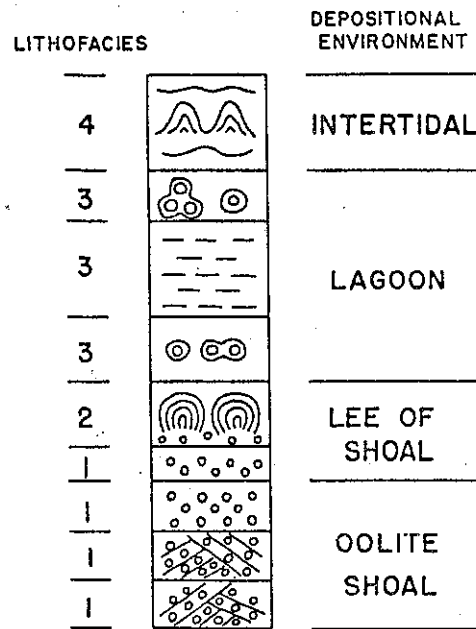


Figure 6. Vertical sequence, lower Lester Park section. The vertical sequence shown by this section reflects a vertically continuous progradational sequence. The upward increase in lithofacies number suggests progressively shoreward deposition. (R. W. Owen and G. M. Friedman, 1984, Fig. 8, p. 230.)

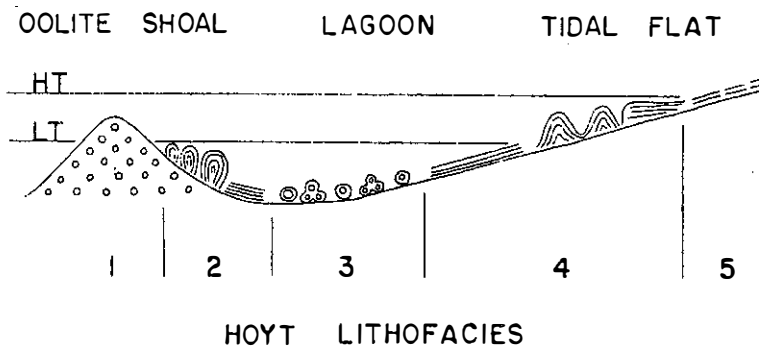


Figure 7. Hypothesized depositional model, cross-section view. Note the similarity in horizontal sequence of lithofacies and vertical sequence of lower Lester Park section (figure 8). Vertical scale greatly exaggerated. (R. W. Owen and G. M. Friedman, 1984, Fig. 13, p. 233.)

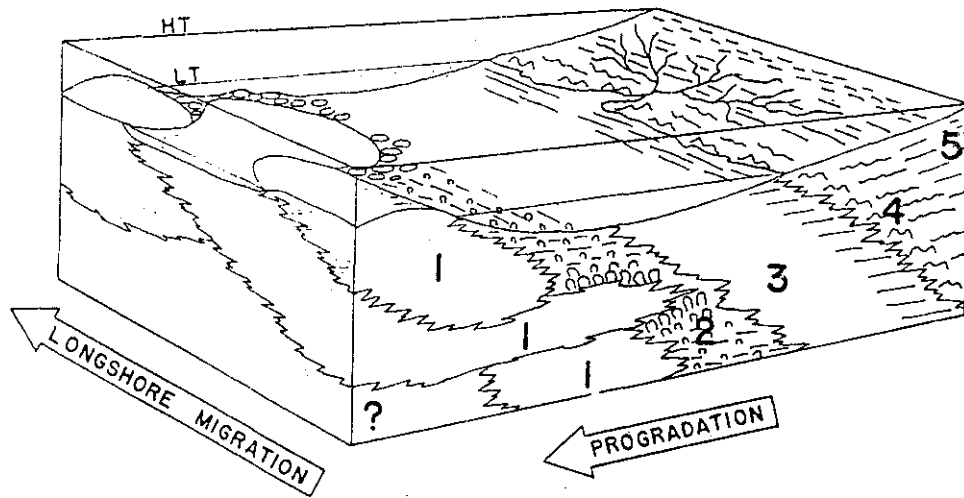


Figure 8. Facies relations resulting from longshore migration of oolite shoals and progradation of carbonate build-up. Block diagram shows generalized facies relations interpreted for dynamic Hoyt depositional mode. Note that high-relief columnar stromatolites and low-relief columnar stromatolites may be found in reversed sequence due to migration of oolite shoals. (R. W. Owen and G. M. Friedman, 1984, Fig. 15, p. 233).

The evidence for deposition under tidal conditions for the Hoyt Limestone at Lester Park includes: (1) mud cracks, (2) flat-pebble conglomerate, (3) small channels, (4) cross-beds, (5) birdseye structures, (6) syngenetic dolomite, and (7) stromatolites (for characteristics on recognition of tidal limestones, see Friedman, 1969).

At Lester Park the heads which are circular in horizontal section range in diameter from one inch to three feet; many are compound heads. The size of the larger heads suggests that they formed in highly turbulent waters.

The line of depositional strike along which the domed stromatolites occur was probably where the waves were breaking as they came across the deeper ocean from the east and impinged on the shelf.

Several petrographic observations in these rocks permit an analogy with modern algal mats in hypersaline pools of the Red Sea Coast (Friedman and others, 1973). Mat-forming algae precipitate radial ooids, oncolites, and grapestones which occur in these rocks; interlaminated calcite and dolomite, which in part compose the stromatolites of the Hoyt Limestone, correspond to alternating aragonite and high-magnesium calcite laminites which modern blue-green algae precipitate. In modern algal mats the high-magnesium has been concentrated to form a magnesium-organic complex. Between the magnesium concentration of the high-magnesium calcite and that of the organic matter, sufficient magnesium exists in modern algal laminites to form dolomite. Hence the observation in ancient algal mats, such as observed in the Hoyt Limestone, that calcite and dolomite are interlaminated, with calcite probably forming at the expense of aragonite and dolomite forming from high-magnesium calcite.

		Turn around and drive back (south) to NY 29.
1.2	6.3	Turn right (west) on NY 29.
19.1	25.4	Turn left (south) on NY 30.
6.3	31.7	City limits of Amsterdam.
1.4	33.1	Cross bridge over Mohawk River.
0.1	33.2	Drive to Bridge Street (leaving NY 30 and turn north on Bridge Street); turn right on Florida Avenue and go west.
0.5	33.7	Turn right on Broadway.
0.8	34.5	Turn right (west) on NY 5S.
2.4	36.9	Fort Hunter, turn right (north) on Main Street.
0.2	37.1	Turn right (east) to Queen Anne Street.
0.9	38.0	Alight at slight bend in road and walk to Fort Hunter Quarry which is across rail-road track close to Mohawk River. (Fort Hunter Quarry cannot be seen from road; another small quarry visible from road is approximately 0.1 mile farther east, but will not be visited on this trip).

STOP 2. FORT HUNTER QUARRY

Stromatolites in the Fort Hunter Quarry consist almost entirely of dolomite in the form of irregularly bedded, finely-laminated, undulating structures (Figure 9). The rocks in this quarry are part of the Tribes Hill Formation of earliest Ordovician age (Fisher, 1954). The lithofacies of the Tribes Hill formation have been studied in detail by Braun and Friedman (1969) within the stratigraphic framework established by Fisher (1954). Figure 10 is a columnar section showing the relationship of ten lithofacies to four members of the Tribes Hill Formation. At Fort Hunter we will study the lowermost two lithofacies of the Fort Johnson Member (see column at right (east) end of section, in Fig. 10).

Two lithofacies are observed: (1) lithofacies 1, mottled feldspathic dolomite (Figure 10), and (2) lithofacies 2, laminated feldspathic dolomite. Lithofacies 1 is at the bottom of the quarry, and lithofacies 2 is approximately halfway up.

Lithofacies 1

This facies occurs as thin dolostone beds, 2 cm to 25 cm but locally more than 50 cm thick, with a few thin interbeds of black argillaceous dolostone which are up to 5 cm thick. In the field, the dolomite shows gray-black mottling and in places birdseye structures. In one sample, the infilling of the birdseyes shows a black bituminous rim which may be anthraxolite. In the field, trace fossils are abundant, but fossils were not noted. Authigenic alkali feldspar (microcline) is ubiquitous throughout this lithofacies; its identity as alkali feldspar was determined by X-ray analysis and staining of thin sections with sodium cobaltinitrite. The insoluble residue makes up 22 to 54% by weight of the sediment in samples studied with most of the residue composed of authigenic feldspar. An iron-poor yellow sphalerite may be occasionally found in the rocks of this lithofacies.

Lithofacies 2

This lithofacies is mineralogically identical to the previous facies but differs from it texturally and structurally in being irregularly bedded and in containing abundant undulating stromatolitic structures ("pseudo-ripples"), as well as disturbed and discontinuous laminae. In places there are a few thin interbeds of black argillaceous dolostone. The thickness of the laminites of this facies ranges from 1/2 mm to 2 or 3 mm; on freshly broken surfaces the color of the thinner laminae is black and that of the thicker ones is gray. The insoluble residue, for the most part composed of authigenic feldspar, constitutes between 35% and 67% by weight in samples studied.



Figure 9. Stromatolite structures of lithofacies 2 (laminated feldspathic dolomite), Tribes Hill Formation (Lower Ordovician), Fort Hunter, New York. (M. Braun and G. M. Friedman, 1969, Fig. 3, p. 117; G. M. Friedman, 1972, Fig. 5, p. 21.)

- WEST -

- EAST -

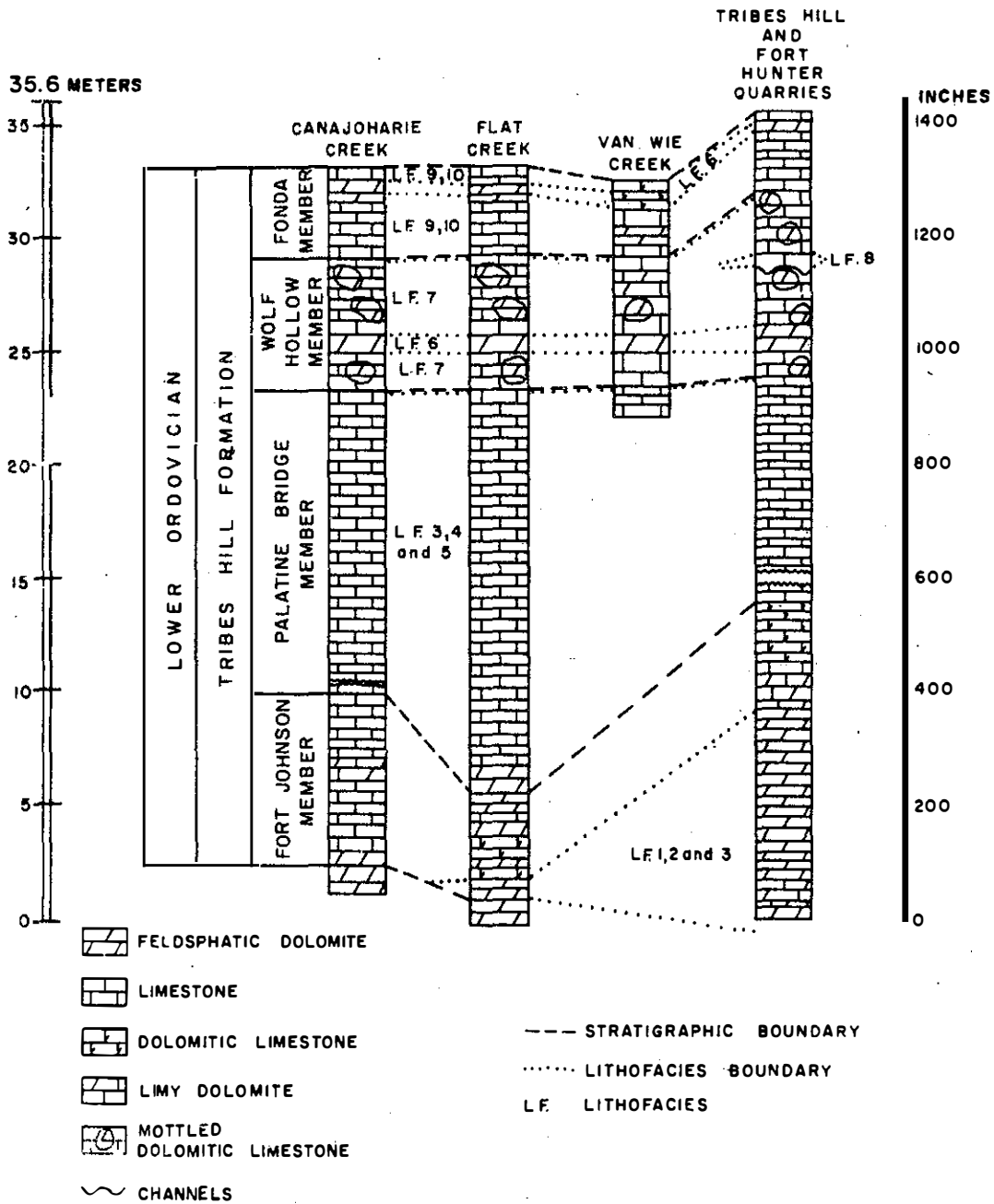


Figure 10. Columnar section showing the relationship of ten lithofacies to four members in Tribes Hill Formation (Lower Ordovician) (after Braun and Friedman, 1969; Friedman, 1972, p. 19, Fig 4.)

These two lithofacies which form the basal unit of the Ordovician, were formed on a broad shallow shelf. Stromatolites, birdseye structures, scarcity of fossils, bituminous material, syngenetic dolomite, authigenic feldspar, and mottling suggest that these rocks were deposited in a tidal environment (Friedman, 1969). Based on analogy with the carbonate sediments in the modern Bahamas, Braun and Friedman (1969) concluded that these two lithofacies formed under supratidal conditions. However, in the Persian Gulf flat algal mats prefer the uppermost intertidal environment and along the Red Sea coast they flourish where entirely immersed in seawater, provided hypersaline conditions keep away burrowers and grazers (Friedman and others 1973). Hence on this field trip we may conclude that the stromatolites indicate tidal conditions without distinguishing between intertidal and supratidal. For more details on these lithofacies refer to Braun and Friedman (1969).

		Turn around and drive back to Main Street, Fort Hunter.
0.9	38.9	Turn right (north) onto Main Street, Fort Hunter.
0.1	39.0	Cross original Erie Canal, built in 1822. Amos Eaton surveyed this route at the request of Stephen Van Rensselaer; after this survey Amos Eaton and Van Rensselaer decided to found a school for surveying, geological and agricultural training which became Rensselaer Polytechnic Institute. Follow Main Street through Fort Hunter.
0.6	39.6	Cross Mohawk River.
0.5	40.1	Turn right (east) on Mohawk Drive (town of Tribes Hill).
0.4	40.5	Turn left (north) on Stoner Trail.
0.2	40.7	Cross Route 5 and continue on Stoner Trail.
2.7	43.4	Turn right (east) on NY 7.
1.5	44.9	Fulton-Montgomery Community College, continue on NY 67.
1.6	46.5	Alight at North Tribes Hill quarry (on left).

STOP 3. NORTH TRIBES HILL QUARRY

Route of Walk

Take the trail toward old abandoned crusher, but instead of heading toward the quarry move uphill to the first rock exposures. The rocks to be examined are near the edge of steep cliff.

Description and Discussion

In the rocks at this exposure the field relationships show typical channels truncated at their bases. Lodged within the channels are limestone blocks of variable shape ranging in diameter from about one to three feet. These blocks resemble similar blocks in tidal channels of the Bahamas which are derived by undercutting of the banks of the tidal channels. The blocks at this exposure are rounded, suggesting that they have undergone some transport.

The rocks composing the channel (the channel fill) and the blocks of rock within the channels have been described as lithofacies 8 (Figure 11) (channel fill) and lithofacies 7 (Figure 12) (blocks) of the Wolf Hollow Member of the Tribes Hill Formation (lowermost Ordovician) (see columnar section of Fig. 10); column at right end of the section) (Braun and Friedman, 1969). The channel fill (lithofacies 8) consists of intrasparite and biointrasparite with sporadic ooids, a high-energy facies, whereas the blocks (lithofacies 7) consist of mottled dolomitic micrite and biomicrite, a low-energy facies of the undercut bank. The micrite blocks which foundered in the channels must have been indurated penecontemporaneously (Fig. 13).

		Turn around on NY 67 and go west.
3.1	49.6	Turn left onto Stoner Trail.
2.7	52.3	Take Route 5 towards Amsterdam. Upon reaching NY 30 turn right (south) and continue south on NY 30.
Approx. 50.0	Approx. 102.0	Turn left (east) on road to Gilboa; stop before bridge.
1.0	103.0	Stop 4

Middle to Upper Devonian Peritidal Deposits

STOP 4. MARSH FACIES

No examples of the marsh facies have been found in situ. However, giant seed ferns of the Gilboa Forest (Goldring, 1924, 1927), which grew in a marsh environment, were discovered in the now-inactive Riverside Quarry near here. More than 200 stumps were taken from this single quarry; some of these have been placed at this site, others are now preserved in museums. The "trees" of Gilboa Forest are among the world's oldest; they grew in a marsh environment of the Catskill Deltaic complex. The bulbous bases of these fossils were found in place in dark-colored shale; the upright trunks were encased in olive-gray, cross-bedded sandstone of probable tidal origin. The age of the "trees" is latest Middle Devonian.

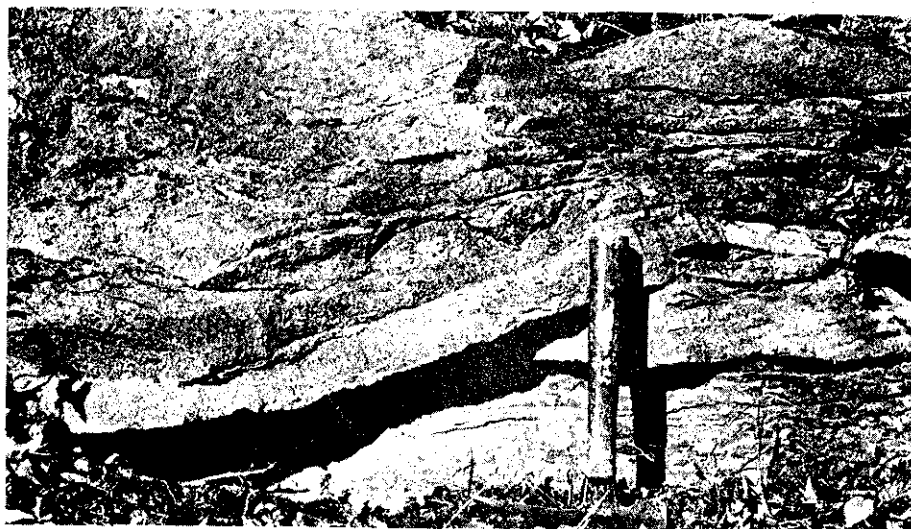


Figure 11. View perpendicular to strata of limestone showing worn and abraded block (light grey) of mottled dolomitic micrite, which is thought to have foundered from eroded bank of ancient tidal channel. Darker grey enclosing rock (intrasparite and biointrasparite). Tribes Hill Formation (Lower Ordovician), North Tribes Hill Quarry (G. M. Friedman and J. E. Sanders, Fig. 11-51, p. 342).

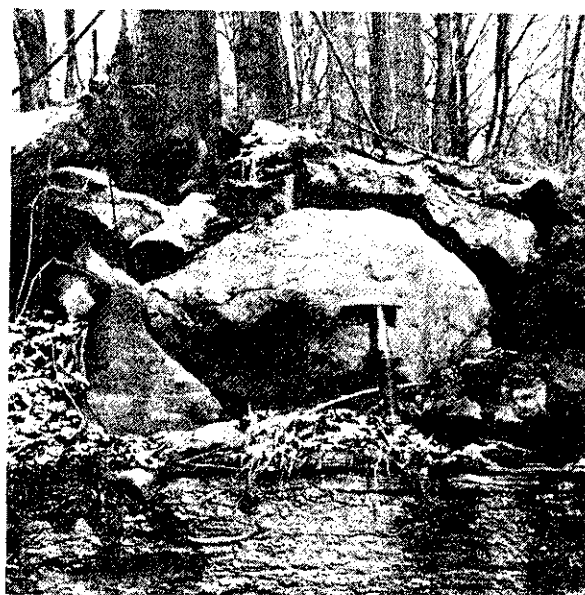


Figure 12. Truncation at base of tidal channel. Rocks in channel consist of lithofacies 8 (intrasparite and biointrasparite), Tribes Hill Formation (Lower Ordovician). North Tribes Hill quarry.

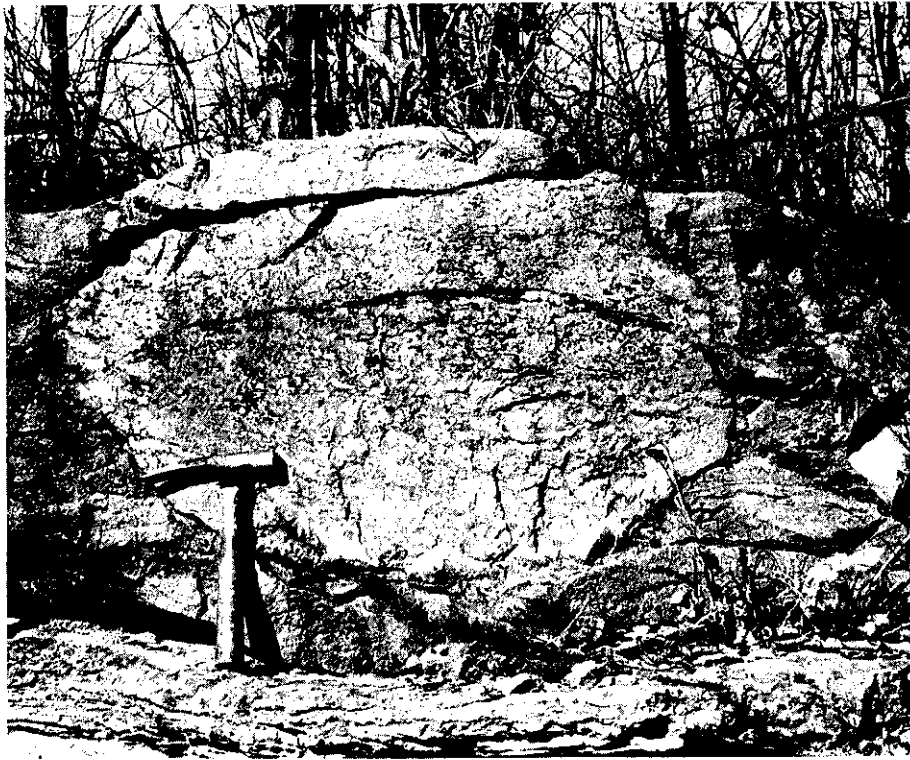


Figure 13. Block of lithofacies 7 (mottled dolomitic micrite and biomicrite) foundered in tidal channel (lithofacies 8), Tribes Hill Formation, (Lower Ordovician). North Tribes Hill quarry.

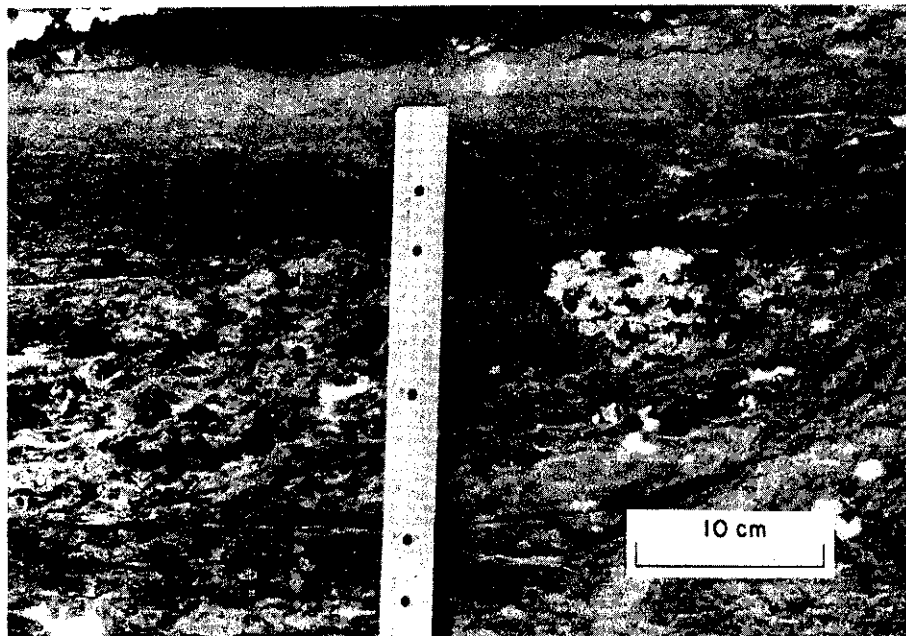


Figure 14. Ancient shell hash that has been deposited at base of tidal channel (margin of channel at lower right); most fossils (here represented by molds and thus appearing as irregular black areas) are of brachiopods. Middle of Upper Devonian, Catskill Mountains, Grand Gorge (Stop 5). (K. G. Johnson and G. M. Friedman, 1969, Fig. 22, p. 475.)

Return to NY 30.

1.0	104.0	Turn left (south) on NY 30.
0.8	104.8	Here is Stop 5, the Grand Gorge Section.

STOP 5. INTERTIDAL FACIES: TIDAL FLATS AND TIDAL CHANNELS

The rocks at this exposure are medium-gray, fine-grained graywackes; tabular cross-beds are ubiquitous, parting lineations are common. The most interesting single feature at this exposure are the tidal channels. These channels are small, about 2 to 10 feet in cross-section; they truncate the underlying strata. The channel fill consists mostly of a lag concentration of transported spiriferid brachiopod shells (Figure 14). Usually the shell material is abundant enough to rate for the channel the name "coquinite." Holes in the coquinites are brachiopod molds. Interestingly, brachiopod shells are confined only to the coquinite lenses; they are not found in the surrounding rock. Hence the brachiopods were treated by the channels as pebbles that were washed in from the open marine environment. In analogous modern tidal channels, typical open sea species are washed into the channels by flood tides (Van Straaten, 1956).

An alternate interpretation for the coquinite lenses is that they may be storm deposits. The lenses are lag concentrates of brachiopod shells; in the contiguous sandstones pelecypods, chiefly Unio, occur. If these lenticular coquinite lenses were tidal channels, then according to this alternate interpretation, lateral cutting should have concentrated the molluscs. Yet these lenses are devoid of molluscs, hence storms rather than tidal action should have caused the coquinite lenses.

Load-flow structures, formerly known as ball-and-pillow structures, load casts or storm rollers are locally present. They represent compactional differential loading. These structures may be related to slumping and are common on the front of modern deltas.

Note that the next exposure south (uphill) is composed of red fluvial rocks.

This exposure has been described by Johnson and Friedman as part of their section 43 (1969, p. 471-475, especially Figs. 22 and 23). These rocks are the clastic correlatives of the Tully Limestone (early Late Devonian or latest Middle Devonian).

Continue south on NY 30.

1.8	106.6	Turn right (west) on NY 23 to Stamford.
7.4	114.0	Turn right (north) on NY 10 through Summit.
16.1	130.1	Stop at roadcut behind sign "Town of Richmondville" (3.5 miles north of Summit).

STOP 6. DEPOSITS OF LAGOONS AND BARS OR TIDAL DELTAS

At this exposure lenticular sandstone bodies interfinger with dark-gray siltstones and shales. The sandstones have a vertically shingled, or en echelon, configuration relative to one another. Even the thickest sandstone, approximately 6 feet thick, thins and pinches out laterally (see

Fig. 25, p. 478 in Johnson and Friedman, 1969). The sandstones contain marine fossils and wood fragments. In places they are crossbedded; ripple marks are locally present. In the siltstones and shales wood fragments are abundant. The presence of marine fossils, the absence of channels, and the lenticular geometric configuration of the sandstones within interfingering siltstones or shales suggests that the sandstones may be bars or tidal deltas. If so, the siltstones or shales are of lagoonal origin.

The rocks at this exposure belong to the Hamilton Group (Middle Devonian) and are about 600 feet below the stratigraphic level of the Tully clastic correlatives.

Approx.
48.0

Approx.
178.0

Continue north on NY 10 to NY 7 and
return (east) to Skidmore College.

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A TRIP TO THE TACONIC PROBLEM AND BACK AND THE NATURE OF THE EASTERN TACONIC CONTACT

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INTRODUCTION

The purpose of this paper is to provide background information needed for both the full-day trip (Saturday, Sept. 28) and the half-day trip (Sunday, Sept. 29). The full day trip involves data from the entire paper while the half-day trip concentrates on the Taconic Problem primarily. However, to understand either day fully, the entire paper must be read. A separate Road Log for each trip is provided at the end of the paper.

The paper describes geologic features to be examined in area from Saratoga Springs, N.Y. to Manchester, Vt. A discussion and overview of the Taconic region and the "Taconic Problem" will be presented. Consideration will be given to both the sequential and fault hypotheses proposed for the High Taconic region.

The Taconic region is subdivided into the High Taconics and the Low Taconics based on the extreme difference in relief. The High Taconics are the mountains of Vermont, west of the Vermont Valley, with elevations of approximately 3000-4000 ft. The Low Taconics are the hills primarily in New York, west of the High Taconics, with elevations up to approximately 1500 ft. (Hewitt, 1961a). Lithologic and other distinctions will become apparent in the later discussion.

LOCATION

The trip extends from Saratoga Springs, N.Y. to the area of Schuylerville, N.Y., across the Hudson River to a location south of Cambridge, N.Y. From there the trip continues eastward to the area of West Arlington and Sandgate, Vt., then to Arlington and north to Mt. Equinox and Manchester, Vt. Figure 1 shows the route. Each Stop is located with the approximate mileage between Stops. The basic geology is superimposed on the map.


Topographic maps useful for the area include the Saratoga, N.Y., Schuylerville, N.Y., Cambridge, N.Y.-Vt. and Equinox, Vt. quadrangles. All are 15 minute maps though 7½ minute maps are readily available.


GEOLOGIC SETTING

Stratigraphy

The Saratoga Springs area is underlain by early Paleozoic shelf deposits consisting of gray, massive dolostones and associated sandstones and orthoquartzites of Cambrian to early Ordovician age and dark to black

LEGEND

LOW TACONICS 

THRUST FAULT 


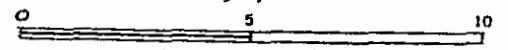
HIGH TACONICS 

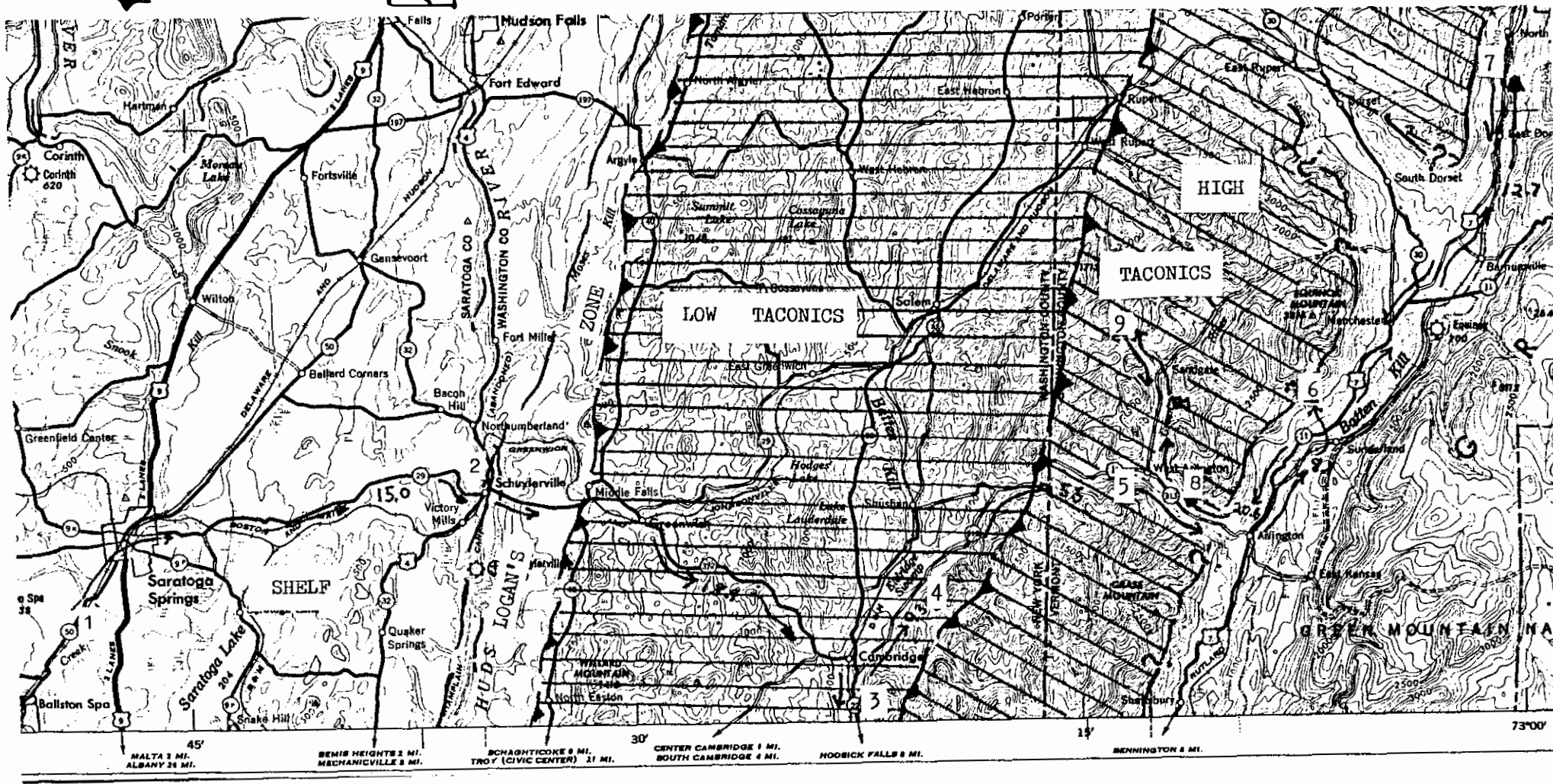
FIGURE 1

SCALE
1: 250,000



GENERALIZED MAP OF FIELD TRIP AREA

C.I. = 100'



shales of the medial Ordovician age. The Vermont Valley portion of the Equinox Quadrangle is remarkably similar to the lower part of this sequence. The Low Taconics and the lower part of the High Taconics are very similar to the medial Ordovician strata at Saratoga Springs except that they have been metamorphosed. The lower part of the Low Taconic sequence is composed of slates (Mettawee slate, Cushing and Ruedemann, 1914). These and medial Ordovician slates in the Low Taconic sequence are best exposed in the northwest part of the Equinox quadrangle and localities to the north of that area. Some green slaty strata on Route 313 east of Cambridge, N.Y. are generally assigned to the Mettawee and these will be examined at that locality. Additionally, clean calcic marbles of commercial quality and quantity (the Marble Belt) appear in the Ordovician sequence in Vermont.

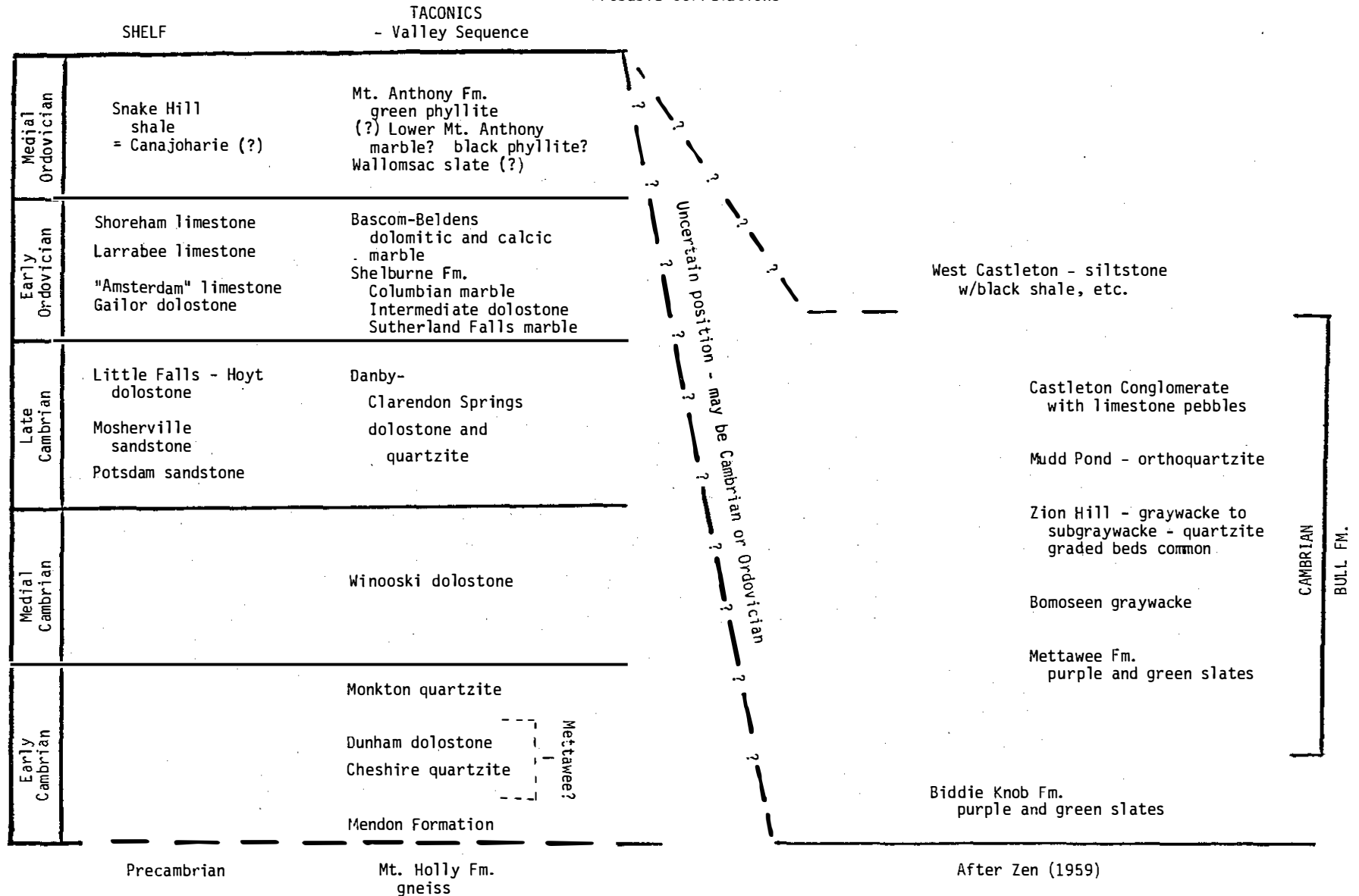
Finally, the topographically highest unit, the age of which is still uncertain, is the green phyllite variously called the Mt. Anthony formation (MacFadyen, 1956; Hewitt, 1961a) and the Bull formation (Zen, 1959). The age of this unit is considered by some workers (Zen, 1959; Schumaker, 1959) to be Cambrian and to be totally allochthonous, that is, thrust over the known medial Ordovician carbonates. Others (Hewitt, 1951a; MacFadyen, 1956) suggest that these highest green phyllites lie unconformably in some places and gradationally in others upon the middle Ordovician carbonates. In this case, the green phyllites capping the High Taconics would be medial Ordovician or later in age and therefore younger than the carbonates. Table 1 is a list of the relevant formations and the correlations which must be considered in understanding the problem. For a more complete discussion of the stratigraphy see Fisher (1965) and Hewitt (1961a) or the several publications listed in the References.

Structure

The beds in the Saratoga Springs area are generally quite flat-lying but are disrupted in many localities by numerous normal faults, some of which give rise to the carbonated and mineralized water of the Saratoga Springs. Although these faults will not be examined on this trip, their presence may be inferred at Stop 1 in Saratoga State Park (Hewitt et al., 1965 p. D3-D10).

East of Saratoga Springs and west of the Hudson River in the vicinity of Schuylerville, N.Y. Logan's Line, better described as Logan's Zone is encountered. This is a broad, extensive north-south trending zone of reverse faults along which rocks of the Low Taconic area were thrust over the correlative westerly shelf deposits. More eastwardly are the very highly folded, thrust faulted and metamorphosed Taconic strata. Thrust faults are well known and documented with plentiful evidence available to demonstrate their presence (Hewitt, 1961a; Zen, 1959, etc.) All of the thrust faults, with one exception, display the usual criteria of faulting such as breccia, mylonite, gouge, displacement of key beds and so on. Slickensides cannot be used in this area because all of the beds display this feature as a result of the shearing which accompanied the intense folding.

TABLE 1
List of Formations with
Probable Correlations



One proposed fault, and a highly important one that does not display such evidence is the thrust suggested by Zen (1959) and others along the east flank of the High Taconics, the so-called "Taconic Thrust", between the middle Ordovician carbonates and the overlying green phyllites. In this case no breccia, mylonite or gouge is present. The lack of this evidence does not of itself preclude the presence of a fault along the bedding (a bedding plane fault). The green phyllites lie in various localities in sharp contact upon black phyllites, dolomitic marble and other units but in other places there is an apparent gradation between the dolomitic marble (medial Ordovician) and the overlying green phyllites (Hewitt, 1961a; MacFadyen, 1956). Both authors refer to these green phyllites as the Mt. Anthony formation. The nature of the gradation is reserved for later in this paper. Zen (1959) and Shumaker (1959) among other authors propose a fault based on their inference of the equivalence of the green phyllites with other strata of known Cambrian age. If this is true and the green phyllites are of Cambrian age and are on top of the carbonates, then older beds are thrust over younger beds and a fault is present. If on the other hand, there is a gradation anywhere along that contact, an unconformity is more likely. This will be further discussed in a later section.

In addition to faulting; very intense folding is evident. The entire Taconic area comprises a large synclorium. With such complex folding it is often difficult to determine whether beds are right-side-up or not. Folds are often severely overturned to the west, isoclinal or even recumbent. Careful and detailed study is required to delineate the major structures. However, both sedimentologic and stratigraphic evidence are available to suggest a solution in most cases. The section along Route 313 from the N.Y.-Vt. border eastward displays the complexity of the folding. Both bedding plane and axial plane cleavage are well developed. In some localities more than one episode of deformation is apparent as shown by the intersection of axial plane cleavage. Folds may be recumbent or have dips as steep as 45°. Most dips are approximately 20°-30°SE.

Unconformities

At least one unconformity has been firmly established in the area of concern. MacFadyen (1956) indicated the presence of an unconformity between the lower Ordovician and the overlying Walloomsac slate. Thompson (1959) apparently recognized the same unconformity and indicated that strata as old as Cambrian were truncated by this erosion surface. Other unconformities exist in the Vermont Valley but they do not affect the area of this paper.

The only other unconformity of interest in the area is the one suggested by Hewitt (1961a) between the Mt. Anthony formation (the highest green phyllites) and the underlying Ordovician carbonates. This unconformity lies at the precise horizon at which the "Taconic Thrust" must lie. Therefore, the basic question revolves around the nature of that contact. Therein lies the "Problem".

THE PROBLEM AND POSSIBLE SOLUTIONS

The discerning reader has already discovered the basis of the present-day Taconic Problem. The original "Problem" was based upon Ebenezer Emmons' use of the term "Taconic System" (1842, 1844). Emmons had failed to recognize that the rocks to which he applied this name were actually a section of Cambrian rocks which were repeated due to faulting. The confusion caused by Emmons was eliminated by Dana (1877, 1887) and Walcott (1888) with their demonstration that the term was invalid.

All of those who have studied the Taconic region agree that the Low Taconics are thrust to the west over the shelf deposits. The evidence along Logan's Zone is very clear. All of the faults from Logan's Zone eastward to the western edge of the High Taconics are well accepted.

Today, the only question to be resolved is the nature of the contact between the carbonates and black phyllites of medial Ordovician age and the green phyllites overlying them on the eastern front of the High Taconics. If the green phyllites, which are the highest units topographically, are really Cambrian in age and equivalent to units far lower stratigraphically, then a fault must exist at its contact with the medial Ordovician carbonates and black phyllites but neither higher nor lower than that contact. If the fault were higher than that contact then the green phyllites, at least in part, might be younger than the carbonates and phyllites particularly if a gradation can be demonstrated anywhere along that front. If the fault were lower than that contact, known Ordovician beds would lie above the fault. Neither situation would satisfy those who would assign a Cambrian age to the green phyllites. No fossils have been found in the green phyllites nor is it likely that any ever will be. The lithology and the metamorphism suggest that no amount of searching will help. Radiometric dating is of no use, for it would provide only the date of metamorphism. If Zen's (1959) Bull formation is of Cambrian age, its equivalence with the Mettawee formation, Zion Hill quartzite and other units which are known to be Cambrian, must be based on lithologic and stratigraphic similarities. According to Zen (1959, 1960) and Schumaker (1959) such equivalence may be inferred if the green phyllite and its included lithologies are up-side-down.

In summary, if the eastern Taconic Thrust exists it lies between green phyllites of supposed Cambrian age which are inverted and above a normal, right-side-up section of sediments that, based on reasonable fossil evidence and tracing extends more or less continuously from early Cambrian through medial Ordovician. This is the only reasonable location for the "Taconic Thrust".

A second hypothesis has been proposed by this author (Hewitt, 1961a, 1961b). In this case, the green phyllites are considered to be younger than the underlying medial Ordovician carbonates and green phyllites. The contact between these units would then be an unconformity and not a fault. In the Equinox quadrangle graded bedding in a lithology similar but not identical to the Zion Hill indicates that the beds are dominantly right-side-up. Structural evidence implies this also since all folding is

congruous. Carbonate and black phyllite folding matches the green phyllite folding in axial trends and scale.

More importantly, along the eastern front of the High Taconics no definitive evidence of faulting has been found. It is, however, possible in some localities (Cook Hollow, Skinner Hollow, West Sandgate Rd., for example) to observe a gradational contact between the carbonate-black phyllite surface and the green phyllite. Certainly the beds are interfolded but they also appear to be interbedded. In particular, the highest and last bed of carbonate displays the gradation. The bottom of the bed is totally carbonate and the top is totally phyllite. In other localities the contact between the carbonates (and/or the black phyllites) and the upper green phyllites is quite sharp.

If the above statements are accepted then the sequence of events using this second hypothesis is clear. Following deposition of the carbonates and black phyllites, uplift resulted in the erosion of these middle Ordovician strata. An irregular erosion surface, such as in our present landscape was formed with hills in some places and valleys in others. Erosion cut away at this surface, in part deeply into the carbonate and elsewhere into the black phyllite. As the sea advanced over this surface, erosion continued. Carbonate was worn off of the hills and into the submerged valleys. At the same time the sediment that was to become the green phyllite (after metamorphism) was added. This caused the gradation to occur. Once submergence was complete erosion of the small local hills ceased. Additional deposition buried both the hills and the valleys in the only sediment available., that is, the phyllite material. This would result in sharp contacts over the buried hills and gradational contacts in the buried valleys. Both sharp and gradational contacts were reported by MacFadyen (1956) in the Bennington quadrangle and by Hewitt (1961a) in the Equinox quadrangle.

CONCLUSION

If there is to be a solution of this problem it is important that sections such as the one at Cook Hollow be studied with care. The traverse westward from Rt. 7 to the top of the landslide scar permits observation of a virtually complete section of rock including the relatively fossiliferous carbonate beds of medial Ordovician age (and other older units) and the green phyllites as well as the contact between them.

This paper will not describe what the author concludes is present at the Cook Hollow exposure. Rather, each individual should be permitted to decide what that observer notes along the traverse without further bias by the writer. However, certain factors should be considered by those who wish to examine the rocks along this traverse. The first factor of concern should be the nature of the carbonate sequence and its fossil content and the relationship of these strata to the green phyllites. Second is the character and lithology of the beds between the known middle Ordovician carbonate and the green phyllite. A third factor would be to consider the structural elements present. Fourth, the precise nature of the contact between the carbonates and overlying green phyllites should

also be carefully examined. The precise lithology and sedimentology of the last bed or beds at the contact is a fifth point of importance. Care should be taken to note whether detrital or chemical (or both) carbonates are present. Lastly, one should note the scale of the proposed erosion surface. Other factors as well will undoubtedly occur to any qualified observer at the site.

There is no unanimity of opinion as to which concept is correct or if either is correct. It is possible that some other hypothesis will resolve the issue. What is certain, however, is that any solution must be based upon evidence in the field and not merely on regional considerations. Too often facts are ignored merely to satisfy "the big picture". This is not now nor has it ever been the way of science. It is important that careful research by impartial observers be pursued along the eastern face of the High Taconics.

ACKNOWLEDGEMENTS

Thanks are due to Drs. Robert Cassie and Victor Schmidt of the Department of the Earth Science at the State University of New York College at Brockport for critically reading the manuscript. Their ideas and suggestions were very helpful in clarifying issues. Nonetheless, the author assumes full responsibility for the content of this paper.

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ROAD LOG FOR THE TRIP TO THE TACONIC PROBLEM AND BACK

This trip begins at Geyser Spring Parking Lot, Saratoga Springs State Park. To reach the Park from the center of Saratoga Springs, drive south on Routes 9 and 50 to the junction south of town. Bear right (southwest) on Route 50, 2.4 miles to the Park entrance on left (east) side of Route 50. Enter Park and drive 0.7 miles following signs to Geyser Springs Parking Lot. Park opposite the "Island Spouter". Please gather at the Spring. NOTE: NO HAMMERS IN THE PARK PLEASE!

STOP 1. THE SPRINGS, TUFA TERRACE, AND FLAT-LYING SNAKE HILL SHALE

The Spring along the pathway is typical of the mineralized and carbonated springs in the region. Do taste the water but with caution. Firstly, the water at this Spring passes through the dark shale and therefore, contains iron and sulfur. The amount of sulfur is sufficient to "surprise" the unwary. Secondly, the water contains the radioactive gas radon. Thirdly, the bedrock from which the water rises is a dolostone and in addition to the calcium it contains magnesium. Therefore, this water is an excellent laxative. "A word to the wise is sufficient."

All of the springs are the result of the expansion, along the faults, of carbon dioxide gas released by the weathering of dolomite at depth. Acid water percolates downward to the dolostone, weathers the rock and forms mineralized water plus gas. As the water reaches the faults the carbon dioxide gas expands with the reduction of pressure and the gas carries the water to the surface.

The "Island Spouter" is, of course, not truly a geyser. In this case it is gas within a constricting pipe which allows the water to spurt into the air.

Walk north approximately 500 ft. along the path. Note dark gray to black flat-lying shale. Approximate equivalents to these shales (Snake Hill, Canajoharie?) will be seen later as metamorphic rock. These shales are medial Ordovician in age.

Note the Tufa Terrace. Formed of colloidal and precipitated calcium carbonate from the Spring on the hill above (west) the terrace. Here leaves and insect fossils are formed each year as the organic material is trapped, coated and then permineralized with the calcium carbonate.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0	0	Park entrance. Exit here. Turn right (north) onto Rt. 50.
2.4	2.4	Junction Rts. 9 + 50. North.
2.9	0.5	Turn right (east) onto Rt. 29.
8.5	5.6	Sand dunes. Some totally and partially exhumed. Probably from Lake Albany equivalent. Note long axes to west. Possible 5 minute "extra" stop here if time permits.
8.9	0.4	View of Taconics ahead (east).
13.1	4.2	Saratoga National Monument on right. Battle of Saratoga took place here during Revolutionary War.
13.9	0.8	Junction Rts. 4, 32, 29. Turn left (north) at light. Canal and Hudson River on right (east).
15.0	1.1	Turn left (west) onto Stark's Knob Rd.

STOP 2. STARK'S KNOB AREA. FOLDED, DISTORTED SHALE

Note badly distorted black shale on right side of road. These are equivalent of those at Stop 1 (Snake Hill). This is part of Logan's Zone and the rocks are faulted, badly fractured and somewhat metamorphosed. Note limestone and dolostone pebbles (gray to blue-gray) in shale and oxidation of parts of shale surfaces. Limestone and dolostones are not indigenous to this locality. They are from the area far to the east. We will see these later in the day in situ. The red oxidized zone probably represents a "baked" zone as the area moved westward during faulting. The "baking" might also have resulted from the emplacement of the basaltic pillow lavas of which Stark's Knob is composed.

Walk uphill and to the right for a quick examination of Stark's Knob. This is a flow of basalt (now pillow basalt) which apparently formed when lava flowed into the sea and across a shaly (or muddy) shoreline with fragments of limestone and dolostone present. The lava and the shale which enclosed it were later thrust westward during the faulting which produced Logan's Zone. We will see basic material similar to this lava but as dikes on Rt. 7 in Vermont. Stark's Knob was formerly used as road metal.

The basalt and the shale are both of medial Ordovician age. Return to cars.

- | | | |
|------|-----|---|
| 15.0 | 0 | Turn right (south) onto Rts. 4 & 32. Note folded black shales on right side of road along route. |
| 16.1 | 1.1 | Drive past light at intersection with Rt. 29. |
| 16.3 | 0.2 | Turn left (east) onto Rt. 29. Low Taconic area straight ahead (east). |
| 19.0 | 2.7 | Junction Rt. 40. Continue east on Rt. 29. |
| 19.4 | 0.4 | Crossing Batten Kill. |
| 20.8 | 1.4 | Greenwich, N.Y. Straight ahead on Rt. 372, through town and under old Railroad Bridge. |
| 29.5 | 8.7 | Cambridge, N.Y. |
| | 1.0 | Junction Rt. 22. Turn right (south). |
| 32.9 | 3.4 | Slow. Caution. Outcrop on left (east). Turn with <u>great</u> care facing cars to north (the direction from which we came). Park. |

STOP 3. FOLDED WALLOMSAC FORMATION

This outcrop exposes typical black slate and metamorphosed sandstone (now quartzite) of the Walloomsac formation. Strata here are strongly folded and thrust faulted. Cleavage is readily visible. There is some mineralization along the faults. Folds of various magnitudes may be observed here. This outcrop expresses well the folding in the Low Taconics. Virtually every bed is slickensided. Some folds show evidence of refolding.

No fossils have been found to verify the age of this outcrop. However, it maps well into the Walloomsac which is generally considered to be medial Ordovician (Trentonian) in age. It is probably correlative with the Snake Hill. However, lithologically it resembles the Austin Glen member of the Normanskill formation more closely. This unit is believed to be older than the Snake Hill but still medial Ordovician. Return to cars and continue north on Rt. 22.

- | | | |
|------|-----|--|
| 36.1 | 3.2 | Junction Rt. 313. Turn right (northeast) onto Rt. 313. |
| 37.4 | 1.3 | Black slates and phyllites on both sides of roads. These are visible in many locations along the road. |
| 42.2 | 4.8 | Park cars on right (southeast) side of road. |

STOP 4. GREEN SLATE AND BLACK SLATE OUTCROP

Green slate (or phyllite) is exposed on the left (northwest) side of the

road. Black slate (or phyllite) lies across the road on the southeast side. The decision as to whether these are slates or phyllites is rather subjective since they appear to border both lithologies. Beds appear to dip to the southeast which is common in the area. The green slates appear to lie under the black beds. The age of the black phyllites is probably medial Ordovician since they are on strike with the Walloomsac beds. If so, they lie above green beds which, in many ways, resemble those of the beds further east in the High Taconics. The green slates are also on strike with known Cambrian beds of the Mettawee slates (the famous purple and green slates) in the Taconic sequence. Some few purple beds are seen at this locality also but they are better exposed 1.6 miles northeast along Rt. 313. Purple and green Mettawee slates are well known in the northwest part of the Equinox quadrangle. The author considers the green slates to be Cambrian Mettawee formation and the black slates to be Walloomsac. In this case a major unconformity is present. This is probably the unconformity recognized by MacFadyen (1956), Thompson (1959) and others. Return to cars. Continue on Rt. 313 to northeast.

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| 43.1 | 0.9 | Interfolded black and green slates. |
| 43.8 | 0.7 | Purple and green slates. |
| 45.9 | 2.1 | Tight folding, chevron folds in green phyllite (Mt. Anthony fm.) in Vermont. On left (north). These are the same phyllites which lie over the carbonate in the High Taconics. Since crossing the State Line into Vermont, we have been in the High Taconics. |
| 47.7 | 1.8 | Covered Bridge on right (south) and dolomitic marble outcrop on left (north) Pull to right past Covered Bridge and park. |

STOP 5. ORDOVICIAN CARBONATE OUTCROP

This outcrop of medial Ordovician gray to blue-gray dolomitic marble contains many fossil fragments (crinoid, cystoid and related groups) and a few remains of a Trentonian cephalopod (probably Endoceras proteiforme). This establishes these strata as medial Ordovician in age. Although these beds resemble closely the Bascom-Beldens (undifferentiated), the age is too young. The Bascom-Beldens is generally considered to be of early Ordovician age. Therefore, these fossiliferous middle Ordovician rocks were mapped separately and with the associated black phyllite as the lower Mt. Anthony formation (Hewitt, 1961a). If the upper part of the Beldens could be demonstrated to be Trentonian (medial Ordovician) these beds could easily be placed, on purely lithologic grounds in that formation.

The strata at this outcrop directly underlie the green phyllites of the High Taconics assigned to the Mt. Anthony formation (MacFadyen, 1956). It is the nature of the contact between these units that is the crux of the present Taconic problem (see paper preceding this Road Log for details. Some evidence of that contact will be seen at a later stop and more definitive evidence is presented at Stop 2 of the Road Log for the trip entitled

"The Nature of the eastern Taconic Contact."

Although some observers may conclude that the folding at this locality is not extreme, it should be noted that green phyllite probably lies below the surface as well as above the carbonate. Many of the beds are up-side-down and generally the outcrop is an inverted section at road level. Further up the hill above (north) the road the strata are right-side-up. Some sandy beds show cross-bedding that helps to establish this but the extreme overturning of these folds will be very apparent as the field trip progresses. The nature of the synclinorium actually requires this as our eastward travel will demonstrate. Please return to the cars and drive east, staying on Rt. 313. Note carbonate on drive eastward. We will examine these later.

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| 51.8 | 4.1 | Junction of Rt. 313 and Rt. 7. Turn left (north). Red Mtn. on left. This is the west side of the Vermont Valley. Outcrops within the Valley are Cambro-Ordovician Valley sequence strata. On right (east) are the Green Mtns. of Precambrian to earliest Cambrian age. |
| 52.7 | .9 | View of Mt. Equinox ahead. |
| 54.1 | 1.4 | Delta deposit on left (west) from post-glacial lake (Lake Bennington?). |
| 55.8 | 1.7 | Turn left to entrance to Skyline Drive. <u>Pay toll</u> (approximately \$5 per car.) Rest stops here, at first terrace and at top. |

STOP 6. MT. EQUINOX

No mileages will be provided for the drive up Mt. Equinox since easily recognizable stopping places have been provided. Drive carefully both up and down the mountain! If you do not have faith in your car's brakes and transmission do not attempt the drive. The drive will test your car.

The road up starts gently in the Shelburn formation with a lower member (Sutherland Falls) of creamy to white calcitic marble, a middle (Intermediate dolomite) member and an upper Columbian marble, the commercial marble of the Vermont Marble Belt. None of this formation is exposed until the first bench or terrace is reached. Elsewhere on the mountain, excellent exposures of all three members are easily observed.

Park at the Parking Lot at the first terrace. This is our lunch stop. Rest rooms are opposite the Parking Lot about 300 ft. to the south. Enjoy the view but please keep the area clean.

Before returning to the cars, gather at the picnic tables for a discussion of the geology, history and culture of the mountain. If time permits we will visit a small marble quarry about 900 ft. north of the Parking Lot at an elevation 100 ft. lower than the Parking Lot. You may collect at

this quarry. Return to cars and continue drive up the mountain. Do not stop on the road but note when green phyllite first appears. This occurs after first private road on your right (northeast). Continue climb.

Park at Parking Lot on second terrace. This locality is in the green phyllite. It provides excellent samples of the phyllite, pyrite cubes, and pseudomorphs of limonite (goethite) after pyrite, particularly in the northwest part of the exposure. Collect all you want. Return to cars and continue climb.

At first flat area, note Little Equinox Mtn. on right (southeast) and Lake Madelaine on left (west). Note also areas of landslides on right (east) side of sharp turns near top of Mt. Equinox. One of these will be climbed on foot on the trip discussing "The Nature of the eastern Taconic Contact".

At the summit, park but leave car engine running at fast idle for a few minutes before shutting down. This will help cool the engine. Gather in Parking Lot for orientation, geomorphology and overview of Taconic area.

Descend mountain. Keep car in LOW GEAR while descending. Brakes have been known to fade and even burn on descent. Stop at first flat area below summit for view of Lake Madelaine and monastery. Lake Madelaine is totally artificial. That area was formerly Big Spruce Swamp. Continue to base of mountain. Stay in LOW GEAR. Regroup at base of mountain in Parking Lot. Turn left (north) onto Rt. 313.

58.3 2.5 Note Cook Hollow on left (west). White flat outcrop is Table Rock composed of white marble (Columbian?), Landslide Scar visible above Table Rock. This is carbonate-green phyllite eastern Taconic contact. Hewitt (1961a) concludes that this is a gradational contact.

68.5 10.2 Park cars on right (east) side of road. Cross to west side of road. CAUTION: These rocks are loose and dangerous. Do not attempt to move large blocks or undermine surface. CAUTION: WATCH FOR CARS.

STOP 7. DOLOMITE OUTCROP. BASIC DIKES

This is the Winooski dolostone of medial Cambrian age. Bedding and jointing permit blocks to fall easily so caution is important here. Note basic dikes in wall of exposure near north end. Return to cars. Drive north to next right (east). Then next two lefts and back on to Rt. 7. Turn left (south) onto Rt. 7.

85.2 16.7 Intersection of Rt. 313. Turn left (west) onto Rt. 313.

89.1 3.9 Park on right (north) for examination and photo.

STOP 8. OVERTURNED FOLD

This structure is a classic fold in the Bascom-Beldens formation. The lithology is dolomitic marble and the folding is typical Taconic folding. BE CAUTIOUS AT THIS OUTCROP. FOLLOW DIRECTIONS OF THOSE DIRECTING TRAFFIC. THEY ARE THERE FOR YOUR PROTECTION. Return to cars and continue on Rt. 313 (west).

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| 91.6 | 2.5 | Corner Sandgate Rd. Turn right (north). |
| 95.1 | 3.5 | Turn left (northwest) over one lane bridge. |
| 99.8 | 4.7 | Corkscrew turn in folded Mt. Anthony formation. Drive through turn and turn at next intersection and reverse direction. Park at end (southeast) of large outcrop. |

STOP 9. CARBONATE-GREEN PHYLLITE CONTACT

The green phyllite (Mt. Anthony formation of MacFadyen (1956)) is well exposed here. Intense folding is obvious. These are small folds on successively larger folds in this area. With care, small folds may be collected here. All of this section appears on first glance to be green phyllite. However, at the southeast corner of the last outcrop on this road the application of cold, dilute hydrochloric acid results in effervescence at the base. It is impossible visually to locate the horizon at which calcium carbonate ends and the phyllite begins. Only an acid reaction or lack of it can determine the difference. Is there a fault here or not? It is up to you to decide. Note the valley to the south. Is this a depression within the phyllite or the result of solution of a carbonate? No outcrops have been located within that depression but plentiful float is found there. Return to cars.

Drive to Rt. 313. Turn right (west). Follow Rt. 313 to Cambridge, N.Y., then take Rt. 372 to Rt. 29 west to Saratoga Springs.

End of trip.

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ROAD LOG FOR THE NATURE OF
THE EASTERN TACONIC CONTACT

This trip begins at the Covered Bridge on Rt. 313 in Vermont. From the junction of Rts. 9 and 50 and Rt. 29 in Saratoga Springs, drive east on Rt. 29 to Schuylerville, Middle Falls, and Greenwich, N.Y. From Greenwich take Rt. 372 east to Cambridge, N.Y. Then take Rt. 313 to the Covered Bridge. The total distance is 44.8 miles. The Covered Bridge is 11.6 miles northeast of Cambridge, N.Y.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0	0	Drive east on Rt. 313.
0.4	0.4	Sandgate Rd. Turn left (north).
3.9	3.5	One lane bridge. Turn left (northwest) over bridge.
8.6	4.7	Corkscrew turn in road. Drive through turn. Turn around and reverse direction at next intersection.
8.9	0.3	Park on right at south end of outcrop.

STOP 1. CARBONATE-PHYLLITE CONTACT AT SANDGATE

The exposure of green phyllite at this locality lies at the axis of a large anticline that lifts the base of the formation structurally. With favorable topography the lower parts of a formation may be exposed as at this locality. In a synclorium, it is normal to expect that generally, the higher parts of the formations will lie deeper in the earth. When an anticline fortuitously is cut by erosion to expose lower and lower parts of a formation more data become available. In this case, part of the phyllite section responds to hydrochloric acid in a formation that normally has no calcareous beds.

After a general examination of the exposure a study of the lowest part of the formation visible here should be undertaken. This part is located at the southeast end of the outcrop. Note that the base of the exposure appears to be phyllitic and very much like the rest of the rocks here. If cold, dilute hydrochloric acid is applied, the lowest beds will effervesce. Visually one cannot see a difference between those beds that will react with the acid and those that will not. The question that must be asked is "What does this mean?" No other part of the phyllite reacts with acid. Carbonates are known to lie under the phyllite. Therefore, this is probably the contact of the carbonate and green phyllite. The nature of that contact at this locality is for you to decide.

Note also the depression to the south of this outcrop. Two possibilities exist here. The depression may be a combination of structure and topography.

That is, the depression might lie in a syncline and therefore lower as a result of structure. This does not appear to be the case here because the anticline passes across the depression. It is also possible that the depression is the result of weathering of a carbonate exposed at the base of the phyllite. Return to cars and proceed southward.

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| 13.2 | 4.3 | Junction of Sandgate Rd. and Rt. 313. Turn left (east) onto Rt. 313. Note folding along road. |
| 17.3 | 4.1 | Junction of Rt. 313 and Rt. 7. Turn left (north) onto Rt. 7. |
| 23.8 | 6.5 | Turn left onto McCooey Drive. Continue to end drive up hill. Park at end of the street. |

STOP 2. COOK HOLLOW-EXPOSURE OF CONTACT

It is wise, politic and intelligent to request permission to cross the property here to make the climb. The climb will involve a rise of 1200-1400 ft. in elevation. Caution is important. Parts of the climb are steep. Some parts are slippery. A slow, steady climb with frequent stops is the best way to see the outcrops and arrive at the contact safely.

Each of the formations mentioned are described briefly in Table 1.

The drive from Rt. 7 crossed the upper Cambrian Danby quartzite and Clarendon Springs formation both of which contain quartzite and dolostone. These formations are not exposed along that traverse. After leaving the cars the traverse begins in the Shelburne marble. Exposures of these strata are best in the creek south of the traverse. It is best to begin the traverse by approaching the creek in order to examine the beds during the climb. However, higher parts of the climb may be difficult or nearly impossible in the creek since this is a landslide area. The easiest climb is on the north (right) side of the creek.

The contact of the Shelburne marble with the overlying Bascom-Beldens formation is at Table Rock. White marble, similar to that of the commercial marble in the Shelburne is also found in the Bascom-Beldens. However, most of the Bascom-Beldens formation is dolomitic marble which is blue-gray to black in color. Near the top of the dolomitic sequence, several hundred feet below the contact with the green phyllite are fossiliferous beds in the marble which contain fossils identical to those at the Covered Bridge on Rt. 313. These indicate an age of medial Ordovician (Trentonian). Beds containing fossils continue across the sequence almost to the contact.

Continued climb will reach a zone of carbonate and phyllite interbeds. Above this zone is a flat area or bench with the contact easily visible. Carbonate ends and the green phyllite continues to the top of Mt. Equinox.

No further description will be presented. It is up to the observer to decide what is seen here. Is this a faulted zone? Where is the fault? Between which strata? Is this a gradational contact? Where does one

lithology end and the other begin? How would you describe the bed at the end of the carbonates and the beginning of the green phyllite?

It is up to you.

The descent is probably more difficult than the climb but it is much faster. Be careful.

Return to cars.

Field trip ends.

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ROCKS AND PROBLEMS OF THE SOUTHEASTERN ADIRONACKS

PHILIP R. WHITNEY
Geological Survey, New York State Museum*

Purpose of the Trip

This trip is a roadcut tour of the easternmost fault block of Proterozoic rocks in the Southeastern Adirondacks, and has two major purposes. For beginners in Adirondack geology, the trip will provide an introduction to the major rock types of the area, as well as to many of the characteristic structural features. For the advanced student or professional, the emphasis will be on the numerous unsolved or partially solved problems presented by these extremely complex rocks.

Introduction

This article is not a report on a finished project, because the writer has not done detailed mapping in the area. The discussion therefore consists largely of preliminary descriptive material, based on a few reconnaissance traverses by the writer and colleagues, plus more detailed examination of the rocks at the scheduled stops, and some very preliminary petrographic work. Previous work in the area includes mapping by Hills (1965) in the southern part of the Pinnacle Range, and by Berry (1961) in the portions of the Whitehall and Putnam quadrangles W and N of the trip area.

Location

The rocks seen on this trip are exposed in roadcuts along Routes 4 and 22 in the Fort Ann and Whitehall 7 1/2 minute quadrangles. They are part of a tilted fault block of Precambrian rocks at the southeastern edge of the Adirondack Highlands, which has been called the Pinnacle Range by Hills (1965). The eastern side of this block is close to the contact with overlying Paleozoic rocks; the unconformity itself is exposed at stop 3.

*Contribution number 462 of the New York State Science Service

Rock Types

1. "Gray Gneisses". This is an extremely heterogeneous group of gneisses in which the characteristic mineral assemblage is biotite-quartz-plagioclase, with widely varying amounts of K feldspar, hornblende, pyroxene, garnet and sillimanite. Retrograde chlorite is locally present. The gray gneisses form a continuum ranging from essentially granitic or charnockitic gneisses at one extreme to aluminum-rich metapelites at the other. More work is needed before these rocks can be subdivided into consistent mapping units. The rocks have characteristically strong compositional banding and are dominantly gray. Most are migmatites with varying amounts of white-to-pink quartzofeldspathic leucosome. Whether these migmatites originated by partial melting or by metamorphic differentiation, they appear to be early since the leucosomes have been involved in all recognized phases of folding. Garnet-bearing gray gneisses are referred to as kinzigites in some of the Adirondack literature.

2. Metapelites. In addition to the aluminum-rich (garnet + sillimanite bearing) gray gneisses, a still more aluminous metapelite also is common in the southeastern Adirondacks. The dominant minerals are quartz, K feldspar, sillimanite and garnet, the latter having a distinctive lavender color. Biotite and plagioclase also may be present in small amounts. Graphite commonly is present, locally in major amounts. This rock, called the "Hague Gneiss" in Alling's (1927) initial attempt at stratigraphy in the Adirondacks, is often associated with a graphite-rich unit called the "Dixon schist", which has been mined for graphite at numerous locations in the SE Adirondacks. While common in the SE Adirondacks, these aluminous, graphitic metapelites are only known in sporadic thin layers elsewhere in the Adirondack Highlands and Northwest Lowlands.

3. Marbles. Marbles in the southeastern Adirondacks comprise both calcitic and dolomitic varieties, both commonly with numerous tectonic inclusions. Calcsilicate mineral assemblages generally are consistent with granulite facies metamorphism, but some dolomitic marbles register anomalously low metamorphic temperatures. The marbles exposed at stop 7 are of this type, and may be either Precambrian marbles tectonically remobilized at relatively low temperatures, or Paleozoic dolostones interleaved with Precambrian gneisses during the Taconic event. This problem currently is under investigation, and will be discussed at stop #7. The marble layers, based on the abundance of rotated inclusions and local crosscutting of foliation in the adjacent silicate rocks, may have been

zones of substantial shear displacement, "lubricated" by the easily recrystallized carbonates. It is significant that the carbonate rocks rarely show the extreme grain size reduction frequently observed in almost all of the silicate rocks.

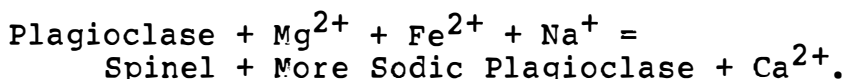
4. Quartzites. Like the metapelites, quartzites also are more common in the southeastern Adirondacks than elsewhere in the region. These quartzites are commonly quite pure (>90% quartz) with minor feldspar, garnet, sillimanite, biotite, chlorite and muscovite. They occur both as thick units (30-100 m, e.g. Stop 10) and also as thinner bands interlayered or interleaved with other rocks.
5. Granitic and Charnockitic Gneisses. Quartzofeldspathic gneisses of granitic (sensu lato) composition are abundant in the supracrustal rocks throughout the Adirondack Highlands; volumetrically they are relatively less important in the SE. These rocks can be roughly divided into five categories:
 - (a) Hornblende granitic gneisses: quartz - 2 feldspar - hornblende \pm biotite \pm clinopyroxene \pm garnet gneisses; commonly pink, gray or white.
 - (b) Charnockitic gneisses: quartz - 2 feldspar - hornblende - clinopyroxene - orthopyroxene \pm biotite \pm garnet rocks. Except for the presence of opx and a generally slightly lower quartz content, these rocks closely resemble the hornblende granitic gneisses mineralogically. The difference in some cases may result from no more than a difference in the metamorphic fluid phase, with CO₂-rich fluids favoring the charnockite assemblage (Newton and Hansen 1983). Outcrop-scale gradations between the two are common in the Adirondacks. Charnockites have a characteristic greenish color, probably resulting from late development of chlorite along grain boundaries and microcracks in the feldspars (Oliver and Schultz 1968).
 - (c) Biotite granitic gneisses: quartz - 2 feldspar - biotite \pm hornblende \pm garnet gneisses. Where strongly foliated, these may grade into K-feldspar-rich gray gneisses and migmatites. Among the more massive biotite granitic gneisses, one distinctive facies contains abundant K-feldspar megacrysts, which have been interpreted elsewhere as either relict phenocrysts or as porphyroblasts.
 - (d) Leucogranitic gneisses. These are quartz - K feldspar gneisses with a variety of minor accessory

minerals, commonly including magnetite. These rocks often have a sugary granoblastic texture and prominent amphibolite interlayers. An albite-rich facies, possibly originating as an analcite tuff, is present locally.

Among the above, on this trip we will see a strongly deformed, leucocratic biotite granite gneiss (stop 5) and a charnockitic gneiss (stop 7).

6. Anorthosite Suite. Meta-anorthosite, anorthosite gneiss, gabbroic anorthosite gneiss, and associated gneisses of ferrogabbro and ferrodiorite composition are of widespread occurrence in the Adirondacks. Rocks of the anorthosite suite underlie much of the High Peaks area, and also are abundant in the Central Highlands near Speculator and Indian Lake. Smaller, sill-like bodies and lenses of meta-anorthosite occur locally throughout much of the Adirondacks. The larger bodies are marked by large negative gravity anomalies. In the SE Adirondacks, scattered outcrops of highly deformed anorthositic gneiss occur along the west side of the Pinnacle Range, and near Fort Ann (stop 1). A larger meta-anorthosite body exists just to the W on Buck Mtn. adjacent to Lake George. The presence of a gravity low centered near Whitehall, with dimensions comparable to those associated with large anorthosite bodies elsewhere, suggests the presence of anorthosite in the subsurface in this region. Anorthosites are plagioclase-rich rocks (anorthosite strictly defined contains 90% or more of plagioclase) with varying amounts of clino- and ortho-pyroxene, garnet and hornblende, as well as occasional minor quartz. Relatively undeformed meta-anorthosite often contains abundant andesine megacrysts; these are only rarely present in the highly deformed anorthositic gneisses in the trip area.
7. Olivine Metagabbros. These rocks occur in numerous bodies throughout the Eastern and Central Adirondack Highlands, ranging from a meter or two up to several kilometers in largest dimension. They commonly show relict igneous (cumulate or diabasic) textures in the interiors of the larger bodies. Primary igneous minerals are plagioclase, olivine and intercumulus clinopyroxene. Under hand lens or microscope, they exhibit "corona" structures of metamorphic minerals. These multilayer reaction rims are of two general types. One consists of layers of pyroxene and garnet between olivine and plagioclase; the other of layers of biotite, hornblende and garnet between ilmenite and plagioclase (Whitney and McLelland 1973, 1983). The latter type appears as prominent dark spots on both weathered and broken surfaces. These rocks, many of which are actually metatroctolites, appear quite mafic at first

glance, but normally contain 50-80% plagioclase. The plagioclase is, however, dark with a characteristic gray-green color resulting from fine-grained (1-5 micron) spinel inclusions. These inclusions form within the plagioclase during metamorphism according to the partial reaction.



This partial reaction is a part of the complex multivariate reactions responsible for the coronas (Whitney and McLelland 1973, 1983). These rocks are best displayed at stop 8, but finer grained, partly recrystallized equivalents form the large lenses at stops 4 and 5. Photomicrographs of thin sections of these rocks will be passed around during the trip.

8. Mafic granulites and amphibolites. This diverse group of rocks is composed largely of plagioclase and mafic minerals, the latter including varying proportions of hornblende, biotite, clinopyroxene, orthopyroxene and garnet. Lesser amounts of quartz and K feldspar are locally present. The relatively competent behavior of these rocks, especially the quartz-free varieties, has resulted in their common presence as boudins and lenses as well as layers. Note the contrasting mineralogy and texture of different mafic bodies even within a single outcrop (stops 2, 4, 7). These may represent different ages of mafic intrusives. Relict igneous textures are commonly preserved in the larger bodies. Some of these mafic rocks are visibly gradational into olivine metagabbros. Those amphibolites and mafic granulites not clearly associated with the olivine metagabbros may represent mafic volcanics in the supracrustal sequence, pre-metamorphic dikes or sills, or mafic members of the anorthosite suite.

Ductile Deformation

The rocks of the Pinnacle Range, like many in the southeastern Adirondacks, show abundant evidence of severe ductile deformation. At least three generations of folds that fold an earlier foliation have been reported in this part of the Adirondacks (McLelland and Isachsen 1980). These comprise isoclinal, overturned to recumbent folds with E to SE trending axes (F2) including large, regional nappelike structures. These are folded by more open, generally upright folds (F3) with axes parallel or subparallel to F2. A later generation of open, upright folds (F5) has N to NE-trending axes. Carefully observe evidence for folding on this trip, and determine

whether it can be fitted into this general conceptual framework.

At least the earliest folds have been overprinted by intense ductile shearing that reflects a period of regional rotational strain. This is recorded in the rocks by the development of enhanced foliation, grain size reduction (mylonite zones are abundant in the SE Adirondacks) and widespread occurrence of stretching lineations. These lineations are most commonly expressed as quartz ribbons (e.g. at stop 5), but lineations defined by streaks of mafic minerals or by oriented elongate minerals (e.g. sillimanite at stop 6) also are common. The lineations generally are parallel to F2 fold axes, possibly as a result of rotation of the folds into their present positions during the rotational strain event (McLelland 1984). A major thrust fault mapped by Berry (1961) in the Putnam quadrangle just NW of the trip area, probably is associated with this event. Another major thrust (or the same one downfaulted by later normal faults) has been mapped by Turner (1984 pers. comm.) in the Silver Bay quadrangle just west of Lake George. In both places charnockitic gneisses have been thrust over metasedimentary rocks similar to those seen on this trip. Strain indicators such as rotated feldspar porphyroclasts, suggest a SE-over-NW sense of rotation. No unambiguous indicators have been found to date in the immediate trip area, but elsewhere in the SE Adirondacks the sense is clear. This major strain event may have coincided in time with the development of the Carthage-Colton mylonite zone in the NW Adirondacks, and both may be associated with a doubling of the continental crust by the thrusting of one (or more) thick slabs of crust over the terrain now exposed in the Central Adirondack Highlands (Whitney 1983). There is also evidence of a later period of shearing at much lower temperatures, possibly coinciding with Taconic deformation which is recorded in the Paleozoic rocks just to the East. This later movement, which may have remobilized pre-existing shear zones, will be discussed at stops 4, 7 and 10.

Metamorphism

Very preliminary observations point to the superimposition of at least three periods of metamorphism in the southeastern Adirondacks. The first is an early, shallow contact metamorphism (Eohlen, et al. 1985) associated with the intrusion of the anorthosite suite. This is represented by the calcsilicates adjacent to the mafic gneiss horizon at stop #7. The inferred original assemblage grossular-diopside-wollastonite in this rock is the same as that which occurs in much larger deposits close to the contacts of the main anorthosite massif in the northeastern Adirondacks. The second metamorphic event was the regional hornblende granulite facies metamorphism which has affected the entire Adirondack region.

Temperatures and pressures in this event ranged from about 650° and 6.5 to 7 kb in the northwest lowlands to close to 800° and 7.5 to 8 kb in the Central Highlands (Bohlen, et al. 1985). Few specific data are available for the SE Adirondacks, but the general pattern of pressures and temperatures in the Adirondacks as a whole as obtained by Bohlen and co-workers is consistent with P and T in the SE Adirondacks somewhat lower than in the Central Highlands but still well within granulite facies limits. Recent work by Glassley (pers. comm. 1985, see discussion under Stop 5) indicates that metamorphic temperature here may have been as high as $810 \pm 40^\circ$ C at pressures of 7.5 ± 0.5 kb. This is consistent with the mineral assemblages found in the anorthositic gneisses (stop #1), charnockitic gneisses (stop #7), olivine metagabbros (stops #5 and #8) and metapelites (stops #6 and #9). A third, retrograde metamorphism has affected some, but not all, of the rocks in this area. Green gneisses interlayered with the quartzite at stop 10 locally contain chlorite, epidote, and muscovite. Quartzofeldspathic mylonites on West Mountain contain abundant, well-crystallized chlorite parallel to the foliation. Ultramafic lenses in the mafic gneisses at stop 4 contain a relatively low temperature mineral assemblage (chlorite-actinolite-serpentine-talc) also suggesting retrograde metamorphism. Other rocks, however, show no clear evidence of retrogression, aside from local development of chlorite. If the retrograde effects are not attributable to hydrothermal activity near late, brittle faulting (an hypothesis that needs to be tested by detailed mapping) they may reflect a second period of movement at lower temperatures, in the high strain zones. This movement may have been localized in the quartz- and carbonate-rich rocks. One curious fact which supports the latter interpretation is the presence of dolomitic marbles at stop 7 which contain angular fragments, some of them polycrystalline, of quartz in unreacted contact with dolomite. This could be explained by a late strain event localized in the marble, at relatively low temperature, during which fragments of quartz-rich rock were entrained in the rapidly deforming marble. Elsewhere in the area where less marble was available strain associated with this late, possibly Taconic event may have been localized instead in quartz-rich units, with simultaneous formation of retrograde chlorite parallel or subparallel to the pre-existing foliation.

ROAD LOG

Miles from Start

- 0 Exit 20 on Northway. Exit and turn L (North) on Route 9.
- 0.6 Jct. of 9 and 149. Take R (East) on 149.
- 10.6 Outcrops of Cambro-Ordovician Beekmantown carbonates.
- 12.4 Jct. of 149 and 4 in Fort Ann Village. Take L (North) on 4. As you leave the village, notice the range of hills straight ahead. The eastern slope is a dip slope on a fault block of Precambrian rocks (known as the Pinnacle Range) bounded on the West by the Welch Hollow Fault (Hills, 1965). The Paleozoic rocks previously noted are on the downthrown (W) side. This is the easternmost of several such fault blocks, all showing a gentle, regional eastward dip of 10-15° on the Precambrian rocks and overlying Paleozoics. The eastern slope of this block is a dip surface close to or at the unconformity, which will be seen in outcrop at Stop 3. Is the tilt of this surface a result of a rotation of the fault blocks, or a reflection of the Tertiary-Recent doming of the Adirondacks (Isachsen 1975)?
- 13.2 Stop #1. Turn into parking area on R (SE) side of road and cautiously cross road to outcrops on opposite side. A plaque on the face of the outcrop commemorates the Battle of Fort Ann (July 8, 1777). The rocks here are intensely foliated and fractured representatives of the anorthosite suite. Although the characteristic andesine megacrysts found in anorthosites elsewhere in the Adirondacks are absent here, they can be found sporadically in other outcrops along the West side of the Pinnacle Range. Minerals in the anorthosite at this stop consists of recrystallized and sericitized plagioclase, hornblende, clinopyroxene and garnet. Large garnets (please do not sample) are surrounded by leucocratic haloes which locally obliterate the foliation, which suggests that the garnet grew at the expense of mafic minerals which define the foliation, and that it postdates at least the first deformation.

At the eastern end of the outcrop is a large mass of gabbroic rocks (plagioclase-clinopyroxene-

garnet-ilmenite) which displays little or no foliation, and around which the foliation in the anorthositic gneiss is deflected. Also present in the outcrop are a breccia zone and numerous closely spaced fractures with a general northeasterly trend; a major high angle fault may exist roughly parallel to the road.

13.4 Outcrops in woods to L of road are coarse marble with numerous detached and rotated blocks of amphibolite and gneiss around which the foliation of the marble is wrapped.

13.9 Flat Rock Rd. on R.

14.0 Stop #2. Roadcut on R (SE) side of road. Strongly foliated quartz- 2 feldspar-pyroxene-hornblende-garnet gneisses, ± biotite. Leucocratic bands contain numerous pyroxene megacrysts, both clino and ortho, the latter showing characteristic rusty weathering color. These rocks are close to the charnockitic end of the migmatitic gray gneiss spectrum. Note the presence of at least two types of amphibolite. One is relatively coarse grained, boudinaged and injected with leucocratic veinlets. The foliation within the boudins is locally truncated by that in the enclosing gneisses. The other amphibolite is dark, fine-grained, biotite-rich, and lacks the leucocratic veining and prominent foliation of the coarser amphibolite. The fine-grained, massive amphibolite forms a megaboudin or recumbent fold (which is it?) near the center of the cut. Do these amphibolites represent one, two, or more generations of mafic intrusives?

Numerous complex minor folds are present within the gneisses; also observe the warping of the foliation by larger, open folds. Measure and record lineations and attempt to relate them to the fold axes of both types. Is more than one lineation present in these rocks?

Thin, folded dark bands near the N end of the cut are a peculiar, fine grained carbonate-rich rock with poorly oriented biotite.

14.2 Stop #3. Turn off main road and park on dead end road which leads downhill toward the Champlain Canal.

The outcrop on the R side of Rte. 4 just beyond the intersection exposes the unconformity between Proterozoic and Paleozoic rocks (missing: roughly

500 million years of the geologic record, and 20-25 km of Proterozoic rock). The Paleozoic rocks here are coarse arkosic sandstones and quartz-pebble conglomerates of the Cambrian Potsdam Formation, locally with carbonate cement. Measure the strike and dip of the unconformity surface, and compare this with the 10-15° easterly slope of the fault block as observed driving N out of Fort Ann.

Observe the lack of evidence for deep weathering of the Precambrian rocks beneath the contact, and the absence of a paleosol layer. This suggests deep erosion and scouring (by waves? ice?) shortly before deposition of the Potsdam.

Walk a few meters along the S face of the outcrop, towards the canal. Note the complex fracturing of the gneisses, and the filling of the fractures with dark, fine-grained dolomitic rock. The significance of this feature is unclear, and it will be discussed in more detail on the trip. Note the deeply weathered zone where these rocks are exposed at the surface.

After examining the unconformity, cautiously cross the road to the cut in complexly deformed gray gneisses on the opposite side. Measure several lineations here and compare with what you saw at Stop #2. Note not only differences in orientation, but also in the nature of the lineation.

- 14.4 Outcrops at edge of woods on R are fine-grained white arkosic Potsdam sandstones.
- 15.7 Outcrops on L are extensively fractured granitic gneisses close to a NS brittle fault.
- 15.8 Road crosses small pond.
- 15.9 Stop #4. Pull off on R side as close to the guard-rail as possible. The rocks immediately to the R are strongly foliated biotite-quartz-2 feldspar-garnet gneisses. This version of the gray gneiss is commonly referred to as "kinzigite". Present in this outcrop are thin quartzo-feldspathic pegmatites in various stages of tectonic disintegration and reorientation. The large K-feldspars survive the tearing-apart process better than quartz, and remain visible as large porphyroclasts, either in strings or as isolated individuals. Be alert for evidence of tectonic rotation of these feldspars, which can be a useful indicator of the sense of shear.

Also observe the variable shape and appearance of the garnets: some are rounded and others elliptical; some are nearly inclusion-free while others are "spongy". Careful study of this variation might, if combined with probe analysis of garnet compositions, yield information on the interrelation of metamorphism and deformation of these rocks.

From here, walk northward along the road past a gap in the outcrop, then enter the S end of a long cut. The first rocks are strongly foliated and lineated gray gneisses with lenses and pods of calcsilicates. Roughly 30 m. northward and uphill, these overlie amphibolitic rocks, which comprise most of the remainder of the cut. The bulk of these rocks are strongly foliated garnet amphibolites and mafic gneisses. Numerous lenses and pods of calcsilicates, garnet hornblendite, and ultramafic rocks are present. (Students: the coarse grained ultramafic pods are a fine opportunity to test your mineral recognition skills). About 90 m. northward along the cut a large pod of calcsilicate granulite (grossular-diopside-quartz) is visible in the mafic gneisses on the opposite side of the road. Near the N end of the cut, still on the R (E) side, two large pods or megaboudins of massive, relatively fine grained, garnet-rich metagabbro are surrounded by strongly foliated amphibolites. The transition between foliated and unfoliated rock is very abrupt. Patches of tourmaline-bearing pegmatite are present at the broken(?) end of one of the megaboudins.

16.3 Jct. of Rtes. 4 and 22; Rte. 22S crosses canal just E of here and goes past the State Prison at Comstock; Continue N on combined 22N and 4.

16.7 Stop #5. S end of next major road cut. Pull over close to guardrail. Cross the road and walk N along the W side. At the S end are more gray gneisses, here with a distinct reddish tinge caused by an abundance of garnet. The gray gneisses here are nearly devoid of K feldspar. They become more strongly foliated toward the contact with overlying pink granitic gneisses. The contact itself is extremely sharp (but note the late spherical, undeformed garnets, some of which are situated directly on the contact). The pink granitic gneisses, which contain biotite, chlorite and garnet, are strongly foliated, approaching mylonitic texture in places, and display prominent quartz ribbon lineation. The less deformed parts of these gneisses contain K-feldspar megacrysts

(phenocrysts? porphyroblasts?) in various stages of deformation and recrystallization.

Continuing N, pass a large gabbro pod, broken at the base and injected with granitic material, in part pegmatitic. Look S across the road; the similarly shaped body of gabbroic rock in the pink gneisses is probably the same pod. Then re-enter gray gneisses, here with somewhat more K feldspar, which is concentrated in the leucosomes. Notice the prominent discontinuity in the foliation which is visible for some distance along the cut. Even though little textural evidence (e.g. grain size reduction) for shear displacement exists along the discontinuity, other explanations for this feature are even more difficult to defend. Toward the N end of the cut is another body of gabbroic rock, which also appears to continue on the opposite side of the road. These mafic rocks, which intrude both the gray and pink gneisses, are generally fine grained and massive with a distinct relict igneous texture. Much garnet is present in the form of indistinct coronas. These rocks are the equivalent of the coronitic olivine metagabbros, a more typical example of which will be seen at Stop #8. These gabbroic bodies (several are present here) are lensoid to sigmoidal in cross section but apparently elongated in a roughly N-S direction. Their crudely sigmoidal shape yields opposite estimates of shear sense depending on whether they are pre- or syn-tectonic in origin.

Cross the road to the E side, and note the prominent minor folds in the migmatitic gray gneisses near the N end of the cut. Also note the open, upright folds, which warp the foliation of these rocks, then compare the orientation of these with the recumbent, isoclinal minor folds and with the lineation. Then walk S along the E side and return to the starting point. The petrology of the rocks at this outcrop has been studied in detail by William Glassley and students at Middlebury College. Dr. Glassley (pers. comm. 1985) reports the following:

"Garnet-clinopyroxene and garnet-biotite temperatures were computed from microprobe data. Average temperatures from eight samples ranged from 770 C to 850 C, with a strong mode at 810 C. Pressures, calculated from the assemblages garnet-plagioclase-clinopyroxene-quartz and garnet-plagioclase-orthopyroxene-quartz using the

method of Newton and Haselton, averaged 7.5 kb + .5 kb.

Two unusual assemblages can be found along the contact between the two gneiss units. Within 50 cm of the contact occur 1-3 cm long augen which contain the assemblages clinopyroxene-garnet-rutile and biotite-sillimanite-hercynite-kspar-garnet. The former assemblage is a typical eclogite assemblage. Garnets from these eclogitic lenses are similar to those reported from basal gneiss eclogites in Western Norway. The clinopyroxenes, however, are poor in jadeite component, with only 5% of this component present. The sillimanite-spinel-bearing assemblage is clearly consumed and biotite and sillimanite are being generated. The significance of this assemblage for P-T conditions remains obscure, in that we do not yet have compositional data for all of the minerals in the assemblages nor do we have water fugacity values that would allow calculation of the equilibrium conditions."

17.0 Stop #6. (Optional) Pull onto R shoulder and briefly examine the outcrops.

The rock here is a pale gray biotite-quartz-2 feldspar-garnet-sillimanite-graphite paragneiss with thin layers and lenses of calcsilicates. Compared to the previously examined "kinzigites", this rock is finer grained, more aluminous, and has distinctive lavender garnets. The abundant white layers look like leucosomes in a migmatite, but they contain significant amounts of sillimanite and are thus probably more aluminous than minimum-melt granite. Note the flattening of the quartz in these layers. Look carefully for lineations defined by sillimanite and quartz.

The protolith of these rocks must have had a significant argillaceous component, as indicated by the presence of both garnet and sillimanite. The lavender-colored garnets are typical of many Adirondack metapelites, a more extreme example of which will be seen at Stop #9.

17.4 South end of next set of roadcuts.

17.6 Stop #7. North end of roadcut. Pull off road on R and cautiously cross to outcrops at N end of cut on west side; walk S along outcrop. Probably the best way to appreciate these rocks is to move rather rapidly to the S end, scanning the rocks on both

sides as you go for major lithologic changes, and then return northward looking at the rocks in detail.

The sequence of rock types going S on the W side is as follows:

- A Interlayered (or interleaved?)
marbles and paragneisses
- B Garnetiferous quartzofeldspathic gneisses
intruded by unmetamorphosed mafic dikes
- Gap -
- C Charnockitic gneiss
- D Thin marble with numerous exotic blocks
- E Mafic gneiss
- F Calcsilicates and marble
- G Interlayered (interleaved?) Paragneiss, charnockite, marble and calcsilicate with amphibolite boudins. An unmetamorphosed mafic dike forms the face of much of this section of the cut.

Details (walking N)

- G. Note the wide variety of rock types, including charnockitic gneisses, amphibolites, marble (carefully examine the marble/amphibolite contact), lineated sillimanite bearing metapelites, and calcsilicates. Note the local slickensides along foliation surfaces as well as on vertical fractures. Has there been late movement parallel to the foliation?
- F. This thin calcareous unit consists of marble near the base and a complex calcsilicate zone adjacent to the contact with the overlying mafic gneiss. Major minerals in the calcsilicate zone are grossular, diopside, quartz, calcite and K feldspar, with lesser amounts of plagioclase and chlorite as well as several minor phases yet to be identified. Some evidence indicates that wollastonite was initially present but none has yet been positively identified. The calcsilicates probably originated by contact metamorphism at the time of intrusion of the igneous precursor of the overlying mafic gneiss. This contact is irregular and appears to have been

folded. The thickness of the calcsilicate layer varies widely, both in this outcrop and on the opposite side of the road.

- E. This mafic gneiss contains plagioclase, clinopyroxene, hornblende, biotite, garnet and minor quartz and K feldspar. The composition is probably similar to a monzodiorite. Similar rocks elsewhere in the Adirondacks have been called "jotunite" and are associated with the anorthosite suite of rocks. The rock is well foliated throughout, but becomes more so towards the sharp upper contact. On the opposite (E) side of the road, a detached sliver of the mafic gneiss is found in the overlying marble, and contains carbonate-filled fractures.

- D. The next unit upward is a thin (generally < 1 m) band of marble with numerous rotated fragments of other rocks. No calcsilicates are developed near the sharp contact with the mafic gneiss beneath, and the foliation both in the mafic gneiss and in the overlying charnockitic gneiss is strongly developed and parallel to the marble band. In the outcrop on the opposite side of the road, foliation in the charnockite is locally truncated by the marble. This marble is a good example of a possible detachment zone, with relative movement of uncertain direction and magnitude, between the mafic gneiss and the charnockite. The absence of a contact metamorphic zone of calcsilicates at the upper contact of the mafic gneiss may result from its having sheared off during displacement. Alternatively, this marble may be a tectonically emplaced younger rock (see discussion under unit "A", below). Considerable displacement may have taken place along most or all of the marble layers in this outcrop.

- C. Above the marble is a thick unit of charnockitic gneiss. This rock, close to granite in composition, consists of quartz, microcline, plagioclase, hornblende, garnet, clinopyroxene and orthopyroxene. The orthopyroxene is extensively chloritized, which is characteristic of many Adirondack charnockites. The typical green color is well developed toward the center of the unit. Near the northern end of the outcrop both green and white varieties are present, with diffuse color boundaries which crosscut foliation.

Immediately beyond the charnockite unit is a gap in the outcrop, possibly indicating the presence of a fault or thick marble layer.

- B. Following the gap is a short section of well foliated, garnetiferous quartzofeldspathic gneisses similar to the charnockite but with green color less well developed. Note the unmetamorphosed mafic dike just back from the face of the outcrop, and roughly parallel to it. A few meters farther N is a complex vertical fault with a zone of carbonate-cemented breccia.
- A. The last section of the outcrop, roughly 100 m long, consists of interlayered (interleaved?) paragneiss and marble, with minor amphibolite and thin calcsilicate bands in the paragneiss. Contact surfaces are frequently slickensided and/or coated with graphite. At least two types of marble are present; one is dark, relatively fine grained, brown-weathering dolomite marble, which has a slightly fetid odor when struck with a hammer; the other is coarser grained, has a somewhat lighter color and considerable calcite as well as dolomite. Both marbles contain abundant rounded to angular silicate rock and mineral fragments, including quartz, feldspar and serpentine, and larger rotated blocks of various rock types including amphibolites, serpentinite, paragneiss and calcsilicate granulite. Quartz, dolomite and serpentine coexist in these rocks with no evidence of mutual reaction, indicating that the rock as presently constituted has never undergone high temperature metamorphism. Temperatures must have been sufficiently low to prevent reaction of quartz with either dolomite or serpentine. It is probable that these marble zones, as well as those of units G, F and D, are tectonic breccias formed along thrust faults or low-angle normal faults under conditions that permitted the carbonates to recrystallize and deform in ductile fashion, while silicates behaved in a more brittle manner. The interleaved paragneisses, by contrast, are similar to the gray gneisses seen in previous stops, have a high-T metamorphic assemblage and show little evidence of retrogression.

The age of the tectonic interleaving of the gneisses and marbles may be either late Proterozoic or Taconic. The marbles themselves may be Proterozoic with retrograde serpentine after forsterite and entrained fragments of quartz and feldspar, or they may be Paleozoic carbonates with entrained fragments of ultramafic rocks. This question is now under study and will be discussed on the outcrop.

- 17.8 Whitehall town line
- 19.3 Stop #8 (Optional). Park as far off the road to the R as possible. Cross with great care to outcrops on the L, and examine them briefly. These are typical Adirondack olivine metagabbros, with well preserved igneous textures as well as coronitic reaction rims around olivine and ilmenite (see introductory section). The interiors of the olivine coronas here have been retrograded to chlorite and carbonate; otherwise the rocks are quite fresh.
- 20.7 Flat outcrops on slopes to the L are a dip slope on foliation in highly strained gneisses. A short distance N, on West Mtn., a mylonite zone close to 300 m thick is exposed. The hills across the valley to the R, and on Skene Mtn. straight ahead, are Cambro- Ordovician carbonates of the Whitehall Formation, resting on Potsdam sandstone.
- 22.6 Entering Village of Whitehall
- 23.2 Intersection of Rtes. 4 and 22; 4 goes E to Rutland, VT; Continue N on 22.
- 24.0 Stop #9. Pull off road to R close to smaller outcrop, and cross to larger cut on L. The rocks here are typical metapelites, consisting of quartz, K feldspar, sillimanite, lavender garnet and varying amounts of biotite and graphite.
- 24.7 Entering series of cuts in highly fractured meta-sedimentary rocks.
- 25.2 Stop #10. Entrance to abandoned quarry and Washington County Highway Dept. Garage. This is posted private property; if following this road log on your own, ask permission at large brick farmhouse 0.2 miles further along road on R. Be extremely careful climbing and hammering here - there is much loose rock and the quartzite is very splintery when hammered.

This thick unit of quartzite is interlayered with lesser amounts of a greenish rock which forms bands and streaks from a fraction of a millimeter up to several tens of centimeters thick, with knife-sharp contacts against the quartzite.

The quartzite, which is visibly foliated in hand specimen, comprises over 95% of strongly flattened quartz; small, flattened and elongated grains of K feldspar and sericitized plagioclase, lensoid garnets, green biotite and chlorite. The inter-layered green rock ranges from plagioclase-quartz-garnet-biotite-hypersthene gneiss to a retrograded epidote-chlorite-quartz-plagioclase rock with some muscovite and at least two minerals yet to be identified. Some well crystallized chlorite is present as flakes parallel to the foliation, but chlorite also occurs locally as an alteration product of garnet. Distribution of the retrograde assemblage within the outcrop has not been determined. If it is related to fracture patterns, it may be low temperature alteration along the E-W brittle fault which parallels the road. If not, it may be evidence for localized retrogression associated with renewed, layer-parallel shearing during the latest Proterozoic or during the Taconic event. Supporting the latter hypothesis are slickensides on foliation surfaces at an acute angle to the lineation.

All rocks at this site show extreme foliation and a well developed lineation, here close to E-W, with a 0-20° E plunge. Numerous minor folds are present. These are of two distinct types, both of which are recumbent with axes parallel to the lineation. One type consists of intrafolial, highly asymmetric, isoclinal folds defined by thin micaceous layers in the quartzite. Among folds of this type is an apparent sheath fold strongly flattened in the plane of foliation. The other type is not quite isoclinal, more symmetric, and visibly folds the foliation in the quartzite. The minor folds and petrofabrics at this outcrop have been described by Granath and Barstow (1980), who attribute the deformation primarily to a severe flattening strain.

Leave quarry and proceed N on 22N.

25.6

Crossing South Bay on Lake Champlain. The rocks underlying the valley to the North are Paleozoic strata downdropped along a major normal fault which here forms the western side of the Pinnacle Range.

Toward the south, this fault intersects the Welch Hollow fault at an oblique angle. The fault follows the shore of South Bay south of the bridge, then strikes inland and follows the line of cliffs visible to the north. Estimated vertical displacement on this fault based on offset of Paleozoic cover rocks is in the vicinity of 300 m. West of the bay, outcrops of gently E-dipping, highly deformed Precambrian rocks resume.

End of trip.

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CORRELATION OF PUNCTUATED AGGRADATIONAL CYCLES,
HELDERBERG GROUP, BETWEEN SCHOHARIE AND THACHER PARK

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INTRODUCTION

The purpose of this trip is to instruct participants in the field application of the PAC Hypothesis. Specific objectives include:

1. demonstration of criteria for recognition of PACs in shallow - water carbonate facies of the Manlius Formation;
2. construction of a PAC column by participants at Schoharie N.Y. in the Manlius Formation;
3. observation and evaluation of the stratigraphic section of the Manlius Formation at Thacher Park from an episodic perspective and comparison of those observations to a PAC column constructed by the trip leaders and
4. discussion of the methods, problems and implications of correlation of Manlius PACs between the Thacher Park and Schoharie sections.

THE HYPOTHESIS OF PUNCTUATED AGGRADATIONAL CYCLES

The Hypothesis of Punctuated Aggradational Cycles (PACs) is a comprehensive stratigraphic model which states that most stratigraphic accumulation occurs episodically as thin (1-5 meters thick) shallowing-upward cycles separated by sharply defined non-depositional surfaces (fig. 1). These non-depositional surfaces are created by geologically instantaneous basin-wide relative base-level rises; deposition occurs during the intervening periods of base-level stability. Thus all deposition occurs in aggradational episodes interrupted by very short periods of non-deposition (punctuation events).

A basic tenet of the PAC Hypothesis is that the shallowing-upward motif on the scale of a few meters of thickness is pervasive throughout the stratigraphic record. We have observed the PAC motif in numerous clastic and carbonate sequences from several geologic periods. In addition numerous published accounts specifically describe depositional patterns comparable to PACs in both scale and motif. The abundance of such examples coupled with a lack of documented small-scale deepening-upward cycles suggests that the PAC Hypothesis is applicable to essentially the entire stratigraphic record which potentially is totally divisible into PACs.

The hypothesis predicts that punctuated aggradational cycles (PACs) exist in rocks representing all environments in which a

THE PAC HYPOTHESIS

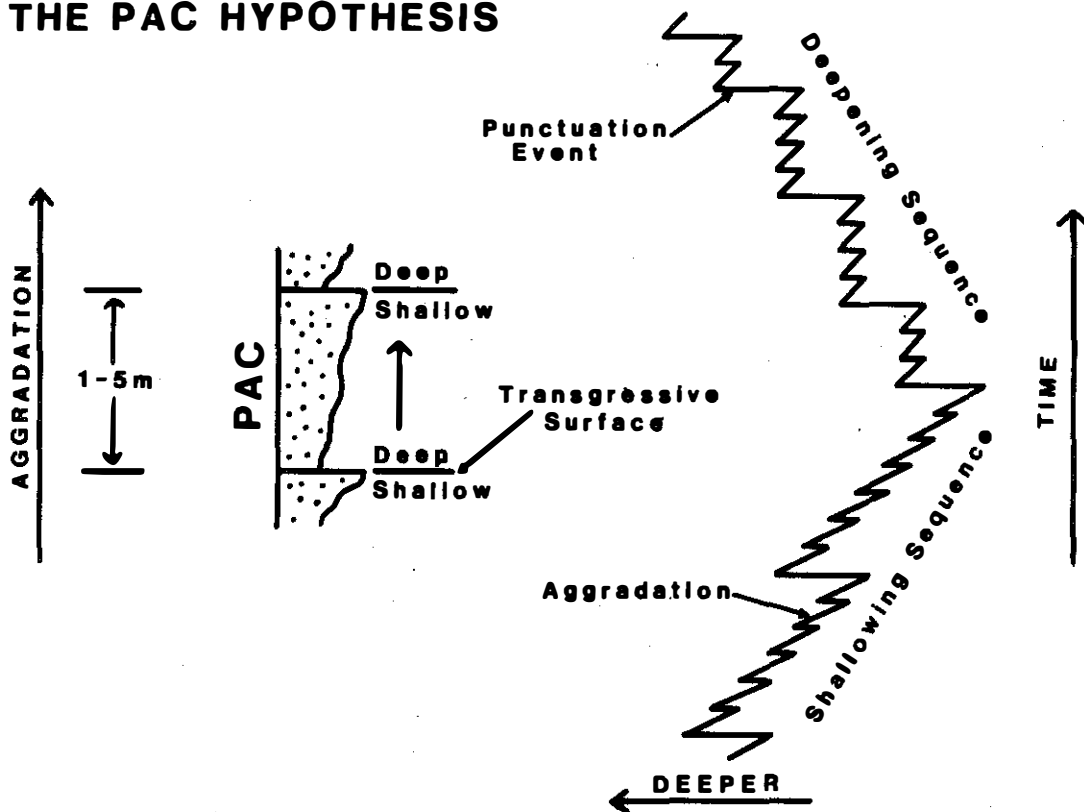


Fig. 1.-General model of the Hypothesis of Punctuated Aggradational Cycles. Each PAC is bounded by surfaces of abrupt change to deeper facies. Facies changes within a PAC are gradational. At a larger scale shallowing and deepening sequences consist entirely of PAC's produced during periods of aggradation punctuated by deepening events.

rapid base-level rise can directly or indirectly influence depositional processes. Thus fluvial, deltaic, tidal, shelf, slope, turbiditic fan, and basinal clastic environments as well as the full spectrum of marine carbonate environments should produce deposits which display the PAC motif. Not only are PACs expected in all sedimentary environments, but also PACs are basin-wide rock units which may be traced laterally through the deposits of a variety of co-existing environments. Theoretically PACs terminate at the lateral limit of all contiguous depositional sites affected by a specific position of sea level. Therefore a particular PAC will be defined by different sedimentologic evidence at different places in the basin. A new and different environmental spectrum is created by each deepening event and modified by aggradation during periods of base-level stability.

PACs are thin rock units averaging 1-5 meters in thickness. This thickness is a function of the magnitude of punctuation events, the amount of gradual sea-level rise occurring between punctuation events, initial topography, and rate of sedimentation. Analysis of PACs (see the Helderberg example) suggests that punctuation events contribute a significant portion of the stratigraphic room available for accumulation. Between punctuations sedimentary aggradation tends to establish equilibrium with distributional sedimentary processes, often depositing sediment to the limits of room available. Gradual sea-level rise permits additional sedimentary accumulation which can be a significant portion of total PAC thickness if sedimentation rates are high and the time between punctuation events is long. Finally PACs will be thinner over topographic highs and in environments where rates of sedimentation are low.

We hypothesize that the punctuation events which produce PACs are geologically instantaneous and at least basin-wide in their influence. Very rapid deepening events are indicated by sharp surfaces of non-deposition at PAC boundaries and by the absence of gradationally deepening-upward cycles. The basin-wide influence of punctuation events is indicated by the lateral persistence of PACs for tens of kilometers across the Helderberg basin and by the traceability of PAC sequences throughout the basin.

Because punctuation events are both frequent and rapid the resulting PACs (punctuated aggradational cycles) are very thin time-stratigraphic units bounded by isochronous surfaces. As thin mappable rock units which are also time-stratigraphic, PACs offer a potential for very detailed chronologic correlations at least on a basin-wide scale. In contrast, correlations based on major facies and formations are less accurate because these units are much thicker and are generally diachronous. Biostratigraphic control, as a consequence of evolutionary rates, is also less precise by perhaps an order of magnitude.

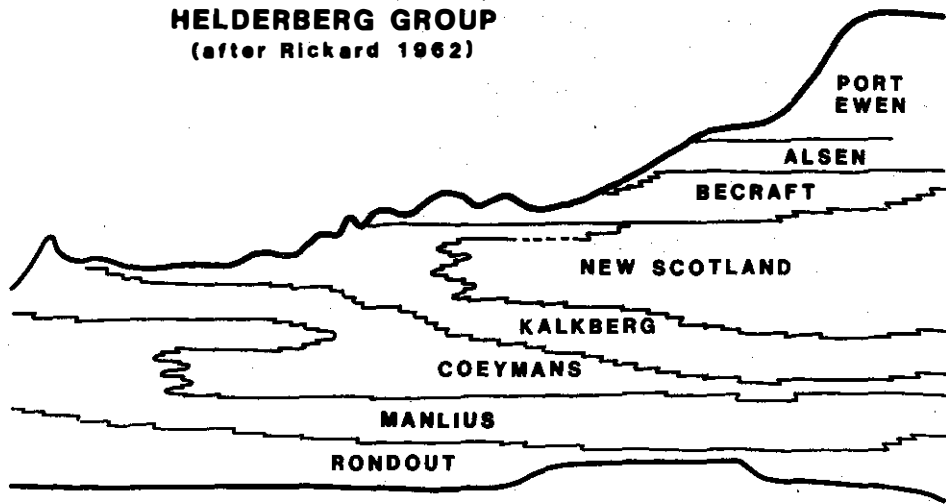
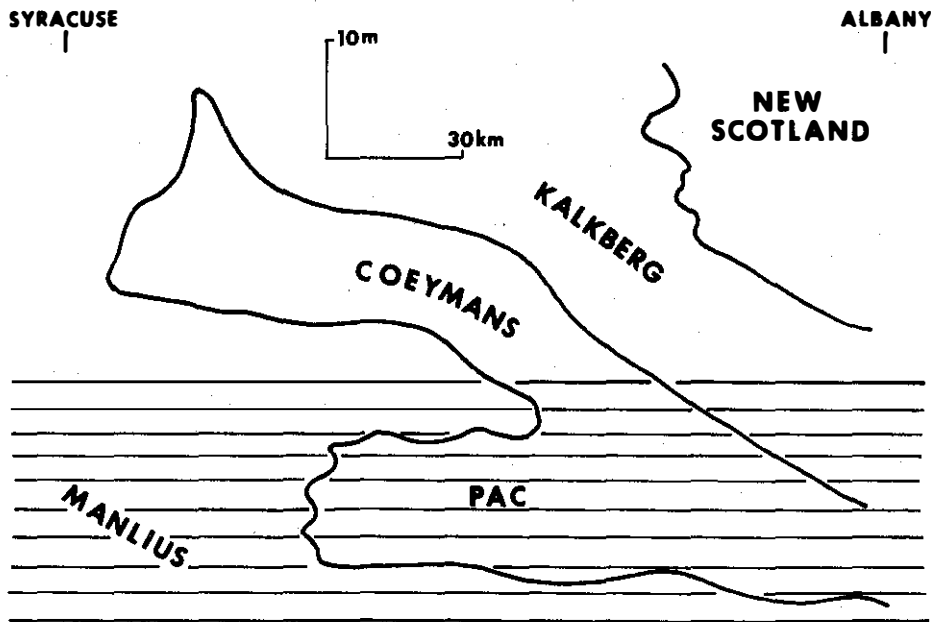
A**B**

Fig. 2.-A) East-West cross-section of formations in the Helderberg Group. B) Conceptual relationship between PACs and Helderberg stratigraphy. PAC's are thin time-stratigraphic units which cut across major facies (generally diachronous formations). For simplicity, PAC's are illustrated schematically only in the lower portion of the cross-section.

In traditional surface stratigraphy only occasional key beds and bentonites provide the degree of temporal control suggested by the PAC Hypothesis. Even in the subsurface, where seismic stratigraphy has traced some isochronous reflection surfaces basin-wide, correlations at the scale of individual PACs have not been achieved except locally when seismic information is combined with logs from closely spaced wells.

In summary, the essential elements of the PAC Hypothesis are:

1. The basic stratigraphic motif is the small-scale shallowing-upward cycle (PAC) separated by sharply defined non-depositional surfaces.
2. PACs are produced by frequent (every 5-100 thousand years) geologically instantaneous base-level rises (punctuation events) which are at least basin-wide.
3. PACs are theoretically traceable throughout a basin of deposition as time-stratigraphic units bounded by isochronous surfaces.
4. PACs are the fundamental rock units for paleoenvironmental and paleoecologic analysis.
5. As mappable rock units which are also time-stratigraphic, PACs offer unequalled opportunity for establishing basin-wide chronologic correlations and paleogeographic reconstructions.

PACs AND HELDERBERG STRATIGRAPHY

General Relationships

The Helderberg Group of New York State has been interpreted as a transgressive carbonate sequence (Laporte 1969) representing a spectrum of paleoenvironments including tidal flat (Manlius Formation) shallow shelf (Coeymans Formation) and deep shelf (Kalkberg and New Scotland Formations) facies. Detailed stratigraphic relationships were established by Rickard (1962) from a series of approximately 160 closely spaced localities along the outcrop belts in the Hudson Valley and in the Mohawk Valley (fig. 2). Using this stratigraphic framework Laporte (1967) and Anderson (1972) developed paleoenvironmental interpretations of Manlius and Coeymans facies, thereby establishing the basic paleogeographic setting of the Helderberg Basin.

More recently Goodwin and Anderson (in press) have developed the PAC Hypothesis and applied it to the Helderberg Group especially in the nearshore facies of the Manlius Formation in central New York State (Anderson and Goodwin, 1980). This approach has aided in refining facies interpretations and in understanding the dynamics of facies succession. Viewed as sequences of PACs, large-scale carbonate facies developed episodically in response to basinwide punctuation events (relative base-level rises). However within individual PACs facies developed gradually in response to aggradation during periods of base-level stability.

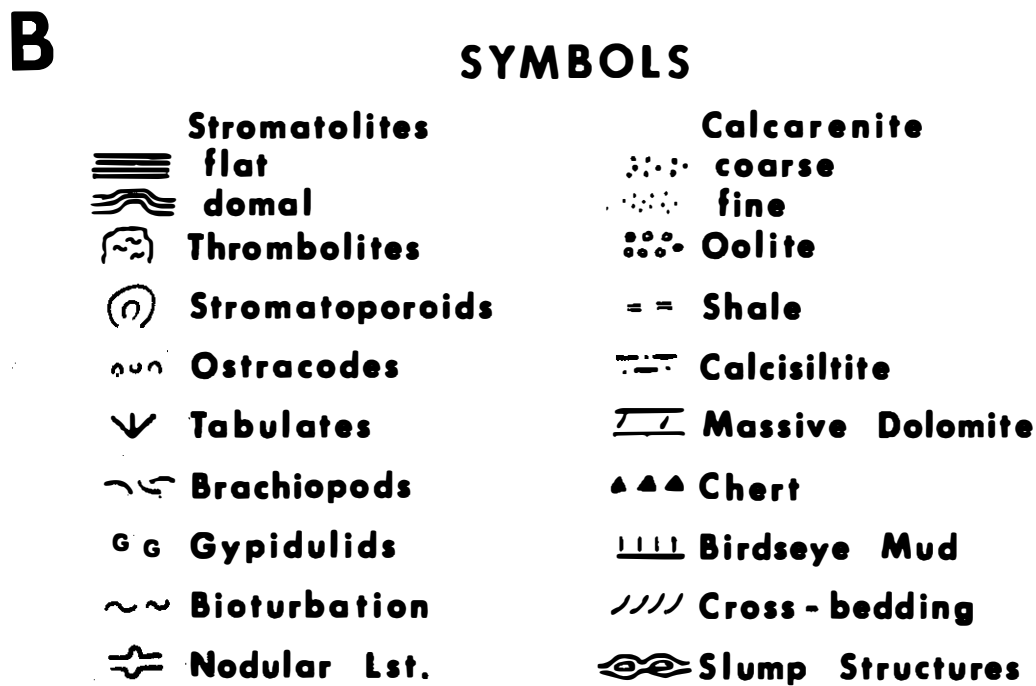
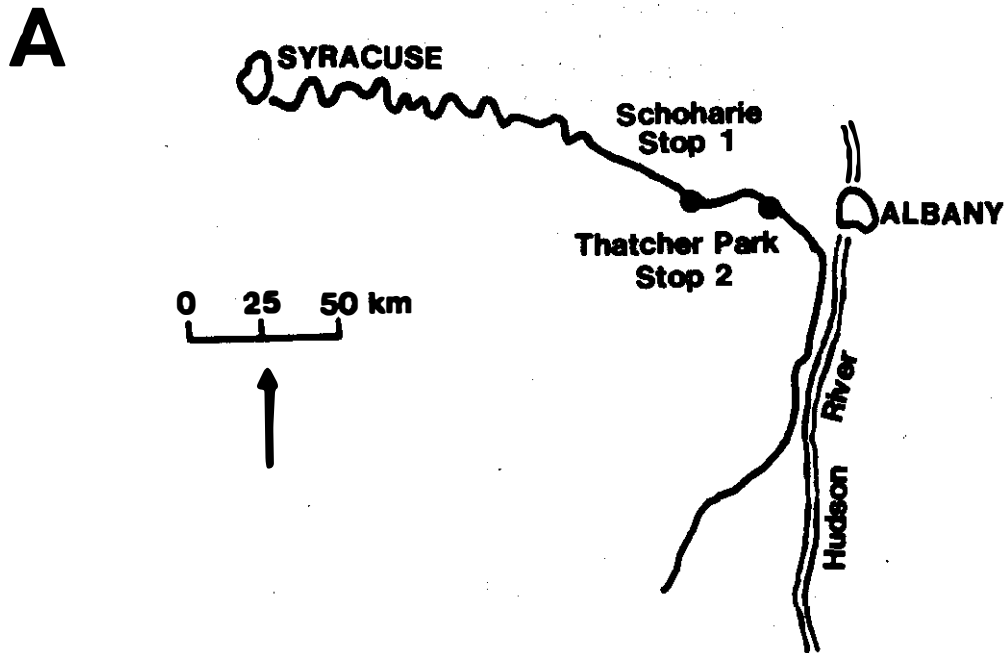


Fig. 3.-A) Outcrop and locality map of the Helderberg Group. B) Legend for stratigraphic columns.

Analyzing the Helderberg Group from an episodic perspective leads to correlation of thin stratigraphic units throughout, reinterpretation of the stratigraphic dynamics that produce formational boundaries and a different concept of the relationship between Helderbergian stratigraphic units and their depositional environments. The PAC Hypothesis predicts that the Helderberg Group is totally divisible into small-scale, time-stratigraphic, shallowing-upward cycles that cut across major facies generally mapped as diachronous formations (fig. 2). Each PAC is bounded by sharp surfaces separating facies representing non-contiguous environments. Therefore each PAC boundary is a significant paleoenvironmental discontinuity which can be traced laterally from one diachronous formation (e.g. Coeymans) into contemporaneous facies mapped as other formations (e.g. Manlius to the west and Kalkberg to the east). At single localities formation boundaries generally coincide with PAC boundaries (Anderson, Goodwin and Sobieski, 1984). Therefore these formation boundaries are discontinuities separating environmentally disjunct facies which were superimposed episodically, not gradually (figs. 3, 4 and 5).

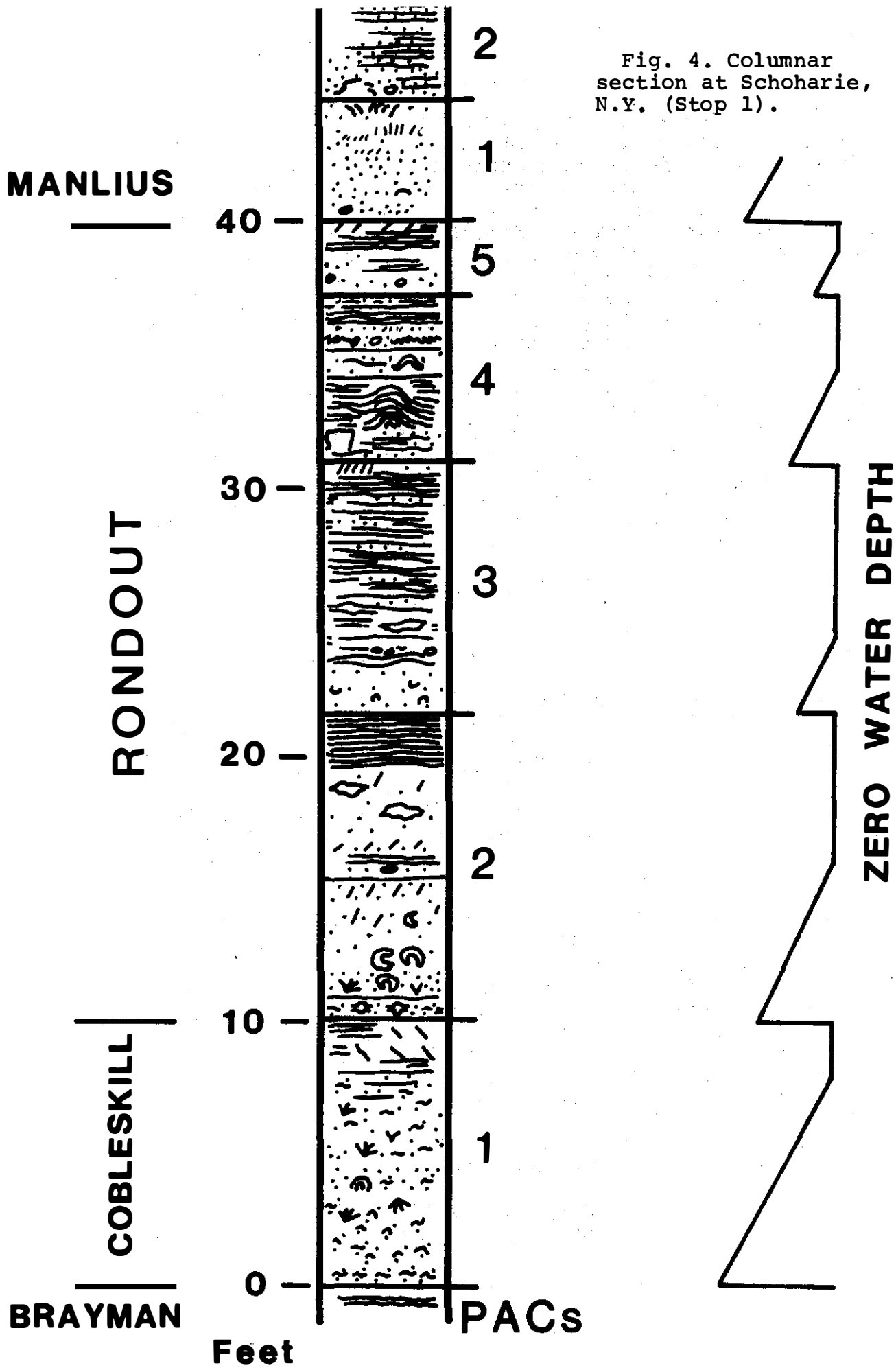
Field Trip Stops

Stop 1. Interstate 88, Schoharie, N.y. The Cobleskill-Rondout-Manlius interval (85 feet thick) completely divisible into 13 PACs (fig. 4). The 5 Cobleskill-Rondout PACs comprise a sequence of peritidal cycles initiated and ended by large punctuation events (see water-depth curve). The first of these events followed a sea-level fall which produced the unconformity with the Brayman Shale. After the deposition of 5 PACs, a second large event terminated tidal-flat deposition and initiated a sequence of basically subtidal PACs in the lower Thatcher Member of the Manlius Formation. Thus each of these major punctuation events is marked by the introduction of significantly different facies.

Within the sequence of 8 Manlius PACs the boundary between PAC 5 and PAC 6 is unique. At this boundary the upper part of PAC 5 is marked by a laminated cryptalgal crust on a scalloped surface, features which suggest subaerial exposure and erosion resulting from a minor sea-level fall. This surface is a widespread marker horizon traceable throughout the Hudson Valley. The subsequent sea-level rise created water depths sufficient to produce the subtidal bioturbated stromatoporoid-bearing limestones of PAC 6. Another significant punctuation event resulted in even greater water depth and the diversely fossiliferous subtidal facies of PAC 7. PAC 8 is like 7 but is truncated by an unconformity.

The Manlius-Coeymans boundary is a surface with a complex history. At Schoharie, at the top of Manlius PAC 8 (fig. 4),

Fig. 4. Columnar section at Schoharie, N.Y. (Stop 1).



COEYMANS



80 -

8

7

6

70 -

5

MANLIUS

60 -

4

3

50 -

2

1

40 -

5

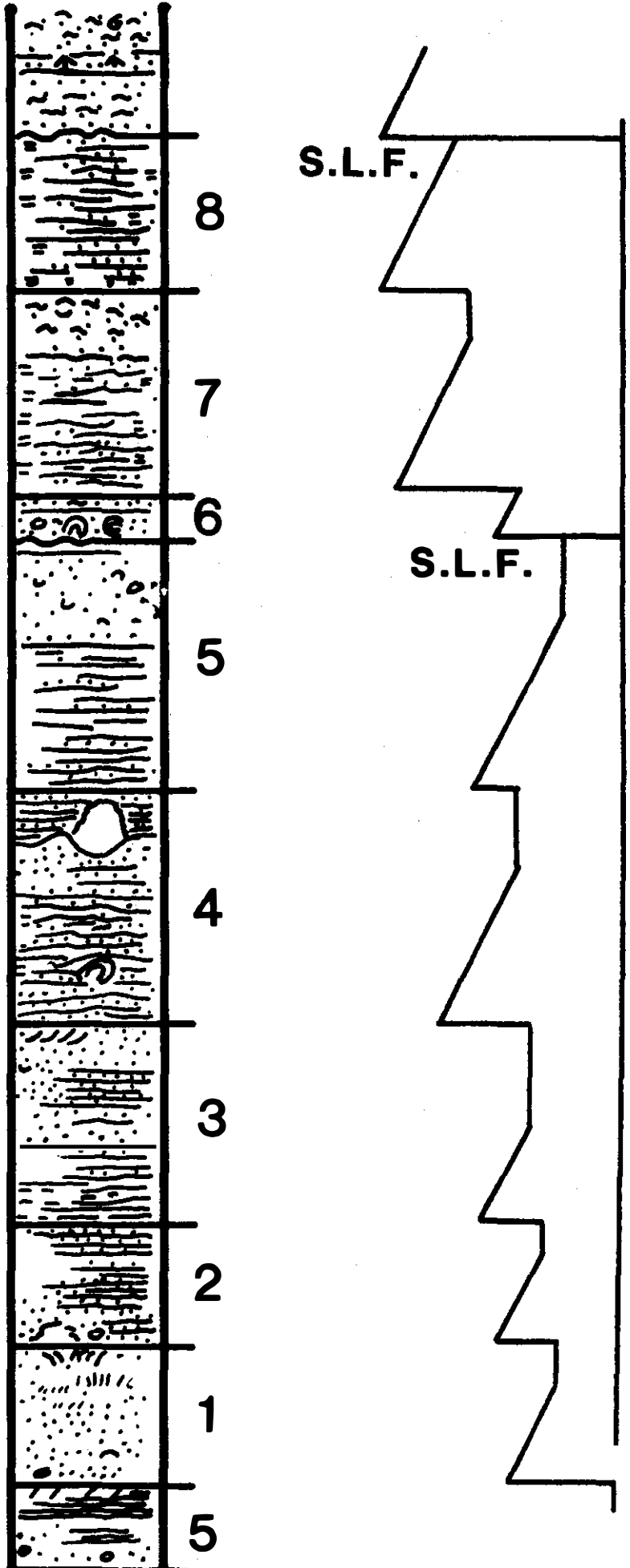
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ZERO WATER DEPTH



it appears to be a normal PAC boundary marking a major punctuation event which introduced facies very different from Manlius facies below. However, correlation of PACs to the east and south indicate progressive erosion and elimination of PAC 8, 7 and 6 in the Hudson Valley as a result of differential uplift. This erosional surface was then inundated by a sea-level rise which initiated Coeymans deposition throughout the area.

Thus the Cobleskill-Rondout-Manlius interval at Schoharie represents episodic stratigraphic accumulation in response to a complex history of small-scale sea-level fluctuations including 3 sea-level falls and 14 sea-level rises. That each of these events is truly allogenic and probably eustatic is suggested by correlating each PAC and PAC boundary between Schoharie and Thacher Park (fig. 5).

Stop 2. Indian Ladder Staircase, John B. Thacher State Park. At this locality the Rondout-Manlius interval consists of 9 PACs, 2 in the Rondout and 7 in the Manlius (fig. 5). The smaller number of Roundout PACs relative to Stop 1 reflects the episodic overstepping of the land mass which was topographically higher at Thacher Park than at Schoharie. Manlius PAC 8 at Thacher Park is absent as a result of pre-Coeymans erosion. Correlation of PACs between the two localities was accomplished by matching unique facies and major facies changes produced by punctuation events. When the columns are correlated by these methods, the number of PACs between major punctuation events is the same at each locality.

Within the Manlius Formation PACs generally consist of facies representing more restricted paleoenvironments than those at Schoharie. For example, PACs 3 and 5 at Thacher Park are capped by a significant thickness of cryptalgal laminites representing aggradation to sea-level. At Schoharie PACs 3 and 5 are capped by shallow subtidal facies reflecting the presence of persistently deeper and less restricted environments at this locality.

Patterns of punctuation events are similar at both localities as interpreted by comparison of facies changes at PAC boundaries. For example a major punctuation event introduced Manlius facies (PAC 1) at both localities; major events also produced marked facies changes at the PAC 3-PAC 4 boundary and at the PAC 6-PAC 7 boundary (fig. 5).

Interpretation of the Manlius-Coeymans Formation boundary as an unconformity at Thacher Park is based on the absence of PAC 8 and on the sharp contact separating markedly disjunct facies. Farther to the south along the Hudson Valley progressively more PACs were eroded as a result of differential uplift of the eastern side of the basin.

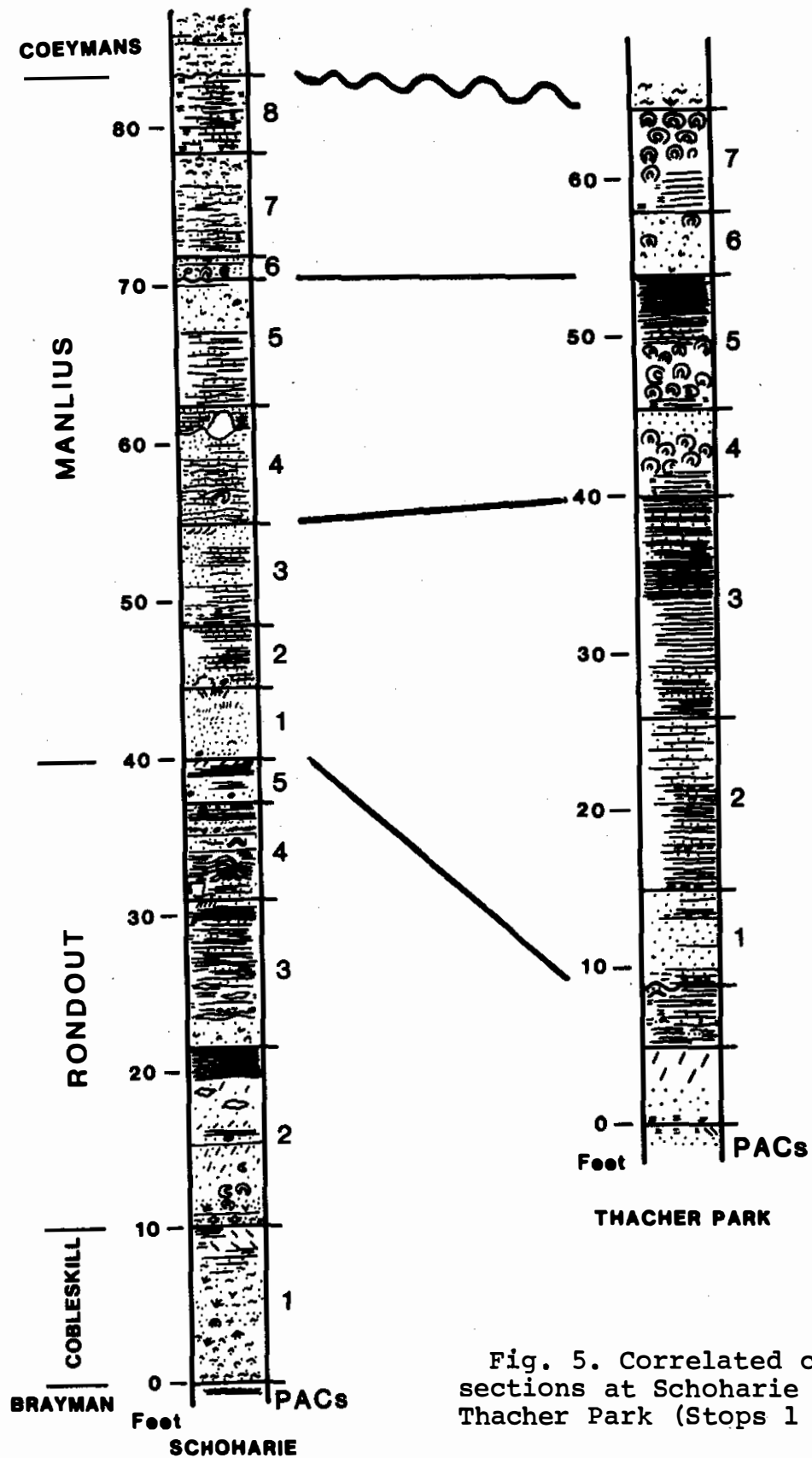


Fig. 5. Correlated columnar sections at Schoharie and Thacher Park (Stops 1 and 2).

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ROAD LOG

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0	0.0	Start at intersection of Interstate 88 and N.Y. State Thruway (Exit 25B), southwest on I-88.
16.7	16.7	Schoharie Exit of I-88. Continue on I-88.
18.4	1.7	Large road cut in lower Helderberg Group (STOP 1) on south side of I-88.
20.4	2.0	Small road cut in Kalkberg Formation on north side of I-88; large road cut on south side in New Scotland and Becraft Formations.
22.0	1.6	Small road cut on south side of I-88 in upper Becraft Oriskany and Esopus Formations.
22.6	.6	Cobleskill exit. Turn around and head back east on I-88.
26.8	4.2	STOP 1. Large road cut on south side of I-88, section includes Brayman, Rondout Manlius and Coeymans Formations.
28.5	1.7	Continue east on I-88 to Schoharie Exit. Turn south on Route 30A.
29.4	.9	End Route 30A. Continue south on Route 30.
30.7	1.3	Intersection with Route 443. Turn east on Route 443.
34.7	4.0	The village of Gallupville. Continue east on Route 443.

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
35.9	1.2	Quarry in the Manlius-Coeymans interval on the south side of road (Rickard Locality 67).
38.3	2.4	The village of West Berne.
41.1	2.8	The village of Berne. Continue east on Route 443.
44.6	3.5	The village of East Berne. Turn left to Route 157A.
45.0	.4	Warner Lake. Turn east (right) on Route 157A toward Thacher Park.
47.3	2.3	Intersection Route 157, Thompson Lake. Continue straight northeast on what is now Route 157.
48.8	1.5	Thacher State Park, pool and recreation area on left.
49.4	.6	Turn left into parking lot for mine Lot Falls. STOP 2.
52.8	3.4	Turn left out of parking lot and continue east on Route 157 to the intersection of Route 85. Turn left on Route 85.
53.7	.9	Village of New Salem. Turn north (left) on Route 85A to Voorheesville.
57.2	3.5	Village of Voorheesville. Continue straight east on 85A.
57.7	.5	Turn left on State Farm Road, Route 155 (formerly Route 310) and go north to Route 20.
61.7	4.0	Turn east on Route 20 to I-87.

END OF ROAD LOG

GLACIAL GEOLOGY AND HISTORY OF THE
NORTHERN HUDSON BASIN, NEW YORK AND VERMONT

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REGIONAL DEGLACIATION

Twelve recessional ice fronts are reconstructed in the northern Hudson basin (figure 1) from field work (LaFleur, private files; DeSimone 1977, 1985) and reinterpretation of existing data (Chadwick 1928; Stewart and MacClintock 1969, 1970; Connally 1973). Five additional ice fronts, A through E on figure 1, were modified from LaFleur (1965a, 1979) and Dineen et al (1983) and are included in a summary chart of deglacial events (figure 2).

Lowland Lake Levels and Transitions

Tilted water planes identify six significant intervals of water level stability punctuated by intervals of falling water level (figure 3). The six stable water levels are: Lake Albany, Lake Quaker Springs, Lake Coveville, Fort Ann I, Fort Ann II, and Fort Ann III. The data also support a distinct lowered Albany water level which may have been stable for a short time. The Albany, Quaker Springs, and Coveville water planes are clearly curved and asymptotic southward. The flat Fort Ann water planes probably represent only the most distal portions of similarly curved water planes originating in the northern Champlain Lowland. The low gradients of the Quaker Springs and Coveville water planes are appropriate for the distal portions measured. The gradients of the Albany and lowered Albany water planes are 2.6 ft/mi and 2.7 ft/mi, respectively. This compares favorably with tilts calculated by Fairchild (1917) at 2.4 ft/mi, by Stoller (1922) at 2.5 ft/mi, and by LaFleur (1965b) at 2.7 ft/mi.

The retreating Hudson Lobe defended Lake Albany through ice position 5. Clay deposited at 380-390 ft near Greenwich and the Greenwich outwash fan at 400 ft record there the maximum level of Lake Albany. A falling or lowered Lake Albany accompanied the retreating ice from position 5 through position 6 to position 7 while sediment was continuously deposited at the mouth of the Batten Kill. The Hudson Lobe defended a stable Lake Quaker Springs from position 7 through position 12 and into the Champlain Lowland. Fluvial-lacustrine sand deposited at tributary mouths, river terraces, terraced clay, and delta morphology delineated the Coveville and Fort Ann water levels, detailed later in the text.

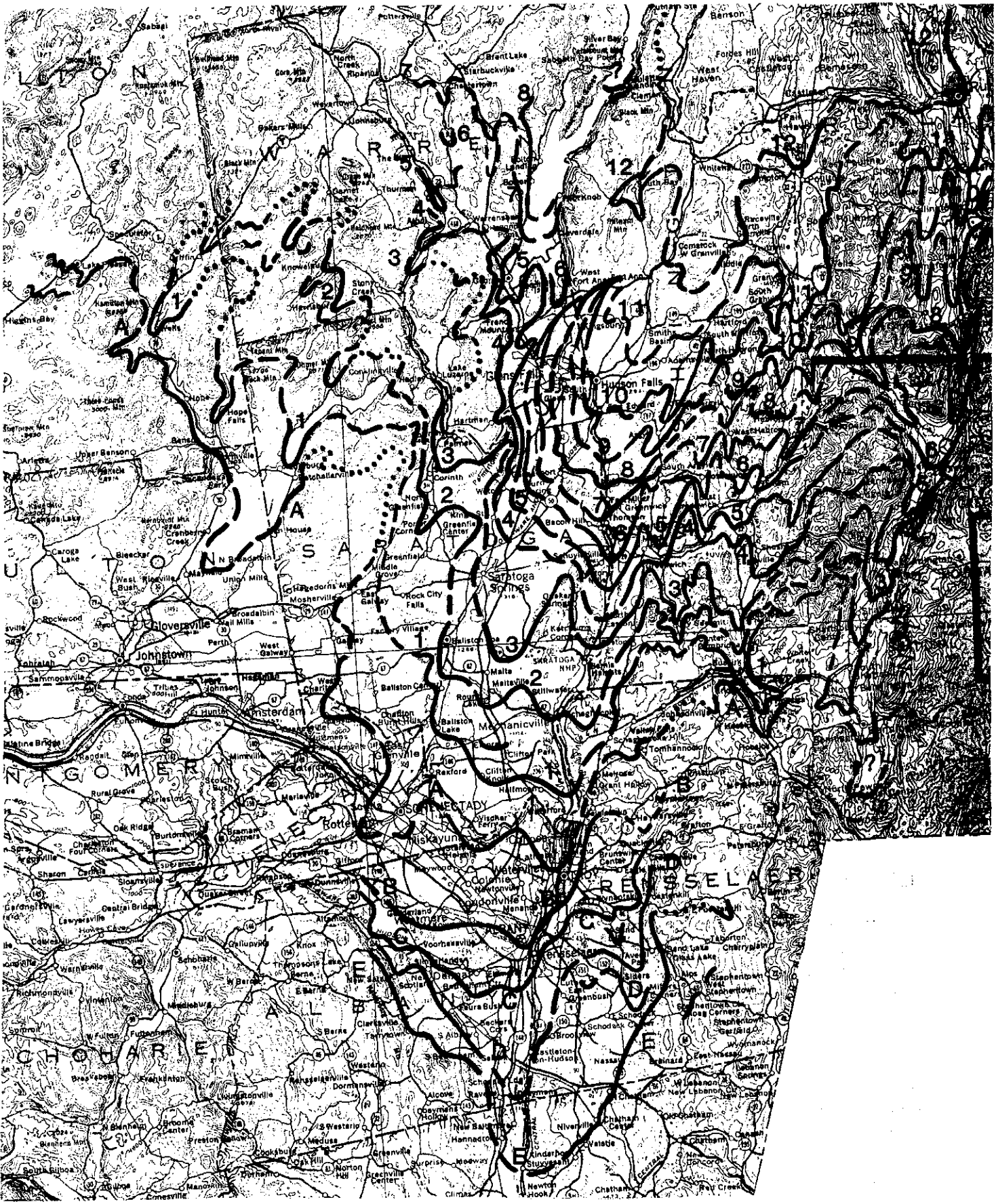


Figure 1: Retretal ice margins in the northern Hudson basin. Scale is reduced to 75% from a 1:500,000 base map.

TIME-STRAT UNITS	APPROX YRS BP	LAKE LEVEL	ICE MARGINS	SIGNIFICANT EVENTS	KM: Kame Moraine KT: Kame Terrace KD: Kame Delta Ksg: Kamic sand & gravel IB: Ice Block OW: Outwash SF: Subaqueous Kame Fan			
MACKINAW INTER- STADIAL	13,700	QUAKER S P R I N G S	Welch Hollow (12)	Welch Hollow KM,KT; Lake Granville 420'; Mettawee & Poultney OW				
			West Pawlet (11)	So. Granville till & Ksg 600'; Blossoms Corners moraine (Vt); Lake Pawlet outlet to Black valley				
			Argyle Valley (10)	Argyle esker 330' & KD 320'; minor ice surge; Tamarack Swamp Ksg; Black valley kames & eskers; Lake Pawlet 700' with ice at Pawlet				
			Danby (9)	Glens Falls Delta & matured Batten Kill Delta; Valley Crossroads SF 260'; Danby Four Corners moraine (Vt)				
			Harper Road (8)	Early Glens Falls Delta 320'; Patten Mills KT; Harper Road SF 270'; Barkley Pond kames; Lake Cossayuna				
			Black Valley (7)	Lake Albany fell to 310' Lake Quaker Springs; Batten Kill Delta 310'; Hoosic Delta 300'; Black valley moraine; Patten Mills KT				
PORT BRUCE STADIAL	14,700?	LOW ER AL B A N Y	Carter Swamp (6)	Lowered Lake Albany 340'; Greenwich OW; local Batten Kill valley impoundments; Hoosic terraces 320'-330'; Hudson 380' Delta; Glen Lake IB; Carter Swamp KM; Manchester moraine (Vt); Lake Sunnyside KM				
			Moreau-Clark Pond (5)	Greenwich OW FAN 400'; Clark Pond KM; Eldridge Swamp IB; Camden valley KT's; Palmertown KT 460' to Moreau Pond KM 420'; Glen Lake Stagnation				
		A L B A N Y	Wilton-Battenville (4)	Wilton KM 450'; Luzerne Mts Ksg 450-500'; Hartman Terrace 670'; Batten Kill OW & KT 420'; Battenville moraine; Saratoga IB; Cambridge OW				
			Archdale-Corinth (3)	Archdale KM; Arlington moraine (Vt); Hoosic Delta 360-370'; Hoosic & Round Lake IB's; Woodland Lake KM (Corinth ice); Lake Corinth 670'; Hidden Valley moraine & local impoundments of Lake Warrensburg				
			Willow Glen (2)	Willow Glen & Country Knolls KD's 350'; early Hoosic Delta 370'; Hale Mt moraine (Vt); Corinth ice @ Porter Corners; Lake Sacandaga 760'; Milton Delta 420'; Ballston IB				
			Waterford (1)	Waterford SF 200'; Halfmoon & Grooms KD's 340'; Hoosic terraces & OW 420-390'; North Hoosick moraine & Lake Hoosic; The Notch & Chestnut Woods Channels; Niskayuna IB; Lake Sacandaga expands to Batchelorville; Clifton Park till; Schenectady Delta				
			Niskayuna (A)	Schen. & Scotia eskers; ice @ Schen. drumlins; Pollock Rd KD 300+'; Poestenkill Delta 320-330'; Speigletown-Melrose KT 400'; Lake Tomhannock ice @ Nipmose Hill & W. Hoosick; Hoosick Falls KM & Lake Hoosic				
			Guilderland (B)	Guilderland KT 350'; McKnownville till; Loudonville Kame Complex 350-390'; Rensselaer SF 300'; North Greenbush KT 380'; Sycaway KT 400';				
			Meadowdale (C)	Meadowdale moraine 400'; Voorheesville KD 350'; Wemple SF 140'; Hampton SF 300'; Wynantskill-Pine Bowl -Poestenkill Ksg 450'				
			Schodack (D)	East Greenbush-Schodack KT 350'; Schodack OW Fan 320'; West Sand Lake-Burdén Lake Ksg 600'; New Salem Ksg & OW 450'				
Pine Swamp (E)	Pine Swamp-Nassau Lake Ksg & OW 500'; Sand Lake-Glass Lake Ksg & OW 800'; Snake Hill OW 850'; Ives Corner Ksg & OW 900'							

Figure 2. Summary of ice retreat events in the northern Hudson basin

Lake level transitions — intervals of falling water level — were either gradual or rapid. Continuous sedimentation of the Greenwich outwash fan from 400 ft to 340 ft and the absence of erosional escarpments or dissection features in the northern Hudson Lowland are evidence for a slowly falling Albany water level. Rudimentary calculations using ice retreat rates of 500-1000 ft/yr (Schafer 1968) suggest an average water decline of 2 ft/yr as the Hudson Lobe retreated from the Moreau-Clark Pond ice margin to the Black Valley ice margin, a distance of approximately 6 miles as measured on the Schuylerville quadrangle.

There is considerable evidence that the Quaker Springs-Coveville and Coveville-Fort Ann I transitions were initiated by high discharge through the glacial Mohawk Valley and eastern outlet channels, which resulted from water level fluctuations in the Ontario Lowland (Stoller 1922, LaFleur 1975, 1979, 1983, Hanson 1977). Extensive erosion in the lower Fish Creek valley from Grangerville to Coveville indicates the Grangerville channel carried high discharge during the Coveville-Fort Ann I transition (DeSimone 1977, p35). The channel topography is strongly fluted in the southeastward flow direction; lake clay remnants are preserved in the shadows of eroded drumlins; and till and bedrock were scoured from 240-200 ft above Coveville.

Clark and Karrow (1984) correlated falling water levels in the Ontario and St. Lawrence Lowlands (lower Iroquois and post-Iroquois) with drainage around Covey Hill into Lake Fort Ann in the northern Champlain Lowland. This inflow to Lake Fort Ann increased outflow from the southern end of the Champlain Lowland along three Fort Ann channels (Fort Edward, Durkeetown, Winchell). Accompanying erosion deepened these outlet channels until the water level stabilized at a lower elevation. Accordingly, the Fort Ann I-Fort Ann II transition is correlated with Clark and Karrow's Level II-Level III transition and the Fort Ann II-Fort Ann III transition is correlated with their Level III-Level IV transition. The final Fort Ann III-Champlain Sea transition, Clark and Karrow's Level IV-Level V transition, resulted in abandonment of the Fort Ann channels and establishment of a late glacial-Holocene drainage configuration in the northern Hudson Lowland.

Timing and Rate of Retreat

Hanson (1977) noted a northward sediment volume decrease in kame deltas, which might suggest an increased melting rate of the Hudson Lobe as it retreated northward. Ice Margins E through 6 (figure 1) are generally well-represented by kame deltas, kame moraines, and kame terraces deposited along the margin of the Hudson Lobe. Kame moraines, kame terraces, and thick outwash sequences accurately delineate these ice margins in the Taconic Highlands. A late Port Bruce age is inferred for these events (LaFleur 1979).

Ice margins 7 through 12, with the exception of the Argyle Valley ice margin (10), record accelerated retreat. Thinner outwash sequences with less kamic sediment in the Taconic Highlands, and a general absence of significant ice-marginal sediment along the Hudson Lobe is consistent

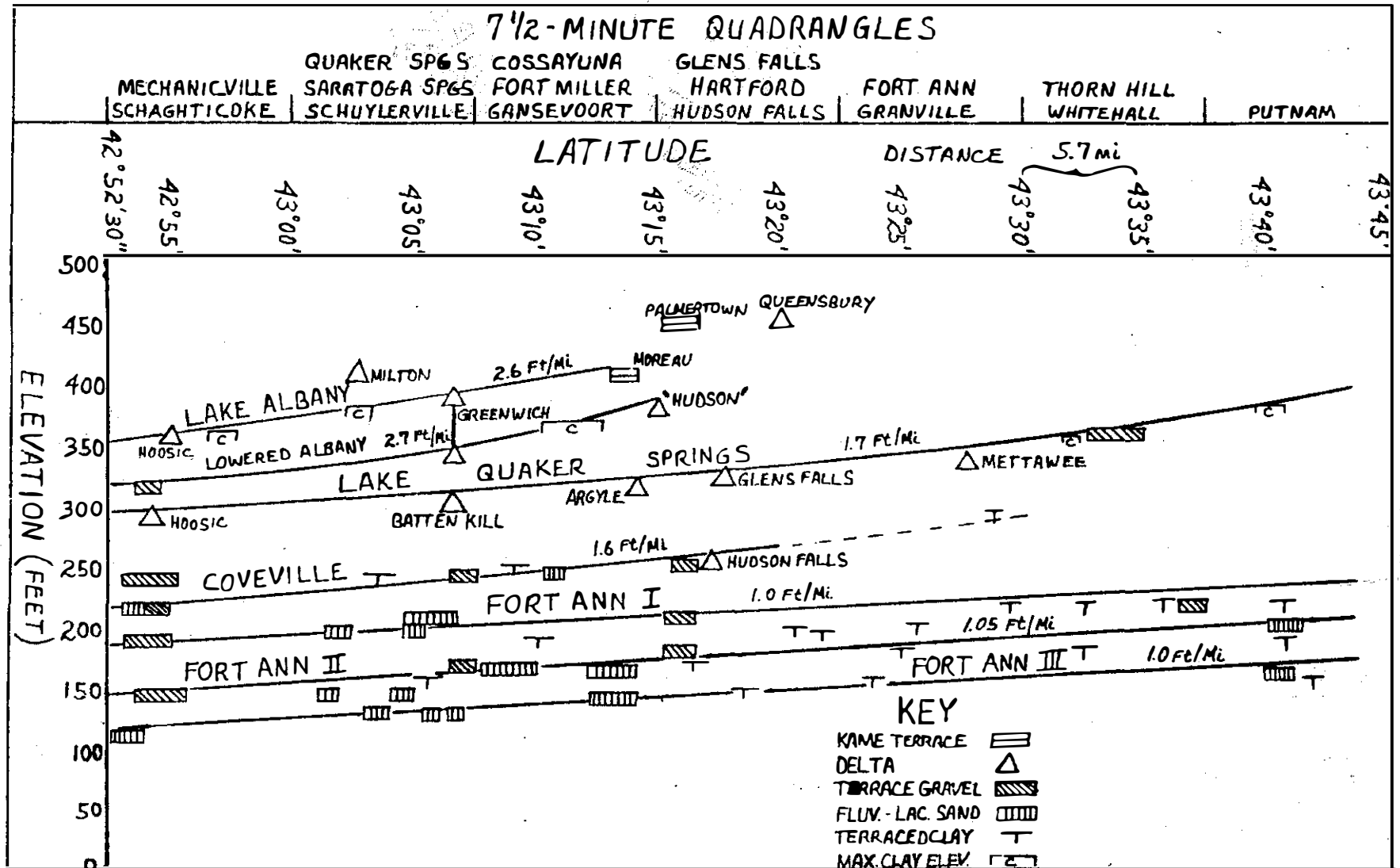


Figure 3: Tilted water planes in the northern Hudson and southernmost Champlain Lowlands. The average gradients were measured between the endpoints of each water plane. Additional data can be found in Woodworth (1905), Chapman (1937), Wagner (1969, 1972), and Parrot and Stone (1972).

with this view. Each of these later ice margins record a shorter pause in an overall more rapid retreat, as documented by the small subaqueous fans in the Argyle Valley associated with ice margins 8 and 9. Undoubtedly, this more rapid retreat through the northern Hudson Lowland was, in part, topographically controlled — a consequence of progressively diminished nourishment of the Hudson Lobe from its four feeder sublobes (Caldwell, Queensbury, South Bay, Whitehall). Ice apparently retreated from the Lake George graben most rapidly because that ice was pinched between the steep bordering highlands at the northern end of the graben. Ice persisted longer in the Taconic foothills and in the South Bay sublobe, both adjacent to the primary Whitehall sublobe. This span of more rapid retreat is tentatively assigned an early Mackinaw age. For the convenience of discussion and in the absence of radiocarbon dates, it may be appropriate to consider the final transition from Lake Albany to Lake Quaker Springs at the Black Valley ice margin (7) as the Port Bruce-Mackinaw "boundary" in the Hudson Lowland.

Deglacial Style

Taconic Highland deglaciation was characterized by a thinning ice cover that exposed till-veneered hills and also by active ice tongues in those valleys oriented parallel to the direction of ice flow. Ice tongue margins retreated sporadically through intervals of rapid retreat, slow retreat, and halted retreat. Topographic control determined the location of distinctive kame moraine sediment bands along the base of moderate to high relief slopes against which an ice tongue impinged for a significant interval. Minor kame moraine segments and isolated kames and eskers record pauses of shorter duration. Breset-type fan or deltaic sediment was deposited from retreating ice margins into local impoundments temporarily dammed by sediment and/or ice. Outwash sequences were deposited in more freely drained valleys. Heads of outwash are recognized on the basis of morphology, profiles of depositional gradients, and textural relationships in the sediment. Abandonment of ice from a valley segment was topographically controlled and had no necessary effect on the retreat of adjacent ice tongues. Hence, continuous stagnation zones were not uniformly present along the ice front.

The retreating Hudson Lobe defended ice-marginal Lakes Albany and Quaker Springs. Melting ice contributed a large sediment volume to the lake basin and a characteristic lacustrine sequence was deposited (Dineen and Rogers 1979). A basal facies of interbedded gravel and sand with turbidites and minor flowtill grades and fines upward to clay and silt rhythmites of the middle facies. These rhythmites grade and coarsen upward to silt and sand beds of the upper facies deposited in shallow-water portions of the basin. Discrete meltwater sources in the Hudson Lobe deposited kame deltas, esker deltas, and smaller subaqueous fans, which generally decrease in number and sediment volume to the north. The typical fining upwards sequence in smaller kame deltas and subaqueous fans deposited from retreating meltwater sources contrasts the progradational sequence of major kame deltas deposited during intervals of halted retreat. Kame terrace and kame moraine sediment accumulated along the margins of the Hudson Lobe predominantly along the base of high relief escarpments such as the Palmertown Range, the Luzerne Mountains, and the Taconic escarpment.

Major tributaries transported a large sediment volume to the lake basin and significant deltas were deposited at the mouths of the Hudson River, Mohawk River, Batten Kill, Mettawee River, and Hoosic River. The typical stratigraphic profile, as illustrated by the Batten Kill delta, consists of horizontally-stratified to cross-stratified topset gravel and sand beds that prograde over and often truncate predominantly cross-stratified foreset gravel and sand interbeds. This facies laterally interfingers with and overlies horizontally-bedded, finely cross-laminated, and ripple-laminated bottomset sand, silt and clay.

No stratigraphic evidence for a major readvance correlative to the Luzerne readvance was observed. All reconstructed ice margins are apparently recessional and record intervals of slowed or halted retreat. Ice positions 1 and 10 approximately coincide, respectively, with the limits of the Shelburne and Burlington drift borders in the Vermont Valley. There is no evidence that these are readvance positions (Larsen 1972; Wagner et al 1972; DeSimone 1985). Minor ice surges probably occurred as indicated at Clifton Park (Dineen et al 1983) and in the Argyle valley (DeSimone 1985).

DETAILED WOODFORDIAN HISTORY

Woodfordian ice advanced generally southward and southwestward along the bedrock structural grain (figure 4). The Taconic Highlands were abraded and streamlined into a drumlinoid landscape mantled by variably-thin till. Deglacial sediment buried a similarly abraded and streamlined topography in the Hudson Lowland. Thick till accumulated in several lowland drumlin clusters and in isolated upland pockets. A well-compacted unoxidized gray lodgement till facies in both lowland and highland regions is composed of an unstratified silty to clayey matrix (75%) with subrounded to rounded pebble, cobble, and boulder clasts (15-30%) of predominantly local lithologies.

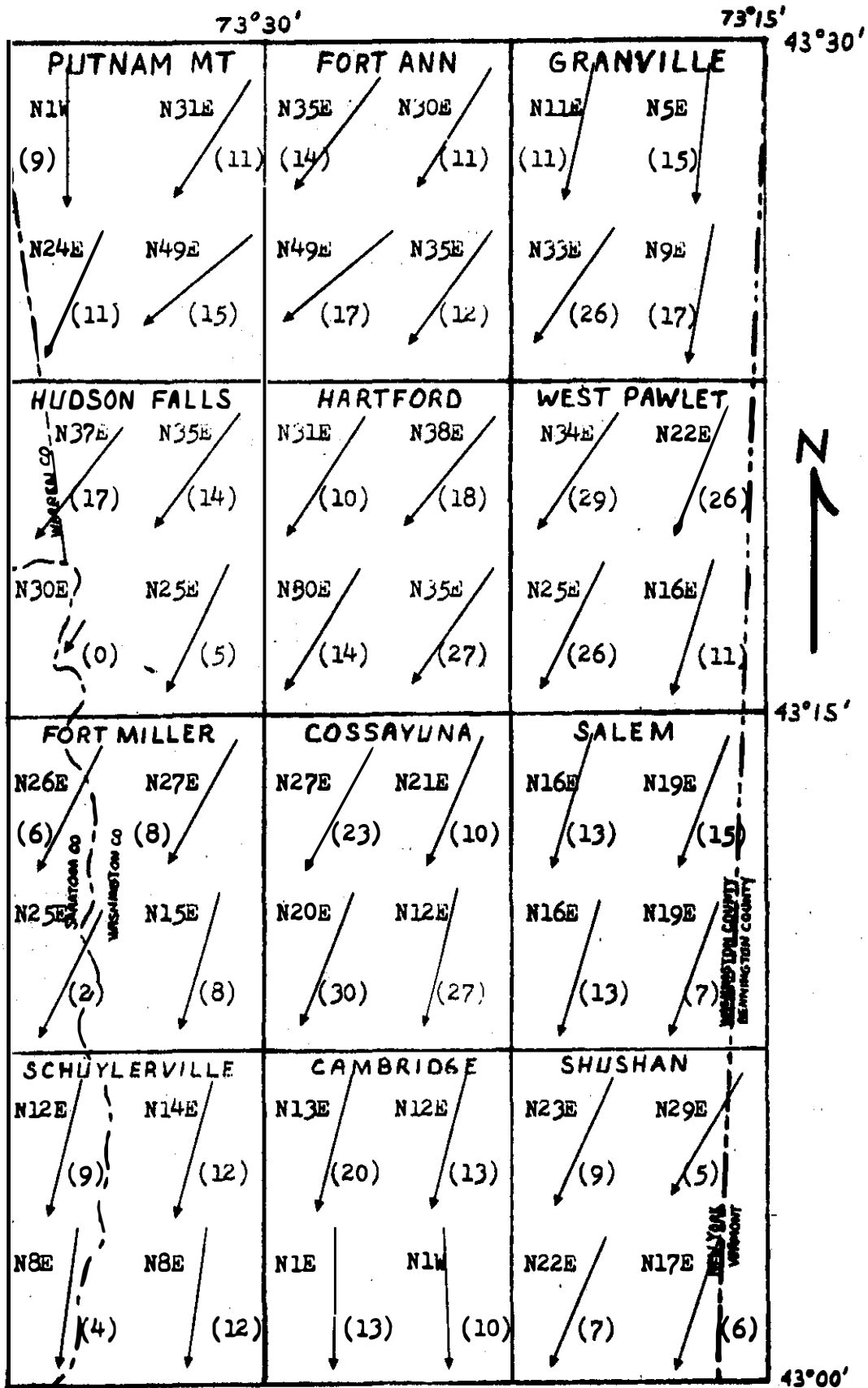


Figure 4: Summarized ice flow directions are depicted at a scale of 1:250,000. Drumlin axes, roc-drumlin axes, and striations were used. The average compass direction for each quadrant of a quadrangle is given and the number of axes used to determine this average is indicated in parentheses.

Albany Deglacial Phase

Waterford Ice Margin (1). Small kame deltas or subaqueous fans were successively deposited into Lake Albany at Waterford, Halfmoon, and Grooms Church. The Hudson Lobe blocked the Hoosic valley east of Schaghticoke and terrace/outwash sediment accumulated from Buskirk (420 ft) to Valley Falls (390 ft), perhaps filling a local impoundment (figure 5). The Wampocack valley ice tongue extended through South Cambridge and South Easton and a meltwater channel was incised along Whiteside Creek. The Cambridge valley ice tongue terminated at North Hoosick and defended glacial Lake Hoosic where considerable silt and clay accumulated south of Hoosick Falls. Meltwater flowed through the Notch (1050 ft) and the Chestnut Woods and Barber Hills ridge and deposited outwash sediment through the White Creek area. The Vermont Valley sublobe approximately coincided with the Shelburne drift border between North Bennington and South Shaftsbury but this is apparently not a readvance position. An ice tongue north of Batchelorville defended glacial Lake Sacandaga and meltwater was contributed from ice that terminated at Hope Falls and Wells on the Harrisburg and Lake Pleasant quadrangles, respectively.

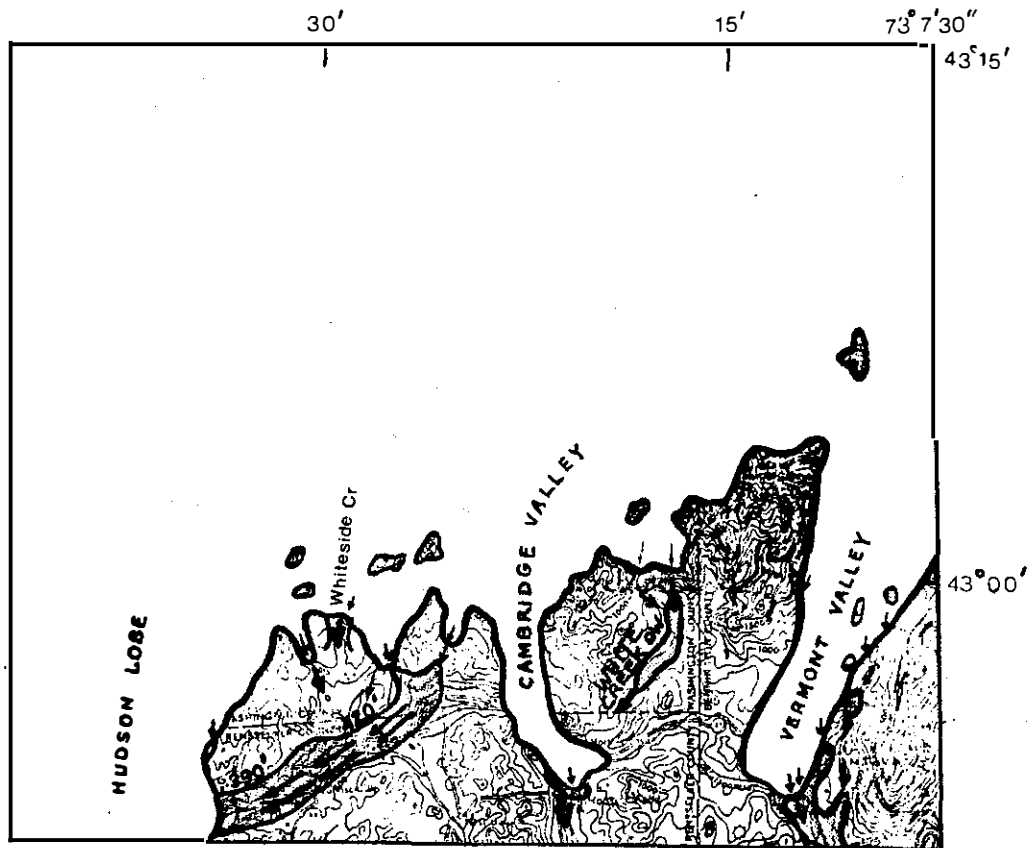


Figure 5: Waterford ice margin

Willow Glen Ice Margin (2). The Willow Glen and Country Knolls (south of Round Lake) kame deltas were deposited along the margin of the Hudson Lobe. The lower Hoosic valley was ice-free and the glacial Hoosic River deposited early deltaic sediment (370 ft) into an expanding Lake Albany (figure 6). The retreating Wampecack and Cambridge valley ice tongues terminated near West Cambridge and Center White Creek, respectively, and deposited outwash sediment and contributed meltwater to the Hoosic River. Glacial Lake Hoosic drained down the Hoosic valley as the Cambridge valley ice tongue retreated northward. Outwash sediment accumulated in the Pencil valley from meltwater originating in ice impinged against Chestnut Ridge and the thin sandy till ridge at the head of the Pencil valley. The Vermont Valley sublobe retreated to the Hale Mountain moraine. The Corinth ice tongue terminated in the Porter Corners area; meltwater flowed down the Kayaderosseras valley and deposited the Milton delta (420 ft) into an ice-marginal impoundment. Glacial Lake Sacandaga lowered to 760 ft but was still defended by ice in the lower Sacandaga valley. The Ballston ice block was abandoned in the Ballston channel.

Archdale-Corinth Ice Margin (3). Sediment northeast of Deans Corners on the Quaker Springs quadrangle and south of Saratoga Lake identified the Hudson Lobe margin as depicted by Chadwick (1928, p903). Basal gravel of the lowermost lacustrine facies accumulated along the edge of the Battenkill-Hudson channel near Bemis Heights (Dahl 1978; LaFleur 1979). Significant ice blocks were abandoned in the Battenkill-Hudson channel near the mouth of the Hoosic River and in the Colonie channel at Round Lake. Deposition of the Hoosic delta continued and Lake Albany expanded to the area west of Willard Mountain. Meltwater flowed through the pass between Schuyler Mountain and the Willard-Whelden ridge and deposited a small outwash fan into Lake Albany. The Archdale kame moraine accumulated against the flank of Herrington Hill and outwash sediment was deposited downvalley from the terminus of the Wampecack ice tongue near Fly Summit (figure 7). Outwash sediment accumulated in the Cambridge and Pencil valleys as the ice retreated and minor ice-marginal kamic sediment was deposited southwest of Coila on the Cambridge quadrangle. The higher Taconics of the Shushan quadrangle and southwestern Vermont were deglaciated. Some meltwater flowed through the Bates pass (1280 ft) and deposited outwash gravel in the White valley east of Cambridge. The Vermont Valley sublobe retreated to the kame and kame moraine sediment of the southern end of the Arlington moraine north of Shaftsbury (Stewart and MacClintock 1969, p85-86; 1970).

Some ice-marginal sediment accumulated on the slopes of the Palmertown Range above the more extensive Wilton kame moraine of later origin. An extensive stagnation kame moraine accumulated at the margin of the Corinth ice tongue through Randall Corners and Woodland Lake on the Corinth quadrangle. Lake Corinth (670 ft) was impounded between this ice margin and accumulated sediment of the previous margin near Greenfield Center. Horizontally-bedded and ripple-laminated sand and silt was deposited into Lake Corinth. The extension of this ice front into the Adirondacks is not precisely known but it may correlate with the Hidden Valley moraine (Connally and Sirkin 1971). Local impoundments amid abandoned ice in the upper Hudson Valley from Stony Creek to Corinth filled with outwash-terrace gravel and sand and constituted Lake Warrensburg, which emptied into Lake Corinth.

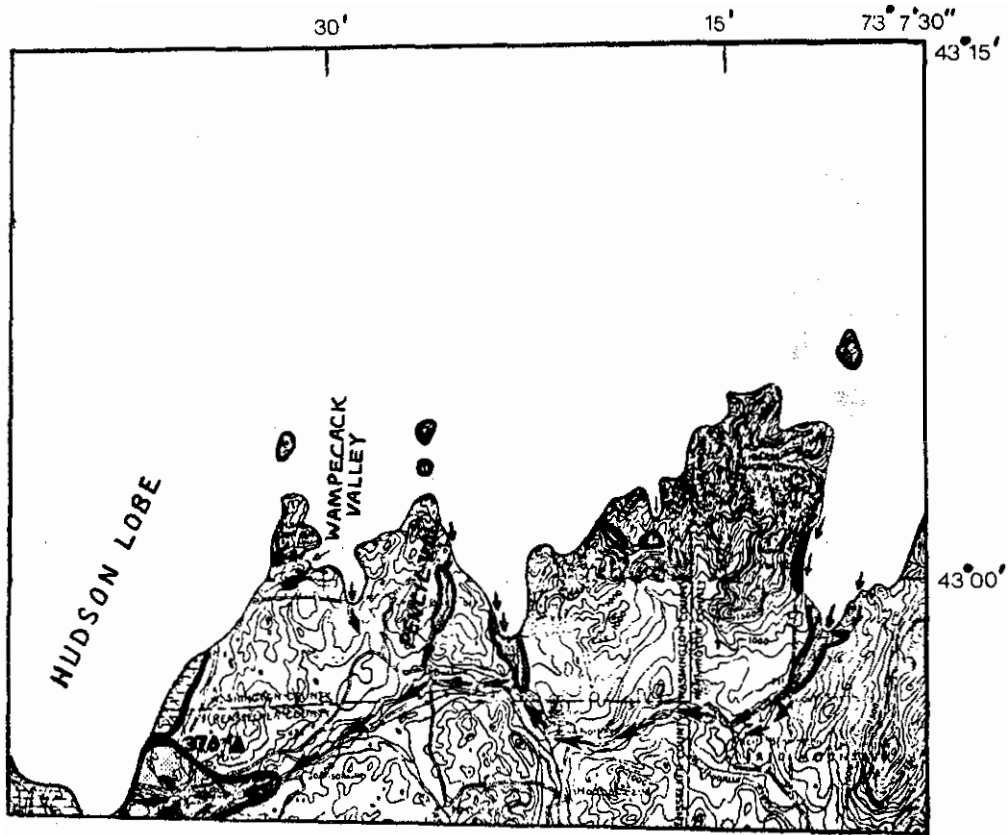


Figure 6: Willow Glen ice margin

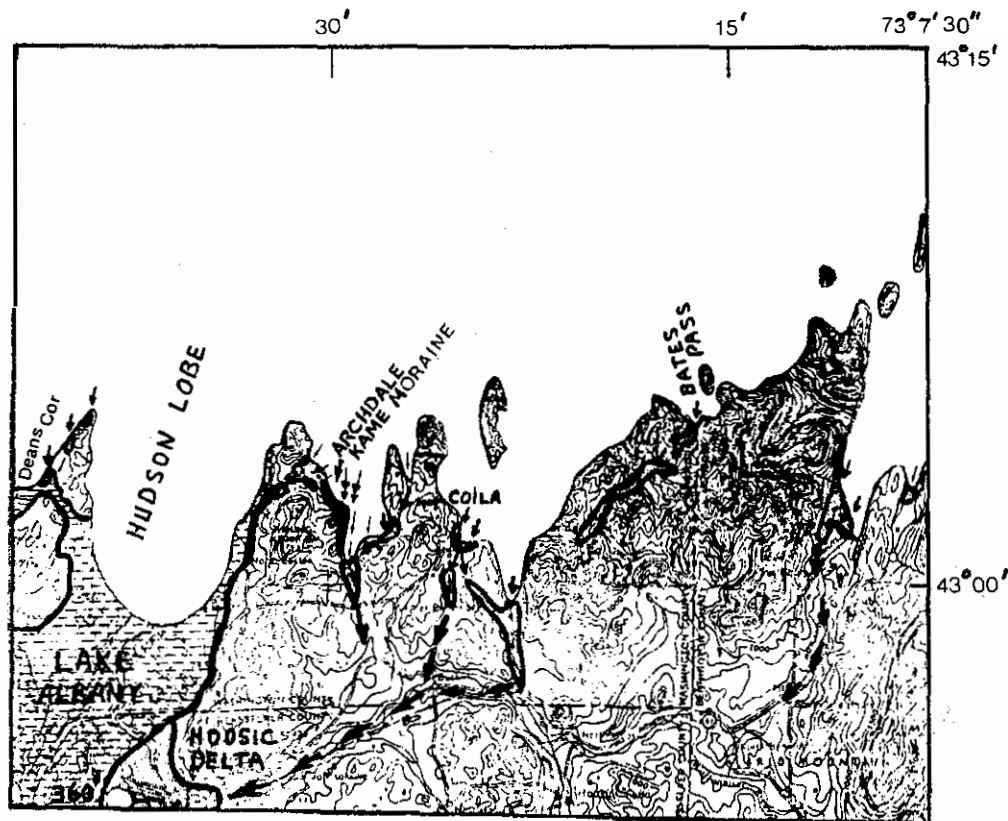


Figure 7: Archdale-Corinth ice margin

Wilton-Battenville Ice Margin (4). The Saratoga ice block was abandoned and Kendrick Hill (Chadwick 1928) was deglaciated. The Hudson Lobe blocked the Batten Kill valley at Greenwich and a small kame terrace (420 ft) was deposited against the northern flank of Schuyler Mountain. The Battenville moraine and associated kames accumulated in the Batten Kill valley and outwash gravel with sand was deposited to 420 ft between till-veneered hills westward to Greenwich (figure 8). Thin (20-45 ft) outwash sediment was deposited from the head of the Lauderdale valley at 540 ft and merged with the extensive (100-150 ft thick) outwash deposited in the Cambridge valley from a head of outwash at Eldridge Swamp. Meltwater from Vermont's Green valley, near West Arlington, contributed to outwash sediment that was deposited up to 580 ft elevation through the NY-VT border area. The Vermont Valley sublobe retreated to the Arlington area and kame terrace sediment accumulated northwest of Arlington. Extensive ice-marginal sediment was deposited in the Wilton embayment along the base of the Palmertown Range at approximately 450 ft and along the base of the Luzerne Mountains from 450-500 ft (Connally 1973). The 670 ft Hartman terrace gravel was deposited and represents the last sediment associated with Lake Corinth. Kamic sediment accumulated along the margin of the Caldwell sublobe (Chadwick 1928) at 800 ft and at 900 ft along Warrensburg Road.

Moreau-Clark Pond Ice Margin (5). The eastern margin of the Hudson Lobe retreated to a position partly located from a water well log which recorded 90 ft of basal gravel beneath later clay in the Battenkill channel southwest of Greenwich. Lake Albany reached its maximum extent as the ice retreated to this position and clay was deposited south of Bald Mountain and in the Hartshorn valley to 390 + ft. Meltwater from the Hartshorn ice tongue and the glacial Batten Kill deposited the Greenwich outwash fan-delta at 400 ft into Lake Albany (figure 9). The Clark Pond kame moraine accumulated against the flanks of the hills south of East Greenwich and outwash sand and gravel was deposited around minor ice blocks at Hedges Lake, Dead Lake, and Schoolhouse Lake. Ice persisted in the Camden valley and kame terrace sediment accumulated to 850 ft along the NY-VT border and at similar locations against the eastern flank of this valley in Vermont. Late active(?) ice may have occupied the large circular basin northwest of Mt. Equinox which would account for the kame terrace sediment above 1000 ft in the upper Green valley as interpreted from Stewart and Mac Clintock (1970). The higher Taconics east of the Camden valley were deglaciated and the Vermont Valley sublobe retreated to the Sunderland area. A local impoundment dammed by sediment at Arlington, Lake Batten, may have expanded against the retreating Vermont Valley ice.

The 460 ft kame terrace at the base of the Palmertown Range just south of the Hudson River and the 420 ft Moreau Pond kame moraine accumulated along the western margin of the Hudson Lobe. The Queensbury sublobe stagnated in the Glen Lake region and sediment accumulated from 500 ft to a 460 ft delta deposited in a temporary impoundment through Queensbury (Chadwick 1928). Ice marginal sediment at 600 ft (Interstate 87, exit 21) located the terminus of the Caldwell sublobe.

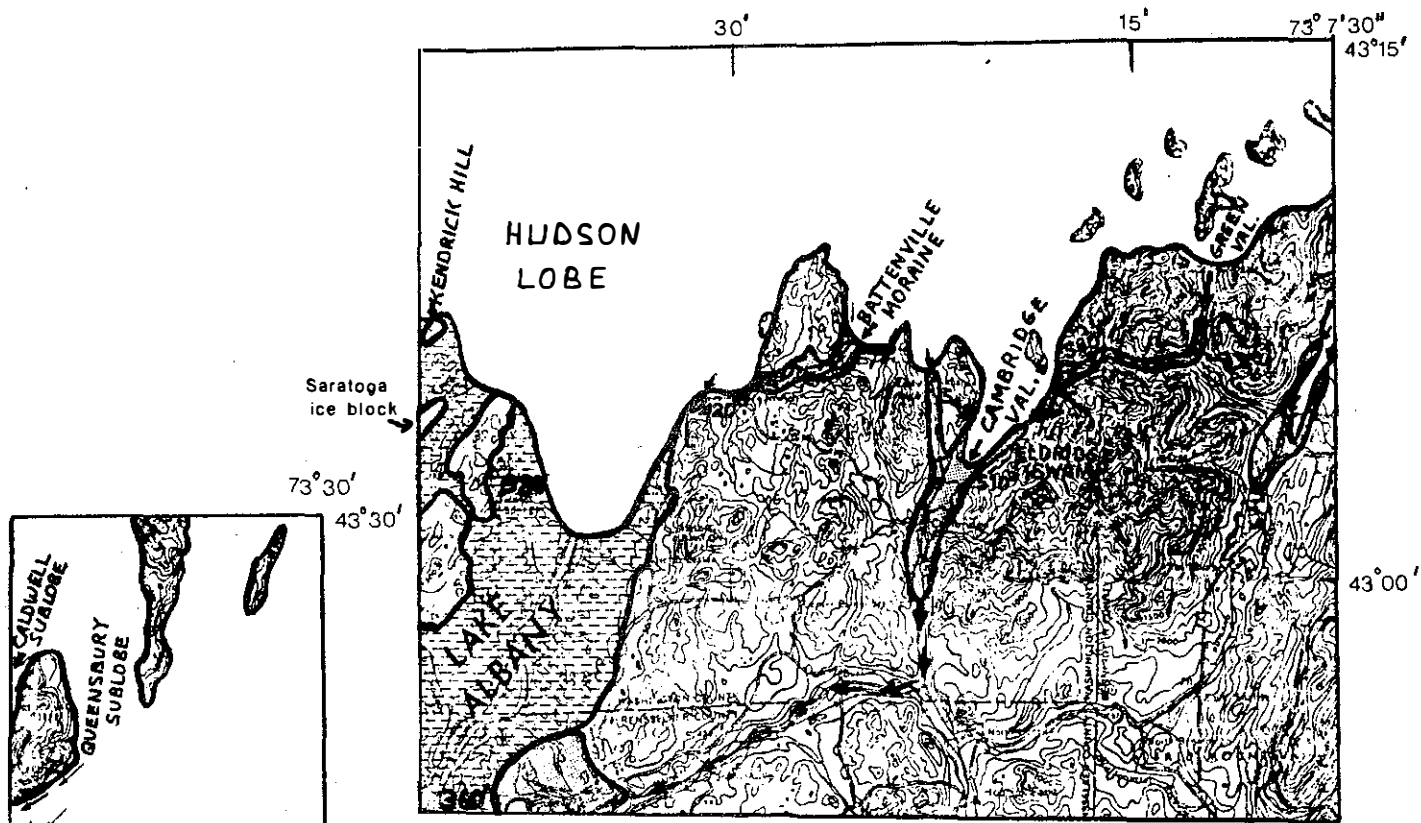


Figure 8: Wilton-Battenville ice margin

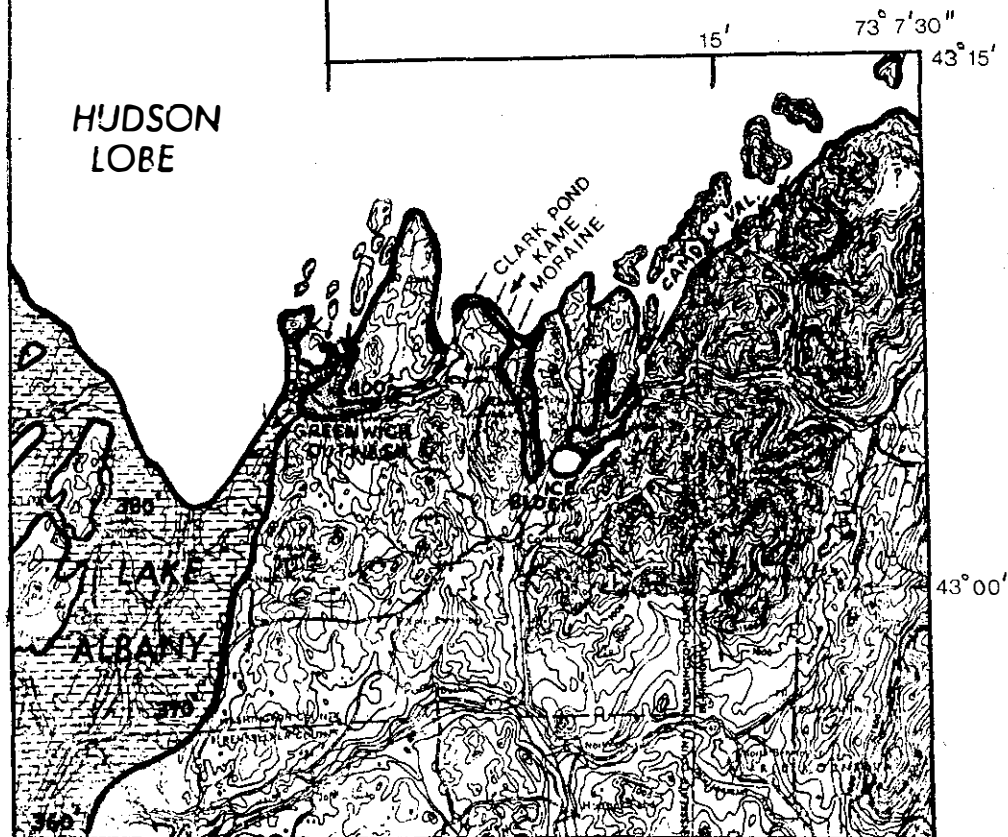


Figure 9: Moreau-Clark Pond ice margin and maximum Lake Albany

Carter Swamp Ice Margin (6). Lake Albany gradually fell to 340-350 ft measured at Greenwich as indicated by continuous deposition of the Greenwich outwash fan without significant dissection or terrace formation as might be expected if the lake level fell rapidly. The 320-330 ft terrace sediment of the Hoosic River was deposited at the time. A Whittaker valley ice tongue terminated across the southern end of Carter Swamp and a small band of kame moraine accumulated west of the swamp. Deltaic gravel and sand prograded into a temporary meltwater impoundment dammed by sediment and/or ice at Battenville. A similar ice and sediment dam at Eldridge Swamp diverted meltwater in the upper Batten Kill through the Shushan-Rexleigh channel (figure 10). The Salem and Black valley ice tongues retreated from their junction and meltwater from the above three sources deposited extensive deltaic and outwash sediment perhaps into the same isolated impoundment dammed at Battenville or a similar one dammed at East Greenwich. Continual retreat of the Salem and Black ice tongues would account for the predominant foreset-type deltaic gravel and sand interbeds observed. The distal foreset sand and fine gravel beds grade southward to ripple-laminated and finely cross-laminated fine sand and silt bottomset beds.

The Manchester moraine through Manchester, Manchester Depot, and Barnumville approximated the terminus of the Vermont Valley sublobe. Chadwick's (1928, p909) 380 ft terrace of the Hudson west of Glens Falls was correlated with deposition of the Greenwich outwash fan. The Glen Lake ice block was abandoned and the active margin of the Queensbury sublobe retreated to the Lake Sunnyside area.

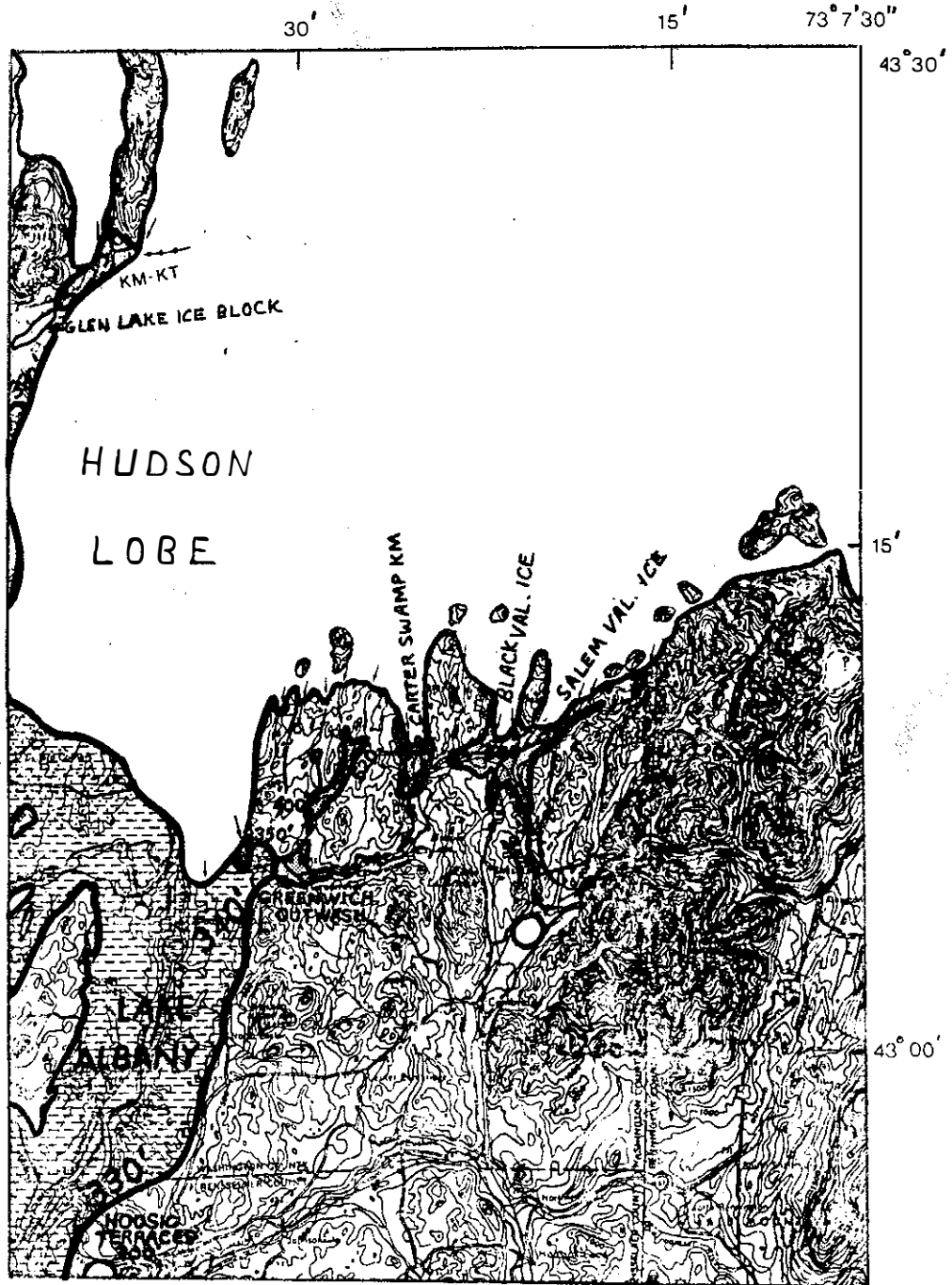


Figure 10: Carter Swamp ice margin and a lowered Lake Albany

Quaker Springs Deglacial Phase

Black Valley Ice Margin (7). Lake Albany continued to fall and stabilized at the 310 ft level of Lake Quaker Springs measured at the latitude of the Batten Kill delta (figure 11). Woodworth (1905, p177) first observed the "... falling off in altitude of the deltas successively northward from that of the Batten Kill" and noted their failure to coincide with an Albany water plane. He concluded, "... these lower deltas were not made in the waters of Lake Albany." Delta elevations and the distribution of lacustrine sediment in the northern Hudson Lowland confirmed an absence of the higher waters of Lake Albany north of the Black Valley ice margin (DeSimone 1983, 1985). The Glens Falls delta (330 ft), Batten Kill delta (320 ft), Argyle esker delta (320 ft), Mettawee delta (330-340 ft) and perhaps the 360 ft sediment at the junction of the Poultney and Castleton Rivers in Fair Haven, VT, were all deposited into a stable Lake Quaker Springs at or near its maximum level.

Numerous ice tongues protruded into minor valleys in the Taconic Highlands of Washington County and small outwash sequences were deposited from these heads of outwash. The Black ice tongue terminated near Bean Rd where kamic sediment and a thick till accumulation may be of morainal origin. Minor kamic sediment reworked by later outwash sedimentation identified the margins of the West Beaver and Beaver valley ice tongues. A distinct meltwater channel with a threshold at 660 ft perched above the south rim of Scott Lake locates another segment of the ice margin. A change in gradient of the outwash sequence profile identified the margin of the Salem valley ice tongue, and meltwater eroded till along the valley flank. The Vermont Valley sublobe and Mettawee ice tongue terminated along the kame moraine and kame terrace sediment at East Dorset and South Dorset, respectively.

Previous sediment and/or ice dams at Battenville and perhaps at East Greenwich and Arlington were breached and any local impoundments drained. Dissection of previously deposited valley fill occurred in response to the lower base level of Lake Quaker Springs and the unimpeded meltwater flow initiated deposition of the extensive Batten Kill delta. A prevailing lake or longshore current transported sand south from the delta and this sand accumulated as a distinct blanket over clay through the central portion of the Schuylerville quadrangle.

The Hoosic River breached its Albany delta and redeposited sediment in its 300 ft Quaker Springs delta. The western margin of the Hudson Lobe may have followed Palmer Ridge and similar ridges through the Fortsville area. The extensive Patten Mills kame terrace and ice-marginal sediment in the Diamond Point and Trout Lake area west of Lake George were deposited.

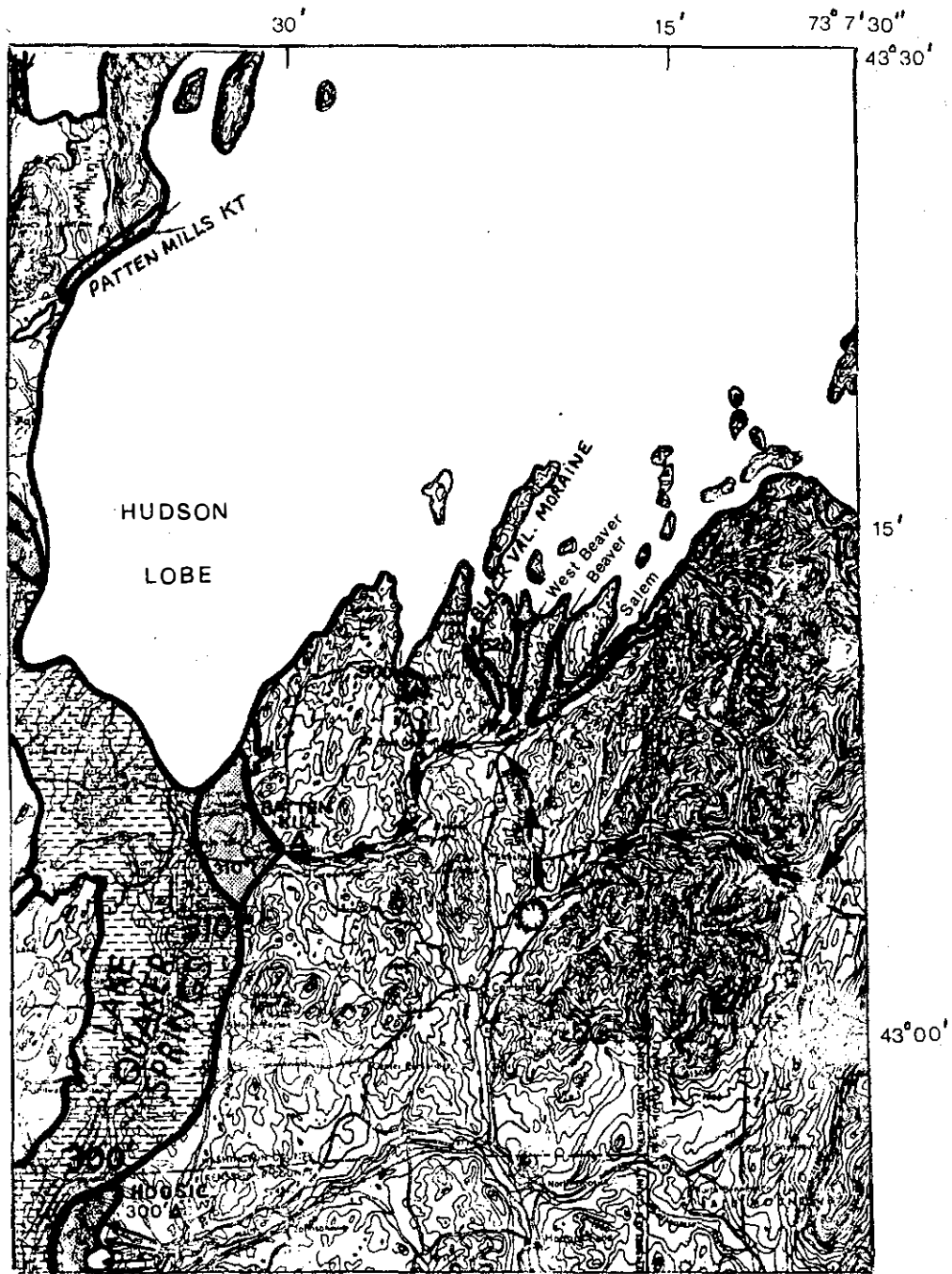


Figure 11: Black Valley ice margin and Lake Quaker Springs

Harper Road Ice Margin (8). Deposition of the Batten Kill delta and the Patten Mills kame terrace continued as the Hudson River initiated its Glens Falls delta at 320 ft (figure 12). The western edge of the Hudson Lobe probably retreated to the bedrock ridges traversed by Chestnut (Sanford's) Ridge Rd on the Glens Falls quadrangle. The Hudson Lobe protruded into the Fort Edward channel north of Fort Miller and into a pre-Woodfordian channel east of Gansevoort identified from water well logs, seismic data, and bedrock exposures. Some stratified gravel and sand accumulated between and on the flanks of drumlins clustered northeast of Fort Miller while the surface till was reworked by meltwater into a gravel-enriched lag. A retreating meltwater source deposited the small lobate subaqueous fan exposed along Harper Road in the Argyle valley. The sediments in the section fines upward from interbedded gravel and sand to lake sand and finally to lake clay, which draped over and buried the deposit.

The ice front east of Barkley Pond was indicated by several small coalesced kames and outwash sediment deposited into glacial Lake Cossayuna. One water well log from an outwash fan along the western shore of Cossayuna Lake recorded 120 ft of clay beneath 15 ft of sand. Outwash sediment was deposited in the Black valley from 500 ft west of Chamberlin Mills to 480 ft near West Hebron. The distal outwash south of West Hebron at 480 ft is silty and suggests isolated impoundments dammed by the Black valley moraine. Meltwater flowed from the head of the West Beaver valleys at 700 ft south of Chamberlin Mills and Tiplady, respectively, and eroded a channel to 600 ft at the Hebron-Salem town line. The Mettawee ice tongue terminated near East Rupert and the Vermont Valley sublobe retreated to the base of Dorset Mountain as indicated by kame terrace and or kame moraine sediment (Stewart and MacClintock 1970).

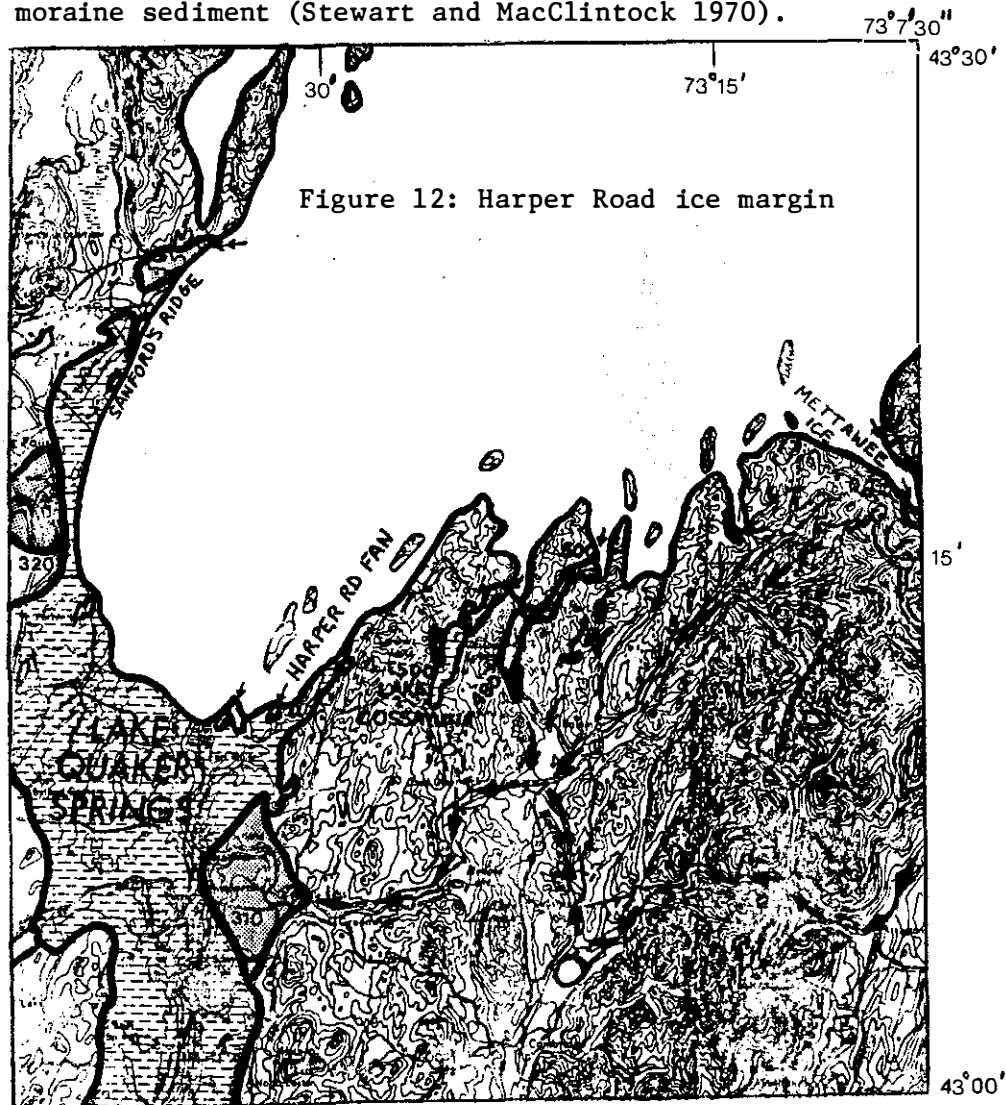


Figure 12: Harper Road ice margin

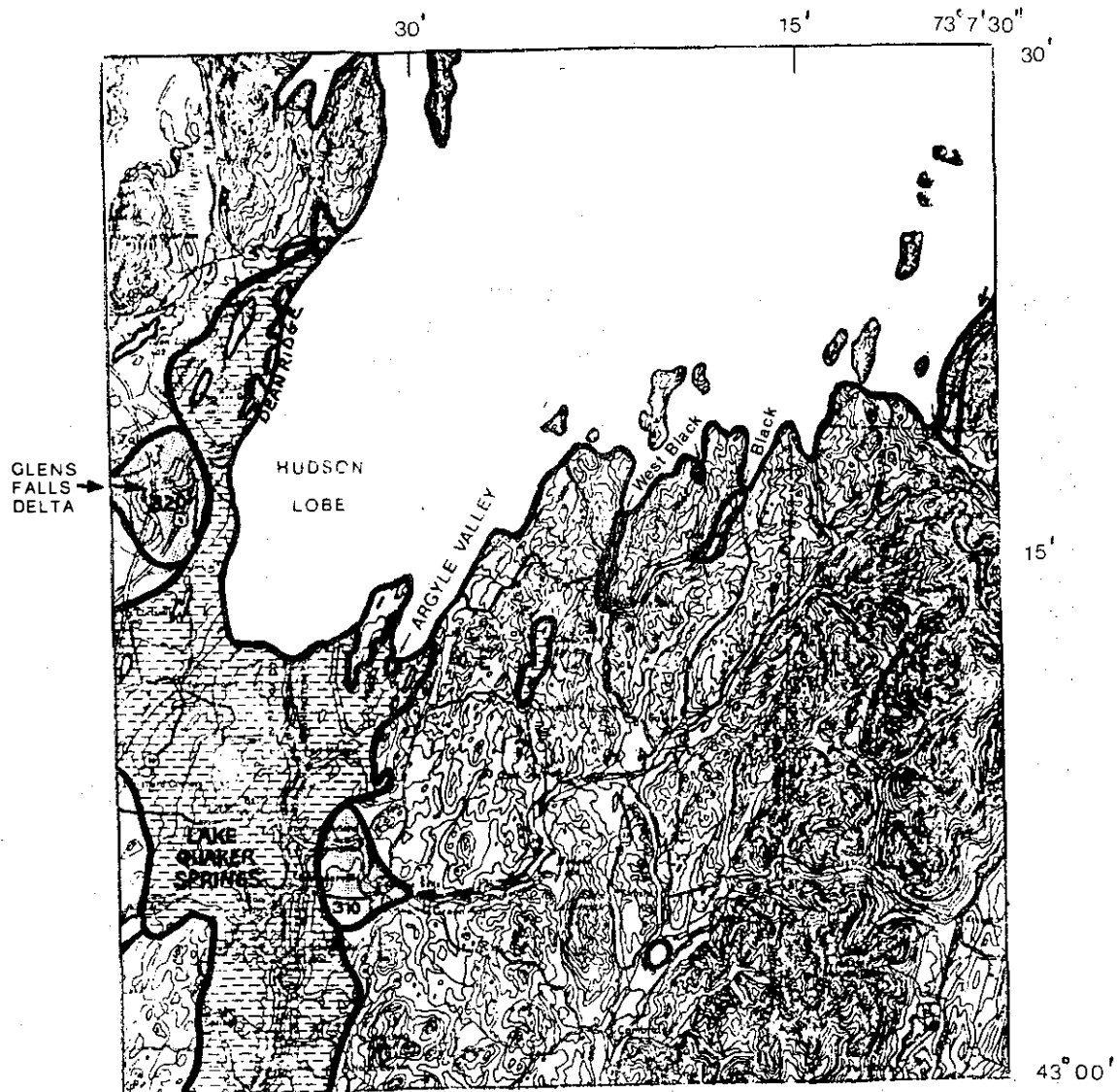


Figure 13: Danby ice margin

Danby Ice Margin (9). The Glens Falls delta prograded into Lake Quaker Springs but retreating meltwater sources decreased the sediment supply to the Batten Kill delta. Another clay-buried subaqueous fan was deposited in the Argyle valley near the junction of Pleasant Valley Rd and West Valley Rd (figure 13). Outwash sequences are recognized in the West Black and Black valleys. The Mettawee ice tongue retreated to the North Rupert area and the Danby Four Corners moraine accumulated along the margin of the Vermont Valley sublobe (Stewart and MacClintock 1969, p119). Two water well logs from Clark Rd and Mott Rd on the Fort Miller quadrangle recorded basal gravel beneath lacustrine clay and helped delineate the Hudson Lobe. The western edge of the Hudson Lobe probably followed the bedrock ridges traversed by Dean Rd on the Glens Falls quadrangle, in accordance with Chadwick's (1928) technique of using these northeast-trending ridges north of Glens Falls to contain the retreating Hudson Lobe.

Argyle Valley Ice Margin (10). An extensive esker and esker delta complex was deposited from a meltwater source in the Argyle ice tongue, and ice-marginal sediment accumulated east of Tamarack Swamp as this ice stagnated (figure 14). The nearly continuous esker at 330-340 ft can be traced from the southern end of the swamp through North Argyle to the apex of the delta at 320-330 ft deposited into Lake Quaker Springs. Lacustrine clay overlapped and nearly buried the fluvial-deltaic gravel and sand. Folded, contorted gravel and clay containing pods of a gravel-derived till on the top and flank of the esker may suggest a minor ice surge but not a major readvance during this interval. The Argyle ice decayed in Tamarack Swamp and enabled lake waters to invade the swamp while the remainder of the ice front was stable. Meltwater in the highlands east of the swamp incised the channel east and south of Black Mountain and flowed across the present town landfill area where an upper section of the lodgement till was reworked to a crudely-stratified gravel lag. Coarse-grained sediment is preserved as short esker segments along the Safford Rd meltwater route and deltaic sediment accumulated against and at least partially beneath dead ice in the swamp. Fine-grained pebble gravel and horizontally-bedded sand in the distal portion of the sequence fine upward to lacustrine silt and clay. The geomorphic expression of this latter sequence suggests deposition in a tunnel beneath the ice or in an open crevasse occupied by Lake Quaker Springs.

A cluster of kames and short esker segments located the margin of the Black ice tongue near Braymer. The Mettawee ice tongue terminated near Pawlet and, to the northeast, along a line approximated by the limits of the Burlington drift border (Stewart and MacClintock 1969, 1970), but this is not a major readvance position (Larsen 1972, Wagner et al 1972). Lake sediment near 700 ft between Pawlet and North Rupert was deposited in a local ice-dammed Mettawee valley impoundment designated Lake Pawlet.

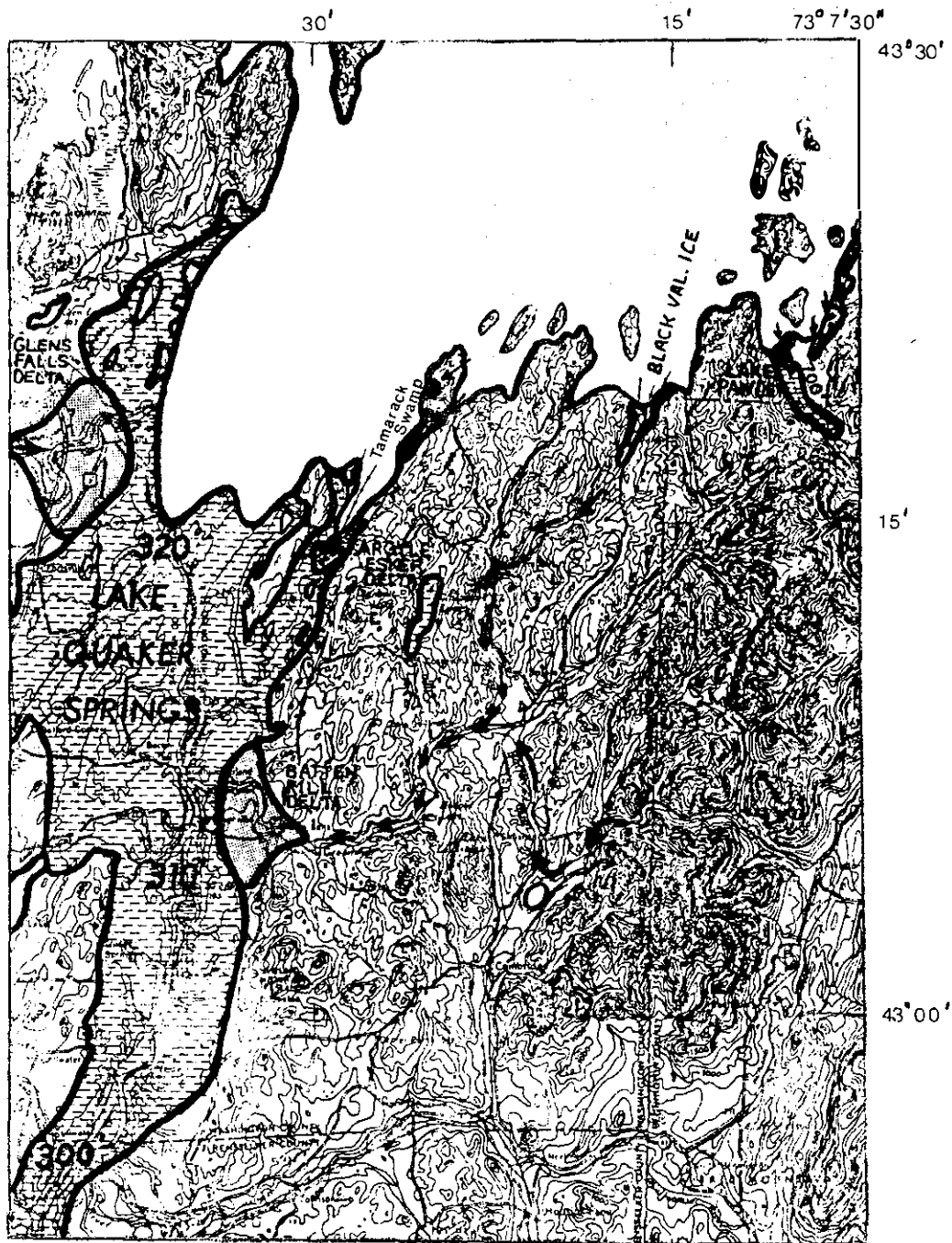


Figure 14: Argyle Valley ice margin

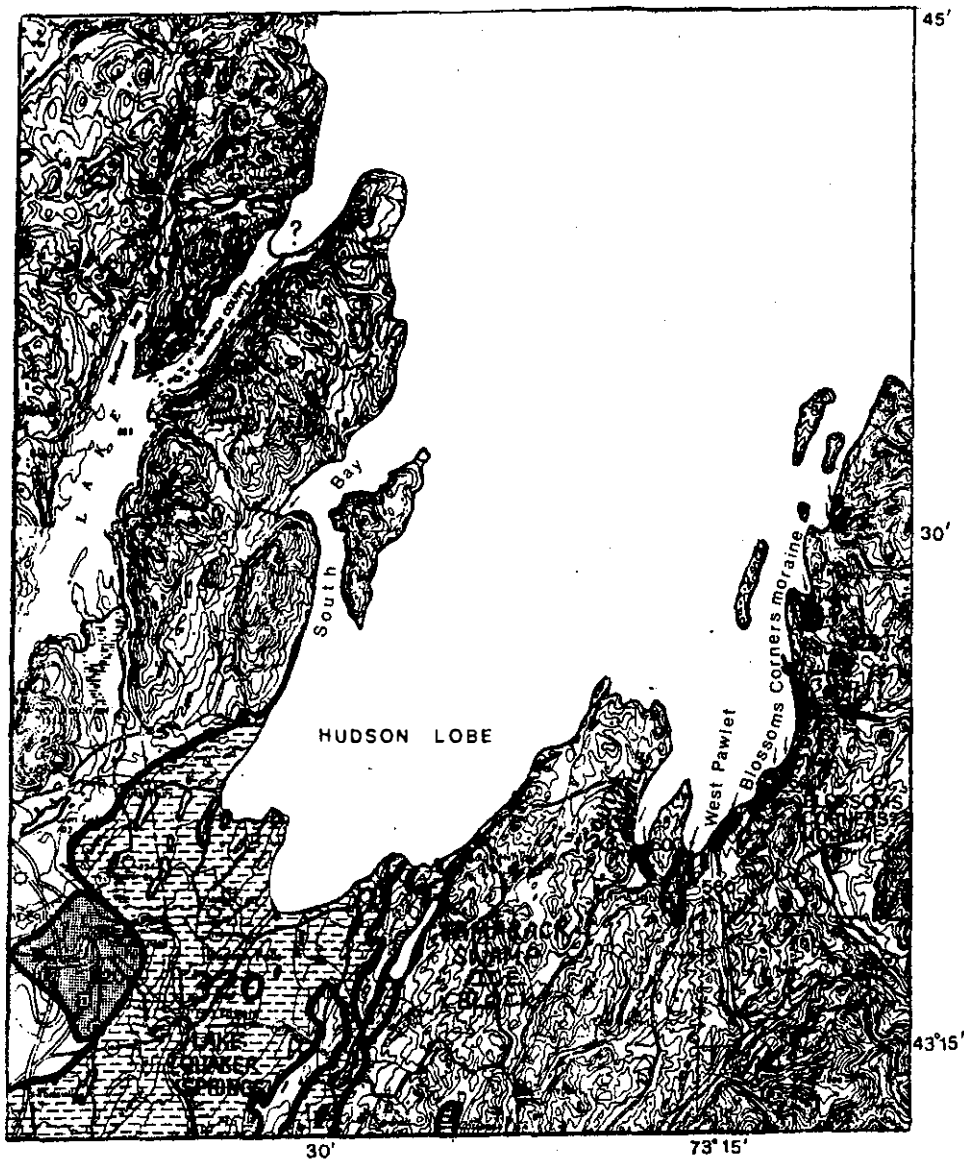


Figure 15: West Pawlet ice margin

West Pawlet Ice Margin (11). The Hudson Lobe, confined to the Whitehall and South Bay sublobes, retreated more rapidly northward (figure 15). A ridge of thick lodgement till confined the ice near South Granville. Stratified gravel and sand accumulated along the western margin of this ice to 600 ft while outwash was deposited into the Black valley. The Black ice tongue retreated to the valley head at West Pawlet and meltwater eroded an extensive area of till and bedrock from 600-560 ft, possibly from the drainage of Lake Pawlet around the ice front to the Black valley. The Mettawee ice tongue retreated to the Blossoms Corners moraine through North Pawlet, Wells, and east of Lake St. Catherine. Kame terrace and morainal sediment in the Vermont Valley at Chippenhook, Clarendon, and East Clarendon are correlated to this ice margin.

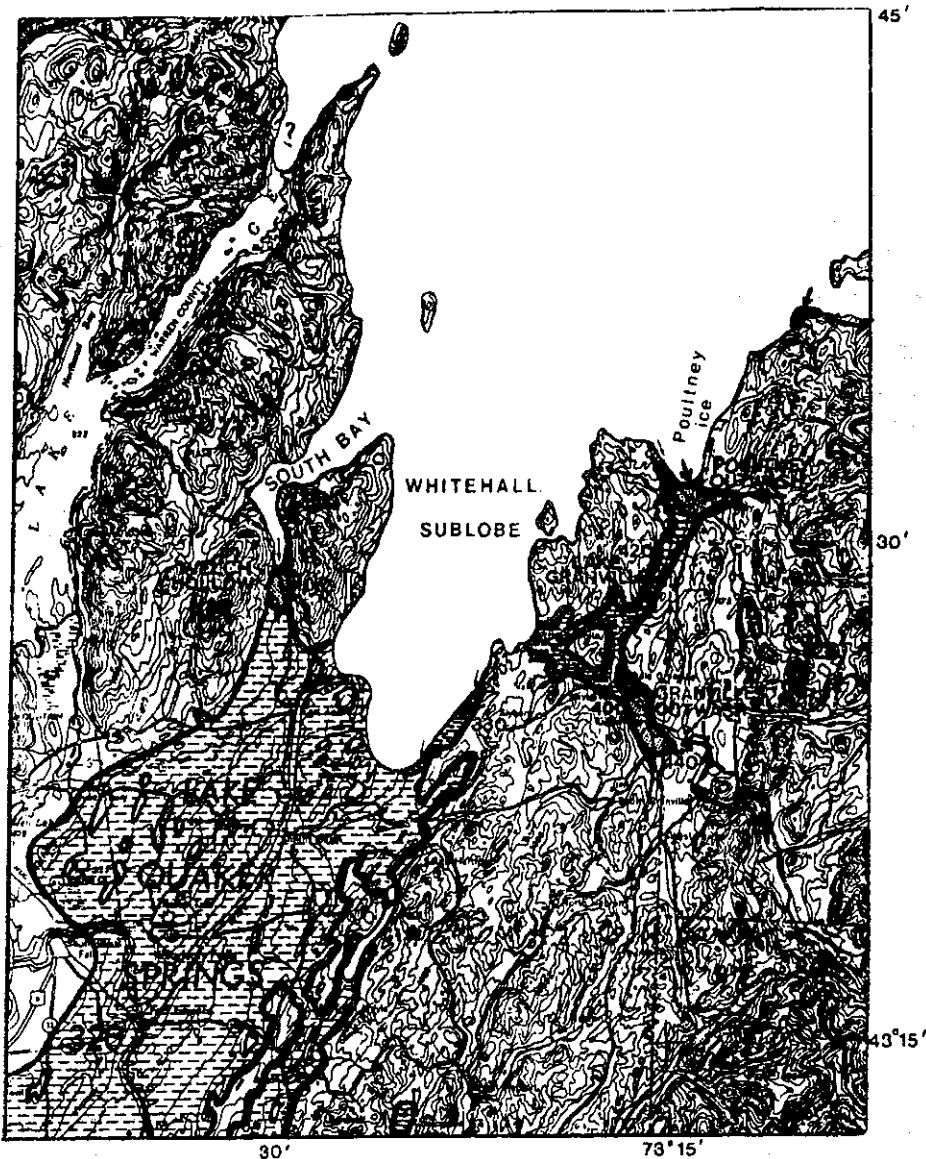


Figure 16: Welch Hollow ice margin

Welch Hollow Ice Margin (12). An extensive kame moraine and kame terrace complex accumulated at the margin of the South Bay sublobe (Connally 1973). Lake Granville at 410-420 ft, redefined from its earlier use (Behling 1966, Stewart and MacClintock 1969) occupied the lower Mettawee valley and was probably defended by the Whitehall sublobe at North Granville or Truthville (figure 16). The Mettawee River deposited outwash into the lake through Granville and meltout of stranded ice in Middle Granville resulted in slumping and faulting of the distal outwash-lacustrine sand and fine gravel. Meltwater from the Poultney ice tongue deposited outwash into the northern arm of the lake at Poultney. Clay, silt, and sand accumulated in the central portion of the lake basin from Truthville to Middle Granville to Raceville. Recession of the Whitehall sublobe from North Granville drained Lake Granville and allowed deposition of the Mettawee delta (330-340 ft) into Lake Quaker Springs. The Castleton, Birdseye(?), and West Rutland(?) moraines of Vermont (Stewart and MacClintock 1969, p123) are correlated to this ice margin.

Lake Coveville

Sediment contribution to Lake Coveville in the Hudson Lowland was limited to the pebble gravel, sand, and silt transported by tributary streams. A stable Lake Coveville was delineated by prominent Batten Kill terrace gravels at 240 ft and the sandy Hudson Falls delta of the Hudson River at approximately 260 ft (figure 17). Terraced clay at 240 ft on the Schuylerville quadrangle, at 250 ft on the Fort Miller quadrangle, at 260 ft on the Hudson Falls quadrangle, and the minor 280-300 ft terrace of the Mettawee River were coeval with Lake Coveville. Hoosic River terraces at 220 ft and the 220 ft sediment east of Hemstreet Park on the Mechanicville quadrangle are similarly correlated.

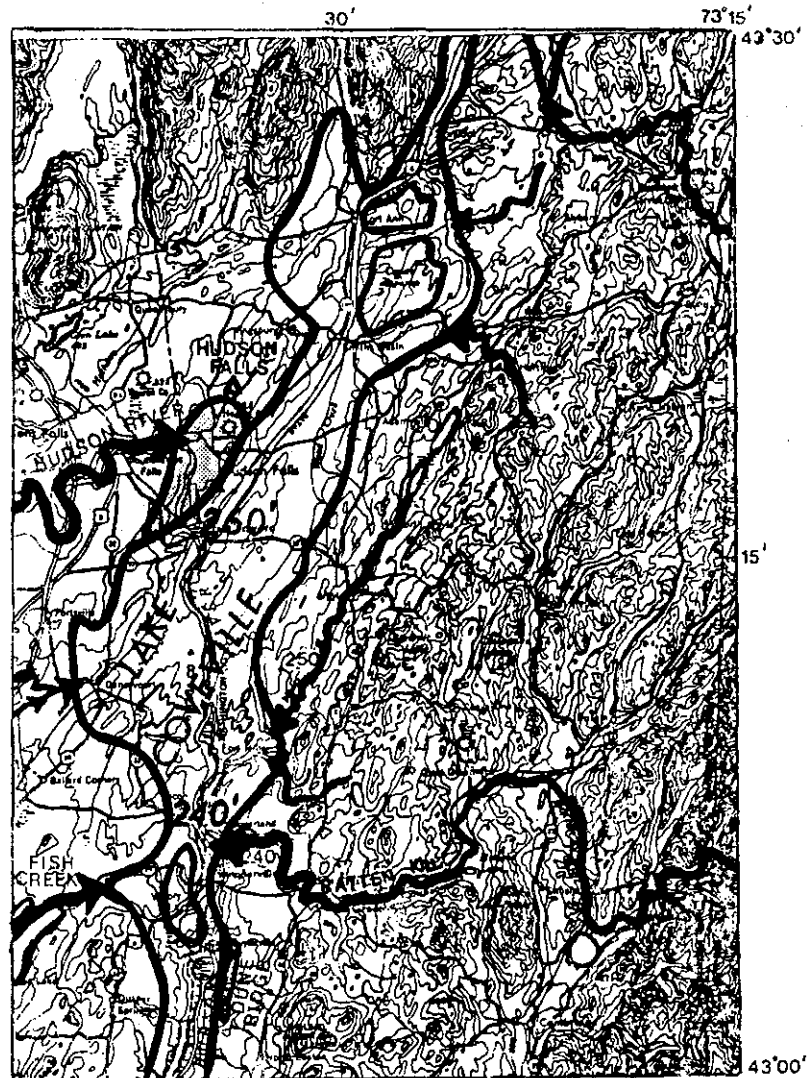


Figure 17: Lake Coveville

Fort Ann Water Levels

Fort Ann Channels. The Fort Ann channels include the primary Fort Edward channel (Woodworth 1905, p198), the Durkeetown channel (Chadwick 1928, p914), and the Winchell channel. These Champlain Lowland outlet channels were broadly defined during the Coveville phase and extensively excavated through clay, till, and bedrock during the Fort Ann phase. The Hudson-Champlain canal and the Hudson River below Fort Edward occupy the Fort Edward channel. Dead Creek, the distal portion of the Moses Kill, and the headwaters of Wood Creek occupy the broad Durkeetown channel. Winchell Creek and the distal portion of Big (Mill) Creek occupy the Winchell channel. All of these modern streams are underfit and follow entrenched courses with narrow floodplains on the channel bottoms. Eroded clay, till, and bedrock comprise the channel escarpments with predominantly eroded clay in the channel bottoms.

Fort Ann I. Fort Ann waters in the Hudson Lowland are most appropriately considered a broad shallow river, 10-20 ft deep, with a significant south-flowing current capable of eroding the soft lacustrine bottom sediment and transporting sand. Tributary streams deposited sediment (fluvial-lacustrine sand) where they joined the Fort Ann waters and the prevailing current transported this sand southward. These thin (<10 ft) sand units were deposited on an eroded clay terrace or till/bedrock surface during times of normal (stable) Fort Ann discharge. The Fort Ann I level in the northern Hudson Lowland was indicated by fluvial-lacustrine sand at 200 ft on the Schuylerville quadrangle, Hoosic River terraces at 180-190 ft, a prominent Hudson River terrace at 210 ft, and Poultney River terraces at 220 ft (figure 18). Terraced clay at 200 ft on the Schuylerville and Fort Miller quadrangles is similarly correlated.

Fort Ann II. The stable Fort Ann II level in the northern Hudson Lowland is indicated by fluvial-lacustrine sand at 160-170 ft through the Schuylerville and Fort Miller quadrangles and by prominent terraces of the Hoosic River at 150 ft, the Batten Kill at 170 ft, and the Hudson River at 180 ft (figure 19). Terraced clay at 180 ft north of Durham's Basin on the Hudson Falls quadrangle is correlated to this level.

Fort Ann III. The final Fort Ann III level is indicated by the 100-120 ft-level sediment near Reynolds on the Mechanicville quadrangle and by fluvial-lacustrine sand at 130-140 ft on the Schuylerville and Fort Miller quadrangles (figure 20). Terraced clay at 130-140 ft on the Schuylerville quadrangle is similarly correlated. The Winchell and Durkeetown channels were abandoned when the water level fell below their present sills at 180 ft and 170 ft, respectively. Lake Fort Ann discharge from the Champlain Lowland was confined to the Fort Edward channel, which was deepened to 150 ft at Smith's Basin and to 140 ft at Fort Edward.

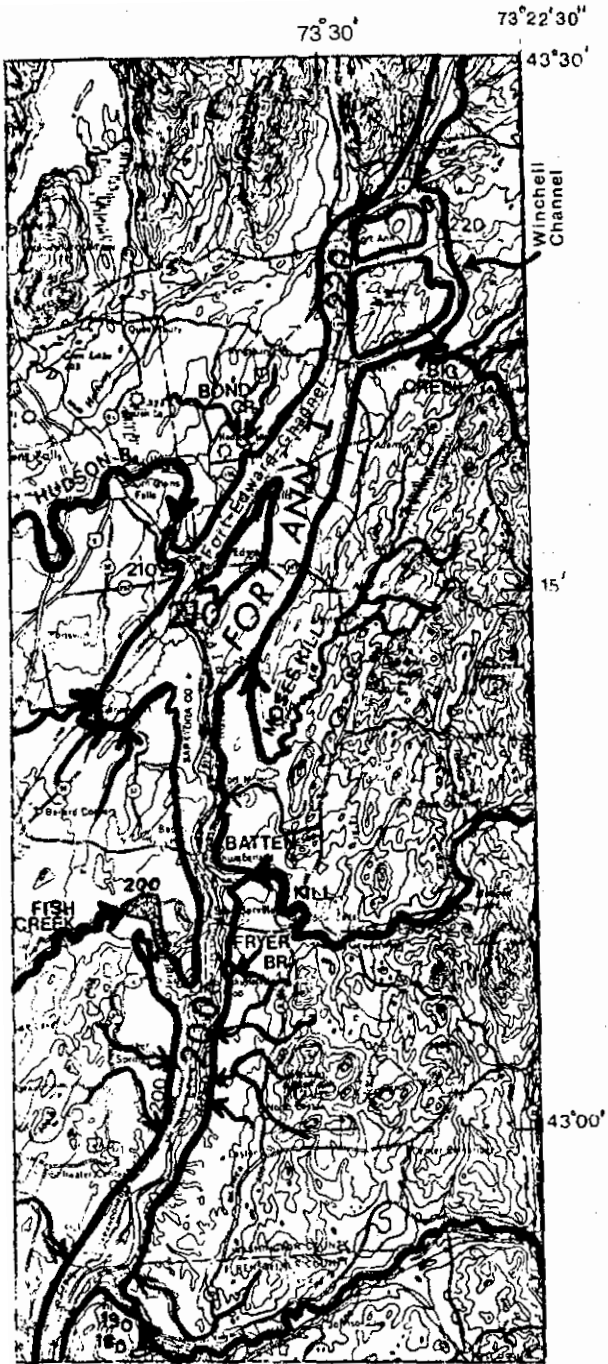


Figure 18: Fort Ann I

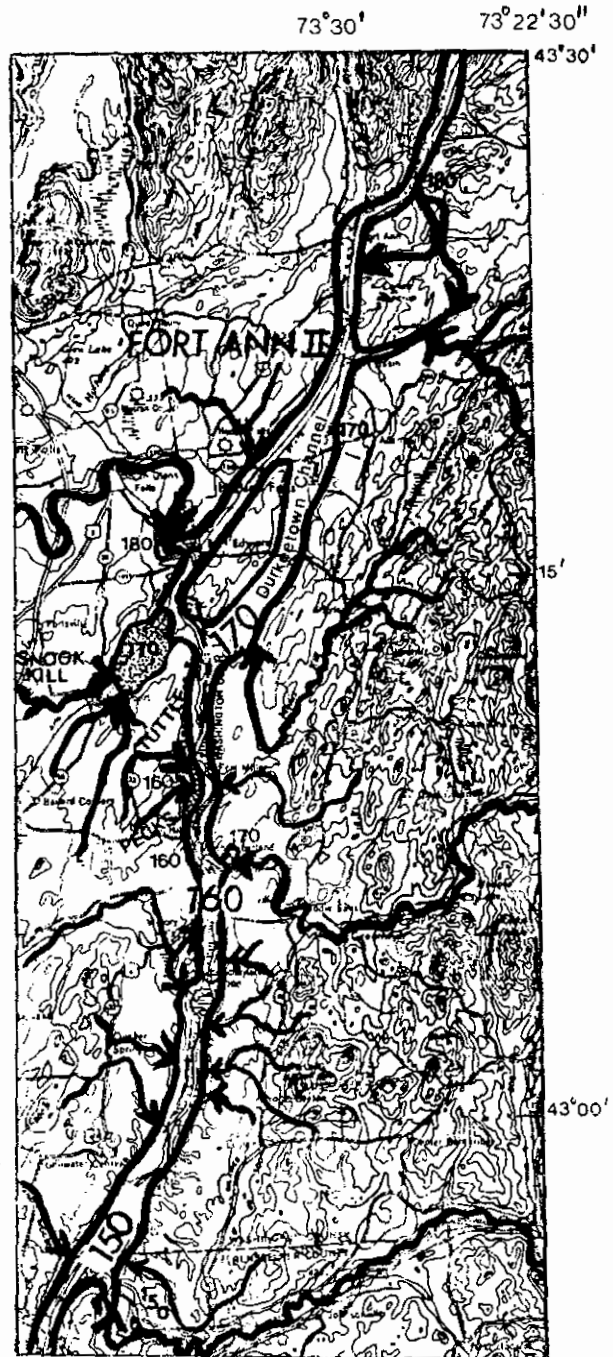


Figure 19: Fort Ann II

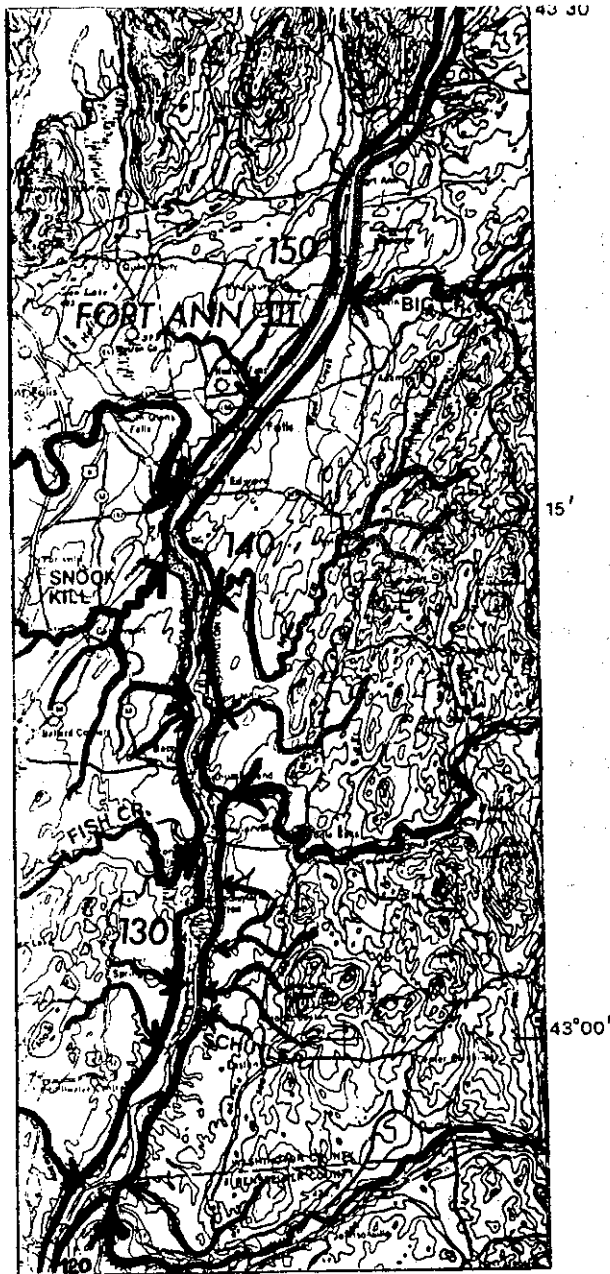


Figure 20: Fort Ann III

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ROAD LOG

Key: US = United States Routes E = East
 NY = New York State Routes W = West
 WC = Washington County Routes N = North
 JCN = Junction S = South

Miles Miles from
traveled last point

0.0	0.0	JCN NY 29 and US 4. Follow NY E across Hudson River. Ahead is the Batten Kill delta (310-320 ft Lake Quaker Springs).
0.9	0.9	NY 29 climbs the foreslope of the delta approximately along the axis of maximum thickness of gravel and sand. The banks along the road reveal the coarsening-up-stratigraphy.
2.2	1.3	JCN NY 29 and Old Schuylerville Road - turn left (N) onto Old Schuylerville Rd. Water well logs record up to 65 ft of deltaic gravel and sand in the area.
3.0	0.8	Hollingsworth-Vose landfill road - turn right.
3.5	0.5	<u>STOP 1</u> : Hollingsworth-Vose landfill. Deltaic topset and foreset beds of the Batten Kill's Quaker Springs delta. Return to JCN NY 29.
4.8	1.3	JCN NY 29 and Old Schuylerville Rd. - turn right (W) onto NY 29. If Hollingsworth-Vose landfill is inaccessible (very possible) continue 0.1 miles past Old Schuylerville Rd JCN to JCN NY 29 and Windy Hill Rd. Turn left (N) onto Windy Hill Rd and continue 0.8 miles to Tracy Bros. excavation where deltaic gravel and sand, lake clay, and lodgement till are exposed. Return to NY 29 and pick up road log at Wilbur Ave JCN.
4.8	0.05	JCN NY 29 and Wilbur Ave - turn S onto Wilbur Ave. Water well logs and exposures indicate deltaic sediment thins rapidly southward through 30 ft to less than 10 ft. Notice the clay dug up from

Option A

Miles Miles from
traveled last point

the pond farther along the road.

6.0 1.2 Groundwater flows out along the SG-clay contact at the heads of these gullies in Fryer Brook. We observed a pipe with a diameter just right for your arm at the head of one gully in 1977.

6.2 0.2 Notice the clay gullies as Wilbur Ave. crosses Fryer Brook.

7.1 0.9 We're traversing the dissected clay plain and delta sand is gone so we cross Flatly Brook and turn to the E.

7.5 0.4 Observe the shoreline profile of Lake Quaker Springs. No beach sediment is preserved.

7.9 0.4 JCN NY 40 - turn right (S) onto NY 40. Till on your left and the lake clay plain on your right with the tops of a few drumlins poking through.

8.7 0.8 JCN NY 40 and Burton Rd.- turn left (E) onto Burton Rd.

8.8 0.1 Meltwater flowed between Schuyler and Whelden mountains and deposited an outwash fan into Lake Albany. Minor exposures along the stream to your right (S) reveal gravel overlying clay and basal lodgement till.

10.0 1.2 JCN Burton Rd and Easton Station Rd Bear right onto Easton Station Rd.

11.2 1.2 JCN Easton Station Rd., Intervale Rd., and Water Rd. Turn left and continue on Easton Station Rd.

11.4 0.2 JCN Easton Station Rd. and WC 74 - turn right (S) onto WC 74

11.7 0.3 STOP 2: Archdale kame moraine. Exposure of clinoform sand and gravel beds in the moraine. Minor slumping of beds.

12.6 0.9 STOP 3: Nettle Bros Meats parking lot.

Miles Miles from
traveled last point

An excellent overview of the Archdale kame moraine deposited against the flank of Herrington Hill. This kame moraine band can be traced southward along the west side of Fly Swamp and across the valley at the southern end of the swamp where a head of outwash is recognized. Return N on WC 74.

16.9 4.3 JCN WC 74 and NY 372 - turn left onto NY 372.

17.1 0.2 Batten Kill crossing in Greenwich.

17.4 0.3 JCN NY 372 and NY 29 - turn right (E) on NY 29 and bear right past the traffic light to stay on NY 29.

20.2 2.8 Note the terrace-outwash gravel and sand we're crossing with thin till and bedrock uplands to the north. At small rises and around curves in NY 29 till and bedrock are often exposed where the upland thin till and bedrock topography protrudes through the gravel and sand.

21.4 1.2 Note the old excavation into a kame ahead on your left. This is associated with the Battenville moraine.

22.0 0.6 NY 29 used up the till and gravel of the Battenville moraine where the moraine crosses the valley in Battenville. There is hummocky kamic gravel and sand ahead on your left.

24.0 2.0 The fairly flat outwash and terrace gravel and sand we're crossing was deposited by meltwater from the ice margin.

24.4 0.4 STOP 4: Tracy Bros excavation. Horizontally-stratified gravel and sand overlies cross-stratified gravel and sand. Meltwater from the Carter Swamp ice margin deposited this deltaic sediment with sediment sources from the N and E. The Batten Kill has terraced the S end of this deposit.

<u>Miles</u>	<u>Miles from</u>	
<u>traveled</u>	<u>last point</u>	
24.5	0.1	JCN NY 29 and NY 338 - continue E on NY29,
25.2	0.7	East Greenwich Post Office - park here and walk 0.1 miles W on NY 29. <u>STOP 5:</u> Lodgement till exposure N side of NY 29. Both lowland and highland lodgement till facies are similar in Washington County. Why? In contrast, the lodgement till of the Adirondacks is quite different from the Hudson lowland till. Return W along NY 29.
25.9	0.7	JCN NY 29 and NY 338 - turn right (N) onto NY 338.
27.0	1.1	JCN NY 338 and Ferguson Rd. Continue on NY 338N. There is an excavation just to your right off of Ferguson Rd where a thick graded gravel bed was observed. How would you describe the sedimentary environment which produced this feature?
27.3	0.3	Notice the hummocky ice marginal sediment on your left.
27.4	0.1	Carter's Pond Nature Trail on your right.
27.6	0.2	Carter's Pond Wildlife Management Area. <u>Lunch Stop.</u>
29.0	1.4	JCN 338 and Bunker Hill Rd.- bear left on NY 338.
32.9	3.9	JCN NY 338 and NY 40 - turn right (N) onto NY 40.
33.5	0.6	Notice the smooth rounded drumlinoid topography developed in these thinly-veneered bedrock highlands.
36.6	3.1	JCN NY 40 and NY 197 - turn right and continue on NY 40. The village of Argyle sits atop a modest esker delta deposited into Lake Quaker Springs. Lake clay nearly buried the delta.
38.1	1.5	<u>STOP 6:</u> Esker gravel and lake clay. NY 40 rides atop this esker which fed the Argyle delta. Lacustrine clay has partly,

Miles Miles from
traveled last point

and in places completely, buried the esker gravel and sand. Observe the deformed clay and gravel beds here. Is the deformation consistent with what you'd expect from meltout of buried and/or adjacent ice or would you suggest a minor ice surge after deposition of the clay to account for the stratigraphy? Continue N on NY 40 along the crest of the esker.

39.5	1.4	JCN NY 40 and WC 45 in North Argyle - turn right (E) onto WC 45.
40.4	0.9	JCN WC 45 and Coach Rd. - bear left on combined WC 45-Coach Rd.
40.9	0.5	Turn left and continue on Coach Rd.
41.7	0.8	<u>STOP 7:</u> Harrington Farm excavations expose part of a meltwater sediment complex deposited at the base of the Taconic front along the eastern edge of Tamarack Swamp. The ice tongue responsible for the esker and delta through North Argyle and Argyle stagnated in the swamp. The major meltwater source for this sediment can be traced eastward along Safford Rd. to the town landfill. Coarser gravel and sand, horizontally-bedded and cross stratified, is exposed east of the road. The more distal portion of the delta fan exposed here contains laminated and ripple-laminated sand. A third excavation to the SW in the middle of the swamp contains the most distal and finest-grained sand, silt, and clay beds. The morphology of this last deposit suggests deposition in a tunnel or crevasse in the ice and indicates the rotting ice in Tamarack Swamp was inundated by Lake Quaker Springs.
44.8	3.1	JCN Coach Rd and NY 40 - turn right (N) onto NY 40.
47.5	2.7	JCN NY 40 and NY 149E - turn right (E) onto NY 149.
55.0	7.5	JCN NY 149 and NY 22 - turn left (N) onto NY 22.

<u>Miles traveled</u>	<u>Miles from last point</u>	
58.1	0.4	Turn right and cross the gray bridge over the Mettawee River.
58.2	0.1	Turn left onto Depot Rd.
58.4	0.2	Turn left at old depot onto Dump Rd (landfill entrance) <u>STOP 8:</u> The north-flowing Mettawee River deposited this outwash gravel and sand in a significant local impoundment. The exposed sand, silt, and clay beds accumulated in this Lake Granville whose elevation was approximately 420 ft. Clay is also preserved in the Mettawee valley from Middle Granville westward to Truthville with more silty sediment north of Raceville. There are some concretions in the clay here. Mildly deformed sediment particularly at the north end of the exposure probably resulted from meltout of abandoned ice in the lake. The Hudson ice lobe probably blocked the lower Mettawee valley at Truthville and contained Lake Granville. Retreat of this ice drained the lake and the Mettawee River deposited its delta into Lake Quaker Springs.
59.1	0.7	Retrace route to JCN NY 22A - turn right (W) onto NY 22.
62.8	3.7	JCN NY 22 and WC 17 - continue on NY 22 This surface is the top of the Mettawee delta.
63.4	0.6	JCN NY 22 and NY 40 - turn left (S) onto NY 40.
70.7	7.3	JCN NY 40 and NY 149W - turn right (W) onto NY 149.
73.4	2.7	<u>STOP 9:</u> Winchell channel overlook. Park as far off the road as possible and be careful of the traffic! The Winchell channel was one of three channels (the Durkeetown and Ft. Edward are the other two) which carried the outflow of Lake Fort Ann in the Champlain valley through the northern Hudson valley. The present surface stream, Big or Mill Creek, enters the channel from the south through a bed-

Miles traveled Miles from last point

rock gorge (seen as a notch in the distance) and meanders across the channel bottom to Smith's Basin. The channel bottom consists primarily of lake clay while clay, till, and bedrock are all exposed on the flanks of the Winchell channel. This pattern generally holds for the other two channels as well except there is considerably more eroded bedrock along the primary Ft. Edward channel.

76.3 2.9 JCN NY 149 and WC 43 - turn left (S) onto WC 43

79.0 2.7 JCN WC 43 and NY 196 - continue on WC43

84.2 5.2 JCN WC 43 and NY 197 - turn right (W) onto NY 197

86.6 2.4 We're crossing the bottom of the broad Durkeetown channel and will climb up its western escarpment. North-flowing Wood Creek and south-flowing Dead Creek are underfit streams in the bottom of the channel.

88.1 1.5 We're descending into the Ft. Edward channel.

88.6 0.5 Hudson-Champlain canal crossing - the canal follows the bottom of the Ft. Edward channel.

88.8 0.2 JCN NY 197 and US 4 - turn left (S) onto US 4.

101.8 13.0 JCN US 4 and NY 29 W - trip ends. Turn right onto NY 29 W to return to Skidmore campus.



THRUSTS, MELANGES, FOLDED THRUSTS AND DUPLEXES IN THE TACONIC FORELAND

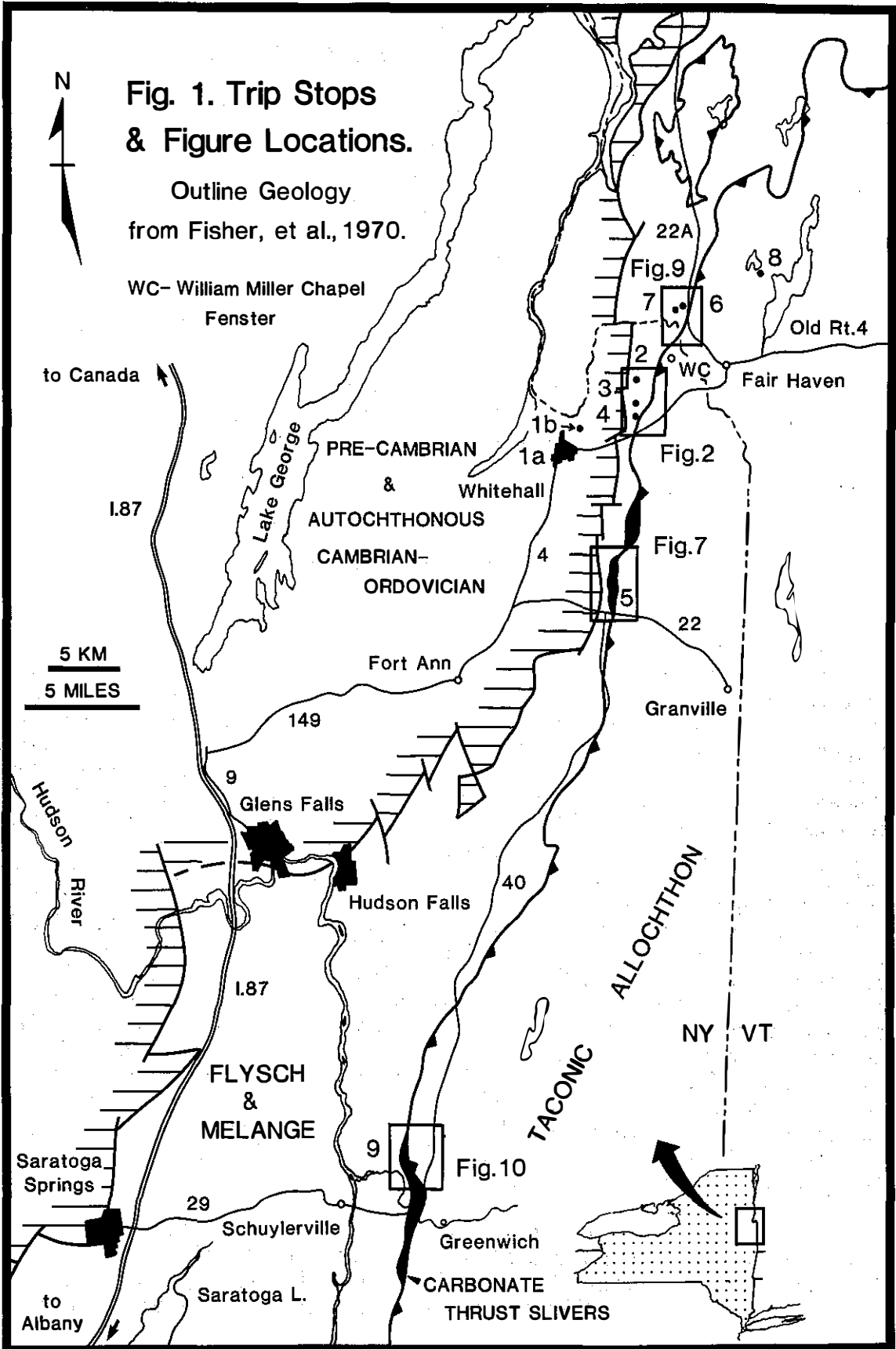
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INTRODUCTION

The western margin of the allochthonous clastic rocks of the Taconic Orogen has long been recognized as a fundamental tectonic and structural feature in the geology of eastern New York. First interpreted as the trace of a major unconformity (Emmons, 1844) between fossiliferous Cambrian and supposedly older and unfossiliferous "Taconic" rocks, it soon was correctly identified as the outcropping of a surface of regional overthrusting (Logan, 1861). "Logan's Line" placed earliest Cambrian through Ordovician deep-water sedimentary rocks above the late Cambrian and Ordovician shallow water clastic and carbonate "standard" sequence of eastern New York. The actual fault contact is generally between Taconic lithologies and medial Ordovician graywackes, siltstones and shales known as the Taconic flysch. The flysch was deposited during the emplacement of the Taconic Allochthon onto the North American continental shelf in a volcanic arc-continent collision (Chapple, 1973; 1979; Rowley and Kidd, 1981). The flysch-Allochthon contact is rarely exposed, although one quarry does cross the boundary and is described below. More commonly the western Taconic thrust is seen at exposures where the contact is with Ordovician shelf carbonates. These masses of shelf carbonate are demonstrably not rooted, vary in size from kilometers to pebbles, and have been variously interpreted as olistostromes (Zen, 1961; 1967; Rodgers and Fisher, 1969) and fault slivers (Walcott, 1888; Ruedemann, 1914; Zen, 1967; Bosworth, 1980; Bosworth and Vollmer, 1981).

Sparsity of outcrops throughout much of the Taconic region has discouraged detailed structural analysis of the Taconic boundary thrusts. The authors and coworkers have completed detailed maps (1:6,000 to 1:12,000 scale) of most of the Allochthon boundary from Schaghticoke, New York, to



its northern limits in western Vermont (Fig. 1). These efforts have revealed several localities where the geometric details of the Allochthon boundary can be discerned, and a corresponding emplacement history proposed. Most significantly, work by Rowley at the northern extremity of the Allochthon (Rowley, 1983a, 1983b) has shown that the present western thrust of the Taconics, referred to as the "Taconic Frontal Thrust" (Rowley and Kidd, 1982), is not the surface along which the continental rise rocks of the Taconics were thrust upon the continental shelf. The initial emplacement structure, the "Taconic Basal Thrust" (Rowley and Kidd, 1982), was subsequently folded during the main generation of folding in the Taconics, as originally suggested by Zen (1961, 1964 and 1967) and Rodgers (1952 and unpubl. ms). Further shortening of the orogen produced a new thrust system including the Taconic Frontal Thrust. These structures cut the folded Basal Thrust and dominate the geometric configuration of the western Taconics and adjacent flysch terrane. Details of the obduction-emplacement history of the Taconic Orogen are discussed elsewhere (Rowley and Kidd, 1981; Bosworth and Rowley, 1984).

Some previous workers have suggested that development of the Taconic Frontal Thrust, or in general the emplacement of the Taconic rocks onto the continental shelf, was a gravity-driven, soft-sediment event (Rodgers, 1951; Zen, 1967, 1972; Bird and Dewey, 1970; Potter, 1972). The presence of olistostromes west of the Allochthon boundary (within the Taconic melange) has long been cited as evidence in favor of this interpretation (Zen, 1967). Other workers have favored a hard-rock emplacement history based on structural characteristics of the Frontal Thrust fault zone (Ruedemann, 1914; Bosworth, 1980), the internal structure and stratigraphy of the Allochthon and adjacent Taconic flysch (Rowley et al., 1979; Rowley and Kidd, 1981; Bosworth and Vollmer, 1981), and through analogy with modern convergent orogens (Rowley, 1980; 1983a; Rowley and Kidd, 1981). This latter group has depicted the Frontal Thrust as part of a large scale imbricate thrust system (see cross-sections in Rowley et al., 1979, for example), similar to that envisioned for other external fold-thrust belts (Bally et al., 1966; Dahlstrom, 1970; Price and Mountjoy, 1970). Recent geophysical studies in the Taconide Zone of Quebec (Seguin, 1982) and western New England (Brown et al., 1983) support this view.

The purpose of this trip is to examine several relatively good exposure of structures immediately below, at and above the western boundary of the Taconic Allochthon. We will attempt to illustrate the following points or opinions:

1. Movement of the Taconic Allochthon across the coeval lower Paleozoic continental shelf took place through a complex, multi-staged series of events.
2. During emplacement on the continental shelf, both the Allochthon and underlying shelf material were well-indurated sedimentary rocks.
3. Small- and intermediate-scale structures produced during Allochthon emplacement are typical of hard-rock, foreland-climbing thrust systems in other well-studied orogens.

4. Much of the displacement during Taconian overthrusting occurred along melange zones at the base of the Allochthon and within the Taconic flysch, but that this was a decidedly brittle, "hard-rock" event involving incorporation (overriding and imbrication) of previously soft olistostromes. The presence of olistostromes of and in itself does not indicate gravity sliding or soft rock emplacement of the Allochthon.

The Taconic Mountains were one of the first North American orogenic belts to be studied, and this trip includes localities central to many of the "Taconic Controversies". We hope that participants will freely present their own ideas about the relationships we will see in the field, as structural geology is still really only in its infancy in the Taconics. For those following this trip on their own, we would ask that hammering at outcrops be kept to an absolute minimum (in many cases, it must be completely restrained from), and that due respect be given to the friendly and helpful land owners of the area.

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STOP DESCRIPTIONS

STOP 1. Gently-inclined strata of the autochthonous Paleozoic shelf sequence, not folded or thrust-faulted. Either 1a. or 1b. will be visited, depending on the size of the group and mode of transport. Locations shown on Fig. 1.

STOP 1a. Quartzites, arenites and dolomitic micrites of the Potsdam Formation (medial Cambrian). Williams Street in Whitehall.

Grenville gneisses are exposed in the riverbed directly below this outcrop; although the unconformity is not exposed here, it is elsewhere along strike north and south. The main purpose of this stop is to see that the strata in this outcrop show no prominent signs of deformation, being part of a gently east-dipping regional homocline. Although not a main focus of this field trip, the evidence for both shallow marine to beach facies (prominently cross-bedded and rippled clean arenites and quartzites) and lagoonal supratidal-flat facies (dolomitized micrites and thin shales, laminated in places with small stromatolites and locally with sand-filled vertical burrows) are well displayed here. Some layers, with pebbles of dolomitized micrite, may well be storm deposits.

STOP 1b. Limestones of the Whitehall Formation (late Cambrian). Sciota Road 1.6 miles from Whitehall.

These strata also are part of the regional gently east-dipping homocline of autochthonous shelf strata (typically 5-10 degrees east dip). No folds or cleavage are visible in these strata, and oolites which are locally abundant in some beds do not appear strained to any significant extent. Stylolites do occur in some beds but they are bedding-parallel, presumably compactional in origin. Laminated algal micrites, locally stromatolitic, can be seen, along with micrite edgewise breccias with oolites, all evidence of shallow marine to intertidal/supratidal facies. Nodular chert layers occur locally in this outcrop. It should be emphasized that most of

the volume of the pre-medial Ordovician autochthonous shelf sequence is dolostone. Limestones form an overall small proportion and this unit (part of the Whitehall Formation) is, after the medial Ordovician limestones, the most prominent limestone in the early Paleozoic shelf sequence. Dolostones occur at the east end of the quarry where the outcrop nears the road - we will not examine these.

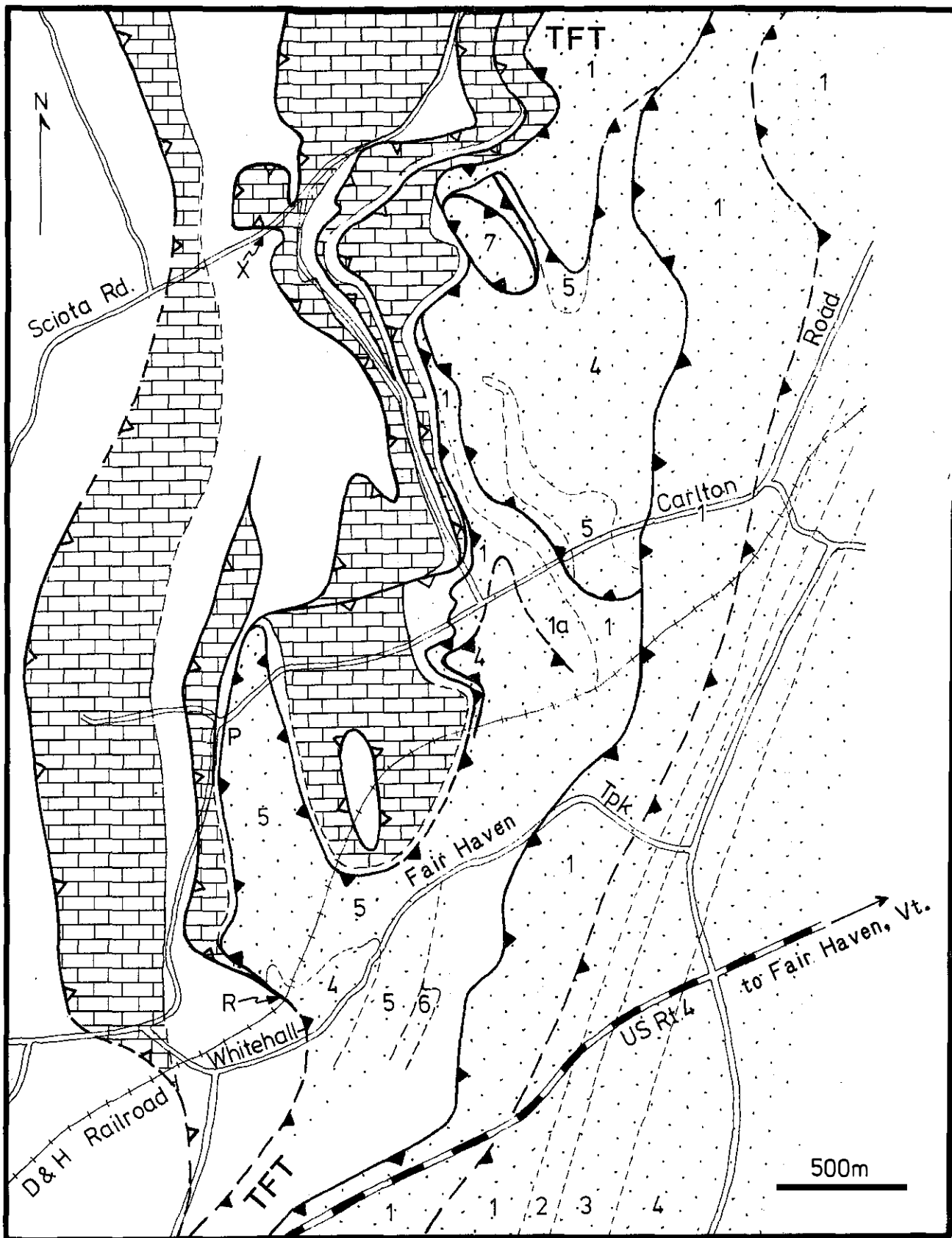
STOP 2. Thrust of medial Ordovician Isle la Motte (or Middlebury) limestones over medial Ordovician shaly melange. Locality indicated with an "X" on Fig. 2.

Carbonate exposures such as this one form lenticular belts bounded by medial Ordovician shales and fine-grained wackes (flysch) in a zone near this vicinity a few kilometers wide between the western edge of the Taconic Allochthon and the eastern edge of gently east-dipping, unfolded strata that rest with intact unconformable relationship on crystalline Grenville basement (such as those exposed at Stops 1a and b).

Where contacts are exposed, such as here, and Stops 6 and 9, evidence for faulted lower contacts of limestone over shale are seen. In particular, the underside of the limestone is coated with fibrous vein-type slickensides, the lineation plunging close to down-dip. Truncation of stratification in the limestone is seen locally. An abundance of veins in the limestone within about 50cm of the thrust surface suggests hydrofracturing and high fluid pressures during thrusting. A crude, lenticular cleavage in the underlying shales is deflected adjacent to the fault surface. A small horse of shale, isolated above the main thrust surface by a duplex mechanism, can be seen approximately half way along the exposure of the thrust (Fig. 3). Towards the western limit of the overlying carbonate sheet a detached sliver of carbonate about a meter long lies in the cleaved shale just below the prominent fault surface. This may be a structurally detached piece or (less likely because of its shape) an olistolith. Similar lozenge-shaped pieces of medium-grained graywacke up to about 1/2 m long occur sparingly in the phacoidally-cleaved shale in the

Fig. 2. Preliminary geological map of a portion of the western boundary of the Taconic Allochthon between Whitehall, N. Y., and Fairhaven, Vt. (see Fig. 1 for location). Brick pattern - carbonates, largely medial Ordovician limestones; blank areas - medial Ordovician shales, in part melange; dotted pattern - lithologies of the Taconic Allochthon: 1 - Bomoseen Formation; 1a - Truthville slate; 2 - Brown's Pond Formation; 3 - Middle Granville slate; 4 - Hatch Hill Formation; 5 - Poultney Formation; 6 - Mt. Merino Formation; 7 - Pawlet Formation. Thrusts shown with teeth in direction of dip; teeth black for thrusts cutting Taconic Allochthon lithologies, teeth open for other thrusts.

Roadcut exposing a thrust of limestone over shale (Stop 2) is marked by "X" (see Fig. 3 for detail). A folded pre-slaty cleavage thrust surface is exposed at Stop 3, Plude's Quarry (P) - see Fig. 4 for detail. The Taconic Frontal Thrust (TFT) is interpreted to pass at the base of this exposure. The easternmost thrust shown (with a dashed line) may be the one exposed, just to the east of the area of this map, at William Miller Chapel fenster (see Fig. 1). Location of the Delaware and Hudson railroad cut, Stop 4 (Fig. 5), given by "R". Mapping by C. Steinhardt (1982), Kidd, Bosworth, M. Ross, J. Piedra and D. Wolf (1983).



Washington Co. Rte. 11 Road Cut

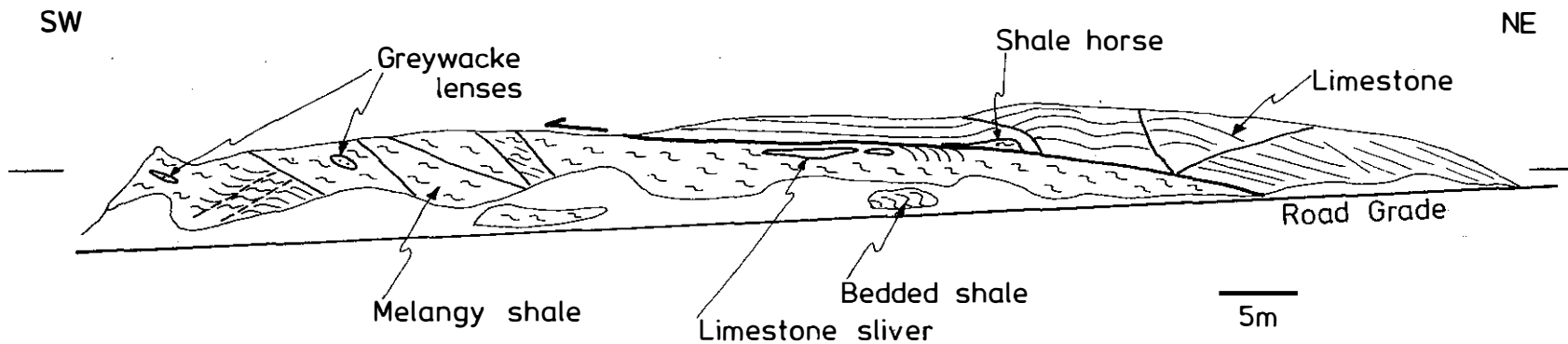


Fig. 3. Profile exposed in road cut on north side of Washington County Route 11, 0.35 mile east of intersection with Sciota Road. Location marked with "X" on Fig. 2. Medial Ordovician limestone thrust over medial Ordovician melangy shales.

western part of the cut. Slickensided surfaces suggest that they too are products of structural disruption ("structural slicing"), although an olistolithic origin cannot be discounted. The shale and siltstone is locally bedded, with minor folds in part of the outcrop. Most is pervasively disrupted by the phacoidal cleavage whose microstructural character, with abundant evidence for shear offsets, is clearly related to faulting (Bosworth and Vollmer, 1981; Bosworth, 1982,1984). This carbonate and other exposures like it are shown on the New York State geological map and by Fisher (1985) as giant olistolithic blocks. We find this interpretation of the outcrops to be unconvincing and prefer an interpretation, as shown on Fig. 2, where the carbonates and stratigraphically overlying shales form thin thrust sheets accreted beneath the Taconic Allochthon. Demonstrable tight folds and internal duplex faults within these carbonate sheets account for the many places where stratigraphic continuity is disrupted within them.

STOP 3. Pre- to syn-cleavage thrust of Poultney Formation over gray slates, above Taconic Frontal Thrust. Locality marked "P" on Fig. 2.

Plude's Quarry (Fig. 4) provides one of the few known exposures of Taconic continental rise rocks lying directly upon the underlying melange/flysch sequence. Several complexities of Taconic thrusting are evident at this stop. Along Carleton Road the shales and graywackes of the Taconic flysch are broken into a melange fabric, that grades up into the quarry with progressively less disruption, until a planar slaty cleavage is found. This is the Taconic Frontal Thrust, and can be mapped as in Fig. 2. Within the quarry a second, earlier fault is present, separating easily identified Lower Poultney slates and thin arenites from an underlying gray slate. The regional slaty cleavage cuts the fault, suggesting that this structure may be of the same generation as Rowley and Kidd's (1982) "Taconic Basal Thrust". The gray slates are interpreted to be a unit within the Middle Ordovician Taconic Flysch (allochthonous? parautochthonous?), and hence the fault is inferred to be a thrust.

STOP 4. Delaware and Hudson Railroad cut 300m NE of crossing Whitehall-Fairhaven Turnpike. Locality shown with "R" on Fig. 2.

At the east end of the cut (Fig. 5), both sides expose thinly laminated, brown fine-grained arenites in dark slate belonging to the upper Hatch Hill or lowermost Poultney Formations (Cambrian - earliest Ordovician) of the Taconic Allochthon. These are in contact across a steep fault with thicker bedded coarse dolomitic (locally calcareous) quartz arenites and quartzites in black slate of the middle to lower Hatch Hill Formation (early Cambrian or older). At the western end of the cut, the last exposure contains a fold in Hatch Hill slate and arenites such that bedding surfaces in the slate form the face of the exposure on one limb of the synformal fold. This western end is close to but not quite at the Frontal Thrust seen at Stop 3. On the hill to the north a southward-thinning thrust sheet of shelf limestones occurs between shaly melange below and Taconic rocks above, such as are seen in this cut and at Stop 3. A unit of shaly melange up to a few meters thick occurs between the limestone and the Taconic rocks, and was seen at Stop 3. The western part of this exposure, with the complex slicing and phacoidal cleavage in the black argillite, can be regarded as transitional, in a structural sense, to the melange. The

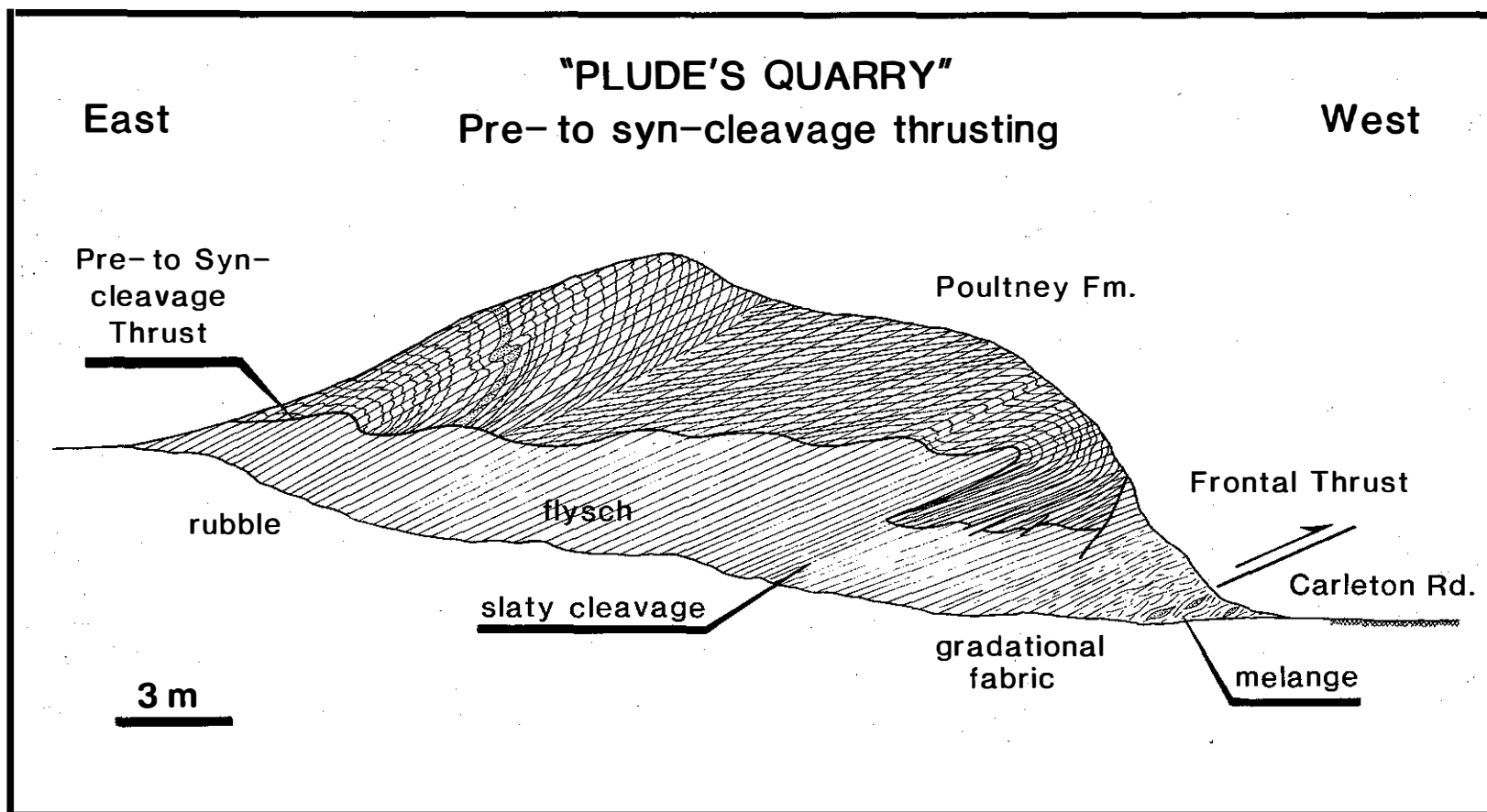


Fig. 4. Exposed pre-slate cleavage thrust in quarry face (Plude's Quarry, Stop 3; location marked "P" on Fig. 2). Allochthonous Poultney Formation rocks were thrust over gray shales and then folded and cleaved. Thrusting and folding were apparently in part synchronous, as the amplitude of the fold in the thrust surface in the easternmost anticline is less than the amplitude in the folded Poultney. The gray slates most closely resemble a flysch lithology, although whether it is allochthonous or parautochthonous flysch cannot be demonstrated without biostratigraphic control.

disposition of the Hatch Hill and Bomoseen can be interpreted as an earlier thrust that has been folded and cut by younger, more steeply inclined thrust faults. Fig. 2 shows that the occurrence of a Bomoseen-derived slice immediately above the Taconic Frontal Thrust, followed by a Hatch Hill/Poultney-derived slice, is characteristic of much of the Taconic area bounded by the folded thrust that occurs near the Allochthon boundary in this region.

Structures in the railroad cut that we connect with the emplacement of the thrust sheet are fault-related features, particularly slickensides, summarized in Fig. 6. A Riedel and anti-Riedel fault set are interpreted to be present and are consistent with thrust movement towards the west-northwest. We emphasize the brittle nature of this deformation.

STOP 5. Parautochthonous flysch in contact with autochthonous(?) shelf carbonates. Lunch stop; location given in Fig. 7.

The Mettawee River here provides a superb series of exposures that cross from autochthonous(?) shelf carbonates (where we will stop for lunch), through alternating zones of flysch and melange, to a large sliver of Chazyan carbonate, and on into allochthonous Taconic lithologies (Fig. 7). The only area that is poorly exposed in the river is the eastern edge of the carbonate sliver, but mapping demonstrates that this fault contact (the Taconic Frontal Thrust) cuts obliquely across Taconic stratigraphy and large-scale fold axes, and is therefore a post-slaty cleavage generation structure (Figs. 7,8).

As at Stop 2, some workers are of the opinion that the allochthonous carbonate at this locality (D.W.Fisher, pers. comm.,1983) and along the western edge of the Allochthon in general (J.Rodgers, pers. comm., 1983; Rodgers and Fisher, 1969) is better interpreted as blocks-in-shale (i.e., olistoliths) than as coherent fault slivers. This locality provides an excellent means to test these two hypotheses. The carbonate/melange contact can be walked from point "X" to point "Y" (Fig. 7) with little difficulty (after wading across the Mettawee....access at "Y" is limited by buckshot). The carbonate is seen to be continuous, essentially unbroken along strike, with internal fold axes approximately parallel to the general contact trend (see Selleck and Bosworth, 1985, Plate 1A). The carbonate must be in the form of a large sheet, or composite sheet, which could be called a single "block". Minor disruption near its margins is undoubtedly present, but the structural style is dominantly detachment of underlying autochthonous shelf rocks and their imbrication at the base of the advancing allochthonous thrust pile. It is misleading to describe the geometry of the large carbonate bodies along the western edge of the Allochthon as "blocks-in-shale", and it is very unlikely that they arose as sedimentary slump features (further discussed in Rowley and Kidd, 1982).

STOP 6. Imbricated medial Ordovician carbonates, shales and melange just below the Taconic Frontal Thrust. Vermont Route 22A 6.5 km north of Fair Haven. Location shown with arrowhead on Fig. 9.

The part of this roadcut to be examined is illustrated in Fig. 9, and consists of the outcrop opposite the parking area and its continuation to the north. A thrust-repeated section of medial Ordovician strata is discernable from medium-bedded limestone (fossiliferous calcarenites to calcisiltites) without shale - Orwell Limestone, passing up abruptly into

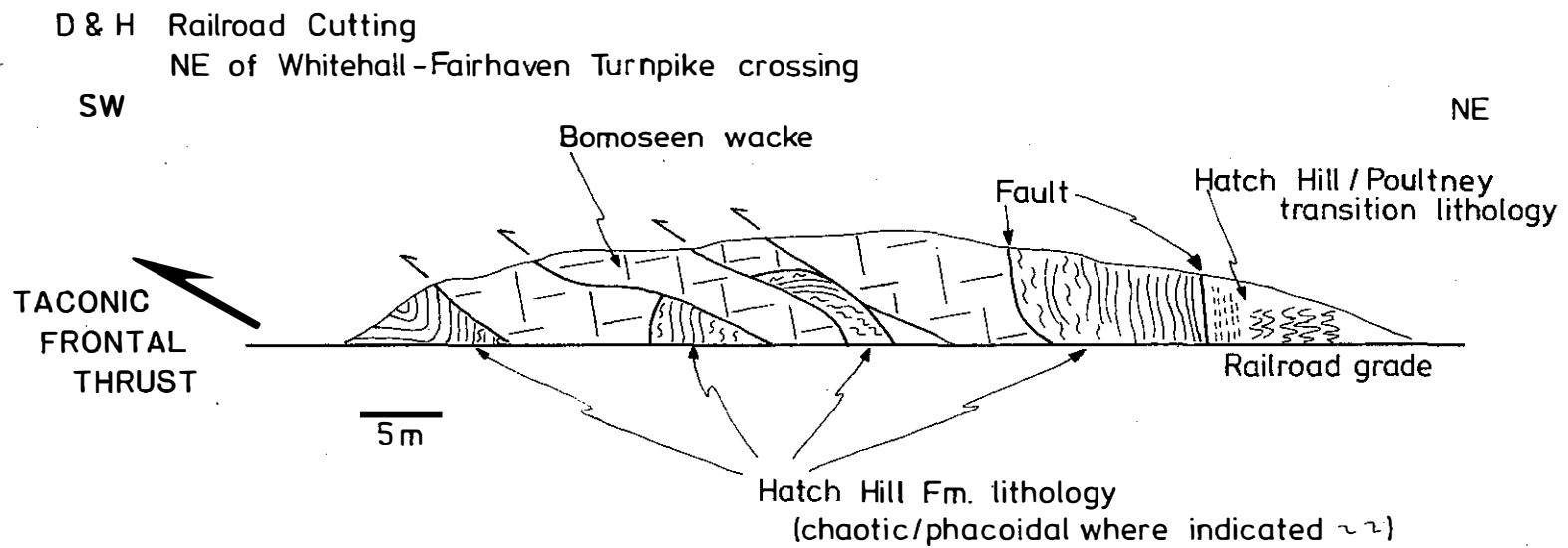


Fig. 5. Delaware and Hudson Railroad cut adjacent to the Frontal Thrust fault zone (Stop 4). Location of railroad track is given in Fig. 2; cut location indicated by "R".

thin-bedded limestones (micrites) interbedded with dark shale - Glens Falls Limestone, overlain by dark shale, in part melange - here referred to as Hortonville shale (and the melange perhaps as Forbes Hill "conglomerate"). It is important to recognize that the dark shale, in the first instance, is a stratigraphic member of this succession, just as it is in the autochthon to the west (e.g., in the Mohawk Valley). That some of it has been structurally damaged by the imbrication and duplication of the sequence is a secondary effect, reflected in the lenticular (phacoidal) cleavage visible especially in the shale closest to the base of the succeeding limestone. Two of the eight sections lack the basal Orwell Limestone, probably because of local ramping of the active thrust, or original irregularities in the depositional arrangement. It is not valid, in our view, to regard this exposure as "all melange" with blocks of limestone floating in shale. Rather, it is a thrust-imbricated repeated lithic sequence, probably forming a thrust "duplex" above more extensive shaly melange, not containing limestone clasts, that is exposed on the slope to the west of the parking lot and in the separate road cut on 22A about 100 m north of this outcrop. The duplex is below the Frontal Thrust of the Taconic Allochthon which comes to the surface about 50 m east of this road cut; wackes of the Bomoseen Formation of the Allochthon form the prominent topographic feature of "the Great Ledge" visible to the east from the parking lot. More extensive massive limestones (Orwell, and perhaps Middlebury Limestone as well) that form road cuts along 22A just to the south are thought to be larger slices in the duplex zone. Noteworthy in the narrow (less than 1 m) zones of shaly melange beneath each slice of limestone in the cut are a few blocks and cobbles of green micaceous arenite identical to the Bomoseen Formation of the Allochthon. The largest of these (approx. 1 m across) occurs at the very northern end of the outcrop, but other smaller ones occur within the outcrop near 30-40 m on the diagram. These we do interpret as olistolithic clasts shed from the front of the Taconic thrust sheet during its motion, and they require that the active thrust outcropped on the sea-floor, at a deep-sea trench-type feature. A similar, but larger (several m across) olistolith of Bomoseen wacke occurs in the outcrop of melange to the north. It is our observation, however, that there is a limit of a few meters to the size of these blocks that are clearly identifiable as olistoliths. Truncated bedding, slickensides and other features characteristic of ramp-flat thrust geometry can be seen in this outcrop. The present attitude inferred for the Taconic Frontal Thrust (about 10° east dip) and the steep east dip of these limestone-shale imbricate slices are consistent with their identification as duplex structures. Their attitude is not consistent with a model of tabular olistolithic slabs lying in the bedding orientation.

STOP 7. Boss Hogg's Quarry. Marked "H" on Fig. 9. Permission must be obtained from the owner to visit this locality.

The quarry exposes part of the early Ordovician Providence Island Formation, mainly dolostones with some limestone, not far below the overlying Middle Ordovician limestones (Middlebury) that outcrop to the east (see Fig. 9). The purpose of this stop is to see the structural condition of carbonates within the areally extensive thrust sheets that exist at this latitude between the Frontal Thrust of the Taconic Allochthon and the autochthonous shelf strata. On the south side of the entrance to

6a

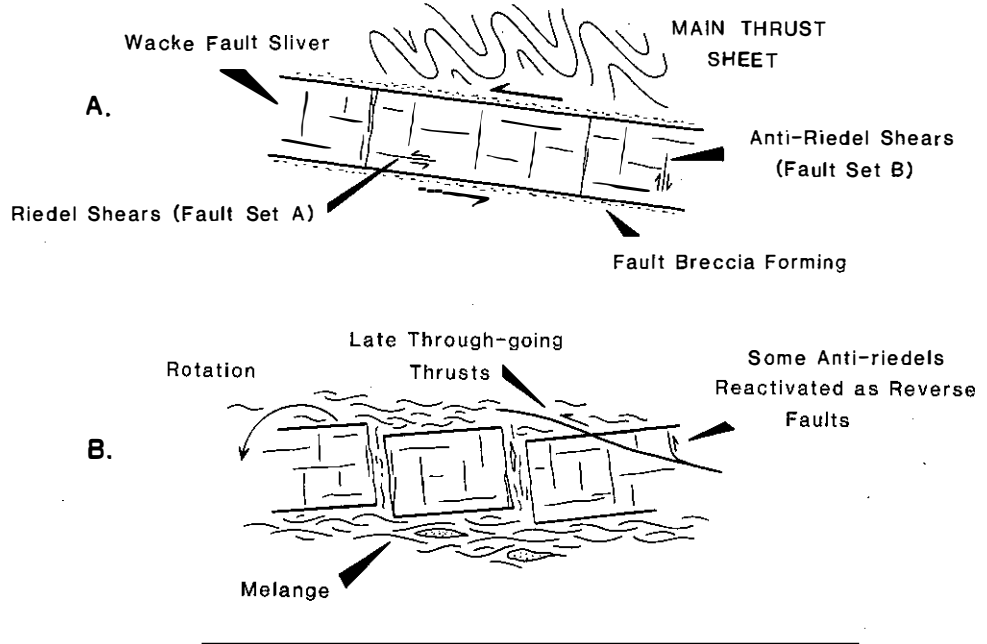
SCHMATIC STRUCTURAL EVOLUTION

MASSIVE WACKE BLOCK

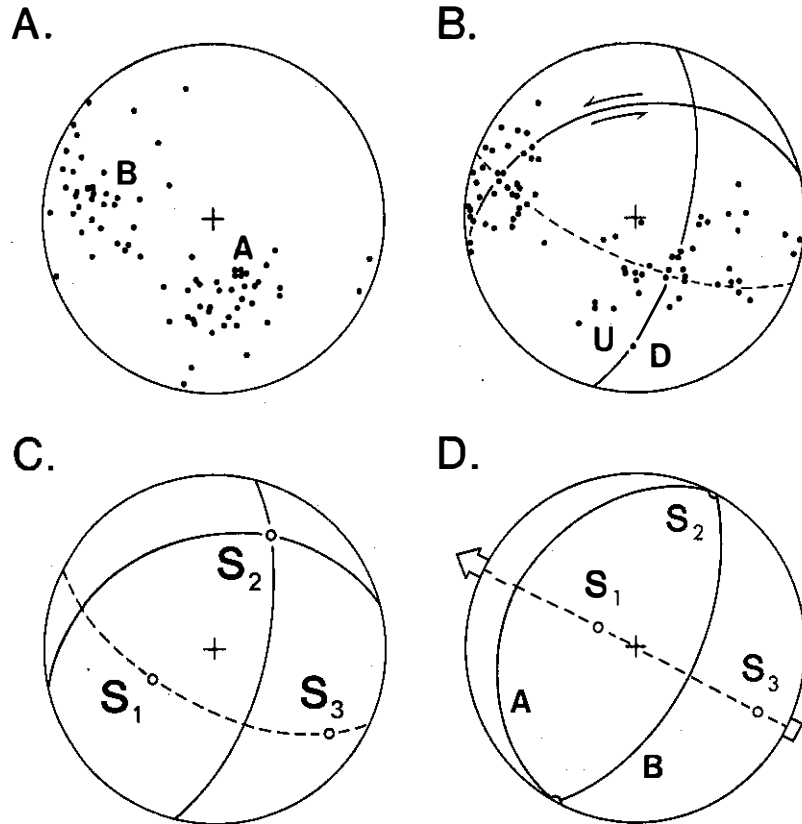
DELAWARE & HUDSON RR CUT

SW

NE



6b



the quarry a close synformal fold displays well-developed solution cleavage and marked changes in thickness from the short, west-dipping limb to the long, east-dipping limb due to more homogeneously distributed ductile shape change. A complementary antiform is exposed on the north side of the entrance linked to a synform that trends along the northeast face of the quarry. A wrench fault passing through the quarry entrance must offset the fold hinges in a left-lateral sense. The contrast between the substantial ductile strain shown in this outcrop and the lack of such features at Stop 1b in the autochthon is a reflection of the thrust translation of these carbonates and deformation during active movement on lower thrusts. The cleavage at this stop is roughly parallel with that in Taconic rocks exposed to the east. However, this does not necessarily make the cleavages the same age; evidence exists to suggest that they are not, and that the Taconic rocks were cleaved and folded before emplacement over this portion of the shelf carbonate terrane.

STOP 8. Scotch Hill syncline at Glen Lake. Permission must be obtained from the owner (in the house across the road). NO HAMMERS ALLOWED. Location shown on Fig. 1.

This outcrop exposes early Ordovician strata of the Poultney Formation, probably about the same age as the carbonates of Stop 7, but a very different facies deposited in deep marine conditions on the continental

Fig. 6a. Schematic structural evolution inferred for a wacke block or sliver exposed in the Taconic Frontal Thrust fault zone at the Delaware and Hudson Railroad cut (Fig. 5).

A. block disrupted from coherent allochthonous mass, overridden and attached to base of Allochthon. Conjugate shear fractures initiated at 30 to 45° from incremental shortening direction.

B. rotation of fractures as block begins to break up and become incorporated into melange.

Fig. 6b. Stereograms of structural data collected in large wacke block at the Delaware and Hudson Railroad cut illustrated in Fig. 5. Lower hemisphere, equal area projections.

A. poles to small-scale faults (n=76). Faults in set "A" are north-dipping, left lateral, strike-slip faults; those in set "B" are east-dipping normal faults.

B. striations on small-scale faults (n=83; a few faults possessed multiple slip directions). Great circles give average fault orientations. Fault striations cluster at points roughly 90° from the intersections of fault sets A and B, the case to be expected if plane strain is dominant. Dashed great circle is plane perpendicular to A-B intersection.

C. interpretation of principal shortening directions given average fault orientations, slip directions and slip senses of shear.

D. rotation of S_2 direction to the horizontal. The trends of S_1 and S_2 now parallel the inferred west-northwest transport direction of the Taconic Allochthon. Fault set A corresponds to Riedel shear orientations, and fault set B to anti-Riedel orientations.

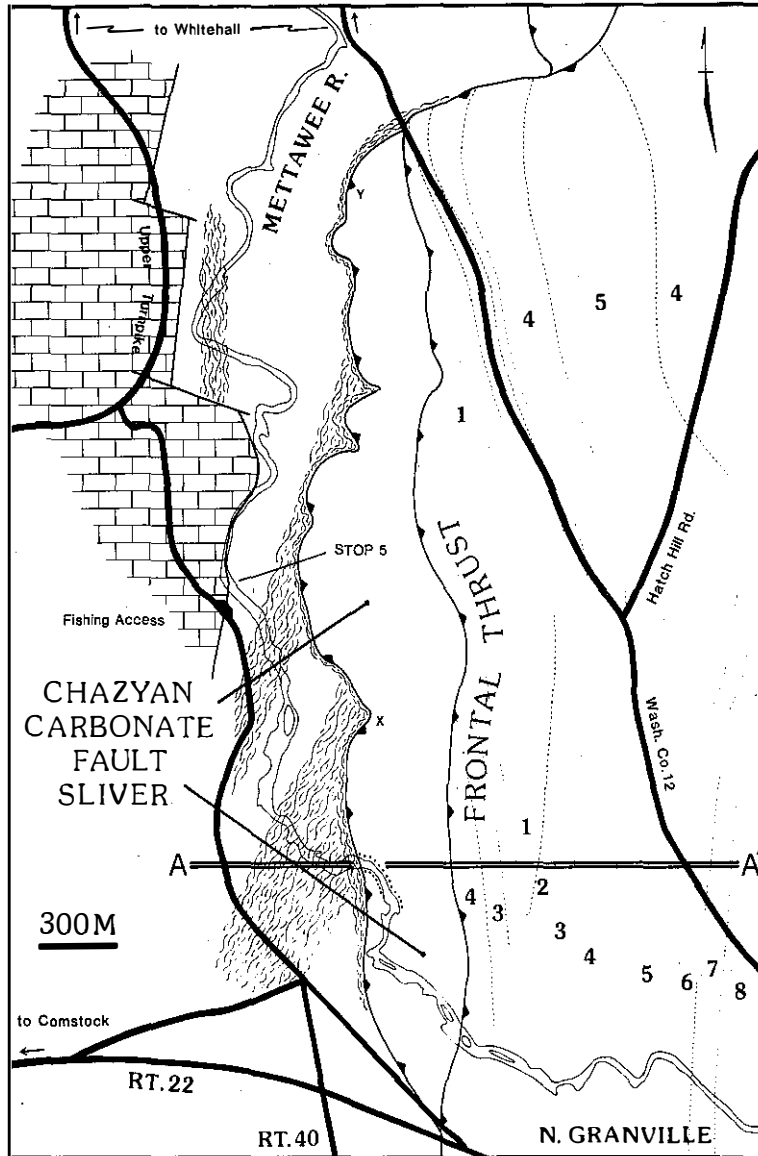
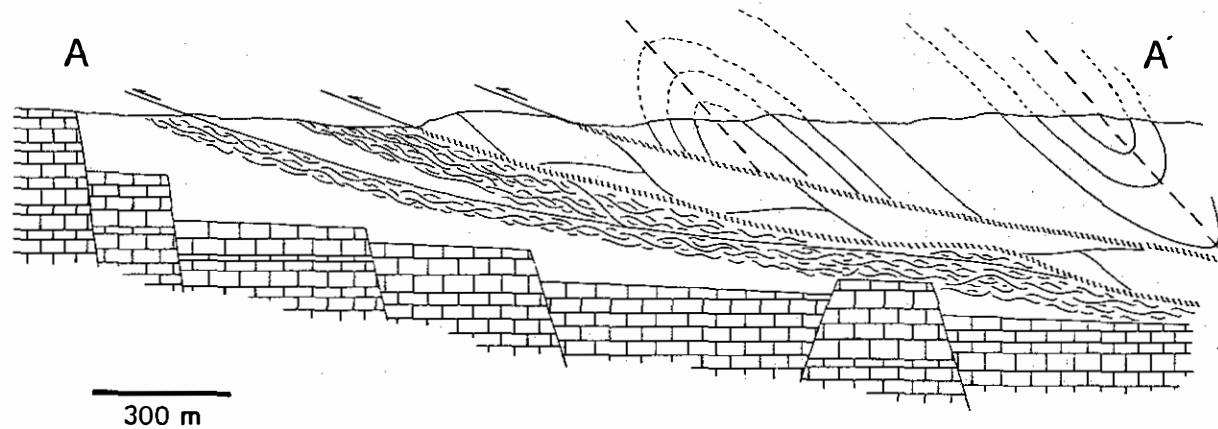


Fig. 7. Geological map of the Taconic Allochthon boundary in the vicinity of North Granville, N.Y. A large sliver of Chazyan carbonate rock lies at the contact between allochthonous Taconic sequence rocks (numbered 1-8) and parautochthonous flysch (unornamented) and melange (scaly pattern). Two generations of melange are observed in this area, one developed along the base of the carbonate fault sliver and one imbricated within the flysch. Structural relationships at the contact between autochthonous(?) shelf carbonates (limestone pattern) and the flysch are poorly constrained but believed to include both normal fault, depositional and probably thrust contacts. 1 = Bomoseen Wacke and Truthville Slate; 2 = Browns Pond Fm.; 3 = Middle Granville Slate; 4 = Hatch Hill Fm.; 5 = Poultney Fm.; 6 = Indian River Slate; 7 = Mt. Merino Fm.; 8 = Pawlet Fm. (from Selleck and Bosworth, 1985).

INTERPRETIVE
 CROSS-SECTION THROUGH THE TACONIC
 ALLOCHTHON BOUNDARY
 FROM A TO A'
 no vertical exaggeration



135






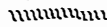
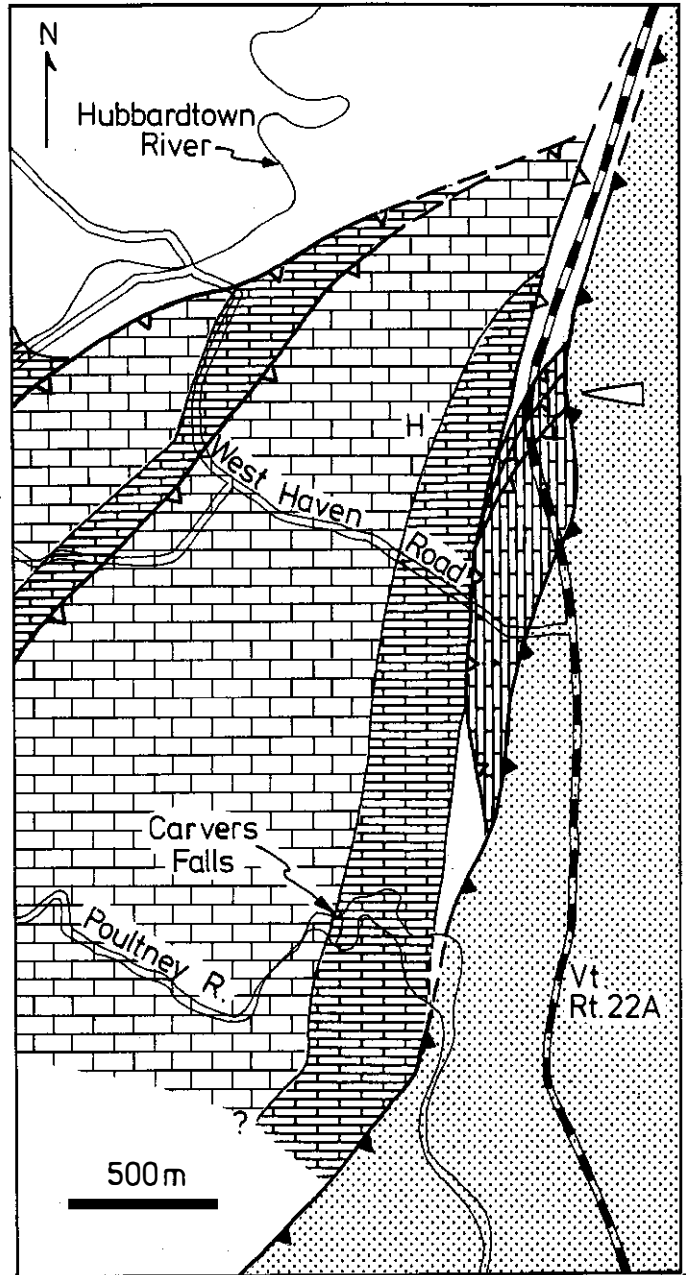
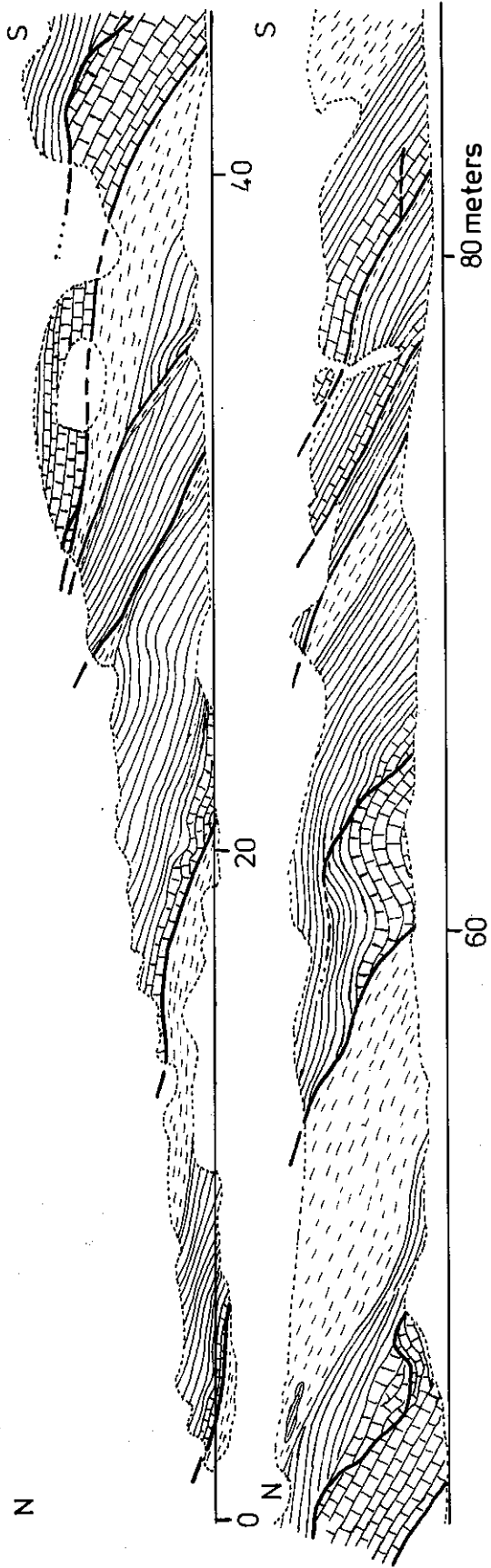
-  Allochthonous Taconic Units
-  Imbricated Slivers of Shelf Carbonate
-  Melange
-  Flysch
-  Autochthonous? Shelf Carbonate
-  Shear Zones & thin Melange

Fig. 8. Interpretive cross-section from A to A' on Fig. 7. The internal structure of the large carbonate fault sliver is schematically shown to consist of fault-bounded packets, probably defining a duplex structure of some form (internal folding of the carbonate is not diagrammed for clarity; from Selleck and Bosworth, 1985).



rise. These rocks consist of green mudrock (slate) alternating with thinner laminated layers of fine sand to silt size arenites and quartzites that are interpreted as contourite deposits, and black/gray mudrock (slate) laminae. The black mudrock layers are probably pelagic; the green are likely mud contourites. The syncline expose here is the single major hinge of a fold that is in a set with wavelengths of the order of 1 to 3 km and amplitudes of similar amount. The folds are tight to near isoclinal in form. This outcrop does not give the impression that the folds are this tight since the full transition to the fold limb bedding attitudes, particularly on the overturned limb, are not seen in this exposure. This particular fold can be traced north for 3 km and south for 8 km from this place; another single fold in this set in the northern Taconics can be traced for at least 50 km along its axis, characteristic of their subhorizontal to gentle plunges. The overturned nature of this fold, with its moderately east-dipping axial surface and near-axial planar cleavage is also typical of the structure of the low Taconics (Giddings Brook Slice). In detail, small parasitic folds in the quartzites in this outcrop can be seen to be transected by the slaty cleavage, suggesting that buckling of thin layers in response to shortening took place, as is usually the case, before thicker composite layers that generate longer wavelength folds. Thus the cleavage may be axial planar to the large-scale folds but not to the smaller ones. Examples of cleavage refraction can also be seen, and cleavage parallel quartz veins (? post-cleavage) are also present. We emphasize the coherent ductile deformation seen in this outcrop, characteristic of all the western Taconics in the northern part of the Allochthon. In our view it does not support the idea of the emplacement of the Allochthon as a gravity slide of unconsolidated sediments. Comparison of structures here with those in the thrust carbonates (Stop 7) and at the western edge of the Allochthon (Stop 3) are consistent only with thrust emplacement of coherent, consolidated rock, undergoing related ductile deformation (folding and cleavage formation) at different times in different places during the overall assembly of the thrust sheets.

Fig. 9. Profile of roadcut (Stop 6) on east side of Vermont Route 22A, 6.5 km north of Fair Haven, Vt. (see Fig. 1 for general location). Roadcut shows imbricated sequence of middle Ordovician Orwell Limestone (bricks), overlain by Glens Falls Limestone (lines), overlain by black shale and melange (Hortonville shale/Forbes Hill conglomerate - dashes). Two profiles shown overlap - the upper one continues to the right in the lower one. Major thrusts shown by thick lines; other faults not emphasized. Line with meter scale is road surface, which slopes to the north, and is not flat as implied by the diagram. Dips shown are those exposed at the outcrop surface - true dips are considerably steeper, typically 50-80° E. Location of roadcut (Stop 6) shown by arrowhead on map. The imbricated zone is shown schematically on the map.

Map units: coarse bricks - Providence Island dolostones; fine horizontal bricks - Middlebury limestone; fine vertical bricks - imbricated Orwell and Glens Falls limestones; blank - Hortonville shale and Forbes Hill conglomerate (melange). Taconic Frontal Thrust shown with black teeth; other thrusts with open teeth. Location of Stop 7 shown by letter "H". Mapping by C. Steinhardt.

STOP 9. Shelf carbonate duplex beneath the Taconic Frontal Thrust at Bald Mountain, N.Y. Location given in Figs. 1 and 10.

Bald Mtn. has been a perennial favorite for stops in field guide books of eastern New York, and several excellent descriptions of the locality are available in the older literature (Walcott, 1888; Ruedemann, 1914). More recent discussions can be found in Platt (1960), Sanders, *et al.* (1961), Zen (1967), Bosworth (1980) and Rowley and Kidd (1982).

We have intentionally placed the Bald Mtn. quarries at the end of our trip, despite their proximity to Saratoga Springs. We have been emphasizing processes related to frontal imbrication, multiple generations of thrusting and the formation of duplexes throughout the day. We feel that the examples we have presented are fairly convincing. Bald Mtn., however, is shrouded with historical overtones, and is also exceedingly complex. The general picture is quite clear: the uppermost portions of the quarries are composed of allochthonous Taconic lithologies, these overly a thin zone of phacoidally cleaved shales, which in turn overly discontinuous masses of shelf carbonate (some quite large) and more phacoidally cleaved shale. But the details are not so clear. Are the carbonate blocks fault slivers, or are they olistoliths within a large-scale sedimentary slump mass, subsequently overridden by the Taconic thrust sheets (Rodgers, 1952; Rodgers and Fisher, 1969)?

We recognize some internal order in the disposition of lithologies in the area of the Bald Mtn. carbonates, with similar lithologies aligned along strike (Fig. 10). Several of the carbonate blocks are probably hundreds of meters in length, not unlike the Chazyan sliver on the Mettawee River (Stop 5). As at Stops 5 and 6, small rounded cobbles of limestone (in this case) within the phacoidally cleaved shale zones may in fact be olistoliths, probably derived at subaqueously emergent fault scarps from the main masses of carbonate themselves (Rowley and Kidd, 1982; Bosworth and Vollmer, 1981). However, we again feel that the structure at Bald Mtn. can reasonably be interpreted as a fault duplex (Fig. 11), as was first proposed by Ruedemann (1932, p. 134). We encourage all participants to share their thoughts with the rest of the group!

A regional compilation of presently identified structures believed to be associated with the Taconic Frontal Thrust System (youngest Taconian deformation) is presented in Fig. 12.

Acknowledgements - Numerous individuals have contributed to recent structural studies of the western Taconics, and we would like to especially acknowledge collaboration with D.B. Rowley, F.W. Vollmer, S. Chisick and B. Selleck.

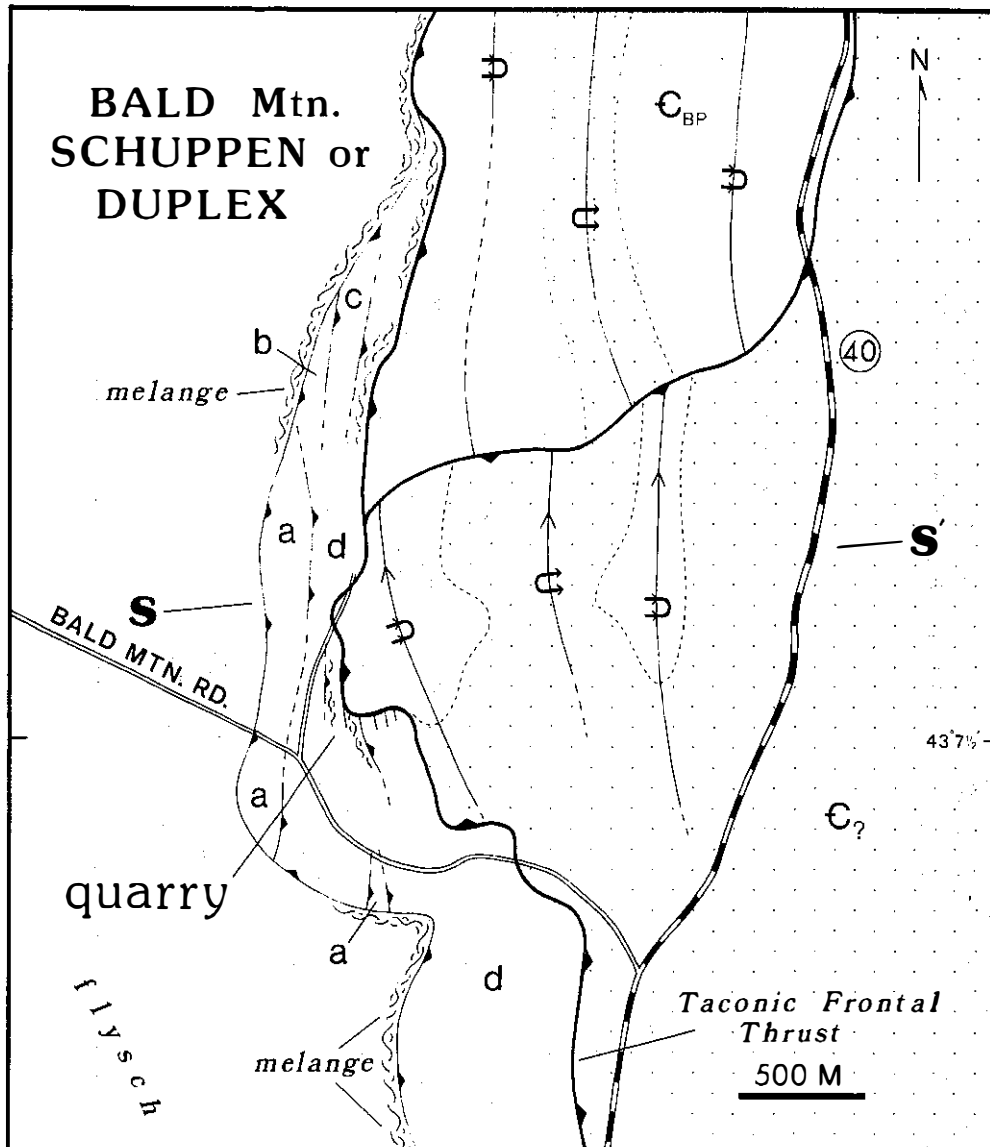


Fig. 10. Geological map of the Bald Mtn. "schuppen" or fault duplex, Washington Co., N.Y. (see Fig. 1 for location). $\epsilon_?$ = Bomoseen Wacke and Truthville Slate; ϵ_{BP} = Browns Pond and probable Hatch Hill Fms. Incomplete exposure prevents interpretation of the entire structure within the duplex itself. Duplex lithologies are identified as: a = hard quartz arenites and mica-speckled quartz wackes (in part possibly Bomoseen lithologies; Elam, 1960); b = limestone and dolostone pebble/cobble conglomerate with sandy dolomitic matrix (Rysedorph Hill Conglomerate; Ruedemann, 1914); c = thin-bedded limestone and dark gray shale; d = undifferentiated limestones and lesser dolostones, often thick-bedded or massive. Numerous melange zones are present within the duplex (anastomosing pattern) and phacoidally cleaved shale is present between most individual horses. Geology modified from Platt, 1960, and Bosworth, 1980.

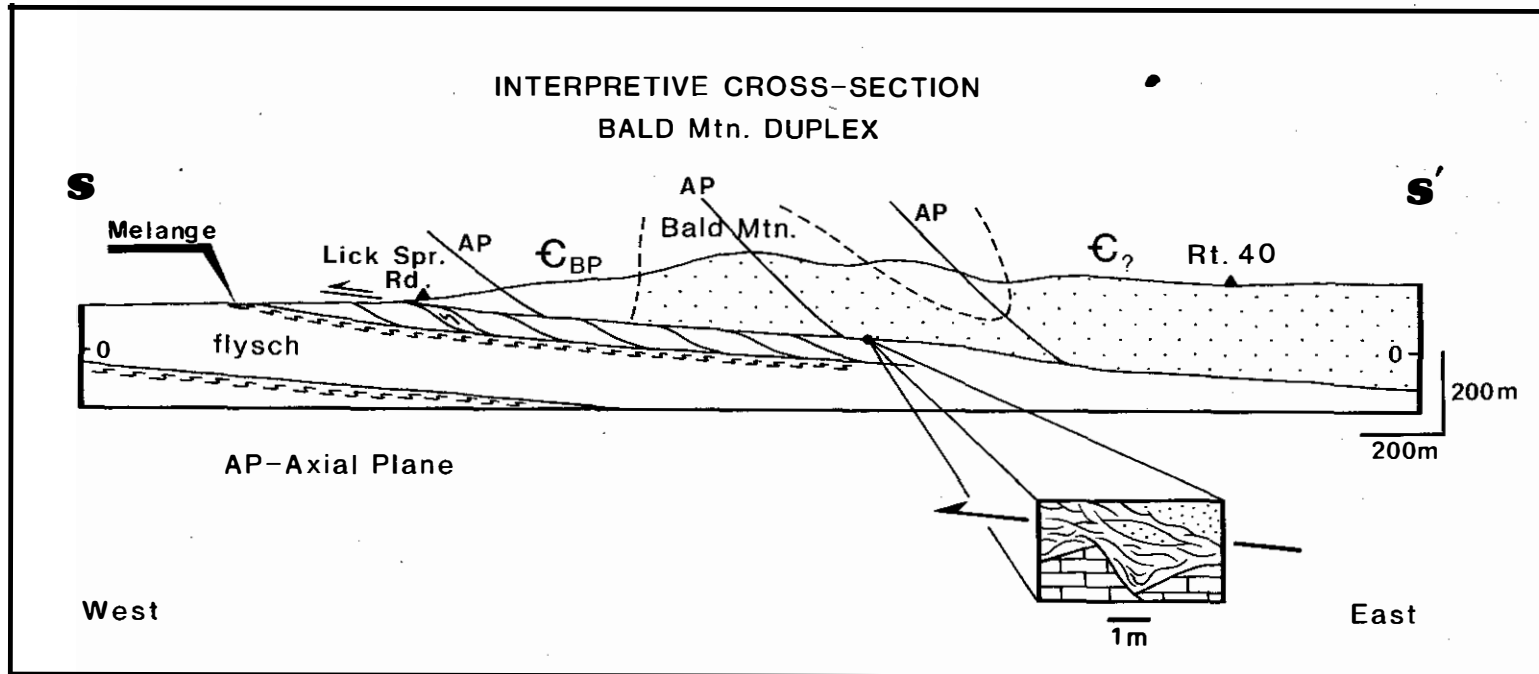


Fig. 11. Interpretive cross-section through the Bald Mtn. fault duplex (Fig. 10). Formation symbols are the same as in Fig. 10. No vertical exaggeration. Inset illustrates the complex nature of the duplex roof fault (fault zone), as exposed at the quarries (Stop 9).

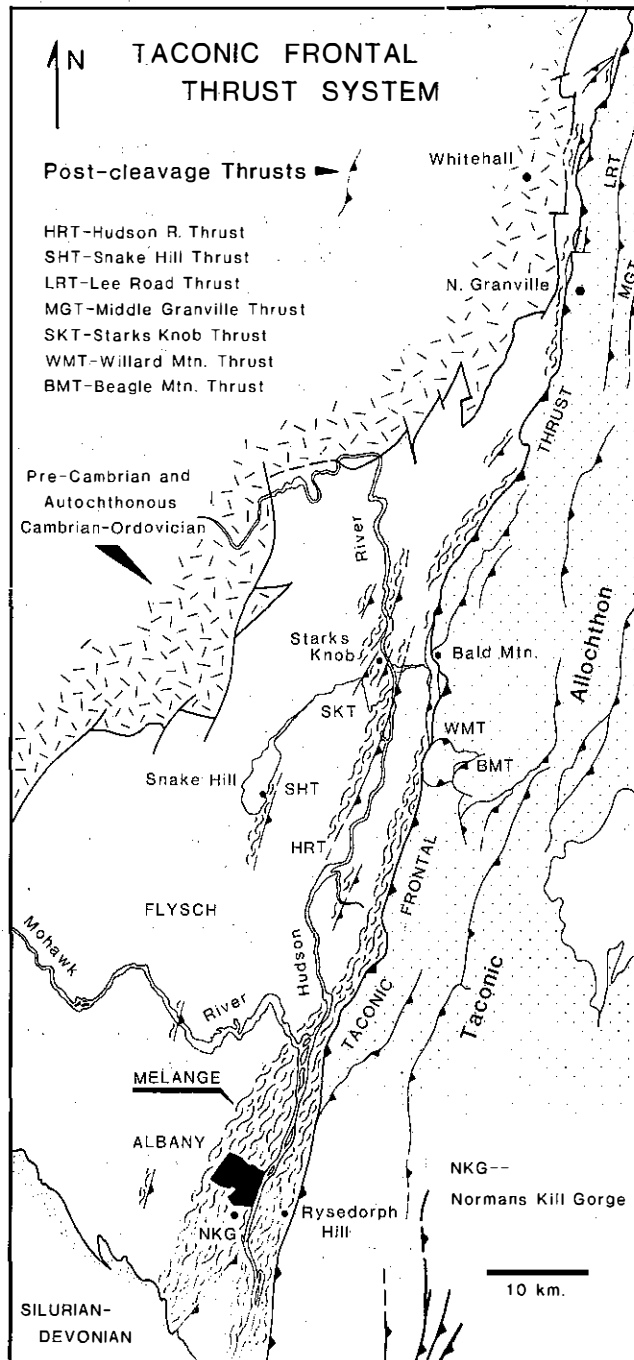


Fig. 12. Compilation of faults believed to belong to the Taconic Frontal Thrust System. These faults accommodated late horizontal shortening of the Orogen and transport of the Allochthon across the autochthonous continental shelf. Total displacement during this generation of thrusting for allochthonous rocks at the present trace of the Frontal Thrust is therefore on the order of 50 kilometers. Regional geology from Fisher, et al., 1970.

ROAD LOG FOR THRUSTS, MELANGES, FOLDED THRUSTS
AND DUPLEXES IN THE TACONIC FORELAND

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.0		Intersection of NY Rt. 50 with I-87, Adirondack Northway. Go north from this exit (#15) on the Northway.
19.9	19.9	Take exit #20. At light at end of ramp, turn left onto NY Rt. 9.
20.4	0.5	Turn right at next light onto NY Rt. 149.
32.4	12.0	Turn left at light in Fort Ann onto US Rt. 4 going north.
43.1	10.7	Turn half right at light in Whitehall; follow US Rt. 4. Cross Hudson-Champlain canal.
43.5	0.4	At next light (Stewart's shop on right) turn left onto Williams Street. Follow Williams Street to second bridge to left over canal.
44.05	0.55	Park on Williams Street just before or after entrance to bridge. STOP 1A - GENTLY DIPPING QUARTZITES OF POTSDAM FORMATION.
44.65	0.6	Go north on Williams Street to intersection of Washington County Rts. 9 and 10. Turn left (north) onto Rt.10 (Doig St/Sciota Rd).
45.25	0.6	Road makes sharp right turn. Continue on Rt.10
45.65	0.4	STOP 1B - GENTLY EAST-DIPPING LIMESTONES OF WHITEHALL FORMATION. Outcrop extends from 45.6 to 45.75. At east end overlying dolostones are exposed.
47.8	2.15	Continue NE on County Rt. 10, Sciota Rd., to T-intersection where Sciota Rd. turns left (N) sharply at intersection with County Rt. 11. Go straight, following Rt. 11 up hill.
48.15	0.35	STOP 2 - THRUST OF MID-ORDOVICIAN LMS. OVER MID-ORDOVICIAN SHALY MELANGE.
48.25	0.1	Continue up hill to T-intersection. Turn

- right (south) onto Westcott Road.
- 49.3 1.05 T-intersection. Turn right (west) onto Carlton Road.
- 50.0 0.7 At next intersection (a Y), where Carlton Road curves to left (south), park just before or after intersection.
- STOP 3 - PLUDE'S QUARRY - EXPOSURE OF TACONIC THRUST.
- 50.7 0.7 Continue south on Carlton Road. At intersection with Whitehall-Fairhaven Turnpike (County Rte 9), shortly after sharp right turn in road, turn left.
- 50.8 0.1 Go down hill and park just before or after the railroad crossing. Walk northeast along the railroad tracks for about 300 meters to
- STOP 4 - D & H RAILROAD CUTTING - TACONIC LITHOLOGIES JUST ABOVE TACONIC THRUST.
- Walk back to vehicles.
- 50.9 0.1 Continue on County Rte 9 to intersection. Turn right (south) onto County Rte 9B (Beckwith Road).
- 51.45 0.55 Go to intersection with US Rte 4 at stop sign.
- 52.45 1.0 Cross Rte 4, continue south on Beckwith Road. At T-intersection with NY Rte 273, turn left (east).
- 53.2 0.75 Go east to next intersection (Beckett Road). Turn right.
- 54.85 1.65 Go south and west to next T-intersection. Turn right (west) onto County Rte 12.
- 55.95 1.1 At next intersection turn left (south) onto Upper Turnpike.
- 56.3 0.35 Cross Mettawee River.
- 56.95 0.65 Long bend to left followed over hill by sharper bend to right.
- 57.65 0.7 Left bend - follow paved road.
- 60.25 2.6 Left bend at intersection with Rathbunville

- Road. Follow Upper Turnpike, which becomes a dirt road at top of hill.
- 60.65 0.4 Start of steep hill down to south.
- 60.8 0.15 Park on left at bottom of valley.
- STOP 5 - METTAWEE RIVER SECTION AND LUNCH.
- Turn around and go back north on Upper Turnpike.
- 65.3 4.5 Cross Mettawee River.
- 65.65 0.35 Intersection with County Rte 12. Go straight, north to Whitehall.
- 67.25 1.6 Intersection at light with US Rte 4. Turn right. Follow Rte 4.
- 73.4 6.15 Cross Poultney River (NY - Vt border).
- 74.75 1.35 Beginning of ramp for Exit 2 (Fairhaven, Vergennes). Take this exit.
- 75.05 0.3 Turn left at stop sign onto Vt Rte 22A going north.
- 77.65 2.6 Pass junction (to left, west) with West Haven Road.
- 78.15 0.5 Drive into parking area on WEST side of road and park.
- STOP 6 - IMBRICATED MIDDLE ORDOVICIAN CARBONATES AND MELANGE.
- Turn and go back south on Vt 22A to West Haven Road.
- 78.65 0.5 Turn right onto West Haven Road.
- 79.0 0.35 Turn right at dirt road with saw mill sign at corner.
- 79.25 0.25 Drive to quarry entrance - park before entrance. (Permission REQUIRED - ask at house halfway along dirt road).
- STOP 7 - BOSS HOGG'S QUARRY - DEFORMATION IN PROVIDENCE ISLAND FORMATION CARBONATES.
- 79.5 0.25 Return to West Haven Road. Turn left.
- 79.85 0.35 Stop sign at intersection with Vt Rte 22A.

Turn right.

- | | | |
|--------|------|--|
| 82.45 | 2.6 | Pass under US Rte 4. Continue south on Vt Rte 22A. |
| 82.8 | 0.35 | Turn left just before Getty gas station. Follow street east. |
| 83.4 | 0.6 | Stop sign at flashing red light. Turn left onto Scotch Hill Road. |
| 83.75 | 0.35 | Pass over US Rte 4. |
| 87.75 | 4.0 | Road reaches bottom of hill next to south shore of Glen Lake. |
| 87.95 | 0.2 | STOP 8 - SCOTCH HILL SYNCLINE - POULTNEY SLATES. PERMISSION REQUIRED. NO HAMMERS. ASK AT HOUSE DIRECTLY ACROSS THE ROAD FROM THE OUTCROP. |
| | | Return to the flashing light at the end of Scotch Hill Road in Fairhaven either by retracing the route above, or by continuing along the paved road without turning around, as detailed below. |
| 88.1 | 0.15 | Pass entrance to Lake Bomoseen State Park. |
| 89.55 | 1.45 | Sharp right turn. Road runs from here along the shore of Lake Bomoseen. |
| 91.55 | 2.0 | Pass under US Rte 4. |
| 92.05 | 0.5 | T-intersection with Rte 4A (old US 4). Turn right. |
| 93.6 | 1.55 | Flashing red light at end of Scotch Hill Road. Turn left, following Rte 4A. Go through centre of Fairhaven. |
| 94.35 | 0.75 | At bottom of hill, branch onto Vt Rte 22A, which goes up a short, steep slope to a railroad crossing. Continue south on Rte 22A. |
| 95.95 | 1.6 | Cross Poultney River - NY-Vt border. |
| 104.14 | 8.2 | Cross Mettawee River. |
| 106.3 | 2.15 | Intersection in Middle Granville. Continue straight on Rte 22A. |
| 106.65 | 0.35 | Intersection at stop sign and flashing light with NY Rte 22. Turn right. |

109.7	3.05	North Granville.
110.4	0.7	Follow straight onto County Rte 17 at fork in road where Rte 22 turns to right.
111.1	0.7	Intersection with NY Rte 40. Turn left. Go south on Rte 40.
128.2	17.1	Sharp left turn at stop sign and junction with NY Rte 197 in Argyle.
136.3	8.1	Pass entrance to Sprague Town Road on left (east).
136.7	0.4	Rte 40 enters a gentle curve to the right.
137.0	0.3	Turn right into Bald Mountain Road at the beginning of the next curve (to the left).
138.05	1.05	Y-intersection. Bear right onto Lick Spring Road.
138.25	0.2	Dirt track forms entrance to right into old quarry. Park on verge before or after entrance.
		STOP 9 - BALD MOUNTAIN QUARRY.
		Continue on Lick Spring Road.
138.35	0.1	Turn around at junction with dirt road. Go back past quarry entrance.
139.7	1.35	Return to NY Rte 40. Turn right.
140.65	0.95	Junction (stop sign) with NY Rte 29. Turn right.
141.65	1.0	Junction with continuation of NY Rte 40 to south. Continue straight west on NY Rte 29.
144.0	2.35	Cross Hudson River.
144.25	0.25	Pass scene of J. Burgoyne's surrender (on right).
144.45	0.2	Turn right at traffic light in Schuylerville.
144.75	0.3	Turn left at traffic light. Follow NY Rte 29.
153.55	8.8	(Entrance to I-87 North on right, to

Montreal).

- | | | |
|--------|------|---|
| 153.75 | 0.2 | Cross under Northway (I-87). |
| 154.1 | 0.35 | Turn left off Rte 29 to find entrance to I-87 South (or continue west on Rte 29 to reach center of Saratoga Springs). |
| 155.0 | 0.9 | Turn left at junction with NY Rte 9P. |
| 155.2 | 0.2 | Turn right onto slip road for I-87 South. |



CAMBRIAN AND ORDOVICIAN PLATFORM SEDIMENTATION - SOUTHERN LAKE
CHAMPLAIN VALLEY

BRUCE SELLECK, Colgate University

BREWSTER BALDWIN, Middlebury College

INTRODUCTION

The Cambrian-Medial Ordovician strata of the southern Lake Champlain Valley record the evolution and demise of passive margin sedimentation on the North American coast of the proto-Atlantic Ocean. The goals of our trip are to examine exposures of key units in this stratigraphy, interpret the depositional environments represented and consider the possible tectonic controls over the history of platform sedimentation during the early Paleozoic in eastern North America.

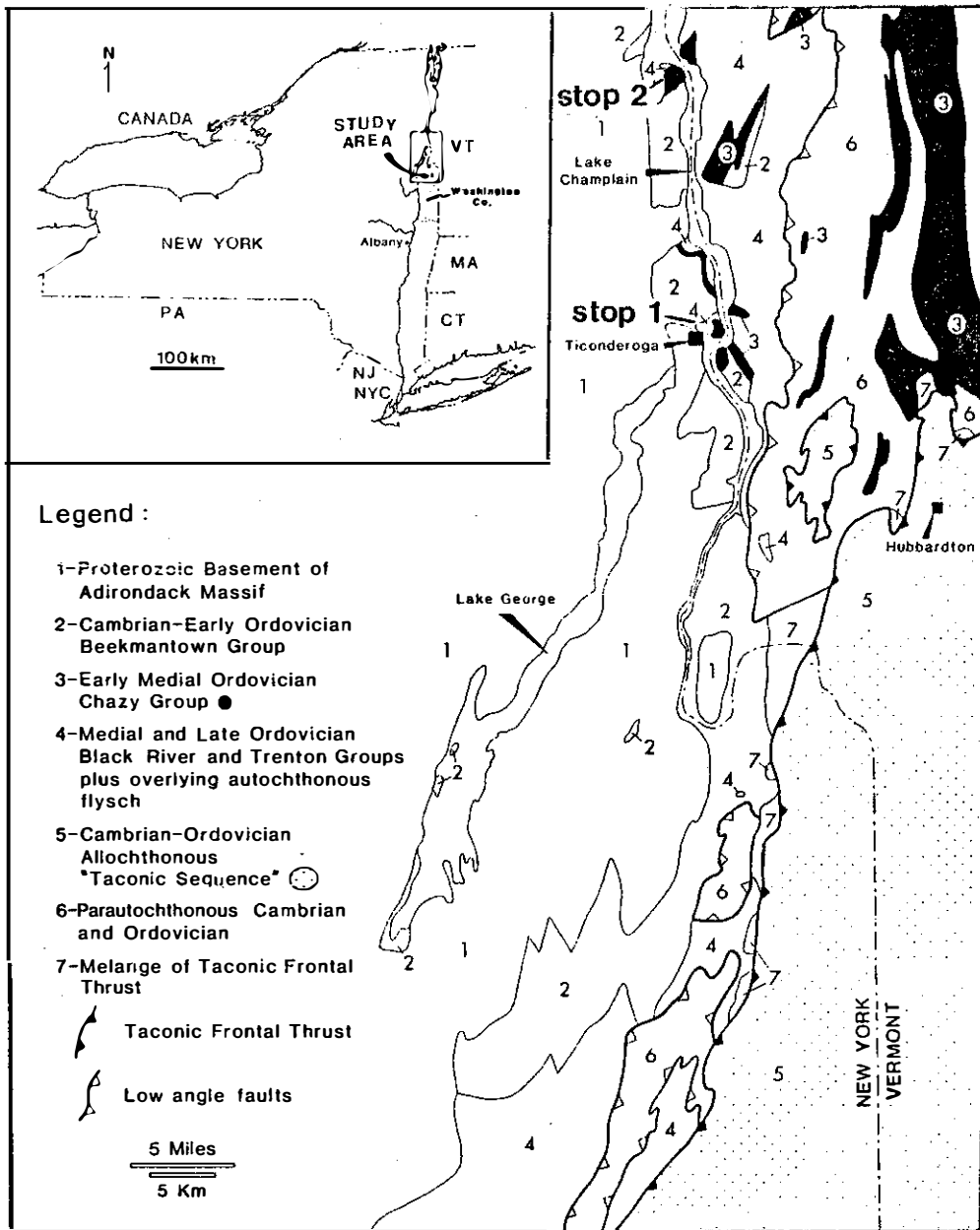
Our trip will focus on two sections of the stratigraphy: (1) the Late Cambrian Ticonderoga Dolostone and basal Whitehall Formation and (2) the Medial Ordovician Chazy, Black River and Trenton Groups. The general area of interest (Fig. 1) lies within the Ticonderoga and Port Henry, N.Y. 15' Quadrangles.

REGIONAL STRATIGRAPHIC FRAMEWORK

The stratigraphic column of Figure 1 illustrates the generalized thickness and lithologies of the strata which comprise the Cambrian and Ordovician of the southern Lake Champlain Valley. The availability of natural exposure in the region, the relative ease of access and the early settlement account for the long history of geological studies in the region. Early workers recognized that the Paleozoic ("Secondary") rock units in northern and eastern New York consisted of basal sandstones (Potsdam Sandstone of Emmons, 1842) overlain by mixed quartz sandstones and dolostones (Calciferous sandrock of Emmons, 1842 and Mather, 1843; later included in the Beekmantown Group by Clarke and Schuchert, 1899), followed by younger calcite limestone (Chazy of Emmons, 1842; Black River of Vanuxem, 1842 and Trenton Group of Conrad, 1837). The stratigraphy of Cambrian and Ordovician in New York has been recently updated by Fisher, 1977, whose usage we generally follow in this report.

Grenvillian Adirondack Basement:

The eastern Adirondack Highlands form the western margin of the Lake Champlain Valley. Granulite facies ortho- and paragneisses, marbles and metanorthosites bear metamorphic age dates of approximately 1.1 billion years (Weiner et al., 1984). Following the Grenville Orogeny, a period of approximately 500 million years of erosion ensued, resulting in the denudation of the ancestral Adirondacks to a relatively low relief topographic surface (Selleck, 1981).



AGE	GROUP	FORMATION/THICKNESS (METERS)		
Ordovician	Medial	Canjoharie/Snake Hill 400+		
		Trenton	Glens Falls 20-50	
		Black River	Orwell 5-40	
		Chazy	Crown Point 10-55	
	Early		Fort Cassin 10-90	
			Fort Ann 15-40	
			Great Meadows 20-70	
			Whitehall 20-110	
		Late Cambrian	Beekmantown	Ticonderoga 30-80
				Keeseville 30-85
Ausable 0-200				
Proterozoic		Potsdam SS		

Figure 1. Generalized geology and lithostratigraphy - Southern Lake Champlain Valley

Basal Sandstones:

The basal Potsdam Sandstone in the region consists of two petrographically distinct facies. Sporadically distributed arkosic arenites and polymict conglomerates form the oldest post-Grenvillian sedimentary rocks in the region. These basal facies are similar to the Ausable Member (Fisher, 1968) of the Potsdam Sandstone in the northern Lake Champlain Valley and comprise a suite of immature terrigenous clastics that were deposited on a relatively uneven topographic surface prior to the onset of Cambrian marine deposition. This "Ausable Sandstone Suite" is thought to represent non-marine deposition in normal fault-bounded basins of small areal extent that developed in response to the uplift and extension of eastern North America during the initiation of rifting of the Proto-Atlantic margin in late Proterozoic-early Cambrian time (Fisher, 1977). The lack of fossils or datable minerals hinders age determinations of these facies. Common themes are the abundance of little-reworked, locally-derived detritus and braided stream/alluvial fan depositional environments. In the southern Lake Champlain Valley, arkosic sandstones and conglomerates of the "Ausable Suite" are exposed in roadcuts on N.Y.S. Rt. 22 near Putnam Center, N.Y.

The Keeseville Member of the Potsdam Sandstone (Fisher, 1968) is an areally extensive, compositionally mature quartz sandstone that overlies both the Ausable Facies clastics, where present, and Grenvillian Basement. In the Southern Lake Champlain Valley the Keeseville is Late Cambrian (Dresbachian) in age and apparently consists largely of shallow marine facies, although detailed investigation of this unit is lacking. Numerous exposures of the Keeseville occur near Putnam Center, N.Y. between Rt. 22 and the west shore of Lake Champlain. Fisher (1977) abandoned previous usage by including the Potsdam Sandstone within the Beekmantown Group.

Beekmantown Group

The transition from siliciclastic to carbonate-dominated deposition occurs within the Ticonderoga Dolostone (Late Cambrian-Franconian) of the Beekmantown Group. The Ticonderoga consist of rhythmically interbedded cross-stratified quartz sandstones and burrowed dolomitic sandstones. This facies is similar to the Theresa Formation which overlies the Keeseville Member of the Potsdam elsewhere in northern New York. The Ticonderoga Dolostone is interpreted as a peritidal deposit, with the cross-stratified facies of low intertidal to shallow subtidal origin and the burrowed facies of higher tidal flat origin (Caplow et al., 1982).

The overlying Whitehall Formation contains the Cambrian-Ordovician boundary (Fisher, 1977, 1984). Relatively pure dolostones, limestones, cherty dolostones and algal boundstone structures characterize the Whitehall and a variety of tidal flat and subtidal carbonate environments are represented

(Rubin, 1975; Rubin and Friedman, 1977). An arid climate coastal setting for the Whitehall is indicated by halite crystal casts and early silicification (Rubin and Friedman, 1977). Exposures of the Ticonderoga Dolostone and Whitehall Formation are numerous in the vicinity of Ticonderoga village.

The younger formations of the Beekmantown Group (Great Meadows, Fort Ann, Fort Cassin/Providence Island Dolostone) are well-exposed in the Whitehall-Glens Falls region. In general, these units consist of dolostones and dolomitic limestones of shallow marine/peritidal origin (Fisher and Mazzullo, 1976; Mazzullo, 1974; Fisher, 1984).

The Beekmantown Group is part of an extensive Cambrian-Medial Ordovician carbonate suite which parallels the early Paleozoic continental margin from Quebec to Alabama and extends west to the mid-continent. Within the Beekmantown Group some recurring themes are evident:

- (1) Tidal (astronomical or storm-related?) depositional processes;
- (2) General facies arrangement consisting of basal quartz sandstone overlain by carbonates (generally dolostones);
- (3) Quartz sandstones more common to west (closer to cratonic interior) with contemporaneous carbonate deposition to east;
- (4) Shifts of sandstone and carbonate facies belts onto more outboard shelf positions during sea-level fall; shifts inboard (toward cratonic interior) during sea level rise;
- (5) Very limited faunal diversity in sandstone and dolostone facies;
- (6) Features suggesting an arid climate coastal setting;
- (7) Lack of fluvial or deltaic facies (except in basal "Ausable Suite"); probable input of terrigenous sand by aeolian transport to marine system;
- (8) Limited terrigenous mud.

The Beekmantown Group records the post-rift, passive margin phase of sedimentation on the Proto-Atlantic margin of North America. Beekmantown deposition ended in late early Ordovician time with a period of emergence of the platform. Erosion of Beekmantown strata extended from the continental interior to the platform margins. Normal faulting of the shelf may have occurred at this time, as well. The unconformity produced during this erosional interval (the "Knox", or "Sauk" unconformity) may document a change in the plate margin from a phase of extension and subsidence to a more dynamic phase. Some workers (e.g., Bird and Dewey, 1971; Rowley and Kidd, 1982) have speculated that this

uplift/erosional interval may be due to the development of a forearc bulge on the continental margin immediately prior to the Taconic Orogeny. Continuous deposition over this otherwise erosional interval may have occurred on the more seaward portions of the shelf, and in those more landward areas that underwent relatively continuous subsidence (including perhaps, the northern Champlain Valley; Speyer, 1982).

Chazy Group

The stratigraphy of the Chazy Group has been investigated most recently by Oxley and Kay (1959) and Hoffman (1963). Fisher (1968) provides descriptions of Chazy strata in the northern Lake Champlain Valley. The Chazy strata of the southern Lake Champlain Valley have generally been assigned to a single formation, the Crown Point (Oxley and Kay, 1959).

The Chazy Group marks the resumption of shallow marine deposition following the post-Beekmantown erosional interval and it is clear that the platform was considerably changed in terms of climate and tectonic regime. The Chazy Group in New York, Vermont, Quebec, and Ontario is characterized by rapid lateral and vertical facies changes, and considerable local and regional thickness variation. Chazy Group strata total 235 meters (800 feet) thickness in the northern Lake Champlain Valley (Fisher, 1968) but thin rapidly to the south, and are absent from the platform stratigraphy in New York south of Whitehall. Chazy Group rocks are present beneath the Taconic thrust sheets to the south and east of Whitehall, based upon the presence of allochthonous fault slivers of Crown Point strata at the base of the Taconic Frontal Thrust (Selleck and Bosworth, 1985).

Rapid facies changes occur along the Champlain Valley outcrop belt, apparently in response to local development of shoalwater barriers and reefs on topographic highs (Fisher, 1968). Tidal flat, shelf lagoon, shoal sands, reef and reef flank facies are exposed in the Champlain Valley. Siliciclastic lithologies are locally present in the basal units and dominate in the Ottawa Valley region, where non-marine (braided stream?) facies are present (Hoffman, 1963).

In the southern Lake Champlain Valley, reef facies are absent from the Chazy, but faunal diversity is high, much in contrast to the poorly fossiliferous Beekmantown Group. Brachiopods, algae, bryozoans, gastropods, nautiloids, trilobites, and pelmatozoans are abundant in subtidal shelf lagoon facies. The occurrence of microkarst erosional surfaces and the absence of evaporitic indicators in tidal flat facies, plus the overall high faunal diversity can be linked to a relatively humid climate during Chazy Group deposition (Selleck, 1983).

A regional disconformity caps the Chazy Group in the southern Lake Champlain Valley, suggesting slight emergence of the shelf prior to deposition of the Black River Group. In places (e.g.

Crown Point) this discontinuity is marked by a thin (approx. 1 meter) arkosic sandstone.

Black River Group

In the type area of the Black River Group in northwestern New York State, four formations are recognized; the Pamela, Lowville, Chaumont and Watertown. Although facies resembling portions of these formations are present in the Black River Group in the southern Lake Champlain Valley, the Group is considerably thinner here than in the type area and a single formation name, the Orwell, is generally applied. Fisher (1984) suggests that the Isle La Motte and Amsterdam Formations are present in the Glens Falls-Whitehall Region, to the south of our area of concern. In general, the basal Black River Group strata consist of quartz sandy dolostones immediately overlain by poorly fossiliferous dolostones and lime mudstones. These facies are rapidly replaced upsection by bioturbated, fossiliferous (gastropods, cephalopods, rugose and tabulate corals, brachiopods, crinoids, stromatoporoids, bryozoa) packstones and wackestones which characterize the Orwell in most exposures. This increase in faunal diversity reflects environmental change from muddy tidal flats (basal Orwell) to a more offshore, relatively low energy, subtidal carbonate shelf setting.

Trenton Group

In the southern Lake Champlain Valley, the contact between the Black River and Trenton Groups is somewhat gradational and characterized by increasing terrigenous mud content. Previous workers have placed the Trenton-Black River contact within the Orwell Limestone, based upon faunal correlations with the type Black River and Trenton. We have followed this rather peculiar usage in this report, but suggest that the natural lithostratigraphic boundary between the Black River and Trenton could be placed at the summit of the massive packstones of the Orwell (= Isle LaMotte). Further study is needed on this problematic contact. Trenton limestone beds are often subtly graded and current lamination is common. Mehrrens (1984) has suggested that similar Trenton Group facies are turbidites and their presence indicates increased local slopes on the Trenton carbonate shelf. Faunal diversity in the Glens Falls limestone is quite high, and the faunas are typically dominated by brachiopods, bryozoans, trilobites, nautiloids and crinoids. Mud-intolerant corals and stromatoporoids are notably uncommon in the Trenton Group.

Canajoharie/Snake Hill

The transition from the Trenton Group limestones to overlying dark mudrocks of the Canajoharie Shale (=Snake Hill of Fisher, 1977) is clearly the result of continued deepening of the Trenton shelf to depths sufficient to reduce biogenic carbonate production, coupled with increased input of terrigenous mud. The

organic-rich character of these dark shales and siltstones indicates poor oxygenation of the bottom waters. The change from carbonate to black mud deposition occurred earlier in the Champlain Valley than in the western Mohawk Valley and Black River Valley/Tug Hill Region (Fisher, 1977). This progressive east-to-west deepening of the foreland basin was initially due to the wedging of the continental margin into the subduction zone. This convergent-margin tectonism (Baldwin, 1980, 1982) is reflected in the Timor Trench today where shallow-water mid-Pliocene limestones are now 2.7 km deep. Soon after, subsidence also reflected the loading of the continental margin by west-directed compression and thrusting of "Taconic Sequence" Cambrian-Early Medial Ordovician rise prism sediments onto the edge of the carbonate platform (Rowley and Kidd, 1981). Cisne et al. (1982) have suggested that the convergent tectonic regime of the Taconic Orogeny and related history of the Medial Ordovician Foreland basin in the Mohawk Valley is analogous to the modern Timor-Timor Trough-North Australia Shelf collisional system. In the Timor analogue, the attempted underthrusting of the northern Australian plate margin has led to progressive deepening and syndepositional normal faulting of the previously shallow water North Australia platform, producing a "deep-over-shallow" facies pattern that is very similar to the Canajoharie Black Shale-over-Trenton Limestone sequence of the Medial Ordovician in New York State. Baldwin (1980) has documented the history of Ordovician shelf subsidence and accompanying changes in depositional rates in the Champlain Valley.

Following the deposition of Canajoharie-Snake Hill black muds on the foundered carbonate platform, synorogenic flysch developed as aprons of sediment that were shed from the rising Taconic accretionary prism. In some areas, these deposits are deformed and overthrust by later thrust sheets. Molasse deposition is recorded in deltaic and marine shelf facies of the Late Ordovician Lorraine Group and Oswego Sandstones in northwestern New York. These deposits do not occur in the Southern Lake Champlain Valley.

Post-Ordovician:

The post-medial Ordovician geologic history of the region is not recorded in local sedimentary sequences and is hence rather difficult to interpret. The pronounced normal faults which form the physiographic boundary between the Champlain Valley and the Adirondack Highlands are clearly post-Ordovician in age (Fisher, 1968) and may be as young as Tertiary (Isachsen et al., 1976). Glacial erosion and deposition, including a late Pleistocene marine invasion in the Lake Champlain Valley, have caused significant modification of landforms in the region. The neotectonics of the region are characterized by minor earthquake activity and possible on-going uplift of the Adirondack massif (Isachsen, et al., 1978).

Field Trip Stop Descriptions:

As this trip involves only two "stops" we have not included a road log. To reach Stop #1 from Saratoga Springs, take Interstate 87 north to the Route 73 exit (Schroon Lake) and proceed east to Ticonderoga. At the Rt. 9N and 22 intersection with Route 73, proceed east, then south (1 1/2 miles) on Rt. 22 to Shore Airport Road. Turn left on Shore Airport Road. Stop #1A is the first of a series of outcrops on Shore Airport Road approximately 0.3 miles from Rt. 22 intersection.

From Stop #1, proceed east, then north on Shore Airport Road to intersection with Rts. 9N and 22. Turn right (north) and follow 9N and 22 through village of Crown Point. Turn right (east) onto Route 8 to Crown Point Reservation State Park Bridge to Vermont and Campground. Proceed east approximately 4 miles to entrance to State Historic Site.

STOP #1 - Shore Airport Road Outcrops - Ticonderoga Village

Relatively new roadcuts on Shore Airport Road provide excellent exposures of portions of the Ticonderoga Dolostone and Whitehall Formation. The generalized stratigraphy of this series of outcrops is presented on the following pages. Stop 1A is wholly within the Ticonderoga Dolostone; 1B is uppermost Ticonderoga Dolostone or basal Whitehall (Finch Dolostone of Fisher, 1984) Formation; Stop 1C is clearly Whitehall Formation, Finch Dolostone Member. We will walk upsection from the base of Stop 1A to Stop 1B, reboard the bus to Stop 1C. Please watch for cars!

Stop 1A - Ticonderoga Dolostone:

A series of normal faults juxtapose blocks containing various sections of the Cambro-Ordovician stratigraphy in the Ticonderoga area. To our southwest, Proterozoic marbles and gneiss hold up Prospect Mountain. The village of Ticonderoga largely sits upon Potsdam Sandstone (Keeseville Member). To our south and east, the younger formations of the Beekmantown Group are exposed in the vicinity of Fort Ticonderoga. At this stop approximately 20 meters of Ticonderoga Dolostone is exposed. The basal 2/3 of the outcrop consists of 0.2 - 1.0 meter units of bioturbated sandy dolostone interbedded with 0.1-1.0 meter units of cross-stratified slightly dolomitic medium to fine sandstones. Rare prism cracks in the fine silty dolostones document sporadic subaerial exposure. "Herringbone" cross-strata, reactivation surfaces and shear-deformed cross-strata are well-exposed on weathered surfaces of the sandstones. Poorly preserved specimens of the gastropod Ophileta sp. are found on the bedding surface of a dolomitic sandstone approx. 8 meters from the base of the section. R. Linsley (personal communication) has suggested that Ophileta was a relatively sedentary grazer or deposit feeder. The upper 1/3 of the section contains relatively more abundant prism cracks, shaly interbeds and intraclast breccia horizons, perhaps indicating more

regular subaerial exposure.

The rhythmically interbedded bioturbated dolostones and cross-stratified dolomitic sandstones are interpreted as high and low tidal flat/shallow subtidal facies, respectively. Carbonate mud and terrigenous sands deposited on a relatively low energy upper intertidal flat provided a suitable habitat for burrowing infaunal organisms. The lower tidal flat and shallow subtidal environment was characterized by more vigorous current action which limited faunal activity and produced cross-strata and associated structures. The repetitive interbedding of these facies suggests repetitive progradation of burrowed sandy muds over current-bedded sands. The upsection decrease in current-produced structures and increasing evidence of exposure indicates an overall shallowing up trend in the Ticonderoga Dolostone at this locality.

Stop 1B - Outcrop on north side of Shore Airport Road
approx. 150 meters east of Stop #1A

This outcrop exposes about 7 m of silty, cherty dolostones assignable to either the uppermost Ticonderoga Dolostone or the basal Finch Member of the Whitehall Formation. The pervasive dolomitization plus outcrop weathering have obscured the primary structures and fabrics. The lower approx. 1 meter consists of laminated silty dolostones with ripple cross-lamination and thin intraclastic horizons. The succeeding 1.5 meters consists of thick-bedded to massive coarsely crystalline dolostone containing calcite-filled voids of various sizes. The succeeding 2 meters consists of bioturbated, dark medium crystalline dolostone with vaguely developed digitate algal (?) structures. Laminated, finely crystalline dolostones follow, capped by dolostones with algal mounds. In the upper 1 1/2 m of the outcrop, cherty, laminated dolostones apparently drape an irregular algal mound (thrombolites) surface. Note laminated silty dolostone between algal mounds.

The lack of diagnostic fossils and primary structures in these lithologies make environmental assignment difficult. If the digitate algal structures and cryptalgal laminites are indeed present, a shallow subtidal to low intertidal environment may be inferred. Bioturbated dolostones could be of intertidal or more offshore origin. Any suggestions?? (We will reboard bus at this point and continue east on Shore Airport Road 400 meters to Stop 1C.)

Stop 1C (outcrop on north side of road)

Approximately 3 1/2 meters of the Finch Dolostone Member of the Whitehall Formation is exposed at this stop. Three facies occur in a somewhat repetitive fashion: (A) Coarsely crystalline, laminated to slightly bioturbated dolostone (dolomitized grainstone); (B) "pin-stripe" laminated cherty finely crystalline dolostone with rare burrows; and (C) dark grey to black dolomitic

chert with dolomitized molluscan debris and dolomitic digitate algal stromatolites and dolomite "knots" (small algal structures??). The uppermost dolomitic chert bed thickens and thins on outcrop scale. The thicker portions of this bed appears to represent local "domes" or mounds formed by the thrombolites or algal stromatolites. Gastropod debris can be seen in one mound, perhaps representing shell material collected between cylindrical algal pillars.

The absence of direct evidence of subaerial exposure again makes exact environmental assignment quite equivocal. We suggest that the coarsely crystalline dolostones represent a "high energy" shallow subtidal/low intertidal facies; the "pin stripe" laminites a relatively lower energy muddy tidal flat facies. The dolomitic chert facies containing algal structures is probably shallow subtidal. We are again open to suggestions.

The origin of the silica for chertification of these rocks is also something of a problem. Rubin (1975) suggested that subaerial "silcretization" involving dissolution of terrigenous silicates and precipitation of opaline silica or quartz in a pedogenic setting on emergent tidal flats was a factor in chertification of Whitehall Formation carbonates. The fabrics indicating pedogenic silicification reported by Rubin are not present at this locality, however. A possible alternative is fabric-selective replacement of primary carbonate mud by silica derived from a biogenic source (sponge spicules) within the original sediment.

Route to Stop #2

Reboard bus, continue east, then north on Shore Airport Road to Rts. 9N and 22. Outcrops of the Whitehall Formation and Great Meadows Formation are seen as we continue on Shore Airport Road. North on Rts. 9N and 22, through village of Crown Point, turn right at sign for Crown Point (N.Y. Rt. 8) Historic Site and Bridge to Vermont. Continue NE to Crown Point Historic Site. Entrance on left. We will disembark by the entrance to the Historic Site. Stop #2A is in the ditch and wall of a small outpost fort on east side of N.Y. Rt. 8. Stop 2 locations are keyed to the map and columnar section on the next two pages.

Note: Absolutely no hammering or collecting at the Crown Point outcrops!

STOP #2A: Outpost fort east of N.Y. 8

Approximately 6 meters of variously burrowed, slightly dolomitic, thin to medium bedded bioclastic packstones are exposed in this section. The dolomite occurs in shaly weathering wisps and laminae and in burrow fills. Abundant "Girvanella" algal oncolites (algal accretionary grains) are present in beds approx. 4 meters from the base of the section. Rounded dark calcite grains (abraded gastropod fragments) form the cores of the

oncolites, and are scattered in other beds. Fossils are relatively abundant and best seen on bedding surfaces. Trilobite fragments, brachiopods, bryozoans, pelmatozoan plates, nautiloids and large Maclurites magnus are present. The relatively high faunal diversity, abundant lime mud and burrowing argue for a normal marine, low energy shallow subtidal carbonate environment. A possible modern analogue is found in the mixed mud and sand shelf to the west of the emergent Andros Island tidal flats, as described by Bathurst (1971) and Purdy (1963). The 5-10 cm thick beds of "oncolite conglomerate" and other more well-sorted grainstone beds may represent periods of storm winnowing of the bottom, with transportation of abraded sand from adjacent sand shoal environments (e.g. Locality 2B). The wavy, irregular dolomite laminae appear to result from post-depositional dolomitization of lime mud, followed by compaction and local pressure solution of calcite, producing irregular, clay- and dolomite-rich stylocumulate seams. Preferential dolomitization of burrows may be due to contrasts in porosity or permeability of burrow-fill versus burrow-matrix sediment. The burrow-fill sediment may have retained permeability longer during diagenesis, permitting pervasive dolomitization. This sort of fabric selective dolomitization is common throughout the Chazy and Black River Groups in the southern Lake Champlain Valley.

STOP 2B - Ledge immediately NE of gate to Historic Site

Cross-stratified coarse lime grainstones with bipolar crossbed dip directions are well-exposed near the entrance road. Siliciclastic sand grains (angular quartz and feldspar up to 2 mm in diameter) are locally concentrated along prominent stylolite seams. The carbonate particles are dominately subrounded, abraded pelmatozoan plates, plus gastropod and brachiopod fragments. Large Maclurites fragments and grainstone intraclasts are present on the upper bedding plane surfaces of the ledge.

We envision the environment of deposition of this facies as shallow subtidal wave and/or current reworked sand bars. Active transport of abraded grains may have been accomplished by tidal currents as suggested by the bipolar cross-beds. The lack of burrows and well-preserved fossils may be due to the inhospitable shifting sand substrate. This environment may have been rather like the unstable sand shoal environments described from the Bahamas Platform by Bathurst (1971) and Ball (1967). The scale and style of cross-stratification present here are similar to that predicted by Ball from his studies of the bedforms and primary structures of the Bahamian sand bodies. Similar Chazyan facies in the Northern Champlain Valley contain abundant oolites (Oxley and Kay, 1959).

STOP 2C - Low Ledges on entrance road approx. 50 meters north of 2B

Brown weathering, slightly shaley dolostone exposed here contains small lenses and stringers of fossiliferous lime packstone. Trilobites, small brachiopods and Maclurites fragments are common. This exposure resembles the shelf lagoon facies of Stop 2A, although dolomitization is more pervasive.

STOP 2D - East point of British Fort, by horizontal water tank and adjacent south moat

Approximately 3 meters of thickly laminated limestone and dolostone is exposed in the southeast "moat" of the British Fort. The dominant facies here consists of alternating 0.5-2 cm thick laminae of limestone and dolostone - often termed a "ribbon rock". The limestone ribbons are mudstones and appear blue-grey on slightly weathered surfaces and as indentations on highly weathered surfaces. The more resistant dolostone weathers tan to brown. An erosional surface with 10-20 cm of relief is exposed near the base of the southwall. Abundant Maclurites shells occur in a shell bed on this surface. Lateral accretion cross-strata consisting of gently dipping ribbon rock are present above the erosional surface. Dolomitized burrows transect the limestone ribbons in the lower 1 meter of the section. On the less-weathered prominence on the SE corner of the moat, shallow scours containing a shell hash of brachiopods and gastropod debris are present, along with intraclasts of lime mudstone in dolostone and "Mexican Hat" structures (rolled intraclasts or pseudoclasts with a dolomitized burrow center).

We interpret this sequence as a tidal flat facies. The rhythmic limestone/dolostone "ribbon" fabric is interpreted as representing alternating slightly finer (lime mudstone) and coarser (dolostone) "tidal bedding" similar to that described by Reineck and Singh (1980) from the clastic mud/sand tidal flats of the North Sea. The Maclurites shell bed may mark the basal erosional level of a tidal channel, with the cross-stratified ribbon laminites forming by draping on the channelled surface. Variations in degree of burrowing record subtle differences in degree of subaerial exposure of the flat and/or reworking by tidal currents. Limited in situ faunal diversity is also expected in the stressed tidal flat environments. The absence of mudcracks and any indication of evaporite minerals suggests that we are seeing only the lower portion of a wet intertidal flat system preserved here.

STOP 2E

Enter Parade Grounds by barracks. Around 1916, gunite was spayed on the interior walls to protect the mortar from deteriorating. Starting in 1976, the N.Y. State Division for Historic Preservation began extensive maintenance, removing loose gunite, replacing rotted stones and repainting the stone walls.

In the outer wall of the first barracks, note at about eye level the stones that are nearly white-weathering. These are lime mudstones from the "Lowville" facies of the Orwell Limestone, exposed at Stop 2F.

The broad limestone outcrop west of the barracks is a cross-stratified lime grainstone with scattered subrounded quartz and feldspar sand grains. Trough cross-strata and "herringbone" co-sets of planar-tabular cross-strata are visible on the low vertical face. Large angular clasts of slightly dolomitic lime grainstones and Maclurites magnus shells are present on the uppermost bedding surfaces.

We interpret this facies as a current-dominated sand shoal environment rather similar to the exposures at Stop 2B.

Westward across the parade grounds there is a massive, bioturbated, brown weathering dolostone unit (similar to Stop 2C), overlain by 0.5 meters of very coarse-grained bioturbated, slightly dolomitic feldspathic quartz sandstone. This sandstone forms the summit of the Chazy Group (Crown Point Formation). The abundant angular quartz and feldspar granules in the sandstone suggest derivation from a relatively close granitic (Adirondack?) source terrane. These sands were apparently transported from the west during an interval of relative emergence of the carbonate platform and were briefly reworked in a shallow marine setting. The basal dolostone bed of the Black River is exposed immediately atop the sandstone.

STOP 2F - Moat Walls at North Entrance to British Fort

The section from here to locality I is within the Orwell Limestone. The basal beds consists of thick-bedded to massive lime mudstones with vertical spar-filled burrows (form - genus Phytopsis) and rare ostracodes. Fossil abundance and diversity increase in the overlying beds, with gastropods (Loxoplocus), corals (Lambeophyllum, Foerstephyllum) and brachiopods appearing. Grain size increases upsection, with sporadic appearance of intraclast grainstones and ripple cross-lamination. Overall this section is similar to the Lowville Limestone of the type Black River Group of the Tug Hill region. The facies pattern here suggests a progression from restricted (tidal or lagoonal?) mud flats (Phytopsis lime mudstones) to more open marine mixed mud/sand shelf environments.

The summit of the moat outcrop exposes a horizon of black chert nodules which can be traced laterally across the road to locality G.

Stop 2G - Ledges extending from service road to lake shore.
Watch for poison ivy!

These exposures closely resemble the Chaumont (House Creek Limestone of Fisher, 1977) facies of the Black River type section.

Thick-bedded to massive richly fossiliferous lime packstones and wackestones document a normal marine, relatively low energy carbonate shelf environment. In addition to the forms mentioned earlier, the large stromatoporoid (calcsponge) Stromatocerium, the high-spined gastropods Hormotoma and Subulites, the nautiloids Actinoceras and Geisonoceras, plus bryozoans, brachiopods and pelmatozoan material are common. On some bedding surfaces, black chert nodules follow large horizontal burrows. The chertification here is post-depositional and involved dissolution and reprecipitation of siliceous skeletal material (sponge and radiolarian). The uppermost bed in this set of ledges is a black chert bed approximately 2 cms thick. This bed can be traced to the lake shore where a similar section can be seen. Glacial abrasion obscures much of the detail that is exposed on more weathered surfaces.

STOP 2H - Blocks and Quarry Walls by Lake Shore

The quarry was established in 1870 by the Fletcher Marble Co. in a unsuccessful attempt to find a source of "black marble" dimension stone. The quarry is reportedly only 1 meter or so deep. The narrow spit going north was built to load blocks on barges, but evidently no blocks were shipped. The quarried blocks consist of medium to thick-bedded fossiliferous packstones and wackestones with some ripple cross-laminated grainstone beds visible in the north quarry bench. Strophomenid brachiopods, bryozoans, pelmatozoan stems and fragments of the trilobite Isotelus are present. The environments represented here are similar to those at 2G. As we continue north and walk along the lake shore, more exposures of the upper part of the Orwell can be examined. The bedding surfaces contain abundant opercula of Maclurites logani, and scattered Forstephyllum, Lambeophyllum and Stromatocerium are found. The byssate bivalve Ambonychia is also present.

The transition from the Orwell to overlying Glens Falls Limestone is covered by beach gravels as we continue west along the lake shore.

STOPS 2I,J,K - Series of exposures of Glens Falls Limestone separated by covered intervals of beach gravels

The westernmost outcrops are on Private Property, beyond Locality K. Do not go onto that part of the shore (marked by fence and stone wall, plus the large dead elm tree).

The Glens Falls limestone consists of medium to thin-bedded lime packstones and wackestones with some well-laminated, fine-grained bioclastic grainstones. Many limestone beds show internal grading from coarse, fossil-rich bases to less fossiliferous, fine-grained tops. Thin shaley interbeds separate the limestone beds. Horizontal trails and burrows (including form-genus Chondrites) are common on some bedding surfaces.

Fossils are abundant and rather diverse. Trilobites (usually fragmental) include Isotelus, Flexicalymene and rare Cryptolithus; the brachiopods Sowerbyella, Rafinesquina; Dinorthis and Dalmanella; bryozoans Prasopora, Eridotrypa and Stictopora; plus orthocone cephalopods and pelmatozoan debris. Gastropods, which are so abundant in the underlying Orwell limestone are exceedingly rare in the Glens Falls.

The environment of deposition for the Glens Falls is a sub-wave base shelf. No shallow water features are observed and the graded limestone beds are evidently deposited by density/turbidity currents generated on adjacent, slightly shallower portions of the shelf. The Glens Falls here records the continuing deepening of the Middle Ordovician shelf that began with the deposition of the Phytopsis lime mudstones at Stop 2F. The shale interbeds and generally more argillaceous character of the Glens Falls document increase in terrigenous mud input, perhaps derived from the rising Taconic Orogenic complex to the east. Quartz and feldspar grains of volcanic origin are also common in insoluble residues of Glens Falls limestones, suggesting increased eruptive activity at this time.

The contrast in terrigenous content of the Chazy Group vs. Black River and Trenton Groups is noteworthy. Insoluble residues from Chazy Group carbonates contain abundant, coarse-grained, rather angular quartz and feldspar grains (e.g. Stops 2B and 2D) plus clay-size material whereas the Black River and Trenton Groups lack coarse sand-size grains and contain either volcanic quartz and feldspar (Black River and Trenton Groups) or clay plus volcanics (Trenton Group). This change is likely related to a shift in available clastic source from the slightly emergent cratonic basement to the west that was exposed during Chazy Group deposition to the rising Taconic volcanic/metamorphic complex to the east during Black River-Trenton Deposition.

Tectonic Significance of the Crown Point Section

Combining the environments of deposition with the time-thickness pattern of sedimentation, the Crown Point section takes on tectonic meaning. The Chazy sediments were deposited just about at sea level -- Girvanella and Maclurites. The Orwell was deposited in shallow sub-tidal conditions -- two corals, the grazing snail Maclurites, and probably the Stromatocerium. The Glens Falls was deposited in a more offshore setting.

A time-thickness graph for the Cambrian-Ordovician sequence of the Champlain Lowlands shows some interesting changes in slope. Sedimentation through the Chazy yields a concave-upward curve that shows a continued slowing of crustal subsidence. Then, starting with the Orwell, the crustal subsidence is greater than the rate of sedimentation, because the water deepens. Using the Middle Ordovician time scale of Churkin and others (1977), it is clear

that Chazy sedimentation was scarcely 5 m/m.y.; the Orwell and Glens Falls accumulated at 30 or 40 m/m.y., and the thick shales accumulated at 200 m/m.y. (solid-grain thickness). This high rate is comparable to the rate of subsidence of the Australian platform entering the Timor trench (600 m/m.y.; Baldwin, 1982).

The Crown Point section, then, fits the picture of a cooling and slowly subsiding continental margin, through Chazy time. Then, the margin began collapsing as it tried to enter a subduction zone to the east, causing water to deepen rapidly. The section is a record of the very early part of the Taconic Orogeny, as the "east-moving proto-North American Plate 'felt' the presence of an approaching island arc" (Baldwin, 1982). collision that constitutes the Taconic orogeny.

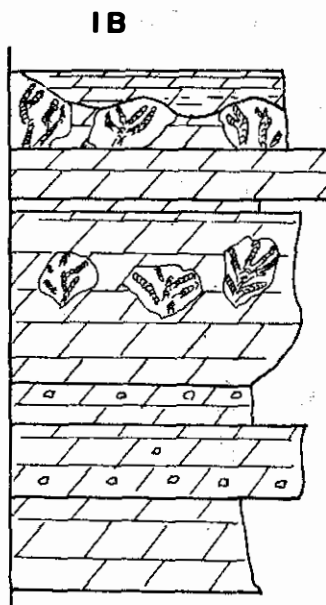
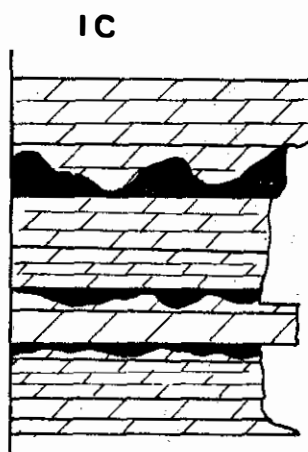
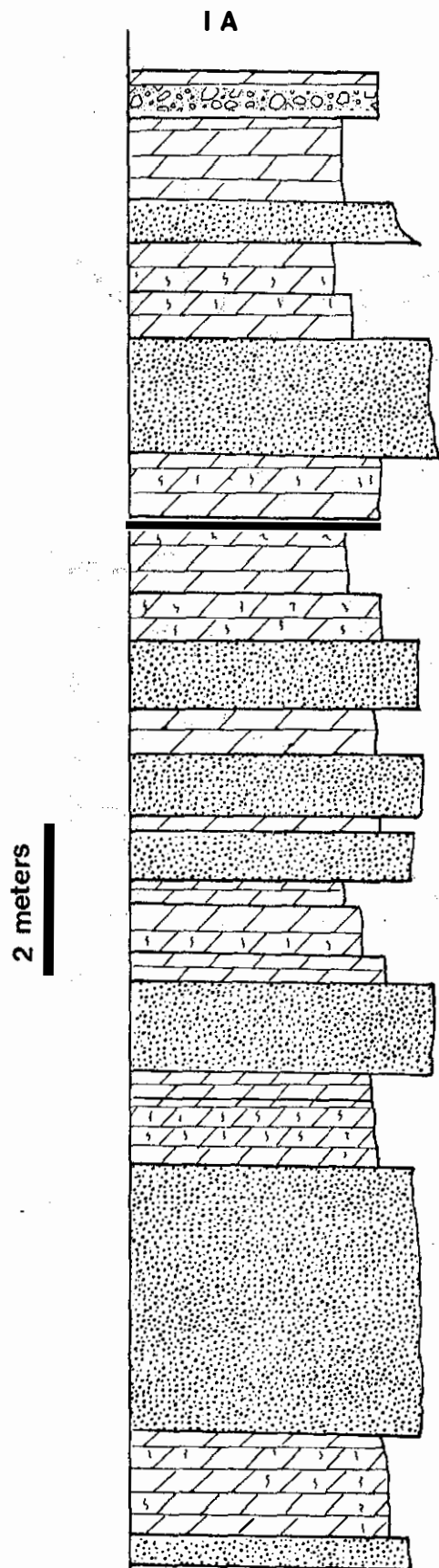


Figure 2. Schematic columnar sections at Stops 1A, 1B and 1C.

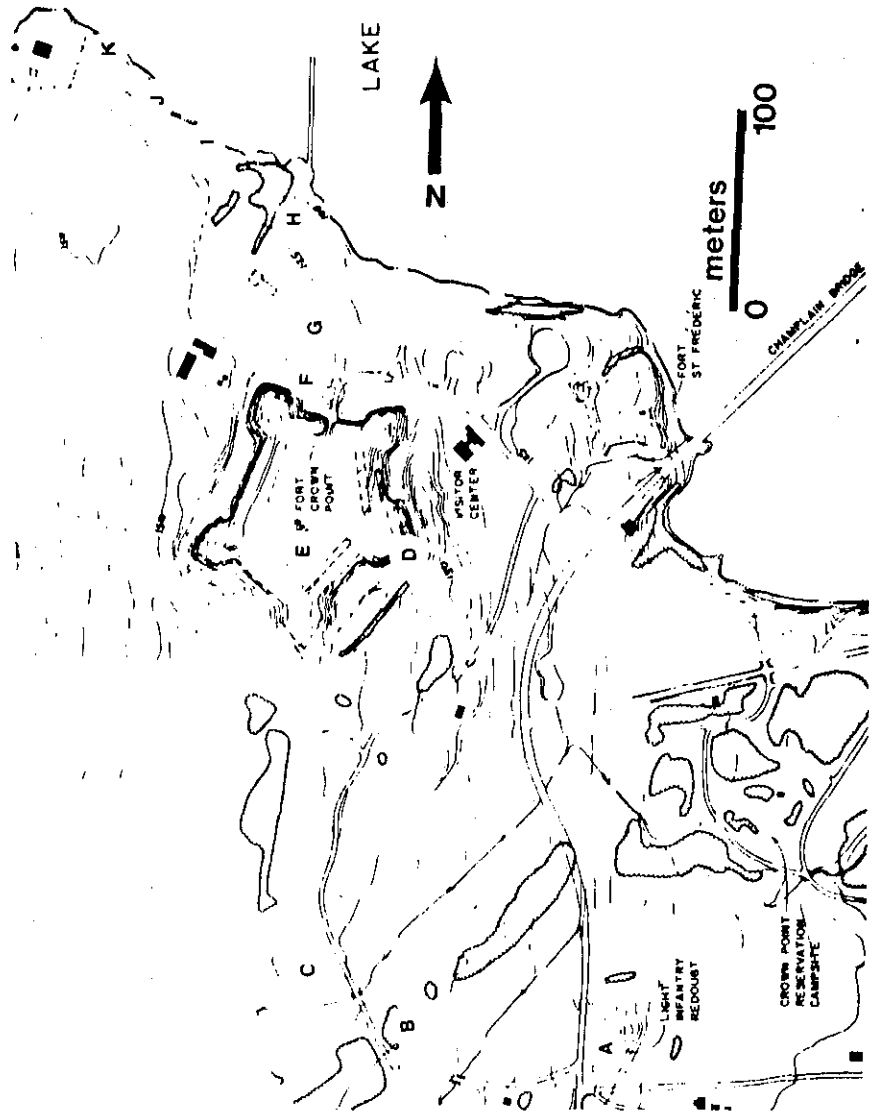
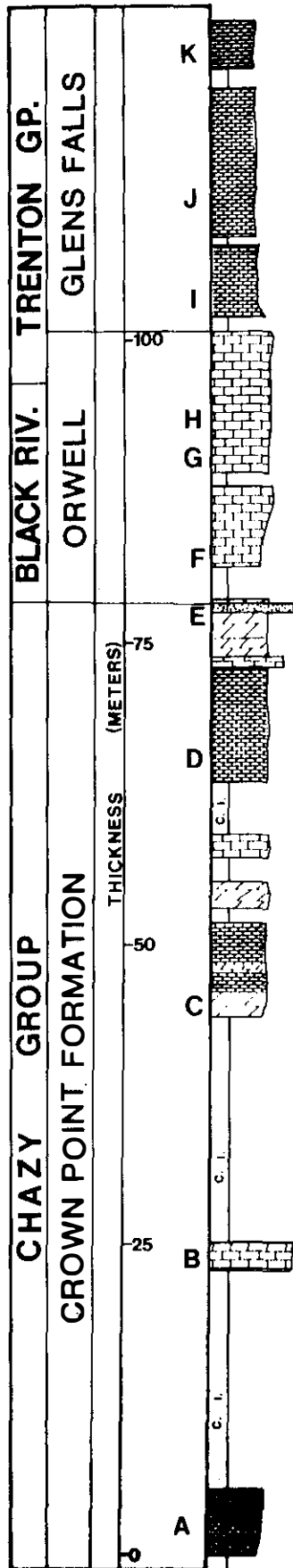


Figure 3. Composite columnar section and location map for Crown Point localities. Note that strata dip approx. $8^{\circ}N35^{\circ}W$.

Acknowledgements

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ROBERTS HILL AND ALBRIGHTS REEFS: FAUNAL AND SEDIMENTARY EVIDENCE FOR AN EASTERN ONONDAGA SEA-LEVEL FLUCTUATION

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INTRODUCTION

While Edgecliff reefs have been the subject of numerous studies since the early 1960's (see references below), our understanding of these reefs is still far from complete. They have, for the most part, been perceived as small, simple patch reefs, with the discussion of their developmental history generally limited to two dimensional descriptions of the succession of reef builders and lithofacies. Such studies of surface exposures have mainly concluded that these were shallow water structures whose growth ceased upon entrance into the high energy, near surface turbulence zone (Bamford, 1966; Mecarini, 1964; Poore, 1969; Collins, 1978; and Williams, 1980).

Coughlin (1980), in a study of subsurface pinnacle reefs in southcentral New York, favored the opposing view that despite evidence for much of reef development in shallow water, termination of reef growth was caused by drowning of the reefs due to basinal subsidence. Cassa (1979, 1980), Cassa and Kissling (1982) and Kissling (1981) have on the other hand advocated a deep-water origin for many of the Edgecliff reefs due to the absence of stromatoporoids and algae from these reefs. More recently Wolosz (1984, p.268) has argued that the lack of a well developed stromatopoid fauna was due to reef growth in a shallow but cool water environment, while Lindemann and Chisick (1984) have reported the presence of algae in these reefs.

STRATIGRAPHY

The stratigraphy of the Onondaga Formation has been extensively described by Oliver (1954, 1956), who divided it into four members. In the type area - "Onondaga County" - the basal Edgecliff member is a massive, coarsely crystalline, biostromal limestone; the Nedrow a thin-bedded, very fine grained and argillaceous shaley limestone; the Moorehouse a fine grained limestone with common chert and shaley partings; while the Seneca (which extends eastwards only as far as Cherry Valley) is differentiated from the Moorehouse on a faunal basis only. For the purposes of this report, the most important aspect of Oliver's stratigraphy is his inability to differentiate the Edgecliff, Nedrow and Moorehouse in the east (where they are mainly crinoidal grainstone and/or packstone) on any but biostratigraphic criteria (Oliver, 1956, p.1457), while these members are quite lithologically distinct only 35 miles to the west in the vicinity of Cobleskill. Further, Lindholm (1967, p.144) found only two microfacies to be present in the Onondaga in the vicinity of Albany as compared to four in the vicinity of Cobleskill. This facies relationship is thought to reflect prevalent shallow water conditions in the east as compared to progressive deepening of the basin to the west.

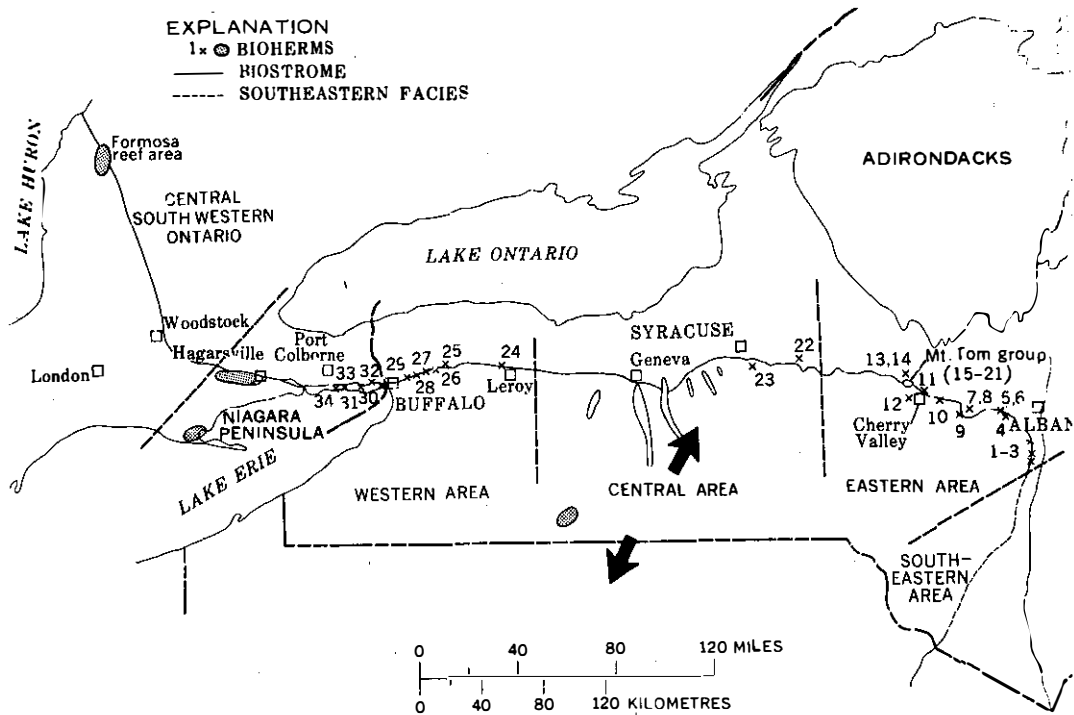


FIGURE 1. Edgecliff outcrop belt in New York and southwestern Ontario with reef locations (numbers). Roberts Hill (#1) and Albrights (#2) Reefs are the southernmost of the eastern reefs. Arrows mark approximate topographic axis of basin. (After Oliver, 1976).

In his eastern Onondaga facies Oliver (1956, p.1446) divides the Edgecliff into two units, the lower C1 and upper C2 units. The C1 unit is defined as a medium gray, rather fine grained limestone; while the C2 unit is a light to medium gray, coarse grained coral zone similar to the Edgecliff at the type area. While the C1 unit reaches its maximum thickness of 6 to 7 feet at Cherry Valley, it thins to the east and is only 1 foot thick at Sharon Springs. This eastward thinning suggests that the C1 unit would not be expected in the Roberts Hill area; however, at Leeds to the south the lower part of the Edgecliff is similar to the C1 unit and is about 12.5 feet thick. A fine grained, dark limestone at the base of Albrights Reef may represent this C1 unit.

The basal contact of the Onondaga is also of importance to our understanding of the Edgecliff Reefs. Westward from Richfield Springs this contact marks a major period of erosion with the Onondaga successively overlying the Oriskany Sandstone, the Helderberg limestones, and the Silurian Manlius Limestone. Oliver (1956, p.1447) states that the unconformable contact at Richfield Springs is marked by the presence of phosphate nodules in a glauconitic siltstone, a lithology more indicative of a period of non-deposition than of erosion. In the vicinity of Roberts Hill and Albrights reefs the Onondaga directly overlies the Schoharie Formation, with the contact between the two having been interpreted as gradational by Goldring and Flower (1942). Chadwick (1944, p.153), however, claimed that the unconformity at the base of the Onondaga is

present in the east, and represented by a glauconitic bed which marks the contact and indicates a discontinuity of sediment deposition.

TECTONIC SETTING

During the Devonian the Appalachian basin was dominated by two major tectonic elements, the mobile Appalachian geosyncline and the stable cratonic platform. To the east of the geosyncline, a land area contributed sediment into the northwestern geosynclinal trough. The Cincinnati-Algonquin Arch System marked the zone of minimum subsidence to the west, and separated the Appalachian basin from the Illinois and Michigan basins.

Prior to Onondaga time, the topographic axis of the Appalachian basin is believed to have shifted first to the east, and then back west. The Middle Silurian Niagara basin is located in Ohio, but by the early Devonian the basinal axis had shifted approximately 200 miles to the east, forming a northeast trending diagonal across Pennsylvania (Mesolella, 1978). Lindholm (1967) inferred this basinal axis to continue northwards to the vicinity of Albany, New York. After the deposition of the Helderberg, Deerpark, and lower and middle Onesquethaw sediments in the basin, two events occurred. The first was a major regression in the basin, exposing the sediments to erosion, and resulting in the widespread unconformity at the base of the Onondaga. The second was the shifting of the Appalachian basinal axis back towards the west. Lindholm (1967) placed the basinal axis in the center of New York State, where the Onondaga is thin, with thickening occurring to both the east and west. Mesolella (1978) confirmed the position of this topographic basinal axis based upon his interpretation of extensive subsurface data. As a result, the Onondaga basin trended in an approximately northeast-southwest direction (Figure 1).

LOCATION OF ROBERTS HILL AND ALBRIGHTS REEFS

The locations of all Edgecliff reefs known as of 1976 are included on Figure 1. Roberts Hill and Albrights reefs are located in the Ravenna 7.5 minute Quadrangle and are the southernmost reefs in the eastern Onondaga outcrop belt (numbers 1 and 2 on Figure 1). Their location is only about 12 miles north of Leeds, where Oliver (1956) placed the boundary between his eastern and southeastern Onondaga facies. This boundary appears to mark a depth related facies change, with depths increasing to the south (see Cassa and Kissling, 1982, p.73).

ALBRIGHTS REEF

Only a small portion of the original reef has been preserved at this locality. Both the hillock on the west side of Roberts Hill Road (Figure 2) and the dipping beds to the east of it are mainly crinoidal packstone/grainstone with large favositids (Emmonsia and Favosites). These exposures represent former low-angle (4 - 8 degree) crinoidal sand flanks, with most of the present dip being tectonically derived.

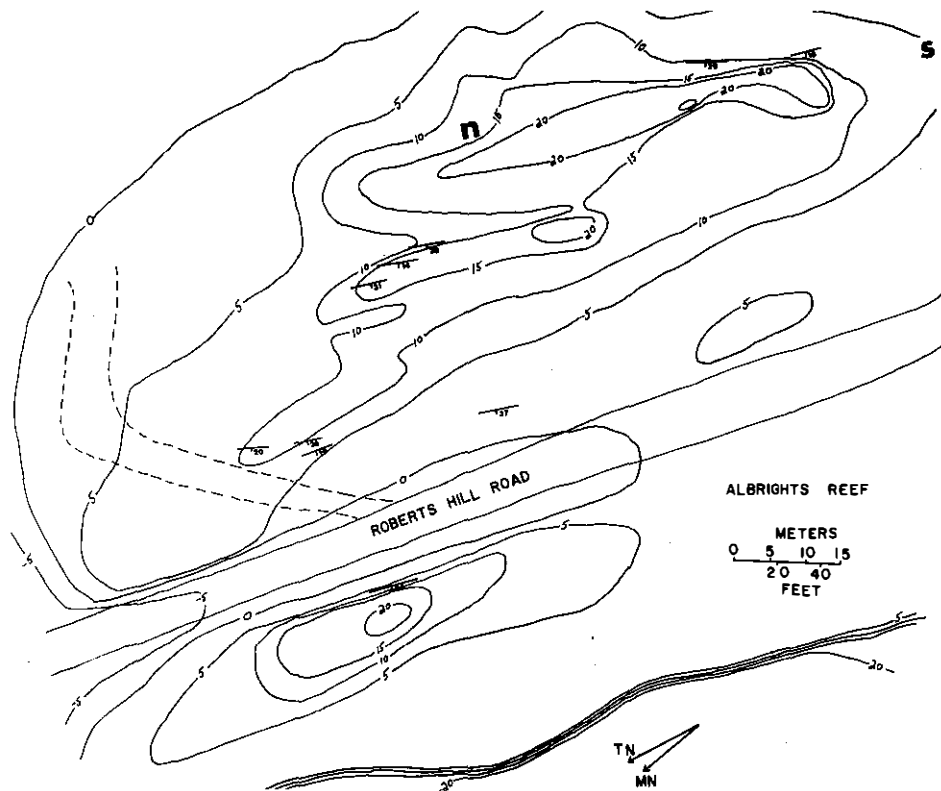


FIGURE 2. Topographic map of Albrights Reef. (n) and (s) on upper part of map mark position of cliff face illustrated in Figure 3. All other exposures are crinoidal flank deposits. Contour values relative to an arbitrarily selected zero point on Roberts Hill Road.

The most notable feature of Albrights Reef is the cliff-face exposure of the rugosan core at the eastern end of the outcrop (Figure 3). Here, a cross-section through the rugosan core displays evidence of the rugosan succession during mound development. As illustrated in Figure 3, initial colonization of the micritic Edgecliff sea-floor was carried out by the phaceloid colonial rugosan Acinophyllum, which was eventually replaced on the southern side of the mound by Cylindrophyllum (a somewhat similar phaceloid colonial rugosan with larger corallites). Cylindrophyllum remained dominant until the core was covered by the flank sands.

The lithology of the rugosan core is mainly a calcisilt bafflestone. Within the basal Acinophyllum portion of the mound there is little evidence of damage to the corals, with most of the present "flattening" of the colonies due to compaction. The first evidence of disturbance of the reef can be seen approximately 3 feet above the base of the mound at approximately the level of the chert nodules on Figure 3. Here the rock at the southern end of the exposure is devoid of rugosans, contains minor biosparites with an erosional base, and marks a temporary shrinkage of the areal extent of the coral thicket, possibly due to storm destruction. This horizon marks the only evidence of interfingering of the core with off-mound sediments. About 10 feet above the base of the mound, within the Cylindrophyllum dominance zone, evidence of storm damage (broken rugosan

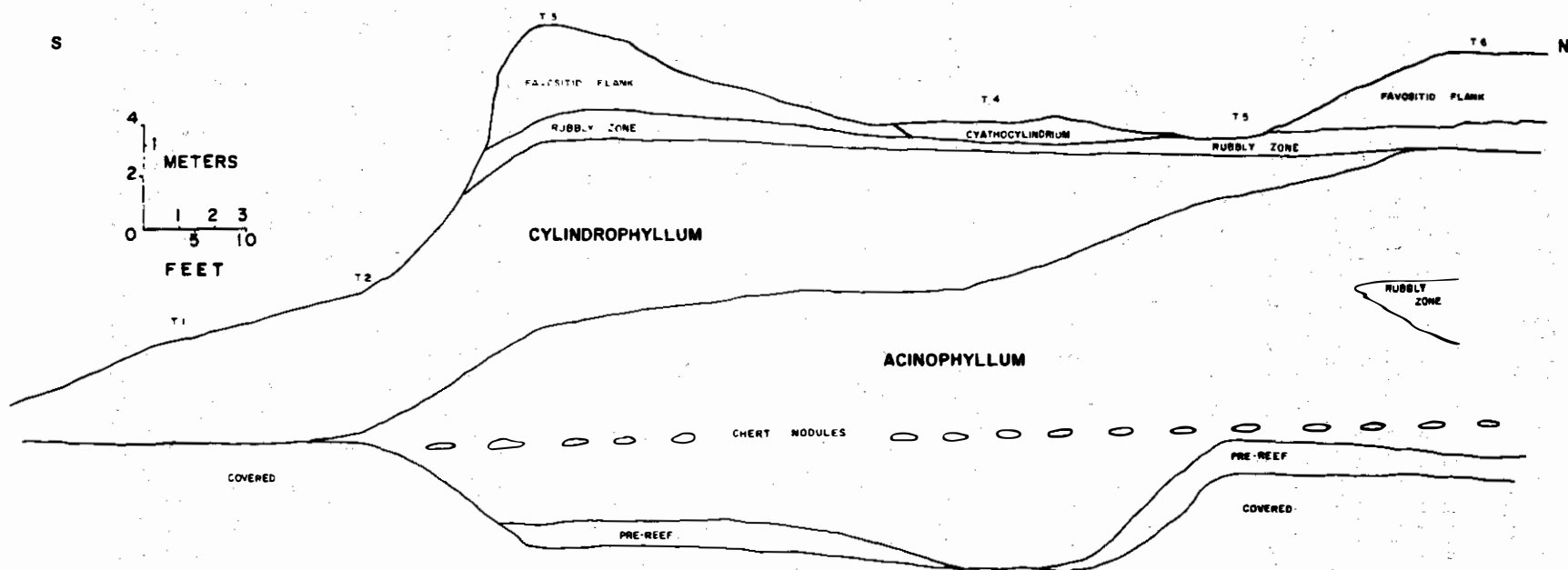


FIGURE 3. Interpretative cross-section of Inner Core exposure at Albrights Reef. Note that the contact between the Acinophyllum and Cylindrophyllum dominance zones suggests replacement over the entire fore-reef, and not a simple vertical successional pattern. Also note that rubble zone marks the contact between the massive Inner Core facies and the bedded Favositid Flank facies. Use (S) and (N) at upper ends of figure to orient cross-section with Figure 2, the topographic map of Albrights Reef.

corallites and small overturned favositids) becomes common although the primary lithology remains calcisilt.

The bed which marks the contact between the core and flanks is notable for its abundant overturned favositids and broken rugosans, which together give it a more "rubbly" appearance than is characteristic of the flank beds in general. Numerous broken Cylindrophyllum corallites with large clumps of micrite still attached indicate partial erosion of the core. This suggests turbulence conditions of greater intensity than had previously existed during the growth of the rugosan mound.

ROBERTS HILL REEF

In contrast to Albrights Reef, Roberts Hill Reef is almost completely preserved, having lost only its crest and minor portions of its eastern flanks to erosion. Solution along joints has resulted in good exposure of the interior of the reef, allowing examination of almost all reef facies and developmental stages.

As illustrated in Figures 4 (topographic map) and 5 (interpretative cross-section), Roberts Hill Reef may be divided into a number of facies. The Inner Rugosan Core, or initial mound facies, consists of a dense colonial rugosan bafflestone similar to that at Albrights Reef. At Roberts Hill, however, the Inner Core is the result of a succession of three rugosan genera, as opposed to the two stage succession at Albrights Reef. Cyathocylindrium, another phaceloid colonial rugosan (with larger corallites than Cylindrophyllum), dominates the final successional stage of Inner Core growth. While field relations support the Cylindrophyllum - Cyathocylindrium succession, the presence of Acinophyllum as the initial core builder in Figure 5 is an interpretation. This interpretation is based upon analogy with Albrights Reef, and in consideration of the fact that Acinophyllum is documented as the initial successional stage in all eastern Edgecliff reefs studied to date (see references in Introduction).

The rugosan succession is both a vertical and lateral succession on the south side of the mound (Figure 5). There is, however, no evidence for the presence of Cyathocylindrium in the northernmost Inner Core exposures where Cylindrophyllum is the dominant rugosan.

The lithology of the Inner Core is also very similar to that at Albrights Reef. For the most part the inter- and intracorallite lithology is a bioclastic calcisilt, but near the edge of the core on the south side of the mound the initial intracorallite calcisilts are often found to have been partially washed out and replaced by a calcisilt packstone with coarse bioclasts. Finely comminuted rugosan septal fragments are also common in this part of the reef. Despite this evidence of higher energy conditions, there is again little evidence of interfingering between the Inner Core and the flanks. A "rubbly zone" also marks the core/flank contact at Roberts Hill, but it is nowhere well exposed.

Surrounding the Inner Core are the crinoidal packstone/grainstone flank beds. On the south and west sides of the hill these flanks contain numerous large overturned favositids. Along the northeast edge of the hill these flank beds can be differentiated into a back-reef debris apron and normal flank beds (Figure 5). The normal flank beds consist of crinoidal debris and are similar to those found on the southern and western sides of the Inner Core, but with large favositids only rarely overturned. On the other hand, the debris flanks are characterized by dense accumulations of the solitary rugosan Cystiphyloides, with large overturned favositids and broken phaceloid rugosans. Packing of the Cystiphyloides coralla is tight, and at first glance these deposits can easily be mistaken for masses of colonial rugosans similar to the Inner Core facies. This unit is interpreted as a debris apron and not a simple back-reef facies because it onlaps the reef conformably to the underlying and overlying normal reef flanks.

To the south the flank beds are overlain by a dense rugosan assemblage similar to that which formed the Inner Core, labeled the Rugosan Recolonization Zone in Figure 4. Just below the contact with the Recolonization Zone the flanks contain a number of features not found previously within these former crinoidal sands. Scours become common, as do erosional contacts along bedding plane contacts. Syndimentary cements and associated framework silt-infills, similar to those noted by James, et al. (1976) on the reef crest off Belize, mark a horizon about 1 foot below the contact. This horizon has been found at both the paleotopographic crest of the reef and at its foot. Finally, wherever the exact contact between the flanks and Recolonization Zone has been found, the upper portion of the flanks (approximately 4 inches of crinoidal grainstone) appears to be barren of corals or other large body fossils.

The overlying Rugosan Recolonization Zone is notable for three reasons: a) it marks a recolonization of the mound by the original core building fauna of colonial rugosans, b) it is characterized by a succession of rugosan genera directly opposite to that noted in the Inner Core (i.e., Cyathocylindrium recolonizes and is succeeded by Cylindrophyllum), and, c) it marks the return of abundant calcisilt in the reef as compared to the well-washed crinoidal sands below the Recolonization Zone.

The units which overlie the Recolonization Zone to the south (Figure 5) are mainly the result of deposition following the death of the reef (as are the exposures along the west side of Limekiln Road). The only possible exception may be the fore-reef debris deposits which can be seen along the cliff exposure on the east side of the hill (Debris lenses in Figure 5). Here, rubble derived from the Recolonization Zone consists of both favositids and phaceloid colonial rugosans. The micrite which fills the intercorallite spaces also forms a rim around these colony fragments, suggesting that these are not simply displaced colonies, but are instead large intraclasts, which would indicate erosion of the reef at this time.

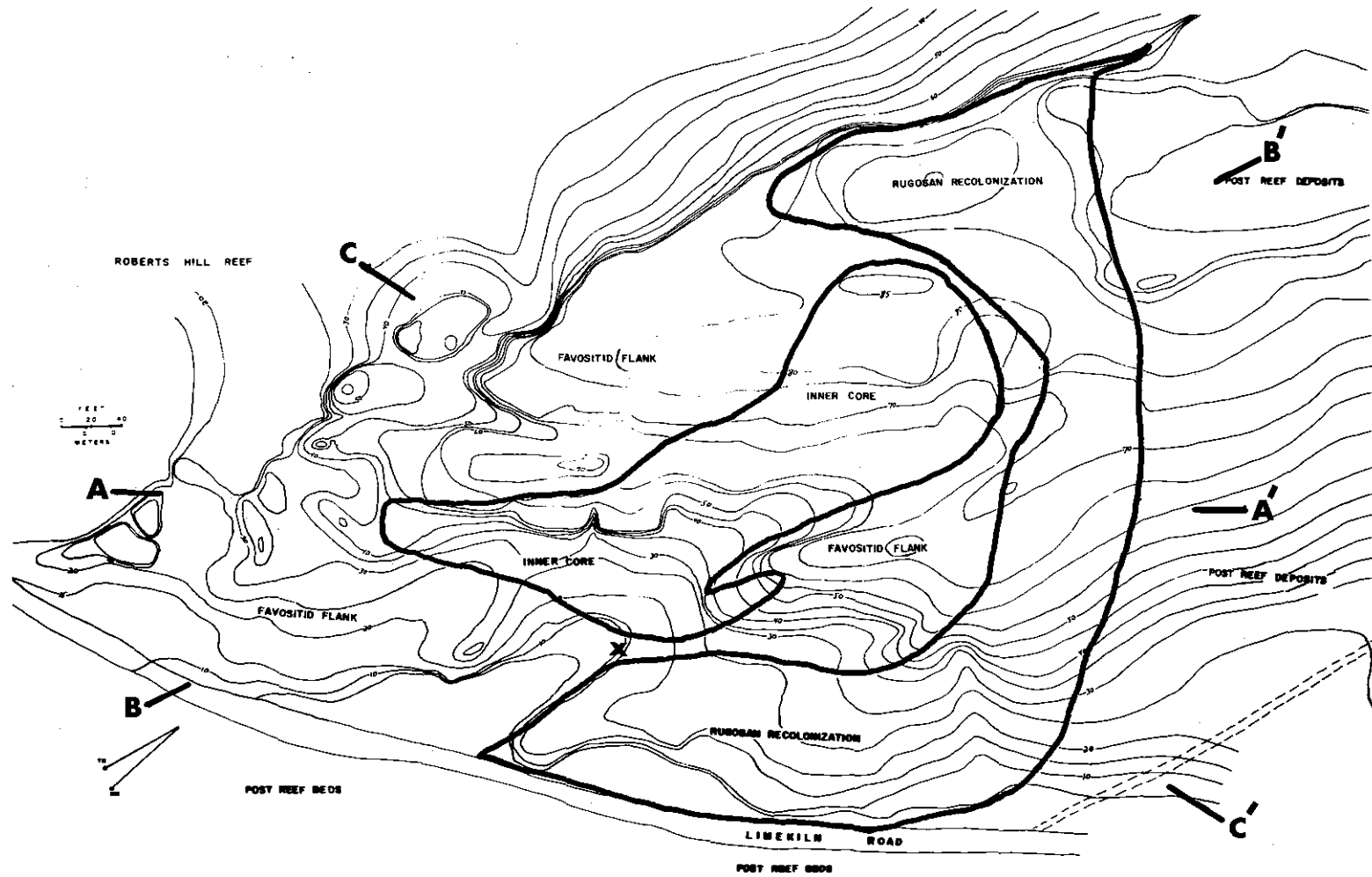


FIGURE 4. Topographic map of Roberts Hill Reef with reef facies boundaries. A - A', B - B' and C - C' marks positions of cross-sections illustrated in Figure 5. Contour values relative to an arbitrarily selected zero point at the intersection of Limekiln and Haas Hill Road.

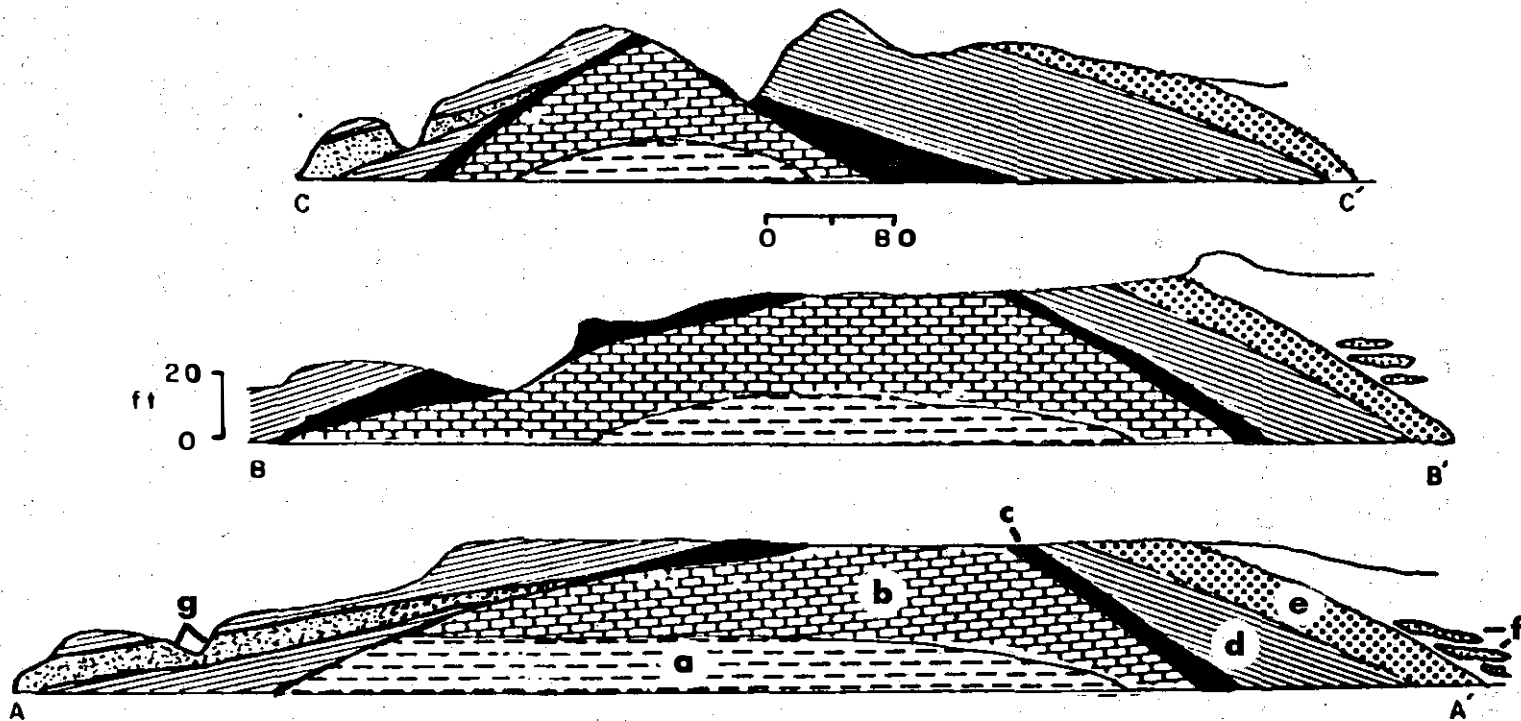


FIGURE 5. Interpretative cross-sections of Roberts Hill Reef. Inner Core consists of three facies: a = *Acinophyllum* dominance zone, b = *Cylindrophyllum* dominance zone, and c = *Cyathocylindrium* dominance zone. Flank facies include d = normal crinoidal sand flank beds and g = back-reef rubble apron. e = Rugosan Recolonization Zone, and f = fore-reef rubble lenses. For positions of cross-sections see Figure 4, topographic map of Roberts Hill Reef.

CRITERIA FOR REEF ZONATION

1) FORE TO BACK-REEF TRENDS

A) RUBBLE APRON TO NORTHEAST

B) PREFERRED RUGOSAN RECOLONIZATION
ON SOUTH SIDE OF MOUND

C) BREAKDOWN OF COMMUNITY STRUCTURE TO NORTH

2) TURBULENCE INDICATORS

A) % OVERTURNED COLONIES

B) EVIDENCE OF RUGOSAN BREAKAGE

C) SYNSEDIMENTARY CEMENTATION

D) SCOURING

E) DEGREE OF WASHING OF CRINOIDAL SANDSTONES

FIGURE 6. Criteria used to identify paleocurrent direction and increased levels of environmental turbulence.

EVIDENCE FOR CURRENT DIRECTION DURING REEF GROWTH

Both paleoecological and sedimentary evidence (Figure 6) can be used to support an interpreted current flow from approximately southwest to northeast. The paleoecological evidence consists of the preferential colonization of the south to southwestern sides of both Albrights and Roberts Hill reefs by rugosans. Note (Figure 3) that at Albrights Reef the replacement of Acinophyllum by Cylindrophyllum took place on the south side of the mound with the formerly dominant coral genus being displaced to the north side of the mound. At Roberts Hill Reef (Figure 5) Cyathocylindrium can be found to displace Cylindrophyllum on the south side of the mound while the north side of the Inner Core exposures offer no evidence for the presence of Cyathocylindrium. Further, the recolonization of the mound took place preferentially on the southern side of the mound, with no evidence to suggest that the major rugosan recolonization extended to the north side of the reef. Finally, while the south side of the mound displays a well developed community structure in the presence of dominance zones, no such zones exist on the northern sides of either Albrights or Roberts Hill reefs. When rugosan colonies are found on the north sides of the mounds they appear to be haphazard groupings of genera. Preferential placement on the up-current side of reefs or mounds is known to occur in both recent shallow and deep-water reefs (Wallace and Schafersman, 1977; Reed, 1980).

Sedimentologic evidence in support of a northeast flowing current consists of the debris apron which is found on the north side of the reef, scours and intercorallite cross-bed like structures on the south side of the reef, and abundant overturned favositids in the southern flanks as compared to almost no overturning in the normal flanks exposed along the cliff wall on the northeast side of the hill.

OBSERVATIONS	POSSIBLE CAUSES		
	UPWARDS REEF GROWTH	FALLING SEA-LEVEL	RISING SEA-LEVEL
INNER CORE RUGOSAN SUCCESSION		X	
INNER CORE - FLANK FABRIC CHANGES	X	X	
LACK OF CORE - FLANK INTERFINGERING		X	
FORMATION OF BACK-REEF RUBBLE ZONE	X	X	
INCREASED OVERTURNING OF FAVOSITIDS	X	X	
TOPOGRAPHIC POSITION OF SYNSEDIMENTARY CEMENT		X	
RUGOSAN RECOLONIZATION WITH REVERSAL OF INNER CORE SUCCESSION			X
CESSATION OF RUBBLE ZONE DEPOSITION			X
INCREASED CALCISILT DEPOSITION			X

FIGURE 7. Listing of observations made at Roberts Hill and Albrights reefs versus possible causes. Note: "Upwards Reef Growth" assumes static sea-level. See text for details.

EVIDENCE FOR AN ONONDAGA SEA-LEVEL FLUCTUATION

As mentioned in the Introduction, most previous studies of Edgecliff reefs have concluded that evidence of increased turbulence found near the tops of these reefs is due simply to upwards reef growth under static sea-level conditions. While numerous observations made at these reefs do suggest increasing turbulence through initial (Inner Core) growth, an alternative hypothesis - that growth took place during a period of falling sea-level - may better explain these observations. In order to test these two hypotheses, Figure 7 lists observations made at these reefs with possible interpretations of their cause.

Three observations appear to be totally neutral with regard to either falling sea-level or upwards reef growth with static sea-level. Sedimentary fabric changes across the core/flank boundary are suggestive of increased turbulence and occur both at the reef crest and at its foot, but since breakage products from the reef crest may easily be transported down the reef as sand and silt sized sediment, this observation is neutral. The same argument holds for the percentage of overturned favositids in either high or low fore-reef positions; and a back-reef rubble zone would be expected to form behind a high energy reef crest regardless of how the reef had managed to enter the high energy zone.

The rugosan succession in the Inner Core may be considered neutral if it is a purely vertical succession, since reef crest communities in the Carribean, for instance, are known to be controlled by turbulence level (Geister, 1977). The succession in the Inner Core and Recolonization Zone at Roberts Hill and Albrights reefs are, however, not only vertical but also lateral, and hence, if controlled by the level of

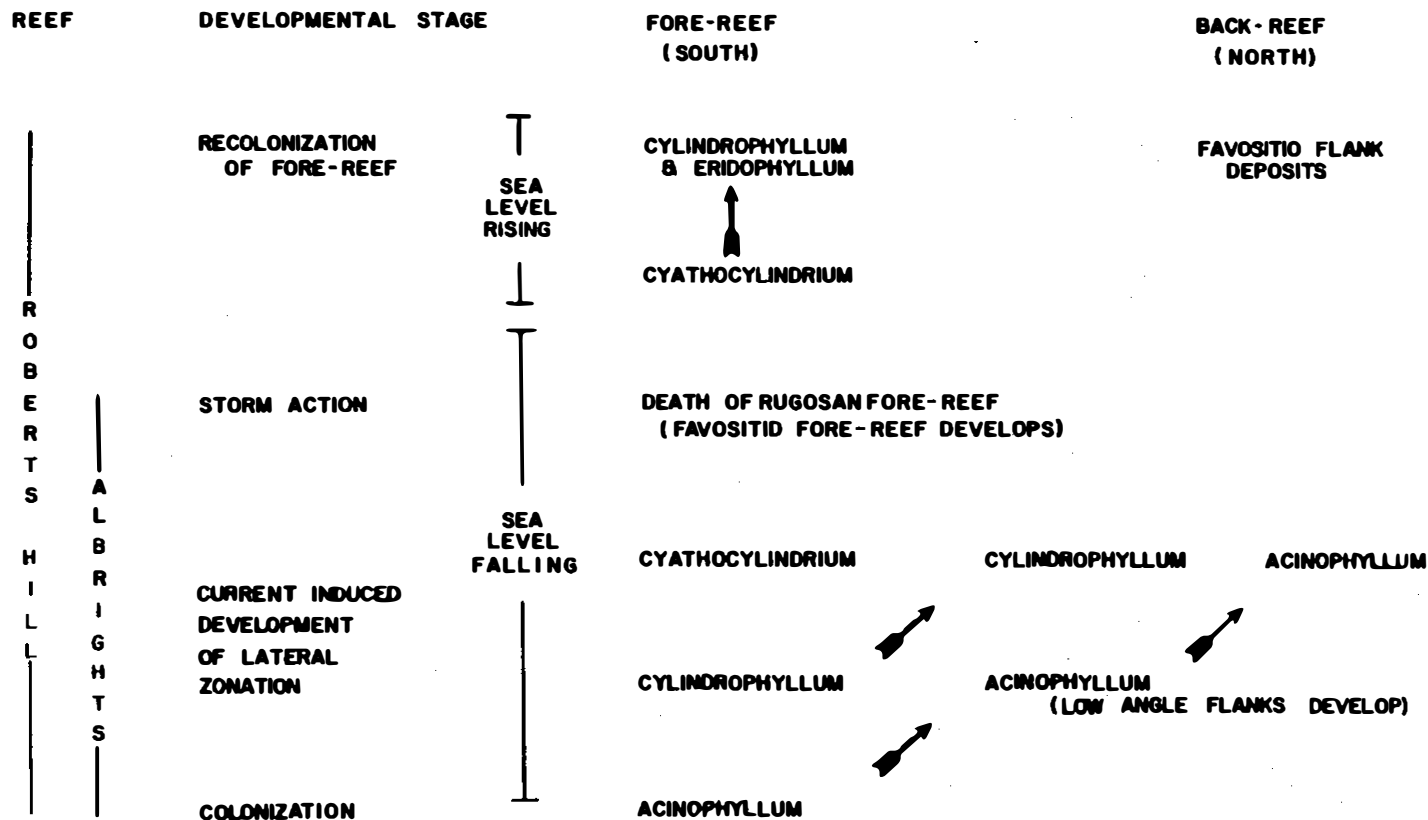


FIGURE 8. Model for the development of Roberts Hill and Albrights reefs. Vertical lines at left mark extent of preserved reef development. Growth of Inner Core is controlled by a succession of three rugosan genera with falling sea-level. Note that early stage genera are displaced to back-reef area (*Cyathocyliodrium* of only minor importance at Albrights Reef). At lowest sea-level Roberts Hill Reef was a crinoïdal sand bank with some favositids. Recolonization Zone marks return of rugosans (in reversed successional order) due to rise in sea-level. Final drop in sea-level ends reef growth.

turbulence, must reflect uniformly changing conditions over the entire fore-reef since the rugosan dominance zones extend from the crest to the foot of the mound. Therefore, the lateral rugosan succession can only be explained by falling sea-level, since simple upward reef growth would not cause such a uniform change in turbulence conditions.

The above argument may also be applied for the topographic position of the synsedimentary cements below the Recolonization Zone/flank contact. Synsedimentary cements occur only below this contact, following it from reef crest to foot, over a vertical range of about 35 feet. Since the lower boundary of the Recolonization Zone is assumed to mark a biological event - a time line - the assumed high turbulence conditions required to form these cement fabrics would have had to affect the entire reef at the same time - a requirement which reef growth into a high energy zone could not meet.

The lack of core/flank interfingering also suggests falling sea-level. Roberts Hill may be considered as a preserved sequence of three consecutive communities: a rugosan mound followed by a favositid/crinoid sand bank, and lastly, a new rugosan mound. That the Inner Rugosan Core originally consisted of a large mound without flanks is supported by the complete lateral rugosan succession within the core. If the core and flanks had been developing simultaneously we would expect to find both extensive interfingering of the core with flank sands, and overgrowth of the flanks by later rugosan successional stages. At point X on the Roberts Hill map (Figure 4) the Cyathocylindrium (final) stage of core development may be seen near the topographic base of the reef underlying the flank sands. A second consideration is simply the concept of "flank" beds. Generally, flank beds are considered to have been derived from the actively growing reef, but in the case of Albrights and Roberts Hill reefs the cores could not have acted as the source for the crinoidal flank sands since they consist of calcisilt bafflestone. Hence, the flanks must be considered a separate, in-place buildup of "normal" Edgecliff grainstone/packstone around the already extant rugosan core. Such a relationship would explain the difference in turbulence levels suggested by comparison of the Inner Core fabrics with those of the flank beds with their large overturned favositids. This would also fit a model of falling sea-level, with the rugosan core being a low energy community and the favositid flanks developing under higher energy conditions. Finally, the rubble zone on the north side of Roberts Hill supports this three community concept. If an actively growing colonial rugosan community had, in fact, reached the high turbulence zone, then the rubble apron would be expected to be heavily dominated by fragments of these colonies. Instead, the rubble zone primarily consists of the small solitary rugosan Cystiphyllodes and overturned favositids - both characteristic of the flank deposits on the south side of the mound - with only minor contributions from colonial rugosans. This similarity of rubble zone fauna to that of the normal flanks, instead of the rugosan core, suggests that at the time the rubble apron began to form the normal flanks were already well developed and possibly the main reef facies. Since it is doubtful that either the solitary rugosans or the widely spaced favositids could account for active or rapid upwards growth of the mound, falling sea-level appears to be the logical answer.

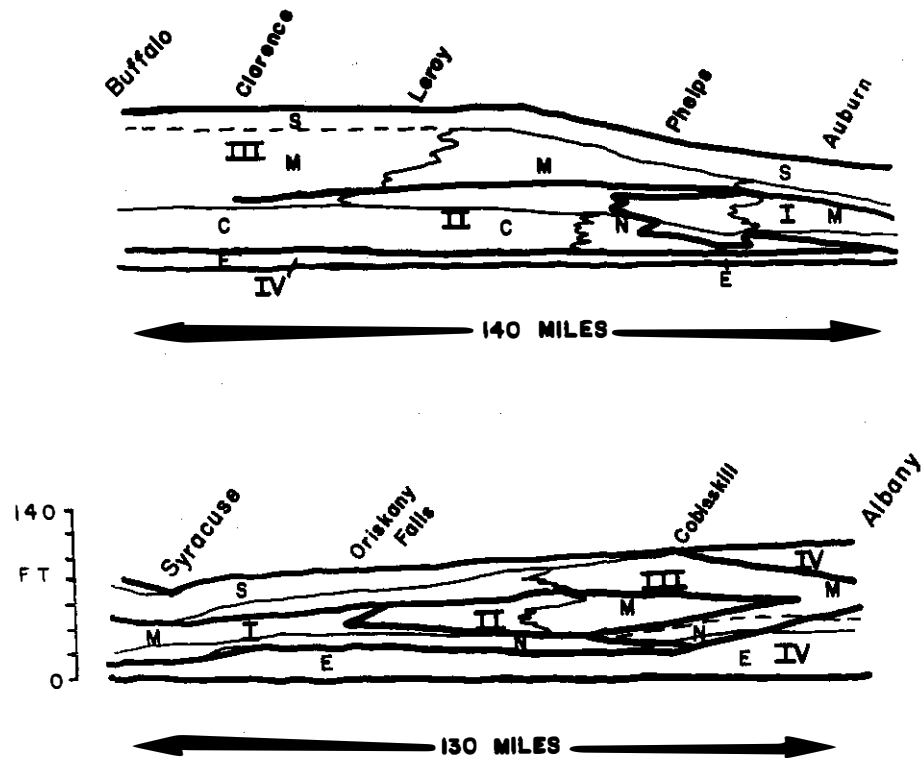


Figure 9. Cross section showing Oliver's (1954, 1956) stratigraphic units (E=Edgecliff, N=Nedrow, M=Moorehouse, and S=Seneca) and Lindholm's (1967) lithofacies (I=fossiliferous calcisiltite with about 25% clay and less than 10% fossils, II=fossiliferous calcisiltite with about 5% clay and less than 10% fossils, III=biocalcisiltite with 10 - 50% fossils, and IV=biosparite and biocalcisiltite with greater than 50% fossils). From Lindholm (1967, p.144).

A reversal of this falling sea-level trend is clearly indicated by the cessation of rubble zone deposition with a return to normal flank conditions, the formation of the Rugosan Recolonization Zone with its reversal of the original Inner Core succession, and the similarity of Recolonization Zone sedimentary fabrics to those of the Inner Core. This reversal in sea-level trend was probably short lived, with return to falling sea-level resulting in the final death of Roberts Hill Reef. Figure 8 summarizes the resultant model for the development of Roberts Hill and Albrights reefs under these fluctuating sea-level conditions.

BASINAL EVIDENCE

The stratigraphy of the Onondaga Formation lends further support to the assumed sea-level fluctuation. As mentioned earlier, the basal contact of the Onondaga in the east indicates at most a discontinuity in sediment deposition as compared to major erosion to the west. Further, the basal C1 unit in the eastern Edgecliff is similar to the assumed deeper water wackestones to the south and passes upwards into the shallow water packstone/grainstone facies of the C2 unit. From that point on the

eastern Onondaga lithology undergoes little change, remaining a mainly shallow water facies, while to the west in the center of the basin at least four facies are present (Figure 9). This suggests that Edgecliff deposition began in the east, but water depth gradually decreased there as the basinal axis shifted westward with the major westward transgression. Following the stabilization of the basinal axis in its central New York position, a sea-level fluctuation took place. This fluctuation may be noted in Figure 9, taken from Lindholm's (1967) study of Onondaga microfacies. Note the classic transgressive/regressive shift of the deeper water facies first to the east and then back to the west. This pattern marks the sea-level fluctuation recorded so well in Roberts Hill Reef.

ROBERTS HILL AND ALBRIGHTS REEFS - A MODEL FOR EDGECLIFF REEF GROWTH?

Figure 8, the model for the sequential development of Albrights and Roberts Hill reefs may be used as a general model for Edgecliff reef growth, but only with caution. The initial Inner Core rugosan succession from Acinophyllum to Cyathocylindrium with the late development of crinoidal flanks may be used as a first approximation of an "average" Edgecliff reef; however, we may well ask whether there is in fact any such thing as an "average" Edgecliff reef. Development of Roberts Hill and Albrights reefs was strongly affected by sea-level change, possibly caused by a shift in the position of the basinal axis. Since these are the two most eastern of the Edgecliff reefs what might we expect to find in the reefs to the west?

Paquette (1982) has presented evidence for the presence of a storm disturbance horizon at the base of the Mt. Tom reef near Richfield Springs. Since the entire exposed core of Mt. Tom lies above this horizon and is made up almost exclusively of Acinophyllum, Paquette has suggested that reef growth may have begun in shallow water but continued under conditions of increasing water depth due to subsidence in the basin. The presence of Mt. Tom near the edge of the erosional unconformity that marks the base of the Onondaga and its closeness to the final topographic basinal axis may support this hypothesis.

Coughlin (1980, p.141) describes a repetition of coral dominance zones (Cylindrophyllum/Acinophyllum - Acinophyllum/Cladopora - Cylindrophyllum) in a drill-core from the subsurface Thomas Corners reef in Steuben County. This may be due to episodic sea-level changes during basinal subsidence.

Finally, Poore (1969) in his study of the Leroy bioherm describes an Inner Core dominated by Cystiphyllodes and Cladopora - a situation apparently unknown in the eastern Edgecliff reefs.

These studies indicate that there is much diversity in the patterns of development displayed by the Edgecliff reefs, but there is also much in common among them. Since it appears probable that major changes were occurring in the Onondaga basin during reef growth Figure 8 may be used as a model only if differences in basinal conditions based upon geographic location are kept in mind. Whether or not an "average" Edgecliff reef

truly exists, Figure 8 may then be a useful first approximation of a model for Edgecliff reef development.

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MILAGE LOG:

- | | | |
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| 0.0 | 0.0 | Toll booth at Exit 21b of N.Y. State Thruway, Coxsackie exit. Make right turn onto Rt. 9W north. |
| 2.2 | 2.2 | Left turn onto County Rt.51. |
| 0.7 | 2.9 | Bear left onto County Rt.54. |
| 0.8 | 3.7 | Right turn onto Roberts Hill Road. |
| 0.15 | 3.85 | STOP I. ALBRIGHTS REEF. Park cars along shoulder of road. Main part of reef lies to the right (east). Exposures along road are crinoidal sand/favositid flank deposits. Cliff face about 130 feet to east exposes rugosan constructed Inner Core. Turn cars around and proceed south on Roberts Hill Road. |
| 1.5 | 5.35 | Right turn onto Reservoir Road. |
| 0.7 | 6.05 | Left turn onto Limekiln Road. |
| 0.3 | 6.35 | STOP II. ROBERTS HILL REEF. Reef lies to the east of the road and makes up the entire northern portion of the hill. Old logging road marks approximate southern end of reef. Exposures to the west of the road and south of the logging road consist of post-reef growth flanks. CAUTION: SOLUTION EXPANDED JOINTS ARE COMMON ON THE TOP OF THE HILL AND ARE COMMONLY FILLED WITH LEAVES. PLEASE WATCH YOUR STEP. Continue south on Limekiln Road. |
| 1.1 | 7.45 | Left turn onto Schiller Park Road. |
| 1.4 | 8.85 | Left turn onto Rt.9W. |
| 0.6 | 9.45 | Right turn for Thruway entrance. |

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Structure and Rock Fabric Within the Central and Southern Adirondacks

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INTRODUCTION

The area referred to as the southern Adirondacks is shown in Figure 1. Within this region, the Precambrian is bounded approximately by the towns of Lowville and Little Falls on the west and Saratoga Springs and Glens Falls on the east (Fig. 2).

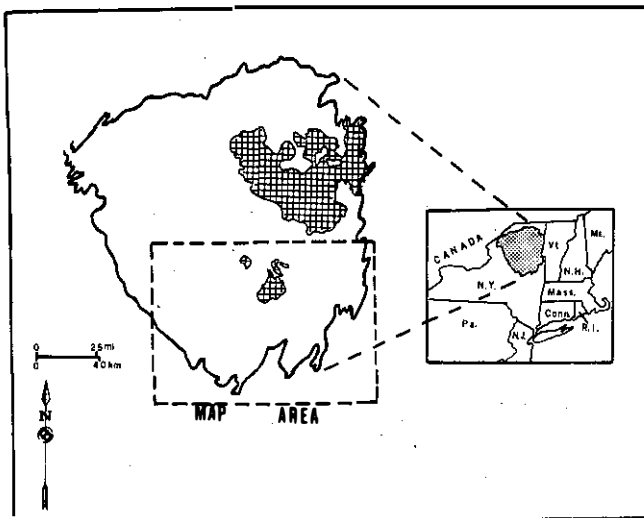


Fig. 1. Location map of the Adirondack Mts. Major anorthosite massifs are represented by the grid pattern. The central and southern Adirondacks lie within the dashed rectangle labeled "Map Area".

Mapping in the southern Adirondacks was done first by Miller (1911, 1916, 1920, 1923); Cushing and Ruedemann (1914); Krieger (1937); and Cannon (1937); more recent investigations were undertaken by Bartholome (1956), Thompson (1959); Nelson (1968); and Lettney (1969). At approximately the same time Walton (1961) began extensive field studies in the eastern portion of the area (Paradox Lake, etc.), de Waard (1962) began his studies in the west (Little Moose Mt. syncline). Subsequently de Waard was joined by Romey (de Waard and Romey, 1969).

Separately and together, Walton and de Waard (1963) demonstrated that the Adirondacks are made up of polydeformational structures, the earliest of which consist of isoclinal, recumbent folds. Their elucidation of Adirondack geology set the tone for future workers in the area. In this regard one of their most important contributions to the regional picture was that the lithologic sequence of the west-central Adirondacks is similar to that of the eastern Adirondacks.

Beginning in 1967 McLelland (1969, 1972) initiated mapping in the southernmost Adirondacks just to the west of Sacandaga Reservoir subsequently this work was extended north and east to connect with that of Walton and de Waard.

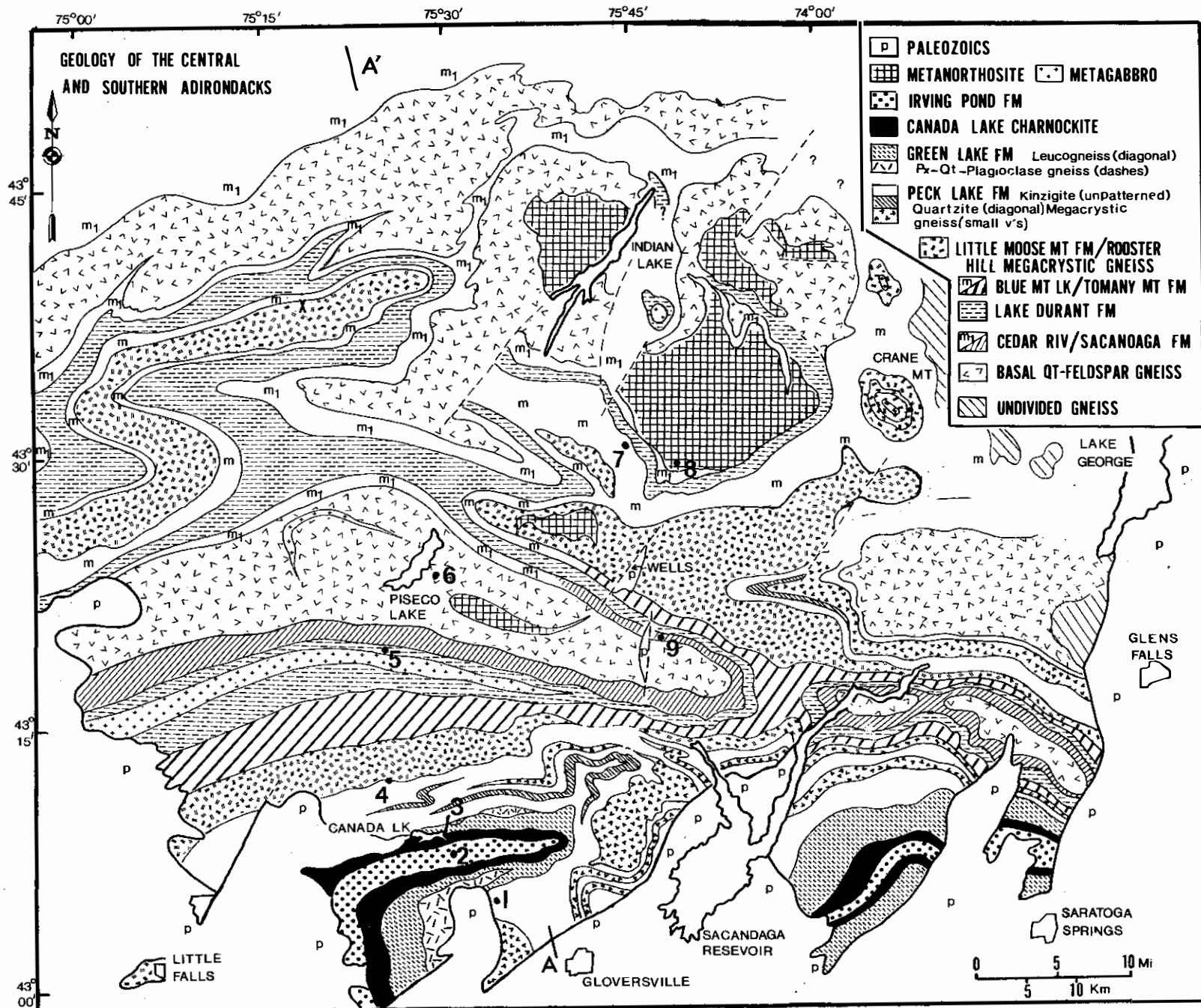


Fig. 2. Formational map and stop localities for the central and southern Adirondacks (from McLelland and Isachsen, 1980)

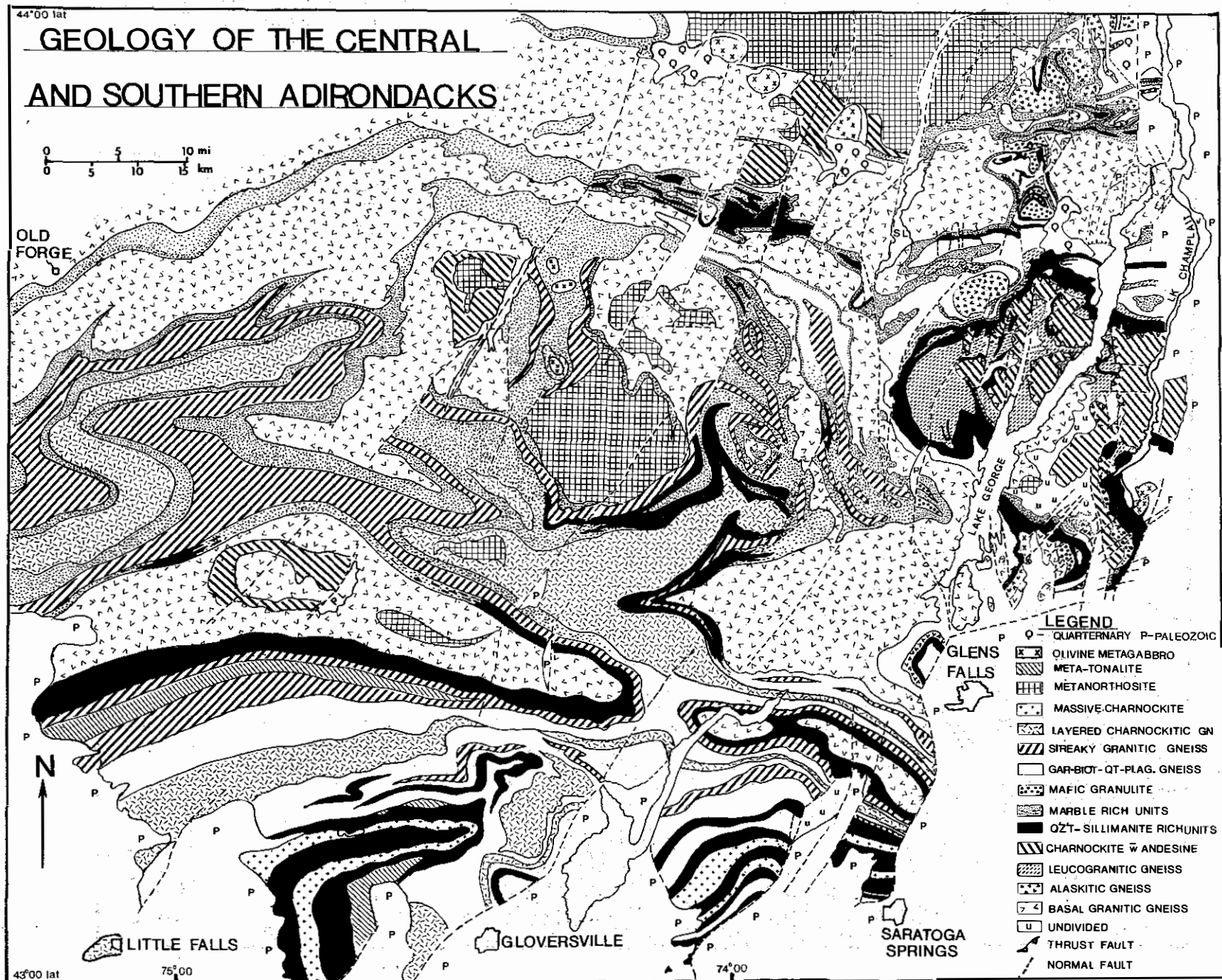


Fig. 3. Lithological map of the central and southern Adirondacks. Note that only a few high angle faults are shown.

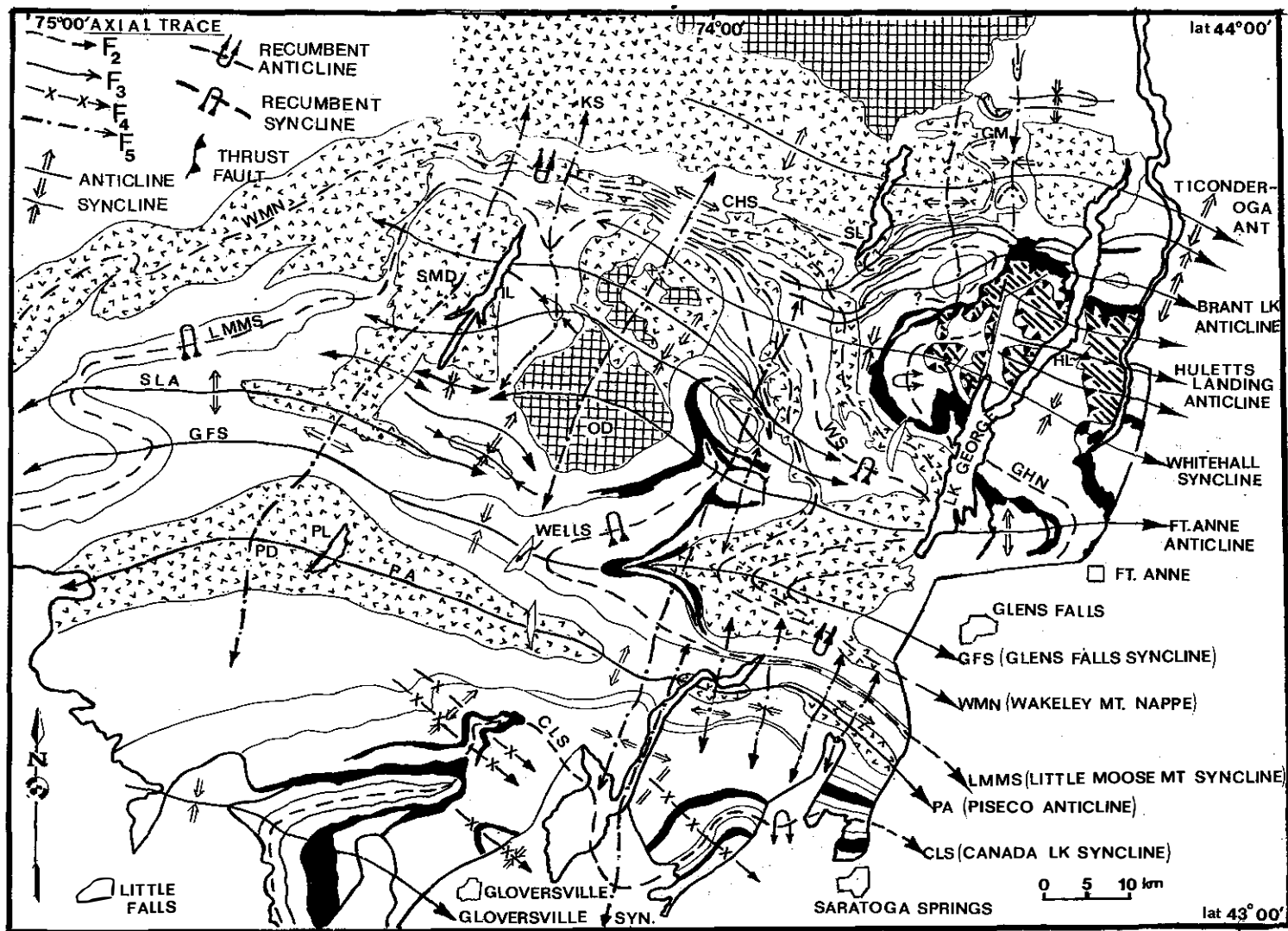


Fig. 4. Axial trace map of the central and southern Adirondacks. For lithological map symbols see Fig. 3. Abbreviations not on map: CHS - Canada Hill syncline; GHN - Green Hill nappe; GM - Glidden Marsh syncline; HL - Huletts Landing; OD - Oregon Dome; PD - Piseco Dome; PL - Piseco Lake; SL - Schroon Lake; SLA - Spruce Lake anticline; SMD - Snowy Mt. Dome; WS - Warrensburg syncline

Geraghty (1973) and Farrar (1976) undertook detailed mapping in the eastern half of the North Creek 15' quadrangle, and tied into investigations in the Brandt Lake region by Turner (1971). Recently, Geraghty (1978) completed a detailed study of the structure and petrology in the Blue Mt. Lake area. Current investigations by McLelland and by the N.Y. Geological Survey are going forward in the general region surrounding Lake George.

The foregoing investigations have increased our knowledge of the southern Adirondacks, and this fieldtrip is designed to show as many examples of the region's structure, lithology, and petrology as time permits.

STRUCTURAL FRAMEWORK OF THE SOUTHERN ADIRONDACKS

The southern Adirondacks (Figs. 2-5) are underlain by multiply deformed rocks which have been metamorphosed to the granulite facies. The structural framework of the region consists of four unusually large fold sets, $F_2 - F_5$ together with an early set of isoclines represented solely by intrafolial minor folds with associated axial planar foliation (Figs. 2-4). Relative ages have been assigned to these fold sets, but no information exists concerning actual time intervals involved in any phase of the deformation. It is possible that several, or all of the fold sets, are manifestations of a single deformational continuum.

The earliest and largest of the map-scale folds are recumbent, isoclinal structures (F_2) -- for example the Little Moose Mt. syncline (de Waard, 1962) and Canada Lake nappe (McLelland, 1969) (Figs. 2 and 5). These isoclines have axes that trend approximately E-W and plunge within 20° of the horizontal. As seen in Figures 4 and 5 the axial traces of each of the F_2 folds exceeds 100 km. They are believed to extend across the entire southern Adirondacks. Subsequent useage of the terms "anticline" and "syncline," rather than "antiform" and "synform," is based on correlations with rocks in the Little Moose Mt. syncline where the stratigraphic sequence is thought to be known (de Waard, 1962).

Close examination reveals that the F_2 folds rotate an earlier foliation defined principally by platets of quartz and feldspar and axial planar to minor intrafolial isoclines. Although this foliation is suggestive of pre- F_2 folding, such an event does not seem to be reflected in the regional map patterns (Fig. 3). However, it is possible that major pre- F_1 folds exist but are of dimensions exceeding the area bounded by Figure 3. If this is the situation, their presence may be revealed by continued mapping. The existence of such folds is suggested by the work of Geraghty (1978) in the Blue Mt. area. In the vicinity of Stark Hills charnockites of the Little Moose Mt. Fm. appear to be identical to supposedly older quartzo-feldspathic gneisses (basal) which lie at the base of the lithologic sequence. Given this situation, then the Cedar River and Blue Mt. Lake Fms. are identical, and there emerges a pre- F_2 fold cored by the Lake Durant Formation. However, careful examination of the Lake Durant Formation has failed to reveal the internal symmetry implied by this pre- F_2 fold model. It is possible, of course, that the pre- F_1 foliation may not be related directly to folding (e.g. formed in response to thrusting, gravity sliding, etc.; Mattauer, 1975). Currently the

origin of the pre-F₂ foliation remains unresolved. In most outcrops the pre-F₂ foliation cannot be distinguished from that associated with the F₂ folding.

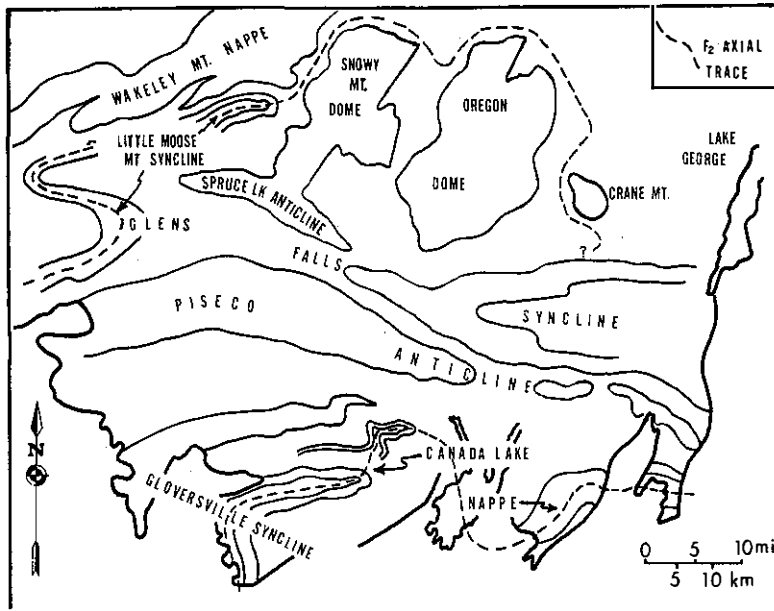


Fig. 5. Blocked out major folds of the central and southern Adirondacks (from McLelland and Isachsen, 1980).

Following the F₂ folding, there developed a relatively open and approximately upright set of F₃ folds (Figs. 2-5). These are coaxial with F₂. In general the F₃ folds are overturned slightly to the north, the exception being the Groversville syncline with an axial plane that dips 45°N. The F₃ folds have axial traces comparable in length with those of the F₂ set. The Piseco anticline and Glens Falls syncline can be followed along their axial traces for distances exceeding 100 km until they disappear to the east and west beneath Paleozoic cover. The similarity in size and orientation of F₂ and F₃ suggests that both fold sets formed in response to the same force and field.

The fourth fold set (F₄) is open, upright, and trends NW. Within the area these folds are less prevalent than the earlier sets. However, Foose and Carl (1977) have shown that within the NW Adirondacks, northwest-trending folds are widespread and play an important role in the development of basin and dome patterns.

The fourth regional fold set (F₅) consists of large, upright NNE folds having plunges which differ depending upon the orientation of earlier fold surfaces. The F₅ folds are observed to tighten as one proceeds towards the northeast.

The regional outcrop pattern is distinctive because of the interference between members of these four fold sets (Figs. 2-5). For example, the "bent-finger" pattern of the Canada Lake nappe west of Sacandaga Reservoir is due to the superposition of the F₃ Groversville syncline on the F₂ fold

geometry (Fig. 4). East of the reservoir the reemergence of the core rocks of the Canada Lake nappe is due to the superposition on F_2 of a large F_5 anticline whose axis passes along the east arm of the reservoir (Fig. 4). The culmination-depression pattern along the Piseco anticline results from the superposition of F_3 and F_5 folds. The structure of the Piseco dome is due to the intersection of the Piseco anticline (F_3) with the Snowy Mt. anticline (F_5). Farther to the north, Crane Mt. is a classic example of a structural basin formed by the interference of F_3 and F_5 synclines (Figs. 2 and 6).

DISCUSSION AND SYNTHESIS OF STRUCTURAL RELATIONSHIPS

Over a decade ago Walton and de Waard (1963) proposed that rocks of the anorthosite-charnockite suite comprise a pre-Grenvillian basement on which a coherent "supracrustal" sequence was deposited unconformably. Rocks which would be assigned a basement status in this model are designated as basal quartzo-feldspathic gneiss in Figure 3. The basal Cedar River Fm. of the overlying "supracrustal" sequence consists of marbles, quartzites, garnet-sillimanitic gneisses, and various calc-silicates. This lowermost unit is followed upward by various quartzo-feldspathic gneisses, marbles, and other metasedimentary sequences shown in Figure 2. Although our own research agrees with the generalized lithologic sequences of de Waard and Walton, two major provisos are necessary and are given here.

(1) Anorthositic rocks intrude the so-called supracrustal sequence, and therefore the anorthosites post-date these units and cannot be part of an older basement complex (Isachsen, McLelland, and Whitney, 1976; Husch, Kleinspehn, and McLelland, 1976). Isotopic evidence (Valley and O'Neill's (1983); Ashwal and Wooden, 1984) suggests that the anorthosites intruded prior to the 1.1 Ma Grenvillian metamorphism probably during a non-compressional stage (Emslie, 1978, Whitney, 1983). Angular, rotated xenoliths within the anorthosites exhibit pre-intrusion foliation and imply an earlier orogenic event(s).

(2) Within the metastratified units of the region, there exists field evidence for primary facies changes. For example, the well-layered sillimanite-garnet-quartz-feldspar gneisses of the Sacandaga Formation grade laterally into marble-rich units of the Cedar River Fm. exposed north of the Piseco anticline (Figs. 2,3). This transition along strike can be observed just south of the town of Wells, and its recognition is critical to the interpretation of the regional structure. Thus the great thickness of kinzigites (granulite-facies metapelites) south of the Piseco anticline gives way to the north to thinner units marked by marbles, calcsilicates, and quartzites. We interpret this lithologic change as due to a transition from a locally deep basin in which pelitic rocks were accumulating to a shallow-water shelf sequence dominated by carbonates and quartz sands.

Given the foregoing information, it has been possible to map and correlate structures and lithologies on either side of the Piseco anticline. In the northwest the sequence on the northern flank proceeds without structural discontinuity into the core of the Little Moose Mt. syncline. There occurs on the southern flank a mirror image of the northwestern lithologic sequence as units are traced towards the core of the Canada Lake nappe. It follows that the Canada Lake nappe and Little Moose Mt. syncline

are parts of the same fold (Fig. 6). The amplitude of this fold exceeds 70 km. and it can be followed for at least 150 km along its axial trace. The major F₂ and F₃ folds of the area are exposed through distances of similar magnitude, but their amplitudes are less than those of the F₁ isoclinal folds. The structural framework that emerges is one dominated by exceptionally large folds.

Accepting that the Little Moose Mt. syncline and Canada Lake nappe are the same fold, and noting that the fold axis is not horizontal, it follows that the axial trace of the fold must close in space. The axial trace of the Canada Lake nappe portion of the structure can be followed from west of Gloversville to Saratoga Springs. Therefore, the axial trace of the Little Moose Mt. syncline also must traverse the Adirondacks to the north. Mapping strongly suggests that the hinge lines of this fold passes through North Creek and south of Crane Mt. (Fig. 6). From here the axial trace swings westward along the north limb of the Glens Falls syncline to a point north of Wells and thence eastward to a point south of Glens Falls. This model is depicted schematically in Figure 6 where the southern Adirondacks are shown as underlain largely by the Canada Lake-Little Moose Mt. syncline. Later folding by F₃ and F₅ events has resulted in regional doming of the F₂ axial surface and erosion has provided a window through the core of this dome. Note the western extension of the Piseco anticline beneath the Paleozoic cover. This extension is consistent with aeromagnetics of the area.

Currently attempts are underway to synthesize the structural framework of the entire Adirondacks by extending the elements of the present model to other areas. A preliminary version is shown in Figure 7 and suggests that most Adirondack structure is explicable in terms of the four regional fold sets described here. Thrust faulting has been recognized in the eastern Adirondacks (Berry, 1961) and high strain zones exist in many other areas of the Adirondacks (McLelland, 1984). Associated with these are distinctive ribbon gneisses (Fig. 8) and sheath folds (Fig. 9). These are further discussed in Stop 6, Road Log.

CONCLUDING SPECULATIONS

The ultimate origin of the structural and petrologic features of the Adirondacks remains obscure. A possible clue to the mechanisms involved is Katz's (1955) determination of 36 km as the present depth to the M-discontinuity beneath the Adirondacks. Because geothermometry-geobarometry place the peak of the Grenville metamorphism at 8-9 kb (24-36 km), a double continental thickness is suggested. Such thicknesses presently exist in two types of sites, both plate-tectonic related. The first is beneath the Andes and seems related to magmatic underplating of the South American plate (James, 1971). The second is beneath the Himalayas and Tibet and is due to thickening in response to collision (Dewey and Burke, 1973) or continental underthrusting (Powell and Conaghan, 1973). The presence of ribbon lineation, sheath folds, and subhorizontal mylonitic foliation within the region strongly suggests regional rotational strain with a dominant component of simple shear (McLelland, 1984). Rotated K-feldspar augen exhibit tails asymmetric to foliation suggesting an east side up and to the west sense of tectonic transport.

Southeastward directed subduction would be consistent with this model. The relevant plate margin presumably lies buried beneath the present day Appalachians.

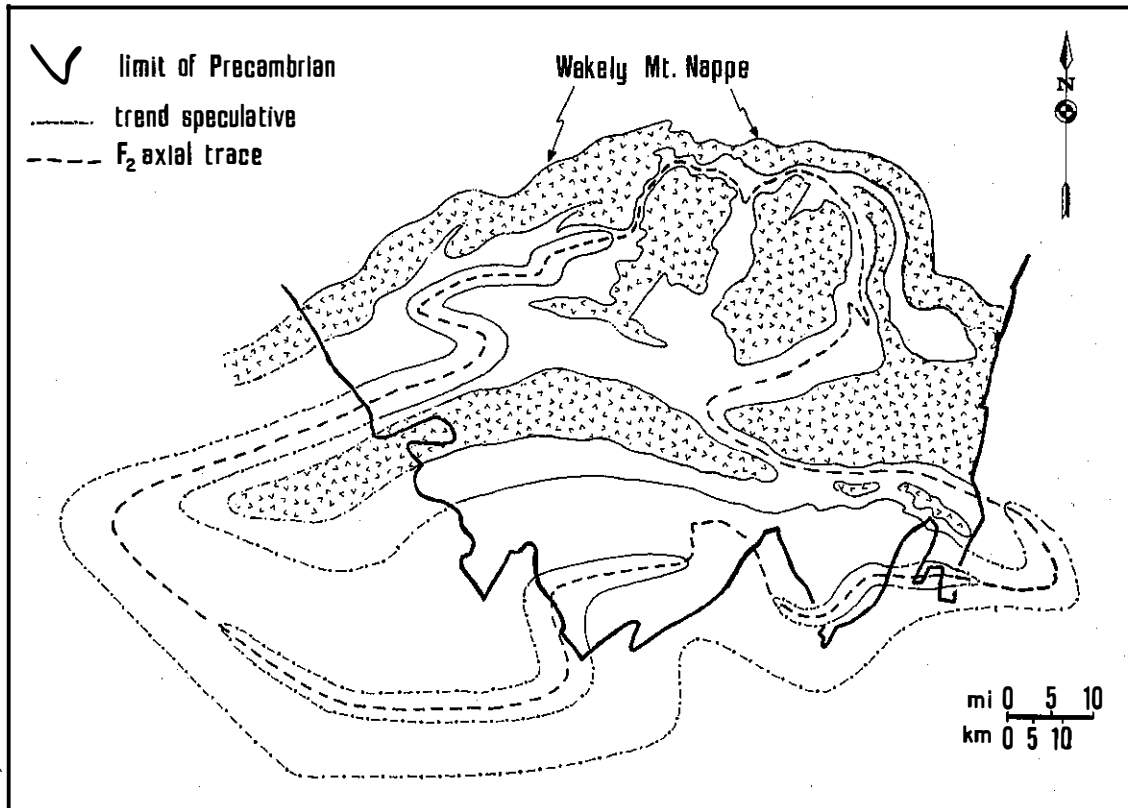


Fig. 6. Geologic sketch map showing the proposed axial trace of the F₂ Little Moose Mt. - Canada Lake syncline. The western extension of the Piseco anticline is inferred from aeromagnetic data (from McLelland+Isachsen, 1980).

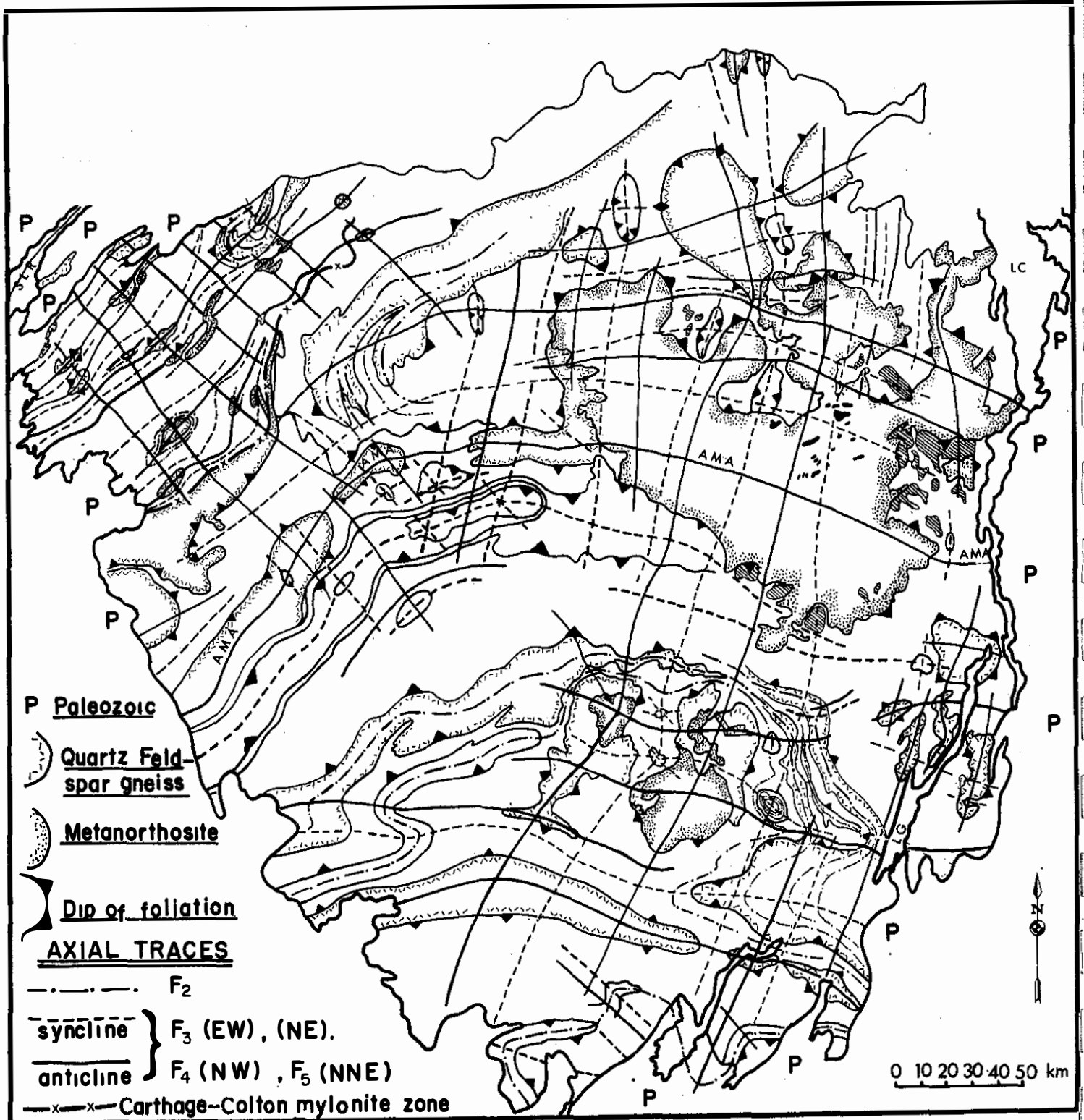


Fig. 7. Axial trace map of the Adirondack Mts. (from McLelland and Isachsen, 1980).

ROAD LOG

Mileage

0 Junction of Willie Road, Peck Hill Road, and NY Rt. 29A

1.3 Mud Lake to northeast of NY Rt. 29A

2.8 Peck Lake to northeast of NY Rt. 29A

3.6 **Stop #1.** Peck Lake Fm.

This exposure along Rt. 29A just north of Peck Lake is the type locality of the sillimanite-garnet-biotite-quartz-feldspar gneisses (kinzigites) of the Peck Lake Fm. In addition, there are exposed excellent minor folds of several generations. Note that the F_2 folds rotate an earlier foliation.

The white quartzo-feldspathic layers in the kinzigites consist of quartz, two feldspars, and garnet and are believed to be anatectic. Note that fish-hook terminations on some of these suggest that they have been transposed. It is also clear that these anatectites have been folded by F_2 indicating a pre- F_2 metamorphic event(s). In a similar fashion some garnets in the rock appear to be flattened while others do not. It is believed that the anatectites formed at the muscovite-quartz reaction and are essentially in situ melts. Further anatexis did not take place due to absence of vapor.

6.1 Junction NY Rt. 29A and NY Rt. 10

8.0 Nick Stoner's Inn on west side of NY Rt. 29A-10

8.6 **Stop #2.** Irving Pond Fm., .5 mile north of Nick Stoner's Inn, Canada Lake.

The outer portion of the Irving Pond Fm. is exposed in low cuts along the east side of Rt. 29A just prior to the crest in the road heading north.

At the southern end of the cut typical, massive quartzites of the Irving Pond are seen. Proceeding north the quartzites become "dirtier" until they are essentially quartzose sillimanite-garnet-biotite-feldspar gneisses (kinzigites).

At the northern end of the cut, and approximately on the Irving Pond/Canada Lake Fm. contact there occurs an excellent set of F_2 minor folds. Polished slabs and thin sections demonstrate that these fold an earlier foliation defined by biotite flakes and flattened quartz grains.

The Irving Pond Fm. is the uppermost unit in the stratigraphy of the southern Adirondacks. Its present thickness is close to 1000 meters, and it is exposed across strike for approximately 4000 meters. Throughout this section massive quartzites dominate.

Mileage

8.8

Stop #3. Canada Lake Charnockite

These large roadcuts expose the type section of the Canada Lake charnockite. Lithologically the charnockite consists of 20-30% quartz, 40-50% mesoperthite, 20-30% oligoclase, and 5-10% mafics. The occurrence of orthopyroxene is sporadic. These exposures exhibit the olive-drab coloration that is typical of charnockites. Note the strong foliation in the rock.

Although no protolith is known with certainty for these rocks a metavolcanic history is suggested by their homogeneity and lateral continuity. Their bulk chemistry corresponds to dacites.

10.0

Canada Lake Store. Good exposures of Royal Mt. member of Green Lake Fm.

11.8

Pine Lake. Junction NY Rt. 29A and NY Rt. 10. Proceed north on NY Rt. 10.

17.5

Stop #4. Rooster Hill megacrystic gneiss at the north end of Stoner Lake.

This distinctive unit is believed to be, in part, correlative with the Little Moose Mt. Fm. Here the unit consists of a monotonous series of unlayered to poorly layered gneisses characterized by large (1-4") megacrysts of perthite and microcline perthite. For the most part these megacrysts have been flattened in the plane of foliation as well as elongated in an E-W direction with concomitant developed tails of grain-size reduced tails asymmetric to foliation. However, a few megacrysts are situated at high angles to the foliation. The groundmass consists of quartz, oligoclase, biotite, hornblende, garnet, and occasional orthopyroxene. An igneous rock analogue would be quartz-monzonite or granodiorite depending on concentration of K-feldspar.

The origin of the Rooster Hill is obscure. Its homogeneity over a thickness approaching 2.5 km suggests an igneous parentage. This conclusion gains support from the presence of localities where megacrysts appear to retain a random orientation, and from the occasional presence of what may be drawn out xenoliths of biotitic or amphibolitic gneisses. However, these features may be explained by other models. The contacts of the Rooster Hill are always conformable with enclosing units, and this suggests a metastratified (metavolcanic?) origin. However, the anorthosites of the region also show conformable contacts, and this may, in part, be due to tectonic flattening.

Recently Eckelmann (pers. comm.) has studied zircon population morphologies in the Rooster Hill and similar lithologies. His results strongly suggest an igneous plutonic origin. This would be consistent with the igneous origin assigned the Hermon granite of the northwest Adirondacks - a rock that is markedly similar to the Rooster Hill.

Mileage

- 20.0 Low roadcut in kinzigites of Tomany Mt. Fm.
- 21.4 Avery's Hotel on west side of NY Rt. 10
- 22.5 Long roadcuts of quartzofeldspathic gneisses and metasediments of Lake Durant Fm. intruded by metagabbro and anorthositic metagabbro.
- 23.6 Roadcut of anorthositic metagabbro and metanorite.
- 23.9 Roadcut on west side of highway shows excellent examples of anorthositic gabbros intrusive into layered pink and light green quartzofeldspathic gneisses. The presence of pegmatites and cross-cutting granitic veins is attributed to anatexis of the quartzofeldspathic gneisses by the anorthositic rocks.
- 24.0 **Stop #5.** Lake Durant and Sacandaga Fms. intruded by anorthositic gabbros and gabbroic anorthosites.

These roadcuts are located on Rt. NY 10 just south of Shaker Place.

The northernmost roadcut consists of a variety of metasedimentary rocks. These lie directly above the Piseco anticline and are believed to be stratigraphically equivalent to the Sacandaga Formation. The outcrop displays at least two phases of folding and their related fabric elements. These are believed to be F_2 and F_3 . A pre- F_2 foliation is thought to be present. Both axial plane foliations are well developed here. Several examples of folded F_2 closures are present and F_2 foliations (parallel to layering) can be seen being folded about upright F_3 axial planes.

Farther to the south, and overlooking a bend in the west branch of the Sacandaga River, there occurs a long roadcut consisting principally of pink and light green quartz-perthite gneiss belonging to the Lake Durant Fm. About half-way down this roadcut there occurs a large boudin of actinolitic and diopsidic gneiss. To the north of the boudin the quartzofeldspathic gneisses are intruded pervasively by anorthositic gabbros, gabbroic anorthosites, and various other related igneous varieties. At the north end of the cut and prior to the metastratified sequences these intrusives can be seen folded by upright fold axes. They are crosscut by quartzofeldspathic material.

Within this general region the Lake Durant Fm. and other quartzofeldspathic gneisses seem to have undergone substantial anatexis. This is suggested by the "nebular" aspect of the rocks. Good examples of this are seen in the manner in which green and pink portions of the quartzofeldspathic gneisses mix. Note also the clearly cross-cutting relationships between quartzofeldspathic gneiss and mafic layers at the south end of the roadcut. Here it seems that mobilized Lake Durant is cross-cutting its own internal stratigraphy. Also note that the quantity of pegmatitic material is greater than usual. This increase in anatexis phenomena correlates closely with the appearance of extensive metagabbroic and metanorthositic rocks in this area. It is believed that these provided a substantial portion of the heat that resulted in partial fusion of the quartzofeldspathic country rock.

Mileage

31.0 Red-stained basal quartzofeldspathic gneisses that have been faulted along NNE fractures.

31.5 Junction NY Rt. 10 and NY Rt. 8. End Rt. 10. Turn east on NY Rt. 8.

33.0 **Stop #6.** Core rocks of the Piseco anticline.

Hinge line of Piseco anticline near domical culmination at Piseco Lake. The rocks here are typical basal quartzofeldspathic gneisses such as occur in the Piseco anticline and in other large anticlinal structures, for example Snowy Mt. dome, Oregon dome.

The pink "granitic" gneisses of the Piseco anticline do not exhibit marked lithologic variation. Locally grain size is variable and in places megacrysts seem to have been grain size reduced and only a few small remnants of cores are seen. The open folds at this locality are minor folds of the F₃ event. Their axestrend N70W and plunge 10-15° SE parallel to the Piseco anticline. Co-axial F₂ isoclinal folds are also present.

The most striking aspect of the gneisses in the Piseco anticline is their well-developed lineation. This is expressed by rodding and ribbon fabrics. These may consist of alternating ribbons of quartz, quartzofeldspathic gneiss, and biotite-rich layers. In some instances the rods represent transposed layering on the highly attenuated limbs of early, isoclinal minor folds. Near the northeast end of the roadcut such minor folds are easily seen due to the presence of more massive layers in the rock. Slabbed and polished specimens from this and similar outcrops demonstrates that these early folds are exceedingly abundant in the Piseco anticline. Examination of these folds shows that the dominant foliation in the rock is axial planar to them.



Fig. 8a. Example of ribbon lineation on a foliation surface of quartzofeldspathic gneiss of the Piseco anticline. The dark ribbons are quartz and the light ones K-feldspar.

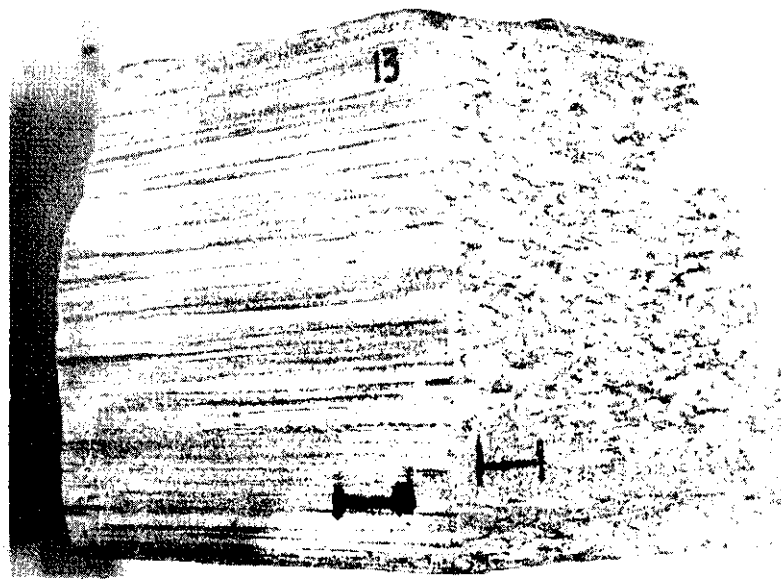


Fig. 8b. Quartzo-feldspathic gneiss of Piseco anticline cut perpendicular to foliation and parallel to lineation (left face) as well as perpendicular to lineation (right face). Note the elongation of the light colored K-feldspar augen in the direction of lineation. Bar markers are 1 cm long.



Fig. 9. The development of tails on K-feldspar augen in a gneiss less deformed than shown in Fig. 8. The face shown is perpendicular to foliation but parallel to lineation. The tails suggest a sinistral shear sense. The bar marker is 1 cm long.



Fig. 10. Sheath fold developed in calcsilicate band in marble. Steep, down dip lineation visible on right hand side. Key is 5 cm long.

The lineation in these outcrops is shown in Fig. 8a while slabbed sections are shown in Figs. 8b,c. Fig. 8b is cut perpendicular to foliation and both parallel to (left face) and perpendicular to (right face) lineation. As can be seen K-feldspar augen have been elongated in the direction of lineation. Together with elongated quartz aggregates, these grain size reduced minerals form the prominent mineral lineation that characterizes foliation surfaces (Fig. 8a). Note that the K-feldspar augen exhibit shapes closer to equant on the right hand face at perpendicular to lineation. This strongly suggests that the rock fabric is the result of rotational strain in the direction parallel to lineation, i.e., the lineation is an elongation, or stretching type. Fig. 9 shows a less deformed sample slabbed perpendicular to foliation and parallel to lineation. The development of tails on K-feldspar augen are clearly visible. These are the result of grain size reduction during ductile rotational strain. A sinistral (east over west) sense of motion is indicated. At more extreme conditions of strain the K-feldspar augen and quartz aggregates are drawn into ribbons as in the present outcrop. Long dimensions of 40-60 cm are common along with thicknesses of a millimeter, or less. Clearly strain has been extreme and elongations of 30-40 times are not unusual.

Ribbon gneiss origin by rotational strain is also suggested by the parallelism between lineation and F₂, F₃ fold axes. It is believed that these fold axes were drawn into parallelism with the lineation by ductile, rotational strain directed from east to west. The most satisfactory mechanism for this configuration is the stacking of thrust sheets and thrust nappes during plate collision. Thrusts have been recognized to the east of Lake George (Fig. 4) and others probably exist although the intense, ductile nature of the deformation has resulted in extremely subtle truncations that are difficult to recognize. Sheath folds (Fig. 10) with tube axes parallel to lineation are consistent with this model. Presumably crustal thickening during the Grenville Orogeny was caused by the stacking of these thrusts.

Mileage

43.5 Junction NY Rt. 8 and NY Rt. 30 in Speculator. Head southeast on NY Rt. 8-30.

47 Stop #7. Northern intersection of old Rt. NY 30 and new Rt. NY 30, 3.3 miles east of Speculator, New York.

The Blue Mt. Lake Fm. is exposed in roadcuts on both sides of the highway. These exposures show typical examples of the extreme ductility of the carbonate-rich units. The south wall of the roadcut is particularly striking, for here relatively brittle layers of garnetiferous amphibolite have been intensely boudinaged and broken. The marbles, on the other hand, have yielded plastically and flowed with ease during the defor-

mation. As a result the marble-amphibolite relationships are similar to those that would be expected between magma and country rock. Numerous rotated, angular blocks of amphibolite are scattered throughout the marble in the fashion of xenoliths in igneous intrusions. At the eastern end of the outcrop tight isoclinal folds of amphibolite and metapelitic gneisses have been broken apart and rotated. The isolated fold noses that remain "floating" in the marble have been aptly termed "tectonic fish." The early, isoclinal folds rotate on earlier foliation.

Near the west end of the outcrop a deformed layer of charnockite is well exposed. In other places the charnockite-marble inter-layering occurs on the scale of one to two inches.

Exposed at several places in the roadcut are cross-cutting veins of tourmaline and quartz displaying a symplectic type of inter-growth. Other veins include hornblende and sphene bearing pegmatites.

Commonly included in the Blue Mt. Lake Fm., but not exposed here, are quartzites, kinzigites; sillimanite rich, garnetiferous, quartz-microcline gneisses; and fine grained garnetiferous leucogneisses identical to those characterizing the Sacandaga Fm. These lithologies may be seen in roadcuts .5 mile to the south.

Almost certainly these marbles are of inorganic origin. No calcium carbonate secreting organisms appear to have existed during the time in which these carbonates were deposited (> 1 b.y. ago). Presumably the graphite represents remains of stromatolite-like binding algae that operated in shallow water, intertidal zones. If so, the other roadcut lithologies formed in this environment as well. This seems reasonable enough for the clearly metasedimentary units such as the quartzites and kinzigites. The shallow water environment is much more interesting when applied to the charnockitic and amphibolite layers. The fine scale layering, and ubiquitous conformity of these, strongly suggests that they do not have an intrusive origin. Perhaps they represent the metamorphosed products of volcanic material in a shelf like environment. Such intercalation is now occurring in many island arc areas where shallow water sediments cover, and in turn are covered by, ash and lava. Alternatively they may represent metasediments. A large number of minerals are developed within these outcrops. Both calcite and minor dolomite are present in the carbonate horizons. These are accompanied by green diopside and serpentinized forsterite as well as by tourmaline, graphite, and various sulfides. In calcisilicate horizons phlogopite, diopside (white), and tremolite occur. Wollastonite is locally present. The presence of tremolite and wollastonite is believed to be a function of the relative concentration of CO₂ and H₂O in the vapor phase (Valley et al., 1983).

Mileage

47.5 Extensive roadcuts in lower part of Blue Mt. Lake Fm. Quartzites, kinzigites, and leucogneisses dominate. Minor marble and calcsilicate rock is present.

47.9 Large roadcuts in lower Lake Durant Fm. Pink, well-layered quartzo-feldspathic gneisses with subordinate amphibolite and calcsilicate rock.

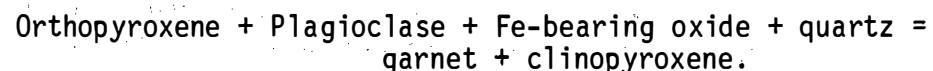
49.0 **Stop #8.** One half mile south of southern intersection of old Rt. 30 and with new Rt. 30.

On the west side of the road small roadcut exposes an excellent example of Adirondack anorthositic gneiss intermediate in character between the so-called Marcy type (coarse) and the Whiteface type (fine grained). About 50% of the rock consists of fine grained crystals of andesine plagioclase. Some of these crystals appear to have measured from 6-8" prior to grain size reduction. Excellent moonstone sheen can be seen in most crystals. In places ophitic to subophitic texture has been preserved with the mafic phase being represented by orthopyroxene.

In addition to the anorthosite there exists a clearly cross-cutting set of late iron-rich orthopyroxene rich dikes containing xenoliths of coarse grained anorthosite. The latter may represent a late mafic differentiate related to cotectic liquids responsible for the ophitic intracrystalline rest magma. This would be consistent with the iron enrichment trend characteristic of Adirondack igneous differentiation.

Near road level there can be found several inclusions of calcsilicate within the anorthositic rocks. These are believed to have been derived from the Cedar River Fm. and are consistent with a non-basement status for the anorthosite.

The upper, weathered surface of the outcrop affords the best vantage point for studying the textures and mineralogy of the anorthositic rocks. In several places there can be seen excellent examples of garnet coronas of the type that are common throughout Adirondack anorthosites. These coronas are characterized by garnet rims developed around iron-titanium oxides and pyroxenes. Recently McLelland and Whitney (1977) have succeeded in describing the development of these coronas according to the following generalized reaction:



This reaction is similar to one proposed by de Waard (1965)

but includes Fe-oxide and quartz as necessary reactant phases. The products are typomorphic of the garnet-clinopyroxene sub-facies of the granulite facies (de Waard 1965). The application of various geothermometers to the phases present suggests that the P,T conditions of metamorphism were approximately 8 Kb and $700 \pm 50^\circ\text{C}$ respectively.

Mileage

- 51.0 Cedar River Fm. Minor marble, amphibolite, and calcsilicate rock. Predominantly very light colored sillimanite-garnet-quartz-K-feldspar leucogneisses.
- 52.0 Junction NY Rt. 8 and NY Rt. 30. Continue south on NY Rt. 30. To the west of the intersection are roadcuts in leucogneisses of the Blue Mt. Lake Fm. A large NNE normal fault passes through here and fault breccias may be found in the roadcut and the woods beyond.
- 52.5 Entering Little Moose Mt. Fm. on northern limb of the Glens Falls syncline. Note that dips of foliation are to the south.
- 54.8 Entering town of Wells which is situated on a downdropped block of lower Paleozoic sediments. The minimum displacement along the NNE border faults has been determined to be at least 1000 meters.
- 58.3 Silver Bells ski area to the east. The slopes of the ski hill are underlain by coarse anorthositic gabbro intrusive into the Blue Mt. Lake Fm.
- 60.3 Entrance to Sacandaga public campsite. On the north side of NY Rt. 30 are quartzo-feldspathic gneisses and calcsilicate rocks of the Lake Durant Fm. An F_1 recumbent fold trends sub-parallel to the outcrop and along its hinge line dips become vertical.
- 60.8 Gabbro and anorthositic gabbro.
- 62.0 **Stop #9.** Pumpkin Hollow.
- Large roadcuts on the east side of Rt. 30 expose excellent examples of the Sacandaga Fm. At the northern end of the outcrop typical two pyroxene-plagioclase granulites can be seen. The central part of the outcrop contains good light colored sillimanite-garnet-microcline-quartz gneisses (leucogneisses). Although the weathered surface of these rocks are often dark due to staining, fresh samples display the typical light color of the Sacandaga Fm. The characteristic excellent layering of the Sacandaga Fm. is clearly developed. Note the strong flattening parallel to layering and the lineation developed on many foliation surfaces. These gneisses are similar to so-called

straight gneisses found in proximity to ductile shear zones. The Sacandaga Fm. may represent mylonitic rocks of this type and its layering may, in fact, be tectonic.

Towards the southern end of the outcrop calc-silicates and marbles make their entrance into the section. At one fresh surface a thin layer of diopsidic marble is exposed. NO HAMMERING PLEASE. Many "punky" weathering layers in the outcrop contain calc-silicates and carbonates.

At the far southern end of the roadcut there exists an exposure of the contact between the quartzo-feldspathic gneisses of the Piseco anticline and the overlying Sacandaga Fm. The hills to the south are composed of homogeneous quartzofeldspathic gneisses coring the Piseco anticline (note how ruggedly this massive unit weathers). The Sacandaga Fm. here has a northerly dip off the northern flank of the Piseco anticline and begins its descent into the southern limb of the Glens Falls syncline.

No angular discordance or other indications of unconformity can be discerned at the base of the Sacandaga Fm. However, this does not preclude the prior existence of an angular discordance which may have been swept into pseudoconformity by tectonism.

Along most of the roadcut there can be found excellent examples of faults and associated pegmatite veins. Note that the drag on several of the faults gives conflicting senses of displacement. The cause of this is not known to the author. Also note the drag folds which indicate tectonic transport towards the hinge line of the Piseco anticline.

Mileage

- 62.5-67.0 All exposures are within the basal quartzo-feldspathic gneisses at the core of the Piseco anticline.
- 67.0 Re-enter the Sacandaga Fm. Dips are now southerly.
- 68.0 In long roadcuts of southerly dipping quartzo-feldspathic gneisses of Lake Durant Fm.
- 70.4 Cross bridge over Sacandaga River.
- 74.4 Bridge crossing east corner of Sacandaga Reservoir into Northville, New York.

END LOG

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THE MINERALOGY OF SARATOGA COUNTY, NEW YORK

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INTRODUCTION

Saratoga County includes within its boundaries the Adirondack Highlands and the Hudson and Mohawk Lowlands. The rock types range from the Precambrian Grenvillian granulites of the Adirondacks, located in the northwest quadrant of the county, through Cambro-Ordovician carbonate and clastic rocks. While the area is predominantly covered by Pleistocene glacial till and sediments of glacial Lake Albany, scattered bedrock exposures afford excellent mineral collecting.

Several of the county's most famous mineral collecting localities are either closed to the public or have been lost. An example of the former is the Gailor Quarry in Saratoga Springs. While the quarry is inactive, the faces have become very unstable and because of collector abuses, the owners no longer allow access. An example of a lost locality is the collection site for chrysoberyl, for which Saratoga County is famous. The original description of the quarry measures its location from Route 9. Since the publication of the location, routes have been renumbered and relocated.

All of the localities that are listed in this guidebook are on private property and require special permission from the landowner to visit.

PURPOSE

The purpose of this field trip is to examine a variety of mining and mineral localities in Saratoga County that are typical of this area and the Southeast Adirondacks in general. The minerals available in large quantity are fairly common, but interesting in terms of size and development. The quarries visited will include a graphite mine and several pegmatites. Opportunities exist to collect a variety of minerals, observe the relationships between them, to study the mines' relationships with the country rock, and to see late 19th and early 20th century mining techniques.

WILTON GRAPHITE MINE

The graphite mine is located to the west of US Route 9. Enter the woods directly opposite Worth Road. There you will find a dirt road leading up the side of the mountain. The following measurements are taken starting from the west edge of US 9. All measurements are in feet.

- 467 - The foundation of a former building on the left.
- 1533 - On the right is the foundation of the boarding house for the mine.
- 1756 - On the left is the foundation for the loading bins. Horse teams took the refined graphite from here to the railroad.
- 1890 - On the left is the waste water dam and settling pond, even then a matter of controversy. Each year the pond was allowed to flush itself out into the fields below. If you follow the stream valley 1,000 feet upstream, on the right you will find the foundations of

- the concentrating plant which originally consisted of five levels. The original turbines are still here. There was also a steam generating plant here that supplied power for the mill and mine.
- 2725 - Stream crossing. Foundations on the left are for the upper level of the mill. A narrow gauge railroad serviced the mine from here.
 - 2840 - A fork in the road, take the road to the right.
 - 2935 - The cut on the right and left was a drainage ditch for the underground mine and connects with it.
 - 2890 - The entrance to the underground mine, known as the mine, on the left.
 - 3411 - Follow the main road.
 - 3591 - Another drainage ditch.
 - 3833 - The trail from the Wilton-Greenfield Road enters on the right.
 - 3982 - On the left is the large open mine, known as the quarry. Water fills the west end.
 - 4326 - The road is now a trail. The end of the quarry.

The following description is taken from the Adirondack Graphite Deposits by H. L. Alling (1917).

The property was first opened about 1910 by the Saratoga Graphite Company which worked it in a small way for two years. After a few years the mine was taken over by the Graphite Products Corporation which enlarged the plant and the mine and worked it until about 1922.

The original mine is 22 by 30 meters and was worked only by the Saratoga Graphite Company. The Graphite Products workings consist of the mine and the quarry. The mine extends 115 meters along strike, inclines 38-42 degrees south. A number of openings have been driven down dip meeting two parallel horizontal drifts. The quarry is an open pit mine extending east-west, 125 by 30 meters. Now water filled, in 1917 it was 10 meters deep.

The rock containing the graphite is described as a quartz schist and occurs in two outcrops, the mine and the quarry, repeated by faulting. From Alling (1917, p. 106) describing a south to north section (fig. 1), "...a serpentinous limestone forms the head of the brook...next rock to the north is a para-amphibolite...grading into the quartzite...injected and saturated by Laurentian Granite...a lenticular mass of metagabbro...a siliceous limestone...beneath the limestone the graphite schist shot through with 'pegmatitic material which forms knots and stringers'...a fault parallel to bedding occurs here...a gap in the cross section...Pegamatite, quartzite, and metagabbro...a reddish garnetiferous quartzfeldspar para-gneiss...The rocks here are faulted and penetrated by pegmatite...It is not possible to name with certainty the rock forming the floor of the quarry...The north end of the section ends in a limestone." The section as described correlates with the Spring Hill Pond Formation of the southeast Adirondacks. A diabase dike 10 meters wide outcrops just west of the mine. A second dike, 25 cm. wide, outcrops west of the finishing mill.

The ore is similar to the American, Hague, Flake and Hooper ores. Graphite content is 7-8% all flakes are less than a millimeter in diameter. The outcrop is badly weathered, but at the bottom of the inclines in the mine is in better condition.

The mining technique was primitive by any standard consisting of steam

drilling, hauling the ore out of the mines with donkey engines, and loading it into wagons. Teams hauled the ore to the narrow guage mine cars which took it directly to the concentration mill. The usual Adirondack milling parctice of crushing, stamping, buddling, screening and drying was used. The finishing mill used Hooper pneumatic jigs which prepared the graphite for market.

Minerals and Rocks

Apatite	Graphite	Phlogopite	Quartz schist
Diabase	Pegmatite		

BLACK POND PEGMATITE

The Black Pond Pegmatites, unreported in the literature, were mined in the early twentieth century for abrasives used in Bon Ami Cleanser. The description of these bodies is taken from a 1984 field report by Tara Mandeville of Skidmore College.

Black Pond is one mile down the logging road from its intersection with Lincoln Mountain Road. The pegmatites are hard to spot from this direction. Directions for finding the bodies follows, the distances are in feet:

- 3450 - First sign of crushed pegmatite in the road.
- 4015 - Pegmatite (M1) on the west side of the road.
- 4150 - Road on the west goes to the big pit (M2).
- 4365 - Pit on the west side of the road (M4).
- 4590 - Side road to the east (M6).
- 5110 - Black Pond.

As one approaches the outcrops from Lincoln Mountain Road (fig. 2), the first evidence of the outcrops is a tailings pile (Ti) adjacent to a small mine pit, M1 (approximately 4.6 m. long by 4.6 m. wide by 2.4 m. deep). The tailings are composed of feldspar, quartz and biotite. The pit contains several small pegmatites varying from pure feldspar to quartz-rich pegmatite with large crystals of biotite. The country rock is a biotite-quartz-feldspar gneiss.

The largest pit in the area (M2) is 30 m. x 12 m. x 9 m and is partially water filled. The coarse grained feldspar-quartz-biotite pegmatite is discordant to the 280,35W striking, medium grained, biotite-quartz-feldspar gneiss country rock.

Pit #3 (M3), 6 m. x 6 m. x 3 m., contains several smaller pegmatites that are partially concordant and rich in quartz. The surrounding fine to coarse grained gneiss contains abundant biotite. The adjacent tailings pile (T2) includes feldspar and rose and smokey quartz, but little biotite.

A very large tailings pile (T3) lies just south of Mine #3 and is probably the tailings from Mine #2. The tailings are dominantly country rock with some pegmatite. Large crystals of tourmaline were found in this dump.

Further south along the logging road a small overgrown trail enters from the east. Opposite this trail is Pit M4. This is a small quartz-

feldspar pegmatite interrupted by a small lens of biotite-rich gneiss. At the entrance to the path is a small tailings pile (T4). Further up the path is a feldspar, quartz, biotite pegmatite mine (M5) 6 m. x 9 m. x 6 m.

South along the main logging road toward Black Pond, a side road enters from the east. Along this road are feldspar-rich tailings (T5), several test pits containing quartzite (Q), and Mine #6 (6 x 3 x 2 m.) which is another feldspar, quartz, biotite pegmatite.

Along the northwest corner of Black Pond is the last of the pegmatites (M7). Here is a small discordant pegmatite in a gneiss which contains coarse grained feldspar and finer grained quartz and biotite. The tailings (T6) associated with this mine contain feldspar, rose and smokey quartz and biotite.

Minerals and Rocks

Rose quartz	Smokey quartz	K-feldspar
Tourmaline	Biotite	Graphic granite
Rose quartz	graphic granite	Granitic gneiss

MOUNT ANTHONY WEST PEGMATITE

The following description is taken from Geology of the Luzerne Quadrangle by W. J. Miller (1923). The pegmatite has not been described in detail, but is referred to several times.

Miller (1923) describes west of Mounth Anthony a terrane of metagabbro-granite rocks where many small pegmatites without sharp borders cut across the foliation. Magnetite, in amounts to be classed as ores, in 1923, is observed associated with granite, pegmatite, and metagabbro. This stop has been selected for this magnetite-pegmatite association. The magnetite is always in moderately coarse grained, gray pegmatite in masses up to 2 or more centimeters across. The country rock is a garnetiferous Grenville gneiss or amphibolite. Mines in this area were worked 90-100 years ago and some ore was shipped. Also, attempts were made to use the white feldspar in the pegmatites.

Minerals and Rocks

Pegmatite	Magnetite	Country rock
-----------	-----------	--------------

OVERLOOK QUARRY

The following map (fig. 3) and description are taken from Tan (1966). Miller (1923) describes the Overlook Quarry as producing pottery feldspar as late as 1920.

The country rocks are granitic gneiss and magnetite-bearing metagabbro.

The border and wall zone (I) is in sharp contact with the country rock. The border zone is difficult to distinguish from the wall zone. The border zone is fine grained in places. A lense rich in andesine which occurs at the west margin of the ore body is interpreted by Tan to represent an incompletely developed border zone, although a segregation (replacement) origin is possible. In the border and wall zone, both pink and white potassium

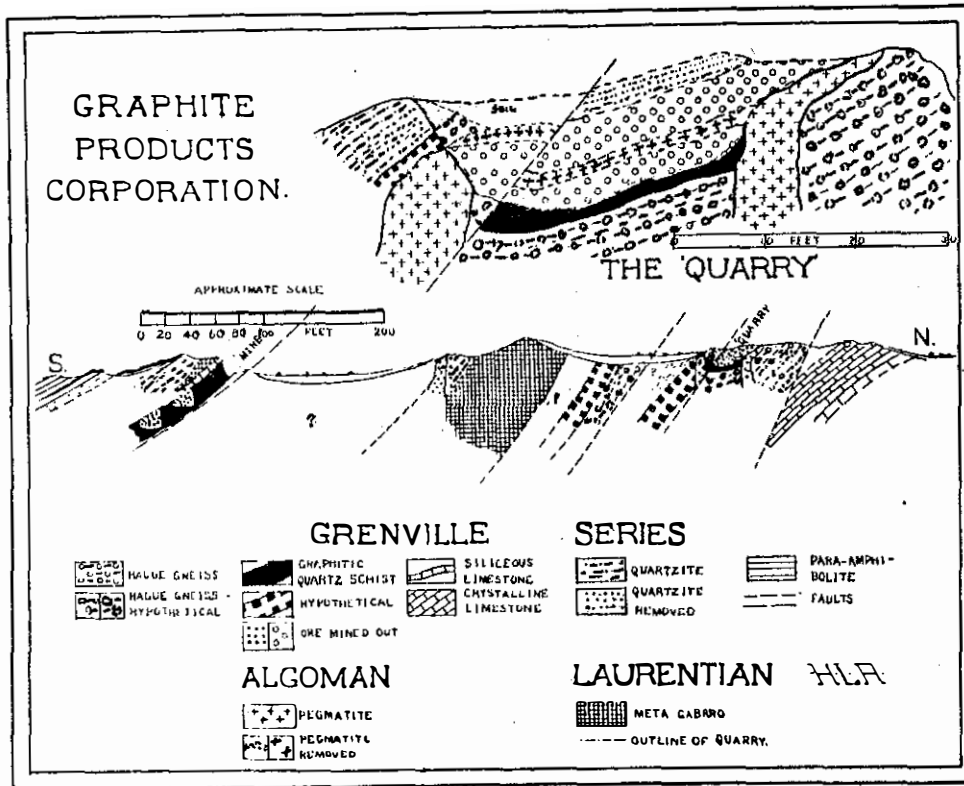


Figure 1. Geologic cross-section of the Graphite Products corporation's property. (Alling, 1917, Fig 24, p. 108)

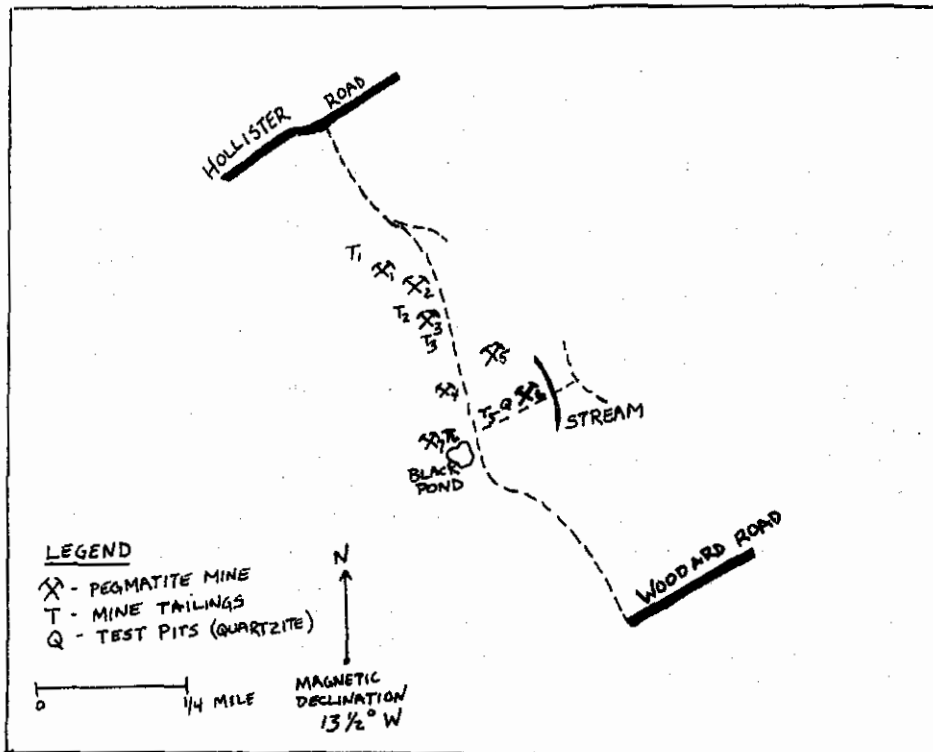


Figure 2. Sketch map of the Black Pond pegmatites in Wilton, New York. (Mandeville, 1984)

List of Minerals

	Gt	Al	Ap	Ur	Pl	Ks	Bi	Mu	To	Be	Fl	Qz	Ja
Garnet Pit													
Zone I	X	X				X						X	
Zone II					X	gr	X		X			X	
Zone III												X	
Lower Pit													
Zone I		X	X	X	An21- 23	X	X	X				X	
Zone II					An16	gr	X	X				X	
Zone III					An15	mi	X	X	X	?		X	
Zone IV												X	
Narrow Pit													
Zone I					An27	gr	X					X	
Biotite Pit													
Zone I					An27	X	X					X	
Zone II					An27	X		X	X	?		X	
Tourmaline Pit													
Zone I					An23	X	X	X				X	
Zone II					An16	X		X				X	
Zone III									X			X	
Flourite Pit													
Zone I					An25	X	X	X				X	
Zone II					An23	gr		X			X	X	
Replacement Vein												X	X
Jasper Pit													
Zone I					X	gr		X	X			X	
Replacement Vein												X	X

(Gt-garnet, Al-allanite, Ap-apatite, Ur-uraninite, Pl-plagioclase, Ks-potassium feldspar, Bi-biotite, Mu-muscovite, To-tourmaline, Be-beryl, Fl-fluorite, Qz-quartz, Ja-jasper, gr-graphic, mi-giant microcline)

In the lower pit, the contact between the pegmatite body and the wall is sharp. On the south wall the pegmatite body lies in a gently folded anticline plunging 30 degrees toward the south. Biotite, uraninite, pink and pale green apatite, and bladed allanite are found along the vertical northwest wall of the pit. In the wall zone (III), scrap muscovite (about 1/4 to 1 cm. in width) appears. White graphic potassium feldspar with parallel short quartz rods is exposed in the south wall. The biotite is partly chloritized. Subhedral high-temperature quartz is intergrown with muscovite. Pyrite and low-temperature quartz crystals, with prism faces, are found in small vugs about an inch across. The intermediate zone (III) consists of giant white microcline about 1 m. long, muscovite columns, and small amount of quartz. The quartz core (IV) near its upper margin contains columnar muscovite crystals with lengths of 15 to 25 cm. Veinlets of quartz extend outward from the core and invade the microcline, but no sign of argillization or sericitization is observed.

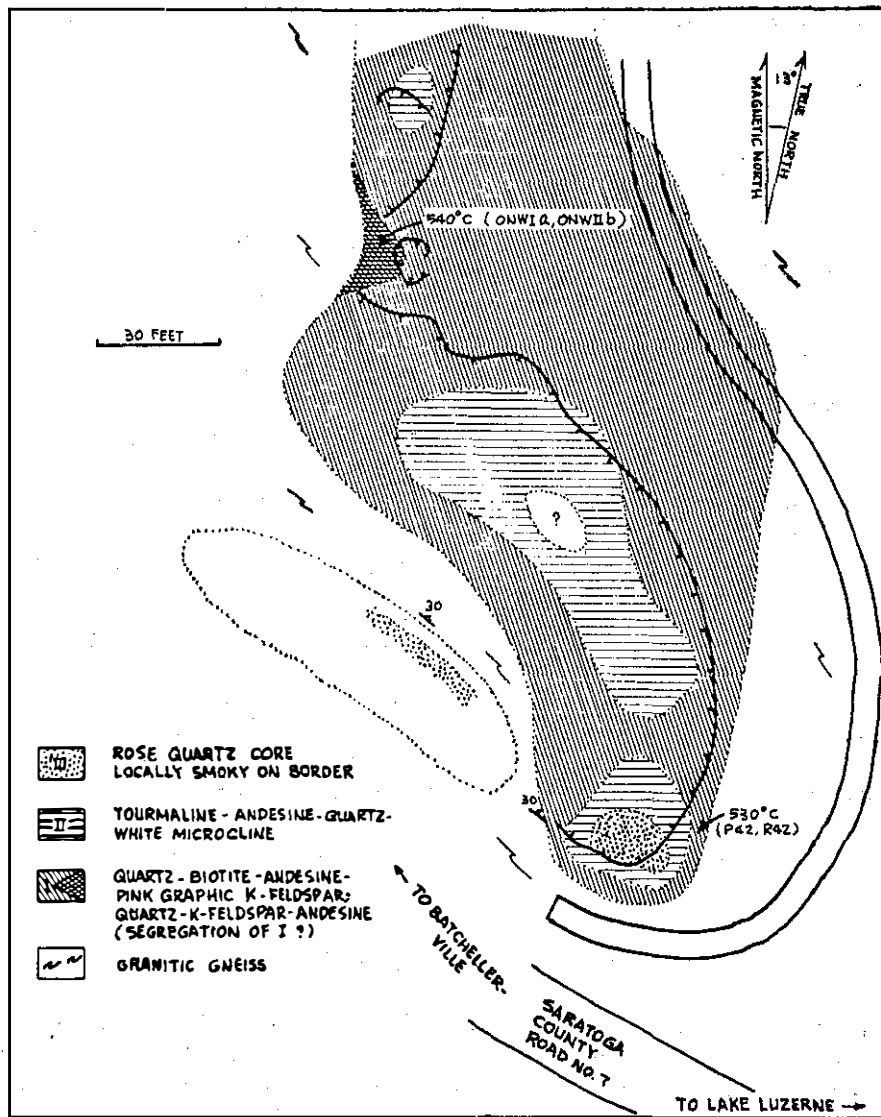


Figure 3. Sketch of Overlook quarry. (Tan, 1966, Fig. 14, p. 45)

feldspars are found and a coarse graphic texture is common. Associated biotite plates are more than 1 m. in diameter.

The intermediate zone (II) is mainly white potassium feldspar crystals up to 1 m. across, with subordinate amounts of quartz, plagioclase, and large black tourmaline crystals which reach lengths of 15 cm. or more.

The core zone (III) is rose quartz and crosscuts the intermediate zone (II).

Approximate Modes at Overlook Quarry

	Zone I	Zone II	Zone III
Biotite.....	10		
	(Green, Ny: 1.646)		
Plagioclase.....	10	5	
	(An34-39)	(An32)	
K-feldspar.....	65	80	
	(graphic)	(giant microcline)	
	(Or82-84)		
Tourmaline.....		5 or less	
Quartz.....	15	10	100
	(smokey)	(smokey)	(rose)

Minerals and Rocks

Albite	Allanite	Andesine	Biotite
Magnetite	Manganoaptite	Microcline	Monazite
Oligoclase	Orthoclase	Plagioclase	Polyclase
Rose quartz	Smokey quartz	Quartz var.	Sericite
Thorite	Tourmaline	Uranite	Uranothorite
Zircon (Cyrtoelite)		Manganoan-flourapatite	
Graphic Granite		Country rock	

BATCHELLERVILLE QUARRY

The following description is taken from Tan (1966). The Batchellerville deposits can be reached by a logging road at the rear of the mobile home park east of Saratoga County Route 7. The outcrops consist of two pegmatite bodies (fig. 4) reported by Newland and Hartnagel (1939) and six more bodies found by Tan (1966).

The bodies were worked by the Claspka Mining Company in 1906 and were still mined in 1916 and 1921. Mining was for microcline for the ceramic industry. Most of the pits show only wall rock with the central productive portions, the pegmatite, having been removed. The small size of the mining pits indicates that the production was never great. The deposits are famous for having yielded the largest beryl reported in the state, 69 cm. long and 25 cm. in diameter. The muscovite contains too many iron inclusions for electrical uses.

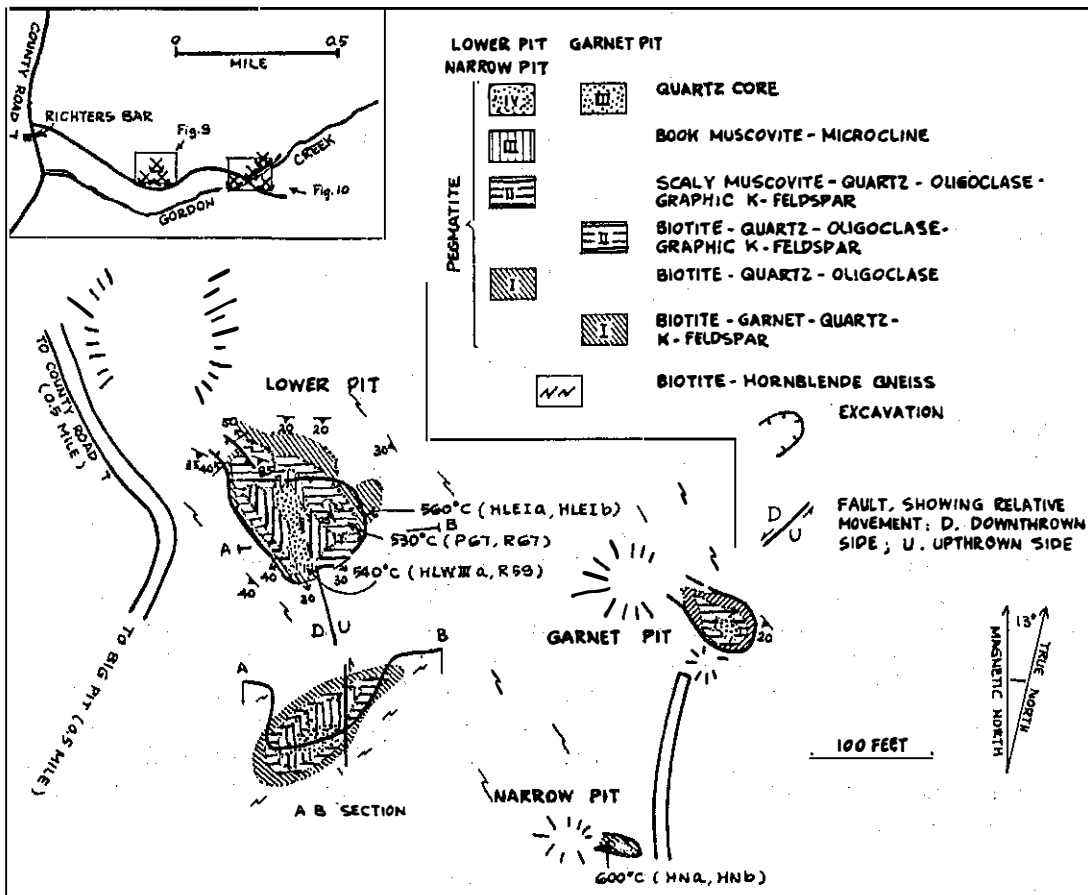


Figure 4a. Sketch map of Garnet pit, Lower pit, and Narrow pit at Batchellerville. (Tan, 1966, Fig. 11 p. 37)

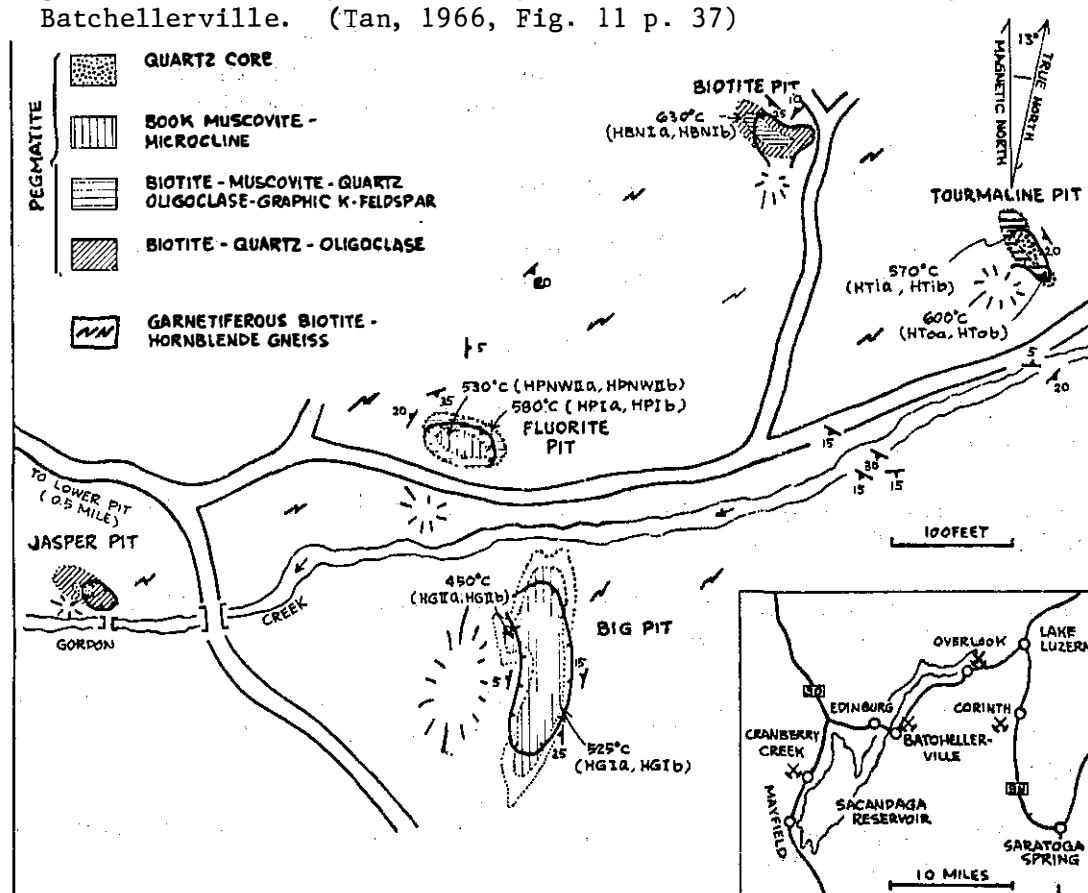


Figure 4b. Sketch map of Bit pit, Biotite pit, Fluorite pit, Jasper pit and Tourmaline pit at Batchellerville. (Tan, 1966, Fig. 12, p.38)

Modes at Lower Pit

	Zone I	Zone II	Zone III	Zone IV
Biotite	10	5		
		(chloritized)		
Plagioclase	57	5	1	
	(An 21-23)	(An16)	(An15)	
K-feldspar	10	72	80	
		(graphic)	(giant microcline)	
Muscovite	3	8	9	
Quartz	20	10	10	

In the Garnet pit, the garnet, quartz, and potassium feldspar are found in the border or wall zone (I). The garnet, which is found only here, is subhedral to euhedral and reaches 2 1/2 cm. in diameter. It is partly to completely chloritized. The composition of the garnet in the pegmatite differs from that in the country rock. In the intermediate zone (II) are allanite, biotite, plagioclase, graphic potassium feldspar, and tourmaline. The allanite is dark and altered. The tourmaline fills fissures in the feldspars. The core (III) is rose quartz. Pink xenoliths consisting of colorless sillimanite and biotite are common in this pit, although no such rocks occur in the vicinity.

Minerals and Rocks

Allanite	Apatite	Aquarmarine	Biotite
Beryl	Cerite	Garnet	Feldspar
Fluorite	Pyrite	Rose Quartz	Pink sillimanite
Uranite	Green muscovite with magnetite and hematite		

ACKNOWLEDGMENTS

The authors thank Barbara R. Thomas and Richard H. Lindemann for reviewing this manuscript and providing helpful suggestions.

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ROAD LOG FOR THE MINERALOGY OF SARATOGA COUNTY, NEW YORK

CUMULATIVE MILEAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
0.00	0.00	Start at the entrance to Skidmore College on North Broadway. Go south toward Saratoga Springs.
0.20	0.20	Turn left on East Ave.
0.55	0.35	Intersection of East Ave. and N.Y. Route 50. Turn left on N.Y. 50.
0.75	0.20	Intersection of N.Y. 50 and U.S. Route 9. Turn left on U.S. 9.
4.00	3.25	STOP # 1. Intersection of U.S. 9 and Worth Rd. Park on the shoulders of Worth Rd.
STOP # 1. WILTON GRAPHITE MINE		
		Proceed north on U.S. 9.
4.80	0.80	Intersection of U.S. 9 and Parkhurst Rd. Turn left on Parkhurst Rd.
5.10	0.30	Intersection of Parkhurst Rd. and Greenfield Rd., Saratoga County Route 36, sign points toward Greenfield. Turn left on Greenfield Rd., Saratoga County 36.
9.90	4.80	Intersection of Greenfield Rd., Saratoga County 36, and N.Y. Route 9N. Turn right on N.Y. 9N.
12.50	2.60	Intersection of N.Y. 9N and Spier Falls Rd., Saratoga County Route 25. Turn right on Spier Rd, Saratoga County 25.
17.20	5.00	Stop sign in the hamlet of Randalls Corners. Turn right on Main St., Saratoga County 25, sign points the way toward Route 9.
17.60	0.40	Intersection with Hollister Rd. on the right. Turn right on Hollister Rd.
18.40	0.80	Intersection of Hollister Rd., Clothier Rd., and Lincoln Mountain Rd. Continue straight on Lincoln Mountain Rd.
19.00	0.60	STOP # 2 - Intersection with a dirt logging road on the left. Park so that you are off the road and so that you can turn around and return the way that you came.

STOP 2. BLACK POND PEGMATITE

Turn around and return on Lincoln Mountain Rd.

19.50	0.50	Intersection of Lincoln Mountain Rd., Hollister Rd., and Clothier Rd. Continue straight on Hollister Rd.
20.40	0.90	Intersection with main road, Saratoga County Route 25. Turn left toward Randall Corners.
20.70	0.30	Stop sign at Randall Corners. Turn right on Hack Rd.
21.70	1.00	Stop sign at the intersection of Hack Rd. and Eastern Spiers Falls Rd., Saratoga County Route 24. Turn left on Saratoga County 24.
24.30	2.60	Intersection of Main St., and Palmer Ave. in Corinth. Turn right on Main St., Saratoga County 24.
24.50	0.20	Intersection of Main St., Saratoga County 24, and N.Y. Route 9N. Continue straight on N.Y. 9N.
26.10	1.60	Intersection of N.Y. 9N and Antone Rd. Turn left on Antone Rd. Antone Rd. becomes Mount Anthony Rd.
28.00	1.90	STOP # 3. Park on the right on the shoulder, there is a slight wide spot in the road here.

STOP # 3. MOUNT ANTHONY WEST PEGMATITE

Continue straight ahead on Mount Anthony Rd.

29.40	1.40	Intersection with Saratoga County Route 7, sign points to South Shore Rd. Bear left on South Shore Rd., Saratoga County 7.
33.05	3.65	STOP # 4. Park in the log loading area on the right.

STOP # 4. OVERLOOK QUARRY

Continue west on Saratoga County 7.

40.85	7.80	Enter Town of Edinburg. Continue on Saratoga County 7.
42.70	1.85	STOP # 5. Park on the left in the parking area.

STOP # 5. BATCHELLERVILLE QUARRY.

Continue west on Saratoga County 7.

45.10	2.40	Batchellerville. Intersection of Saratoga County 7 and Fox Hill Rd. Turn left on Fox Hill Rd.
53.80	8.70	Lake Desolation. Continue straight on Lake Desolation Rd., Saratoga County Route 12.
59.00	5.20	Intersection of Lake Desolation Rd., Saratoga County 12, and Middle Grove Rd., Saratoga County Route 21. Turn left on Middle Grove Rd., Saratoga County 21.
63.15	4.15	Intersection of Middle Grove Rd., Saratoga County 21, and N.Y. Route 9N. Turn right on N.Y. 9N.
65.60	2.45	Stop light, go straight on Van Dam St., do not follow N.Y. 9N.
66.10	0.50	Intersection of Van Dam St. and North Broadway, U.S. Route 9 and N.Y. Route 50. Turn left on North Broadway.
66.80	0.70	Entrance to the Skidmore College campus. End of the trip.

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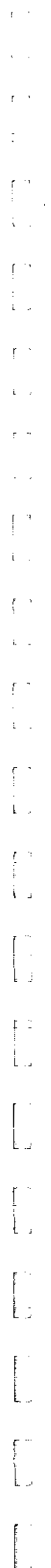
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TRI-CORN GEOLOGY

The Geology - History - and Environmental Problems of the Upper Hudson Champlain Valley

Anson S. Piper

Adirondack Community College

Introduction

The region of the upper Hudson-Champlain valleys provides an excellent locale for the teaching of introductory geology courses. In addition to the desired examples of geologic phenomena there are ample opportunities to relate geology and human activities past and present and areas where various field methods may be used to solve very simple problems. It is the purpose of this trip to tour the area from Saratoga Battlefield north to Ticonderoga, view points of geologic, historic and environmental interest and to try to relate them one way or another together.

The Geologic Setting

The two valleys form a continual slash through the mountains of Vermont to the east and the Adirondacks to the west. Restricted in part between Ticonderoga and Fort Ann, they resemble an elongated hour-glass. The divide between the St. Lawrence and Hudson-Mohawk basins, however, lies south of this restriction on a line trending, just north of the Hudson, through the Village of Fort Edward and the north edge of the city of Glens Falls. A fact which surprises some and was of serious consequence during the 17th and 18th centuries.

The valley floor, lying between the Taconic overthrusts to the east and the Precambrian complex of the Adirondacks is underlain by lower Paleozoic rocks, primarily of the quartz sandstone-carbonate sequence with occasional klippen of allocthonous shales etc. resting atop them.

Structurally, the area is broken up by extensive faulting and some minor folding. The compressional forces associated with the closing Iapetus Ocean resulted in many overthrusts and folds while the tension occurring at the time of the opening of the early Atlantic produced many normal faults yielding tilted fault blocks and grabens, as at Lake George.

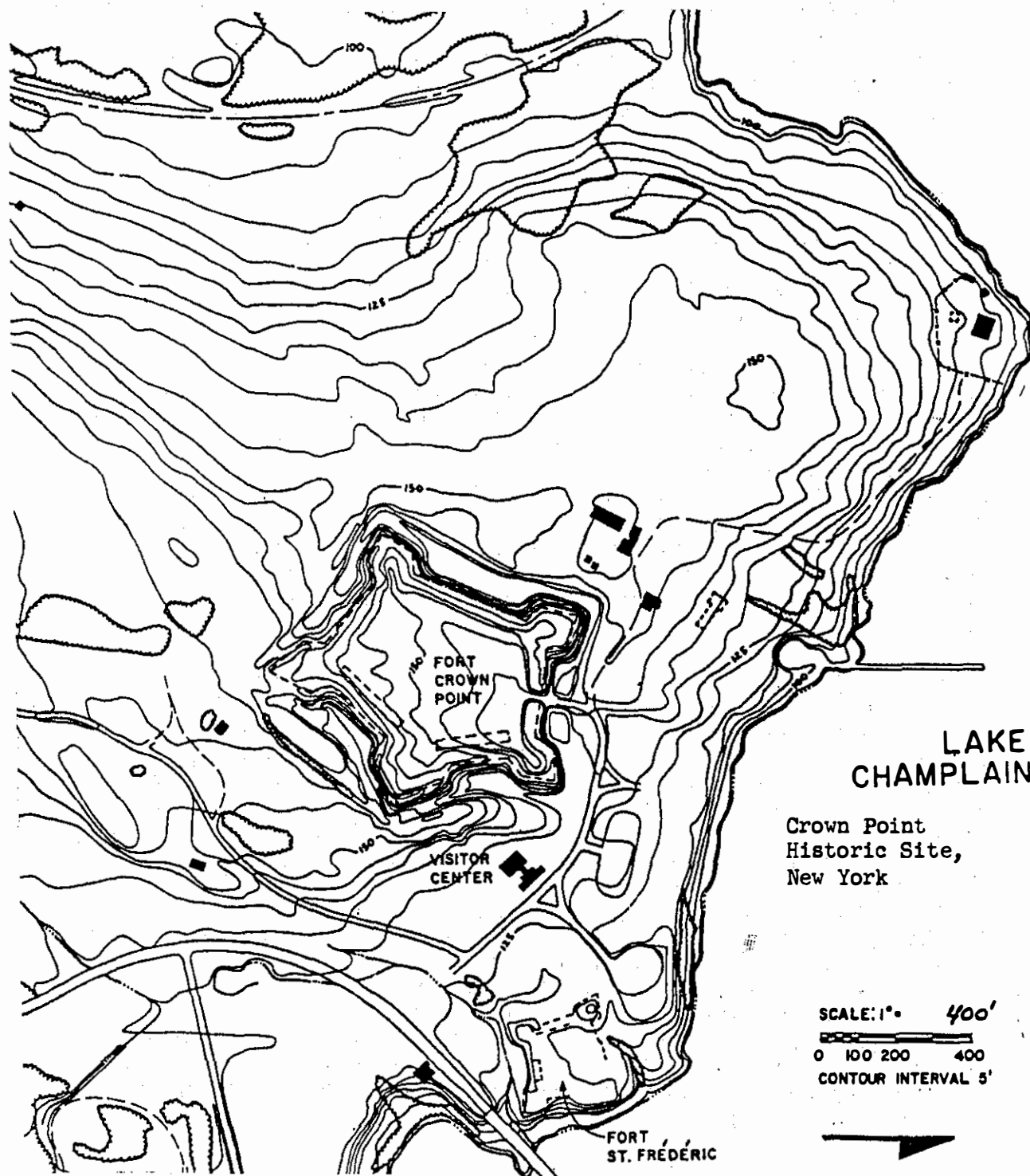
The advance and subsequent retreat of the Pleistocene ice sheets has left a vene of till outwash and lake deposits over most of the bedrock. The till is spread as a thin sheet with thicker deposits formed up, locally, into end moraines, (Gage Hill-Hidden Valley) and drumlins (Pickle Hill). A cluster of drumlins in Kingsbury along with striations record the direction of ice flow of the Whitehall lobe as it merged with those from South Bay (Champlain) and others north-south trending valleys. Meltwater formed a great kame terrace-esker complex which cuts across the south face of the mountains and sweeps down the western side of the valley. The void left by the Lake Albany, Quaker Springs, Coyeville and Ft. Ann, each leaving its own record of strandlines, deltas and lake floor deposits.



The Gallery, Glens Falls, New York Reprint from the London Magazine, 1778

The post glacial drainage systems reflecting the structural control by following joint and fault patterns, deflected by glacial deposits, present varied and occasionally startling patterns.

Ground water is equally varied. Depending on bedrock some water is simply hard, other is rendered almost unpalatable by the "sulfur" content, and then, the intriguing "mineral waters" of the spas. The best water for human consumption appears to be that taken from the glacial sands and gravels.



Regional History and Development

The opportunity to relate geology and history begins with the initial settlement of the region. The native peoples migrated into the area following the easiest paths through the primordial forest - usually along the waterways. The early people also initiated the "mineral" industries by producing flint, slate, quartzite, mica and clay for implements and pottery. Since the waterways were utilized extensively, it is not surprising that encounters with rival tribal groups occurred along these routes and that these chance meetings led to confrontations and conflict over territorial claims, (a pattern repeated by their European successors). Oral and recorded history relate the native hostilities and how these occasionally led to the involvement of Europeans in support of their local allies. A mistake of this sort by Champlain in 1604 drove the "Mohawks" and subsequently the remainder of the "Iroquois" League into the arms of the Dutch and English.

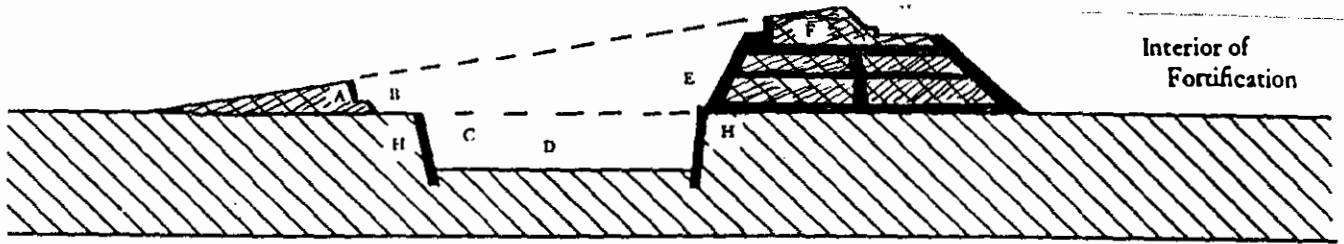
The Europeans similarly utilized the network of rivers, lakes and portages to advance into the interior. The French quickly moved up the St. Lawrence Great Lakes system, laid claim to all the drainage thereof and thence down the Ohio-Mississippi drainage. The Dutch, followed by the English, moved up the Hudson-Mohawk rivers with some claims overlapping the St. Lawrence drainage.

The Europeans brought with them their own methods of waging war: strong forts, sieges and defenses. Field tactics were, to various degrees, adapted to the terrain and circumstances of the forest. The forts were built at strategic points and usually were of the traditional "star-fort" design which had evolved in response to the development of artillery. The high curtain walls and turrets of the castles were sunk down into the moat, the round towers replaced by flanking bastions with thick walls from which enfilading fire could be delivered. The "blind spots" at the corners were eliminated by including them in the angle of the bastion and outworks placed in front of the walls to further protect them.

The materials, time, money and labor available determined the type of construction. Local material, either timber or stone masonry, was used for walls and facings which were then filled in with the spoil from the moat. The composition of the spoil affected the durability of the construction. Sand, once the facing of the wall was breached, would stream out. It was well drained and could increase the rate of decay of wood in some cases and reduce it in others. Clay, on the other hand, produced problems of expansion when wet. Wood, from logs as much as three feet in diameter, was squared into timbers usually 15" - 18" on a side and employed either as facings and cribbing or as palisades and blockhouses. It was abundant easily worked by men already familiar with it and inexpensive. While subject to decay within a few years and burned easily, it was considered adequate for the brief periods of use on the rapidly advancing frontier where it would be only subjected to raiding parties armed with light field guns. Fort Edward, William Henry, and Crown Point were examples of the traditional construction and were destroyed by decay, bombardment and fire respectively. Fort Ann was a palisaded blockhouse.

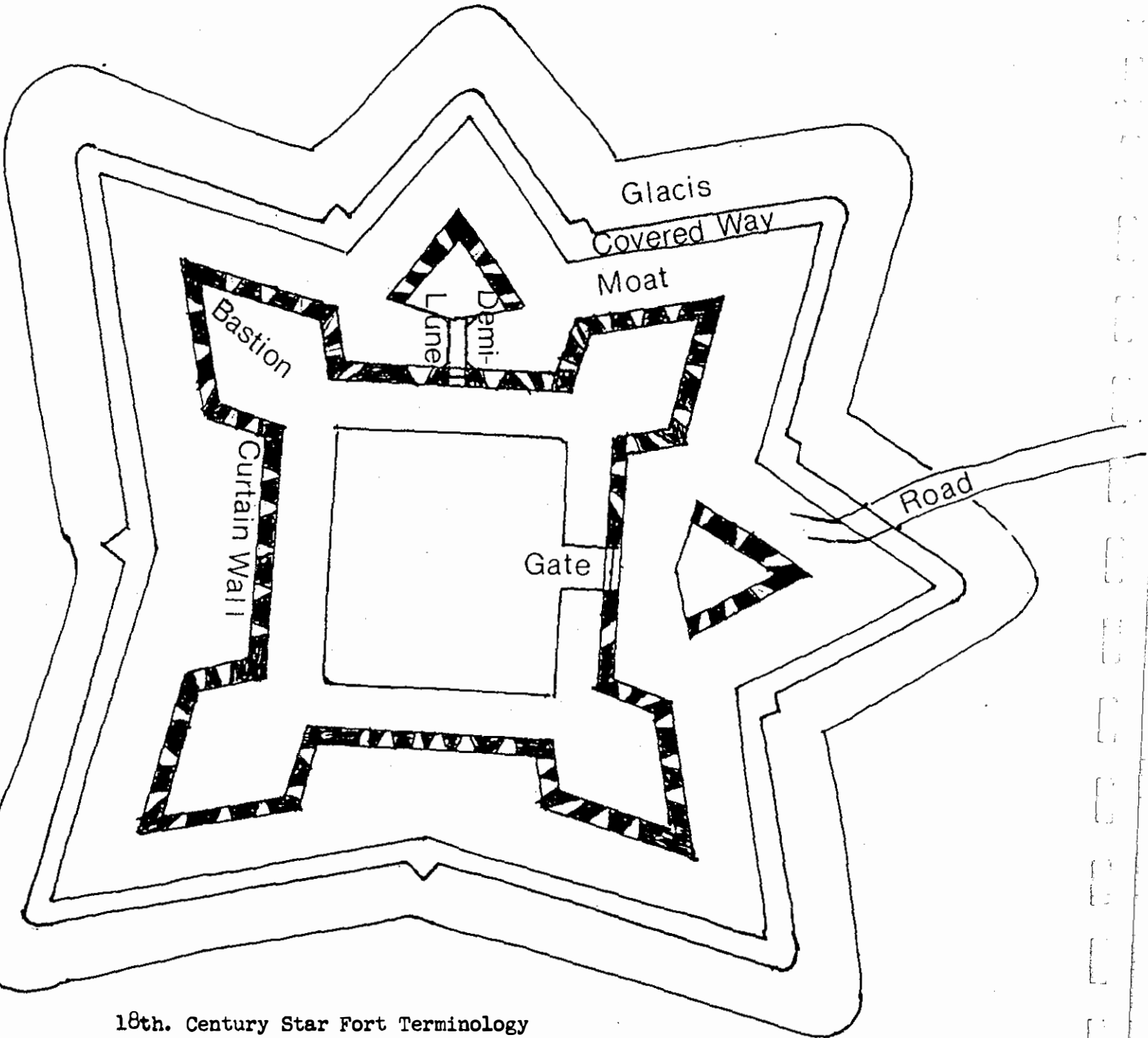
CHRONOLOGY OF REGIONAL WARS

- 1609-1660 French and Iroquois Wars
- 1618-1648 Thirty Years War -
S. Champlain taken prisoner
- 1688-1698 War of the Grand Alliance -
King Phillip's War
Frontenac's attack on Schenectady
J. Schuyler's raid on LaPraire
- 1703-1713 War of the Spanish Succession
- Queen Anne's War
1709 Nicholson's expedition against Montreal - built
fort at site of Ft. Edward and road to Wood
Creek - withdrew to Albany.
1711 Nicholson tried again, withdrew and burned his forts.
- 1740-1748 War of the Austrian Succession
King George's War
1745 Louisbourg besieged and taken.
Border raids in New York and New England.
- 1748-1755 Period of intense fort building and raids
Washington's and Braddock's campaign in the west.
Johnson's and Shirley's campaigns in New York
- 1756-1763 Seven Years War - French and Indian War.
- 1775-1783 American Revolution
May 10th, 1775 Siezure of Ticonderoga
September 1775 Invasion of Canada began.
1776 Retreat from Canada - Battle of Valcour Island.
1777 Burgoyne Campaign
1780 Carleton's Raid
- 1812-1815 War of 1812
September 11, 1814 Battle of Plattsburg



Interior of
Fortification

- | | |
|----------------|----------------------|
| A—Glacis | E—Escarpment (Scarp) |
| B—Covered Way | F—Parapet |
| C—Counterscarp | G—Firing Platforms |
| D—Ditch | H—Revetments |



18th. Century Star Fort Terminology

Stone masonry was used more often by the French than the English. This required a local source of limestone for mortar some easily quarried rock which often turned out to be limestone also and skilled stone masons. Construction was slow, so quite often a fort, as at Ticonderoga, was started on a solid stone formation and quickly built up with timber which in turn was replaced by stone work as time permitted. Masonry, while less likely to deteriorate from decay and not flammable, was not necessarily more resistant to bombardment, since smaller blocks would shatter under impact, while ball would often imbed in timbers. The stone walls gave way to the forces of frost heave, expanding clay and solution of the mortar. Besides Ticonderoga, the French Fort St. Frederic and one bastion of Fort George were of stone.

The major works were placed at strategic points, such as major landings and junctures, and provided the bases for the operations of the opposing armies. Fort Edward and Fort Carillon (Ticonderoga) were typical. The former was placed at the northern end of the navigable Hudson to guard the southern juncture of the two portages from Lake George and Lake Champlain. It was the third fort to be built there and the largest British installation in North America at the time of its construction. Built during the year preceding the seven years war by Sir William Johnson, it served as his base of operations during his pre-war campaign and for all of the campaigns that followed. It was the base of the famous Roger's Rangers.

Ticonderoga, in contrast, was built at the same time and was positioned at the juncture of the portage from Lake George and Lake Champlain. It became the forward base of operations for the French taking over from Fort St. Frederic at Crown Point.

Lesser works such as Fort Ann and Fort Miller, were placed for tactical purposes such as outposts in the first case and to protect portages as in the latter or along military roads as "way stations" as at Fort Amherst.

A network of military roads were cut through the forest, first along the portages and later to connect each military post to its neighbors. Usually these paralleled the waterways and were little more than "jeep trails" or "logging roads". They followed as level a route as possible, skirted swamps when they could or corduroyed through them. They were slow and tedious to travel, at the best, and required constant maintainance. Many of our modern highways still follow in part these routes.

It is said that the fabric of our nation was held together by the string of forts which stretched north through this valley from New York City to Canada. During the interval of 1610 to 1815, seven wars were fought, six of them (plus the years of non-peace between some) involved fighting along this valley. The chronology of two intervals are outlined in Table II the Seven Years War (French and Indian) and able III the American Revolution.

During the years that followed the area developed rapidly. Following the French and Indian Wars, settlements sprang up around the military posts along the Hudson and at Skenesborough (Whitehall) with numerous

farms scattered throughout the area. The military roads were utilized and extended by the settlers coming in. The area was still heavily forested and agricultural at the time of the Revolution.

During the years of peace preceding and following the Revolution the military roads were improved somewhat and extended as settlements grew, usually around the sites of the old forts. The falls and rapids which necessitated their construction, became the source of energy for their water powered grist and saw mills. The 19th century saw the scattered farms and towns better linked and the valley floor eventually lumbered off. The exploitation of the Adirondacks began for lumber and tanning bark. To bring out the timber the Hudson River was again utilized - log drives down the river from the Schroon began in 1813 and continued until 1951. By the 1840's 100 million board-feet of lumber was moving down stream each year. By 1890 the paper industry began to supplant lumber and the saw mills in the Glens Falls area were gradually replaced by pulp mills and their satellite industries.

The "mineral" industries expanded with the demand for building materials. Stone was quarried for blocks, slate for roofing and limestone for mortar and cement. Iron ore (magnetite) was discovered and produced at West Fort Ann and Mt. Hope. The product was shipped down river along the waterways which had been improved by the Hudson-Champlain canal. The plates from which the USS Monitor was made were forged in Troy from iron produced, in part, from here.

The conversion from water power to hydroelectric led to the influx of new industries in the 20th century and a subsequent population growth. The utilization of the rivers for water supplies, transportation, waste disposal, and energy production has produced a series of environmental problems, while the careless dumping of wastes into the landfills or just onto the ground, has produced serious groundwater pollution.

CHRONOLOGY OF FRENCH AND INDIAN CAMPAIGNS

Table II. Pre War

August 8, 1755	Johnson left Albany for site of old Fort Lydius
14th	Johnson joined Lyman at Fort Lydius where Fort Edward was under construction
26-28	Johnson moved bulk of forces to Lake George building road enroute
August 28-Sept. 7	Johnson laid out camp for 5000 men, started building batteaus, sent out scouts
September 3rd	Baron Dieskau left Crown Point (Fort St. Frederic) to attack Fort Edward. 216 regulars, 684 Canadian, and about 6-700 Indians

CHRONOLOGY OF FRENCH AND INDIAN CAMPAIGNS

Table II cont.

7th	Dieskau intersected Johnson's road - abandoned attack on Fort Edward because of cannons, moved against Johnson
8th	<u>Midnight</u> - Johnson alerted to Dieskau's presence <u>Dawn</u> - Council of War dispatched a 1200 man scouting party - relief column to Fort Edward, command of Col. E. Williams and "King" Hendrick. - Head of column ambushed and Hendrick killed, Whiting's men covered withdrawal to Bloody Pond where with 300 reinforcements under Col. Cole a stand was made. - Withdrew to Lake George camp - partially fortified - French assault on camp repulsed - Johnson and Dieskau wounded - the latter captured. - French fled to Bloody Pond where they were scattered by a relief column from Fort Edward.
Fall of '55	Campaign against Crown Point abandoned. Construction of Fort William Henry and Ticonderoga begun and Fort Edward continued.
1756 May 17th	War declared. Construction continued on Forts. Montcalm takes over in Canada Raids continue
Aug. 10-14	Montcalm takes Oswego
1757	Continued Raids
August 3-9	Montcalm took Fort William Henry - massacre followed.
1758 June 26	Amherst takes Louisburg.
July 5-8	Abercrombie Expedition and disaster at Ticonderoga
1759 July 21-26	Amherst moves on Ticonderoga French abandoned and exploded magazines there and at St. Frederic
Sept. 13-14	Quebec fell to British
1760 May 16	Levi's forced to withdraw from beseiging Quebec
Sept. 7	Montreal surrendered.

Environmental Problems

The environmental problems, in this area, center around water pollution and, to a much lesser extent, mass movements, spring flooding and the remote but never the less possibility of earthquake damage.

Foremost among the problems are those which have been produced by industrial wastes and among these PCB's (polychlorinated biphenols) and TCE (trichlorethalene) are the foremost. Both of these chemicals are widespread but in this area they seem to be especially significant.

PCB's were first used locally during the 1930's in the production of electrical transformers and capacitors. In all fairness it must be said that their use seriously reduced the number of fires started in transformers and saved many lives by doing so. Since they were considered "safe" they were handled very carelessly and disposed of in a carefree manner, often just dumped on to the ground or into the river, sprayed on roads to settle dust or to kill vegetation. This practice has led to widespread ground water and stream pollution.

TCE, an industrial degreaser and solvent, has been used extensively to prepare material and to clean up PCB spills. It too, has gone into the dumps, rivers, and ground.

There are several main points of concentration of these two chemicals: first the Hudson River sediments, which prior to its removal, were trapped behind a Niagara Mohawk Corporation dam at Ft. Edward. Second, around the General Electric Plants, and last, the dumpsites in Ft. Edward, Kingsbury, and Moreau (Caputo). There are many other point sources (some of which are not known) where individuals have disposed of varying quantities of the waste. The wide distribution of the sources makes it difficult to accurately map the movement of the materials in the sub-surface.

Another type of chemical wastes are the heavy metals which have been produced in the manufacture of paint pigments. These include lead chromate which was produced at the Ciba-Geigy Plant. Previously this was included in waste water entering the Hudson River at the plant. It is now separated at a multimillion dollar waste water treatment plant and disposed of in a monitored waste disposal site.

Additional stream pollution came from the dyes, "black liquor" and escaped fiber from the several paper mills. Most of this has stopped since the clean waters act. An incinerator at one plant burns much of the waste, more or less, cleanly.

The local cement company previously allowed great amounts of fine powder to escape from its stack, the distribution of which was well mapped in a study by Adirondack Community College students. The replacement of the old stack with a new static precipitator has greatly reduced this source of air pollution.

The use of pesticides and herbicides in agriculture along with fertilizers has lead to some ground water pollution near certain local distributors where trucks and tanks are washed out and occassional spills have occurred.

Petroleum spills and leaks have been rather limited locally and usually involve service stations or accidental spills from trucks.

The problem of leachates from now abandoned dumps is still around and one local municipality is still dumping raw sewage into the Hudson and another into the Champlain Canal.

The multiplicity of these problems points out the importance of educating the every day citizen...as to the nature of the problems and getting a positive response to the moves to protect and clean up the environment. Although most of the local industrial waste production is now under control, the problem of dealing with the old sources is extremely complex. Should the Hudson be dredged to remove the PCB laden sediment? If so, where do we put it? Can the PCB's be confined indefinitely in the existing dump-sites? What about existing plumes which are presently polluting water supplies? Many of these questions are of great concern to the local people who are faced with the cost of cleaning up while at the same time feeling that they were not responsible for the mess.

Table III - CHRONOLOGY OF BURGOYNE'S CAMPAIGN

6 May 1777	Burgoyne arrives in Canada
13 July	Burgoyne leaves St. Jean
1 July	Siege of Ticonderoga begins
5 July	Ticonderoga evacuated
6 July	British occupy Ticonderoga and Skenesborough (Whitehall)
7 July	Battle of Hibbardton Road
8 July	Battle of Fort Anne
27 July	Killing of Jane McCrea
30 July	Burgoyne at Fort Edward
6 August	Battle of Oriskany
9 August	British at the Battenkill
16 August	Battle of Bennington
23 August	Stanwix relieved
13 September	Burgoyne crosses to West bank of the Hudson at Saratoga
18 September	Lincoln raid on Ticonderoga
19 September	Battle of Freeman's Farm
6 October	Clinton captures Hudson highland forts
7 October	Battle of Bemis Heights
9 October	Burgoyne falls back on Saratoga
17 October	Burgoyne Surrenders
8 November	British destroy and abandon Ticonderoga

ROAD LOG FOR TRI-CORN GEOLOGY TRIP

HISTORY - GEOLOGY & ENVIRONMENTAL PROBLEMS

CUMULATIVE MILAGE	MILES FROM LAST POINT	ROUTE DESCRIPTION
00.0	00.	Starting Point
STOP 1. SARATOGA NATIONAL PARK VISITORS CENTER		
<p>The battles fought here were, collectively, one of the most decisive actions during the course of North American history. They represented the climax of a complex, three-pronged campaign, which, had it succeeded, would have cut the rebelling colonies in two, probably winning the war for the British. The American victory assured recognition by France and subsequently to the alliance.</p> <p>The choice of ground was made by the Americans, who drew up their lines overlooking a narrow defile along the Hudson. Entrenchments were dug along Bemis Heights under the direction of Col. Kosciusko. The area was sparsely settled, with farms in scattered clearings, connected by wagon roads through the forest. Where the roads traversed sand, they were difficult to move over with heavy loads. Where they traversed clay, they were impossible when wet, and if rutted, nearly the same until beaten down. Burgoyne, with his heavy train of baggage and artillery, was forced to descend the river using batteaus for his supplies while his men trooped along the parallel road. He had crossed to the western side just north of present day Schuylerville (Saratoga). The American defenses, therefore, commanded his route along the river and extended westward to prevent his flanking them.</p> <p>Leave the Visitors Center and follow the access road eastward to Route 4</p>		
.5	.5	This is the "280 ft." level of proglacial Lake Quaker Springs.
.9	.4	The "250 ft." level of Lake Coveville.
2.3	1.4	INTERSECTION with Route 4 Turn left (North)
6.5	4.2	Coveville Plunge Basin. Drainage from the Ballston Channel combined with waters of the Kayderosseras dropped into the almost river-like Lake Fort Ann.
9.8	3.3	INTERSECTION Rt. 29, Village of Schuylerville, Site of Ft. Hardy, Where British grounded arms, is on the flood plain to the right.

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| 10.2 | .4 | Burgoyne's final positions. |
| 11.4 | 1.2 | <p>Stop #2 Stark's Knob. Pull off road and park. Hike up road leading west past the knob. THE EXACT OWNERSHIP OF THIS SITE IS, AT THE TIME OF PUBLICATION, UNKNOWN, BUT IT IS NO LONGER THE PROPERTY OF THE STATE OF NEW YORK, HAVING BEEN DEEDED TO THE TOWN OF NORTHUMBERLAND. THE TOWN IS THOUGHT TO HAVE DISPOSED OF IT TO A PRIVATE INDIVIDUAL, WHO DENIES THAT IT IS HIS. AS THE RESULT OF REPEATED INTRUSION ONTO HIS ADJOINING LAND, HE HAS MADE IT KNOWN THAT HE WILL HAVE ALL PERSONS WHO STRAY ON TO HIS PROPERTY ARRESTED. IT IS THEREFORE IMPORTANT THAT VISITORS STAY ON THE TWO ACCESS PATHS TO THE SITE AND AVOID CROSSING THE OLD FENCE LINES.</p> |

STOP # 2 STARK'S KNOB

The Knob is named for General Stark, who placed his artillery atop of it in the final days of the campaign, thus blocking the withdrawal of the British up the Hudson River and along its western bank. The knob has been formed by the differential erosion of the soft black shale from around the more resistant basalt of the pillow lava. Both the shale and the pillow lava are part of an overthrust block of Ordovician rock displaced a considerable distance from the east during the Taconic events.

The material between the pillows contains fragments of the carbonates through which the lava appears to have passed on the way to the surface. The pillows themselves, have a chilled surface and are laced with quartz and calcited filled fractures. Several small faults cut down through the quarry face and water moving along these has formed a small spring at the base near the large pine tree. The basalt was quarried for "road metal" prior to its acquisition by the state.

Return to vehicles and continue north on Rr. 4

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| 12.1 | .7 | Northumberland & intersection with Rt. 32. Bear right on Rt. 4 over bridge. |
| 16.0 | 3.9 | <p>Fort Miller
The fort was built on the opposite side of the river, to protect the portage around rapids or a small falls on the river. It was a wood stockaded "star fort".</p> |

- 17.3 1.3 The old Champlain Canal on the right. This old canal wanders along, following the contours in order to reduce the number of locks. Rt. 4 crosses its path.
- 19.1 1.8 Exposure of black shale and sandstone in a near vertical attitude. A few graptolites have been collected here dating it as part of the Taconic over-thrust.
- 23.0 3.9 Bridge over the Champlain Canal. The Hudson River is seen below the locks. This water barrier was non-existent during the 18th century so that it was easier to build the military road down this side of the river.
- 23.2 .2 The Fort Hours Museum.
(Time permitting, a brief stop.) This house was built prior to the revolution of materials said to have been scavenged from the buildings at the fort. There is an old, but never-the-less good, model of Fort Edward - a typical earth and timber fort.
- 23.4 .2 Bridge over Fort Edward Creek with an old canal aquaduct over it to the right.
- 23.5 .1 Site of Fort Edward.
All that remains of this, the largest British military installation in North America prior to 1800, is a small portion of the moat. It was essentially a three bastioned earth and timber fort, built over a period of two years on the site of earlier Fort Nickolson. Additional works were built on "Roger's Island" the home base of Roger's Rangers. The fort was never besieged or defended except against small raiding parties. It was placed here at a position of great strategic importance, but like Ticonderoga, it was overlooked by high ground making it indefensible. Seven blockhouses were placed around it to cover the weaknesses in its approaches. This point is the furthest extent of the navigatable

waters of the Hudson and the southern end of the portages to Lakes George and Champlain.

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| 23.7 | .25 | INTERSECTION of Rt. 4 and 197
Traffic Light - Turn left over the Hudson River. This canal was completely plugged following the removal of the power dam. |
| 23.8 | .1 | ROGER'S ISLAND - turn right just after leaving bridge. Continue to north end of island. |
| 24.0 | .2 | STOP #3 - ROGER'S ISLAND |

In the early 1970's, the Niagara-Mohawk Power Corp. received clearance to remove a small power dam located just north of the island. The volume of sediment entrapped behind the dam was greatly underestimated and the P.C.B. content was not recognized as a hazard and ignored. When the spring flood occurred, a huge volume of P.C.B. laden sediment washed down stream, leaving the north channel plugged and the south channel nearly so. This resulted in three major problems: the navigational channels were plugged here and downstream, P.C.B.'s entrapped in the sediment were distributed with them and raw sewage from the Village of Fort Edward was piled up atop of the plugged channel.

The New York State Department of Transportation dredged out the channels and stored the material at the DOT sites on Roger's Island and on the Town of Moreau side of the river. It was an annual event for several years until the bulk of the sediment was washed out and the nature of the P.C.B. problem "surfaced". During the last dredging, the P.C.B. threat, having been recognized, workers were required to wear dust masks and the material was encapsulated, the previous dumpsites were covered with a temporary cap of clay. An unexcavated archeological site was buried in the process.

Continue around the road to Rt. 197

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| 24.1 | .1 | Turn right on Rt. 197 over bridge |
| 24.7 | .6 | INTERSECTION -WEST RIVER ROAD
Turn Left |
| 24.9 | .2 | STOP # 4 D.O.T. SITE |

This is an encapsulated dump site for the P.C.B. laden sediments dredged from the Hudson River at Roger's Island. The debris was placed in a clay lined pit and then covered again with clay. It is a temporary disposal site.

Turn around and return to Rt 197.

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| 25.5 | .6 | INTERSECTION Rt. 197
Turn right toward Ft. Edward |
|------|----|--|

- 26.3 .8 INTERSECTION Rt. 4 Village of Fort Edward. TRAFFIC LIGHT Turn Left
After making turn note marker on left for the McCrae House where Jane McCrae was taken by Indians. Rt. 4 approximately follows the military road to Lakes George and Champlain.
- 26.9 .6 The approximate site of the killing of Jane McCrae. A blockhouse was situated about where the school atheletic field is.
The road is climbing up onto the sand delta deposited into Lake Coveville.
- 27.7 .8 STOP #5 - Pull off road to right.

STOP # 5 - FORT EDWARD GENERAL ELECTRIC PLANT & UNION CEMETERY

This is one of two General Electric plants locally which manufacture electrical components (capacitors chiefly) previously using P.C.B.'s. To the right rear, next to the Grand Union Store, is an Agway Farm Store, which sells pesticides and herbicides to local farmers. Union Cemetery, located to right, is the burial place of several persons of note, including Jane McCrae, Duncan Campbell and Tobert Cochran.

The location is atop a sand delta (Lake Coveville) some 15 to 20 feet thick overlying a shale which crests under the General Electric Plant and slopes away toward the river to the soughwest and the Champlain Canal to the northeast.

Two groundwater problems have developed here, the first involving agricultural chemicals and the second, P.C.B.'s and T.C.E.. Most of the local dwellings have their own waterwells, some of which have become polluted by either or both types of chemicals. The pesticides and herbicides have shown up in wells on Putnam Avenue and Ethan Allen Street southeast of the Agway Store and extend as far as Burgoyne Avenue. The seemingly harmless act of washing trucks appears to have been the cause of this problem. One more good example of why ordinary people need a better education in geology. The P.C.B. T.C.E. problem is more complex. Both chemicals were uses extensively at the General Electric Plant and the deliberate and accidental spills over many years have gradually polluted the groundwater about the buildings. In addition, some individuals have dumped the industrial chemicals at their homes where they have been salvaging materials or using T.C.E. on their own projects. Wells along adjoining streets have been abandoned and these homes have been connected to municipal water systems, the cost being borne by G.E. There is very extensive litigation involved in these cases and little information can be gained from the parties involved.

CONTINUE NORTH ON ROUTE 4

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| 28.4 | .75 | John St. Intersection & Traffic Light. continue straight on Rt. 4 |
| 28.9 | .5 | HUDSON FALLS VILLAGE PARK
Traffic Circle - Leave Rt. 4
continue around park (left turn)
and down the River Street hill. |
| 30.3 | 1.4 | INTERSECTION - Traffic light,
Quaker Road. Turn right. |

NOTE: Ciba-Geigy Plant and wastewater treatment plant.

Prior to the construction of the treatment plant, waste water containing heavy metals was discharged into the Hudson adding to the pollution from the paper mills upstream. Following the imposition of environmental controls, this installation was built to separate the toxic components from the water which is returned to the river cleaner (supposedly) than when it is taken out. The solids are then hauled to the Queensbury Landfill where they are placed in a disposal basin.

The road climbs up onto another sand deposit, this one is probably related to Lake Quaker Springs.

Across the river to your rear, is the Glens Falls Cement Quarry showing the thickness of the sand overlying the carbonates. The cement plant was the center of an air pollution study done by Adirondack Community College students many years ago. The study pinpointed the plant as a major source of particulate matter in the air and with the passage of clean air regulations, the old stack was replaced with one containing "scrubbers" and the problem was essentially solved. The Glens Falls Limestone quarried here was previously produced from tunnels underlying the Village of South Glens Falls.

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| 30.6 | .3 | Intersection Traffic Light Dix Avenue. Dix Avenue is following the route of the old military road to Lake George. It skirted the low area through which we have just passed, and swung west and then north to avoid the swamp through which Quaker Road passes. |
| 31.8 | 1.2 | Prospective PEAT FARM.
Peat deposits have formed in swamps which developed on Lake Albany clay which sealed the underlying limestone. The development is stalled pending a decision related to the Wetlands Protection Act. |

CONTINUE ON QUAKER ROAD THROUGH
THE RIDGE ROAD INTERSECTION.

- 33.3 1.5 INTERSECTION AND TRAFFIC LIGHT BAY ROAD - TURN RIGHT. You are now entering "New France" as you cross Halfway Brook and enter the St. Lawrence drainage basin.
- 34.8 1.5 BRIEF PAUSE - ADIRONDACK COMMUNITY COLLEGE QUARRY.

This exposure of Ordovician, Beekmantown Carbonates, contains a breccia, (fault or collapse ?) some small cephalopods and burrows of a sort. The campus is located on a downfaulted block (a graben) with a fault running approximately across Bay Road and another somewhere between the rear of the buildings and the next ridge to the east. Other structures are suspected because of the change in the attitude of the rocks in the several outcrops on campus. A small fault with a 2 inch displacement has been found. In addition, there is an exposure with enlarged solution joints, perhaps formed during the post-glacial interval while Lake Albany was draining. The soils on campus are lake clays (some varves were found in the building excavations) and to the west and north, is the kame and esker complex.

CONTINUE NORTH ON BAY ROAD.

- 35.1 .3 INTERSECTION - BLIND ROCK ROAD
TURN LEFT
The road climbs up onto the kame and esker complex. Blind Rock was a locality where native warparties often took prisoners for torture.
- 36.4 1.3 Round Pond and Paradise Beach.
A kettle lake with an esker on each side at the far end. The one extending along the north side continues along the right side of the road.
- 37.1 .7 INTERSECTION - Rt. 9 - Turn right.
This is near the epicenter of a number of very small 'quakes (.5 Richter or less) which were detected during a study done by the N.Y.S.G.S. Rt. 9 passes over 5 Mile Run, the site of several ambushes, just in front of the Great Escape Amusement Park! The low area on the right, past the park is an extension of Glen Lake, an iceblock lake.
- 37.9 .8 Kame terrace capped by Lake Albany sands.

39.7

1.8

STOP #6 COL. WILLIAM'S AMBUSH
PARK ALONG ROAD SIDES WHERE IT
IS SAFE. THIS IS A DANGEROUS SITE.

STOP # 6

The outcrop is on the west side of the road and is extremely hazardous because of traffic. The bedrock is Precambrian (Grenville) Gneiss and is cut by several nearly strike-slip faults running parallel to the road. At one point a small dike is cut into three sections by the faulting. Prior to the widening of the road, there was a fine, fluted, slicken-sided surface exposed. French Mt. opposite, is a horst.

The military road passed below the present road and this was the site of the French ambush of the Provincials and Iroquois, known as "The Bloody Morning Scout". Col. Ephraim Williams, whose estate founded Williams College, was killed standing on a glacial boulder, while old "King" Hendrick toppled from his horse and was bayoneted. The colonials and Mohawks successfully withdrew from "Rocky Gulch" to Lake George, leaving about 100 casualties behind.

CONTINUE NORTH ON RT. 9

40.5	.75	Bloody Pond, a kettle lake and the scene of two skirmishes.
42.	1.5	INTERSECTION - TURN RIGHT
42.4	.4	STOP #7 FORT GEORGE AND BATTLE-FIELD

STOP #7

Here is another exposure of Ordovician, Beekmantown carbonates, dipping about 5° northeast and lying between two mountains of Precambrian rock. This presents an opportunity for solving a very simple structural problem. Three responses are usually evoked from beginning students when asked to explain it:

1. The rocks were derived from the older rocks and deposited here.
2. They were downfolded into the valley form.
3. They were downfaulted.

The first choice is eliminated by the character of the sediment, and the others require further information to be gained at the next stop.

The carbonates were first used to build the stone bastion of Fort George, which was built following the Battle of Lake George. The rocks provided both the building stones and the mortar to hold them in place. The present structure has been partially restored.

The battle here followed the Bloody Morning Scout. Dieskau, the French commander, launched a series of assaults on Johnson's camp and was repulsed with heavy losses. Both officers were wounded and Dieskau taken prisoner. The French and their allies fled to Bloody Pond to loot the packs of the men killed there earlier, where a relief column of over 600 men from Fort Edward caught them disorganized and scattered the survivors.

After the battle, Fort William Henry was finished on the sand terrace overlooking the lake. The fort was built of timbercribs filled with sand from the moat. The main gate was on the south side, and a stockaded area on the north. The choice was poor in the sense that the sand, being easy to dig, allowed Montcalm to advance his saps and parallels very quickly when he laid seige two years later in 1757. His artillery quickly reduced one bastion. The sand pouring out through broken timbers caused it to collapse and the fort surrendered. The attack on the unarmed British prisoners following the surrender is a matter of historic record.

CONTINUE NORTH TOWARD LAKE GEORGE.

42.7	.3	INTERSECTION - BEACH ROAD TURN LEFT. Note: Fort William Henry reconstruction..
43.1	.4	INTERSECTION - RT 9 - Turn right.
43.7	.6	INTERSECTION - RT 9 & RT 9-N Bear right on Rt. 9-N
44.1	.4	INTERSECTION - NORTHWAY I-87 ACCESS TRAFFIC LIGHT - TURN LEFT AND PARK - STOP #8

STOP #8

This exposure of the upper Cambrian Ticonderoga Formation dips gently toward the northeast and consists of mostly sandstone which places it in the upper third of the formation but not at the top which contains some chert. There are ripples and stromatolites present, the latter being in the reddish-brown dolomitic layer at the top of the ledge. The upper surface has been planed smooth by glaciation and the direction of movement has been recorded in striations found there. Visible to the west is an exposure of precambrian rock at the bend in the road. These observations tend to support the hypothesis that the valley floor is a downfaulted block or graben. Further support to the idea comes from the existence of two magnetic anomalies between the two outcrops. (Personal communication from John Mead) A similiar relationship between the Precambrian and the carbonates can be seen along the east side of the valley. (Along Rt. 9-L near Crosbyside)

There are two courses open to the trip: 1st double back to Rt. 9, turn right and proceed toward Warrensburg, or continue on to the NORTH BOUND LAND OF I-87. THE LOG WILL DESCRIBE THE FIRST.

HEAD SOUTH TOWARD LAKE GEORGE VILLAGE ON RT. 9-N

44.5	.4	INTERSECTION RT. 9 & TRAFFIC LIGHT TURN RIGHT TOWARD WARRENSBURG. The road follows the trace of the English Brook Fault.
46.5	2.0	BRIEF PAUSE - THE ENGLISH BROOK SAPROLITH

Note: This exposure of deeply weathered rock has been known since the 1930's and has miraculously survived repeated road improvements. Originally, the exposure was topped with two layers of glacial boulders separated by a lake sand. Each spring these came rolling down - some three feet in diameter - to the dismay of the highway department. Their recent removal and the gradual covering of the face in its own debris has greatly altered the appearance of the site. The preservation of the saprolith is thought to be the result of deep weathering along the plane of the fault and the transverse orientation of the fault to the direction of ice movement. This is one of the few such exposures which can be easily seen in New York State.

CONTINUE NORTH ON TR. 9

49.1	2.6	INTERSECTION AND TRAFFIC LIGHT E. SCHROON RIVER ROAD. TURN RIGHT OVER BRIDGE.
49.4	.3	EXIT 23 - I-87 TAKE NORTHBOUND LANE TO EXIT 25
<p>Note enroute: This valley was occupied by Glacial Lake Warrensburg, evidence for which is seen in the numerous sand deposits along its floor. Just short of Milepost 63, the road cuts show Precambrian rocks on one side and layered sediments on the other, the road straddling a fault.</p>		
59.2	9.8	EXIT 25 LEAVE I-87 TURN RIGHT (EAST) ON N.Y. RT. 8 TOWARD BRANT LAKE AND HAGUE
73.4	3.9	HAGUE - INTERSECTION - RT.9 TURN LEFT (NORTH) Toward Ticonderoga
79.1	1.7	ROGER'S ROCK STATE PARK AND CAMP- SITE. Named for Roger's Slide - thought to be the fault scarp forming the east side of the Lake George graben and the scene of Major Roger's escape from the French and Indians, March 13, 1758.
84.3	5.2	IN TICONDEROGA - INTERSECTION LEAVE RT's 9-N & NY 8, CONTINUE STRAIGHT ON NY RT. 73
84.7	.4	Ticonderoga Creek - The outlet from Lake George flowing into Champlain
86.0	1.3	INTERSECTION - LEAVE RT. 73 GO STRAIGHT THROUGH TO FORT TICON- DEROGA
87.0	1.0	STOP #9 FORT TICONDEROGA

STOP #9 FORT TICONDEROGA (CARILLON)

This fort is built near if not on the site of Champlain's skirmish with the Iroquois in 1609. Construction was started in 1755 and essentially completed by 1758. Modifications, repairs and improvements continued until the end of the American Revolution, when it was allowed to fall into total disrepair.

The original construction was of earth and timber, later on improved by stone facints. The fort was designed for a small permanent garrison with extensive outworks for a larger "summer" army. The location was poorly chosen, since the works are well within range of seige guns placed on the heights of Mt. Defiance.

The stone fort was built from Ordovician limestone, quarried on the site, and was in total ruin prior to reconstruction. The stone work, weakened by solution and frost action, had collapsed into the moat, and hauled off to build "celler walls" by the post war settlers. The original foundations can be recognized in the walls by their weathered appearance.

Mt. Independence, on the opposite shore, was linked to the fort by a bridge consisting of 22 sunken piers connected by 12' X 50' "pontoons" chained together. The piers still survive in the muddy floor of the lake and are currently being salvaged (?) along with numerous other artifacts of the Revolutionary War.

RETURN TO RT. 73

88.1	1.0	RT. 73 CONTINUE STRAIGHT ON 73
88.8	.7	INTERSECTION - RT. 22 TURN LEFT (SOUTH) ON RT. 22
112.4	23.6	South Bay, Lake Champlain
113.3	.9	Note Rock Falls along road cuts.
114.5	1.2	IN WHITEHALL - INTERSECTION & TRAFFIC LIGHT, TURN LEFT AND TAKE FIRST RIGHT, BEAR LEFT AT FORK TO PARK AREA.
114.8	.3	STOP # 10

STOP # 10 - THE HUDSON-CHAMPLAIN CANAL

The canal follows the general path of wood creek which rises near Fort Edward. During the spring of 1984 this area was badly flooded when water backed up behind a coffer dam following a heavy rain. The dam, installed to permit repairs on the canal, was not designed to accommodate the sudden rise of waters and considerable damage was done to the small museum here and other structures.

Historically, the locality was called Skenesborough, after Philip Skene, a prominent Tory. The claim to be the "birthplace of the United States Navy", stems from the fact that Benedict Arnold's fleet was built here, the first continental squadron. Although it was defeated at Valcour Island, the fleet delayed the Burgoyne campaign until the next year. The hull on display here is a survivor of the Battle of Plattsburg Bay, during the War of 1812. A military road was built from here to Fort Edward and later improved by Burgoyne.

115.1	.3	INTERSECTION - RT. 4 TURN RIGHT
115.2	.1	INTERSECTION - TRAFFIC LIGHT BEAR LEFT ON RT. 4, SOUTH. This road will follow closely the old military road parallel to Wood Creek. It travels over the floor of Lake Fort Ann.
121.2	6.0	LAKE CLAYS ON RIGHT - NOTE SLUMPING Champlain Canal Locks on left.
121.7	.5	Note: ROCKFALLS IN ROAD CUT.
123.1	1.4	BRIEF PAUSE - ROAD CUT IN PRE- CAMBRIAN GNEISS.

The foliation and some joints in the gneiss dip toward the east so that the road cut intersects or "daylights" them along the west side of the road. In order to reduce the chance of failure along these planes, the threatening blocks have been bolted into place with heavy threaded rods which penetrate into "solid" bedrock.

123.3	.2	SLUMPING IN LAKE CLAYS. This area was "corrected" in 1984 by reducing the slope angle. Slumping reoccurred in the spring of 1985
123.8	.5	Additional slumping
124.9	1.1	STOP # 11 UNCONFORMITY

STOP # 11

The base of the Potsdam Sandstone is exposed here in contact with the precambrian gneiss. The basal conglomerate above the unconformity contains many large quartz pebbles here. Additional exposures of the Potsdam may be found by walking down the side road to the left and just past the small valley, climb down over some old concrete slabs to a flat exposure. Graded bedding, crossbedding and ripples can be found here and in the railroad cut. Glacial striations, chatter marks and quarrying faces may also be seen. A commercial building stone quarry across the canal was previously operated and many local houses are built of this rock.

125.6 .7 BATTLE MT. A rear guard action was fought here by the Americans fleeing Burgoyne's army. This was one of the first times that the "Stars and Stripes" were flown in battle.

127.7 1.6 ENTERING FORT ANN VILLAGE

The reconstructed blockhouse (bank) was originally intended for a museum. It is fairly accurately constructed and very close to the actual site of the fort which guarded the crossing of Halfway Brook where it entered Wood Creek. There was a stockade surrounding the blockhouse. Note the use of Potsdam sandstone in several of the older buildings.

127.3 .1 Intersection and Traffic Light Junction with Rt. 149W
CONTINUE SOUTH ON RT. 4

Burgoyne's line of march probably followed Route 4, but it is also possible that he did follow this lower route.

131.3 2.0 SMITH'S BASIN. INTERSECTION WITH NOTRE DAME EXTENSION. BEAR RIGHT UP THE HILL.
On the farside of the canal is an excellent section of Cambrian and Ordovician carbonates described by Donald Fisher in the N.E.I.G.C. Guidebook 61st mtg. 1969. An old limestone quarry and kiln was operated just across the bridge in an exotic block or thrust slice of Orwell and Glens Falls limestone. The basin was an old canal basin and at one time was a fairly large settlement.

136.1 4.8 INTERSECTION - BURGOYNE AVENUE
TRAFFIC LIGHT - TURN LEFT.

137.0 .6 KINGSBURY LANDFILL (Closed)

Note also, the Feeder Canal, five "combines" Locks and small house at right of intersection beyond canal.

The Kingsbury Landfill is now probably the chief source of P.C.B.'s entering the Hudson River. Many capacitors were disposed of here and on hot summer days, their sweet odor can be detected. The P.C.B.'s are leaching out of the site, into the canal and into the Hudson River. Another path is into the groundwater and the lowlands below the site to the river. Current plans call for the capping of the site hopefully sealing it. General Electric has made a major contribution toward the cost, but the remainder must be borne by the local taxpayers.

The feeder canal served two purposes: to move barges to Hudson Falls and Glens Falls and to maintain the water level of the lower section of the canal.

The small house may have been Burgoyne's Headquarters when his army camped here. In any event, it is thought to be one of only two buildings not burned down during Carleton's Raid in 1780.

- | | | |
|-------|----|--|
| 137.7 | .7 | INTERSECTION - JOHN STREET - RED
FLASHER - TURN RIGHT
Continue on John Street through the
intersections at Oak, Wright,
Popular, and Main Street, where
there is a traffic light. |
| 138.6 | .9 | GENERAL ELECTRIC PLANT. TURN
RIGHT AT INTERSECTION |
| 138.9 | .3 | INTERSECTION - TURN LEFT OVER
BRIDGE. |

This is Baker's Falls, the highest falls on the Hudson. While it is capped by a dam to increase its generating capacity, it is probably due to a fault. The river has cut a deep gorge through the softer shales below the falls.

It was the presence of this falls which caused Fort Edward to be built and the settlement of "Sandy Hill" to develop into the Village of Hudson Falls. The falls and dams upstream provided the water power for the early mills and later the hydroelectric generating plants, ultimately leading to the locating of the General Electric plants and the P.C.B. problem. It was also found that some P.C.B. was used to produce carbon paper upstream at a paper mill.

- | | | |
|-------|-----|--|
| 139.6 | .7 | INTERSECTION - BLUEBIRD ROAD
TURN LEFT. |
| 141.3 | 1.7 | CAPUTO DUMPSITE. |

This site which is located along the right side of the road, in back of the houses was used to dispose of industrial wastes from the General Electric Company from about 1958 to 1970. It was an open pit into which barrels were placed, filled with waste P.C.B.'s and T.C.E. The sub-surface consists of glacial sands and lake clays overlying bedrock. The watertable is about 25 feet down. ENCON. well information indicates the following:

0 - 70 feet	Medium to fine sand
70 - 95 feet	Fine to very fine sand with silt lenses 1/8 to 1/2 " thick.
95 - 100 feet	Fine sand - clay lenses with brown varves.
100 feet +	Gray clay and silt lenses over bedrock.

The site has been enclosed by 1600' slurry wall 100 feet deep and three feet thick in an attempt to contain the leakage. The slurry consists of 70% soil, 28% native clay and 2% bentonite. The whole is capped to shed water. The P.C.B.'s appear to be more or less contained and saturate the soil above the watertable. The T.C.E.'s on the other-hand appear to have sunk down rapidly to about 70 feet. A plume has formed between 45 and 70 feet, spread out about one mile down gradient in 2-2½ years. The water at the watertable appears clean as does the water below 70 feet, thus the plume appears to be moving toward the southeast in a sheet about 25 feet thick at a present rate of eight feet per day.

Many residential waterwells have already been polluted and some properties in close proximity are claiming unsafe levels of vapors within the structures. Because of pending litigation, it is difficult to obtain specific and valid information from some parties. The plume which is moving toward the Fort Edward water supply has shown up in a stream feeding it. A system of aeriating the water has been installed which allows the T.C.E. to dissipate. Additional P.C.B.'s were sprayed along the Fort Edward road to settle dust and this has recently been removed by scooping up the contaminated soil and placing it at the Caputo Site where it is to be encapsulated.

CONTINUE TO ROUTE 9

142.7

1.4

INTERSECTION WITH ROUTE 9 - Turn
left toward I-87 - Exit 17

TO SARATOGA TAKE SOUTHBOUND LANE

TO GLENS FALLS AND NORTH TAKE NORTHBOUND LANE

DEGLACIATION OF THE MIDDLE MOHAWK AND SACANDAGA
VALLEYS, OR A TALE OF TWO TONGUES*

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PURPOSE

The middle Mohawk Valley contains a record of the interaction between the Mohawk and Sacandaga glacial lobes, including evidence for several readvances. We will examine exposures in deposits that document these interactions and features.

INTRODUCTION

Interest in the glacial geology of New York State has experienced a renaissance during the past twenty-five years. Researchers have examined old interpretations of the glacial history of the State in the light of new geologic mapping, using techniques, hypotheses, topographic maps and airphotos that were not available to the earlier workers. The previous surge of glacial mapping lasted from the turn of the century to the thirties.

New York State was covered by glacial ice during the Wisconsin Glaciation. This glaciation commenced about 120,000 years ago, reached its maximum 22,000 years ago, and ended in New York State about 12,500 years ago (Mickelson and others, 1983). New York was almost completely covered by ice, except for the Salamanca Re-entrant in western New York and the southern edges of Staten Island and Long Island (Fig. 1). This ice came from the Laurentian

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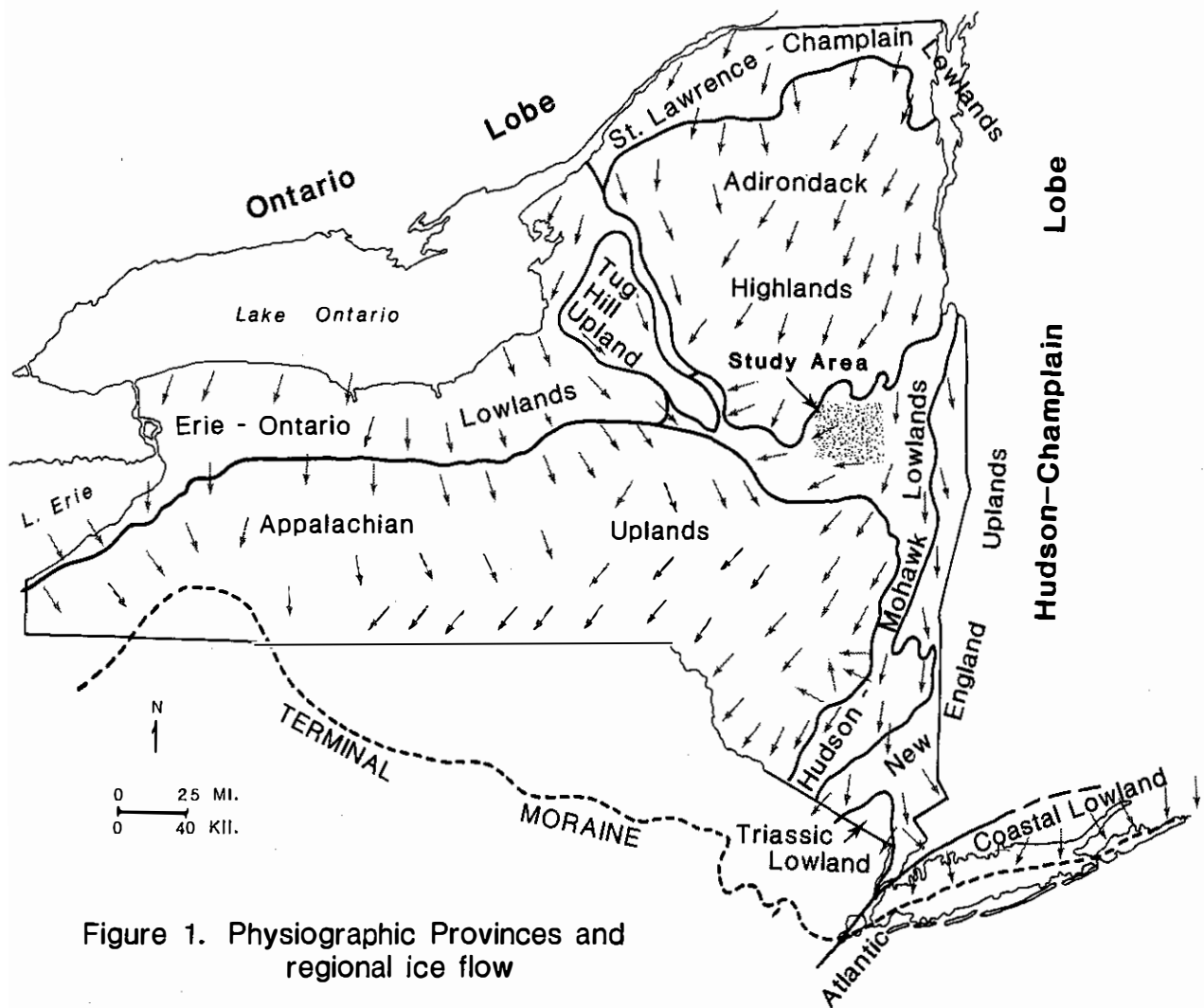


Figure 1. Physiographic Provinces and regional ice flow

Figure 1: Physiographic Provinces and Ice Movement in New York State. The Physiographic Provinces are from Broughton and others (1966), the Terminal Moraine is from Flint (1971), and Ice Movement Directions are from Fairchild (1907), MacClintock and Apfel (1944), Fullerton (1980), and Dineen (1983).

Mountain region of Quebec in two major lobes - the St. Lawrence-Ontario Lobe and the Hudson-Champlain Lobe. The physiography of the State controlled the movement of these great ice streams, which tended to flow around highlands and along the axes of major preglacial lowlands (Fig. 1). Ice flow directions (Fig. 1) are summarized from Fairchild (1907), MacClintock and Apfel (1944), Fullerton (1980), Dineen (1983; in press), Sirkin (1982; in press) and Ridge and others (1984). The Ontario and Hudson lobes flowed around the Adirondack Mountains and were split into sublobes by uplands (Fig. 1). The Hudson-Champlain Lobe was divided into the southward-flowing Hudson lobe, the Mohawk lobe which flowed westward up the Mohawk Valley, and the Adirondack lobe that followed the northeast-to-southwest structural and topographic grain of the Adirondack Mountains. The Sacandaga and Kayaderosseras sublobes of the Adirondack lobe interacted with the Mohawk lobe near Gloversville (Figs. 1 and 2).

The Mohawk Valley connects the Erie-Ontario and Hudson Lowlands across the south edge of the Adirondack Mountains (Fig. 1). The topography of the eastern Mohawk and Kayaderosseras valleys are controlled by NE-SW trending faults that define a series of grabens and horsts (Roorbach, 1913; Fisher, 1965, 1980; McLelland, 1984). Most of the fault blocks are tilted so that their eastern edges tend to be higher than the western (Roorbach, 1913). The east fork of the Great Sacandaga Lake lies in a graben (McLelland, 1984); so do the upper Kayaderosseras and Hudson valleys (Isachsen, 1965).

The preglacial Sacandaga River drained the south-central Adirondacks (Brigham, 1929), the ancient Luzerne River drained the southeastern Adirondacks (Miller, 1911), and the ancient Mohawk River flowed east from Little Falls to the Hudson Lowlands (Brigham, 1929). This preglacial rectangular drainage pattern was towards the southwest, along the bases of the fault blocks. Differential weathering and erosion sculpted a series of east-facing escarpments along the strike-slopes of resistant rock units (Roorbach, 1913). The southwest-flowing streams received only short streams from the fault-line scarps to the west, but long streams drained west across the dipslopes of the horsts (Miller, 1911). The preglacial Sacandaga followed the southwest grain of the rocks until it entered the Mohawk near Fonda (Fig. 2; Miller, 1911; Arnow, 1951; Jeffords, 1950). It divided into two forks north of Broadalbin; where one fork extended into the Adirondacks above Northville, and the other extended to Conklinville.

The preglacial Mohawk River cut across the rock structures, and entered the Hudson Lowlands at Schenectady. The Luzerne River included the upper Hudson Valley; it entered the Kayaderosseras Valley at Corinth where it followed the bedrock structure into the Hudson Lowlands at Saratoga Springs (Fig. 2; Miller, 1911; Heath and others, 1963; Mack and others, 1964). The thickest glacial deposits overlie the preglacial valleys, and blanket the lower portions of the fault blocks.

The glacial geology of the eastern Mohawk and upper Hudson region has been extensively studied ever since Chamberlin (1983) recognized the lobate nature of the ice front in New York State, and observed that the Mohawk Valley was the "key" to correlating glacial events between the Ontario and Hudson Lowlands. He noted evidence that suggested a westward-flowing glacial lobe in the Mohawk Valley, an observation that was confirmed by Brigham (1898). Fairchild (1912, 1917) interpreted terraces and sand plains as evidence for

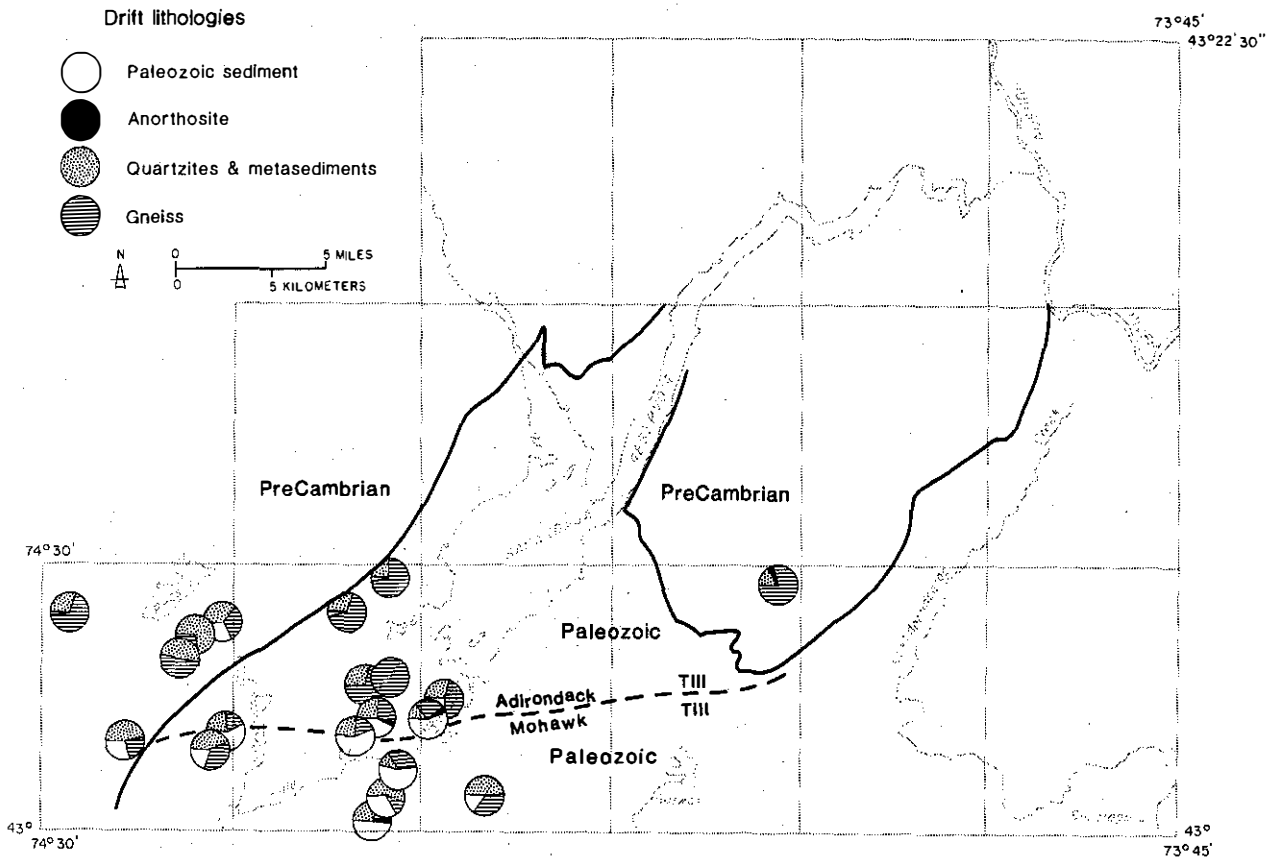


Figure 3. Drift Lithologies

Figure 3: Drift Lithologies. Data are from Yatsevitch (1968) and the authors. Q: metasediment clases, A: Anorthosite clasts, G: gneissic clasts, and S: Paleozoic sedimentary rock clasts. The Solid Line is the contact between Paleozoic and Precambrian rocks. The dotted line is the contact between the sandy, metamorphic clast-rich tills of the Sacandaga and Kayaderoseras sublobes, and the clayey, sedimentary clast-rich tills of the Mohawk Lobe.

a continuous glacial lake in the Mohawk Valley that "girded" the southern Adirondack Highlands, a notion that was demolished by Stoller (1916), Miller (1925), and Brigham (1929, 1931). Lakes in the Sacandaga and Upper Hudson Valley were documented by Stoller (1916), Miller (1923, 1925), and Chadwick (1928). Evaluation of the interpretations and correlations of the early workers was hampered by a dearth of surficial maps, except for Brigham (1929) and Stoller (1916). Thus, correlations between the Ontario and Hudson Lowlands depended on a series of publications that contained interpretations based on a minimum of surficial data.

Beginning twenty-five years ago, LaFleur (1961, 1965, 1969) rekindled interest in the eastern Mohawk Valley. Yatsevitch (1968) mapped the lower Sacandaga in detail. LaFleur (1975, 1979a, 1979b, 1983) has further refined the stratigraphy of the eastern Mohawk Valley, while Muller and others (1983) and Ridge and others (1984) have refined the stratigraphy of the western Mohawk Valley. Dineen (1983; in press), Dineen and others (1979, 1983) and Connally and Sirkin (1971) have documented the deglacial stratigraphy in the Hudson Valley.

Glacial Movement

The directions of glacial movement are shown by the orientations of drumlins and striae. Several streams of ice can be deduced from Figure 2. The Hudson Lobe moved south, down the Hudson Lowlands. The strong north-south striae and drumlin orientations were made by the Kayaderosseras sublobe; southwest striae were carved by this lobe when it veered over the McGregor and Spruce Mountain Ranges. The southwest-trending Sacandaga sublobe flowed down the Conklinville fork of the ancestral Sacandaga River (Fig. 2). These sublobes were part of the Adirondack lobe. The Mohawk lobe formed the east-west and northwest drumlins and striae. Till fabric orientations at Luzerne corroborate the drumlin and striae data in that area (Hansen and others, 1961, Connally and Sirkin, 1971).

Ice movement also can be inferred from drift lithologies, based on pebble counts in tills and stratified drift, and on the texture of the till matrix. Drift lithologies tend to reflect the lithologies of the underlying bedrock. The glaciers deposited most of their sediment load within 5 to 10 km (3 to 6 miles) of the sediment source (Drake, 1983). Areas that are underlain by acidic igneous, coarse-grained metamorphic rocks, and sandstones tend to yield sand-size particles during glacial milling, while areas underlain by mudstones, shales, and carbonates yield silt to clay size particles (Flint, 1971). Thus, areas with abundant igneous, gneissic, or sandstone outcrops are blanketed with sandy tills, while areas underlain by shales and carbonates have a compact, clayey till veneer. The Kayaderosseras and Sacandaga sublobes deposited sandy tills, with many gneissic and metasediment clasts, and the Mohawk and Hudson Lobes deposited clayey tills with Paleozoic sedimentary rock clasts and infrequent boulders of anorthosite (Fig. 3, based on Yatsevitch, 1968).

Several exposures and borings with till over stratified drift occur throughout the area (Fig. 2). Pits with buried soil zones were observed at Amsterdam (Hell Hollow) and West Milton by LaFleur (1983, oral communication),

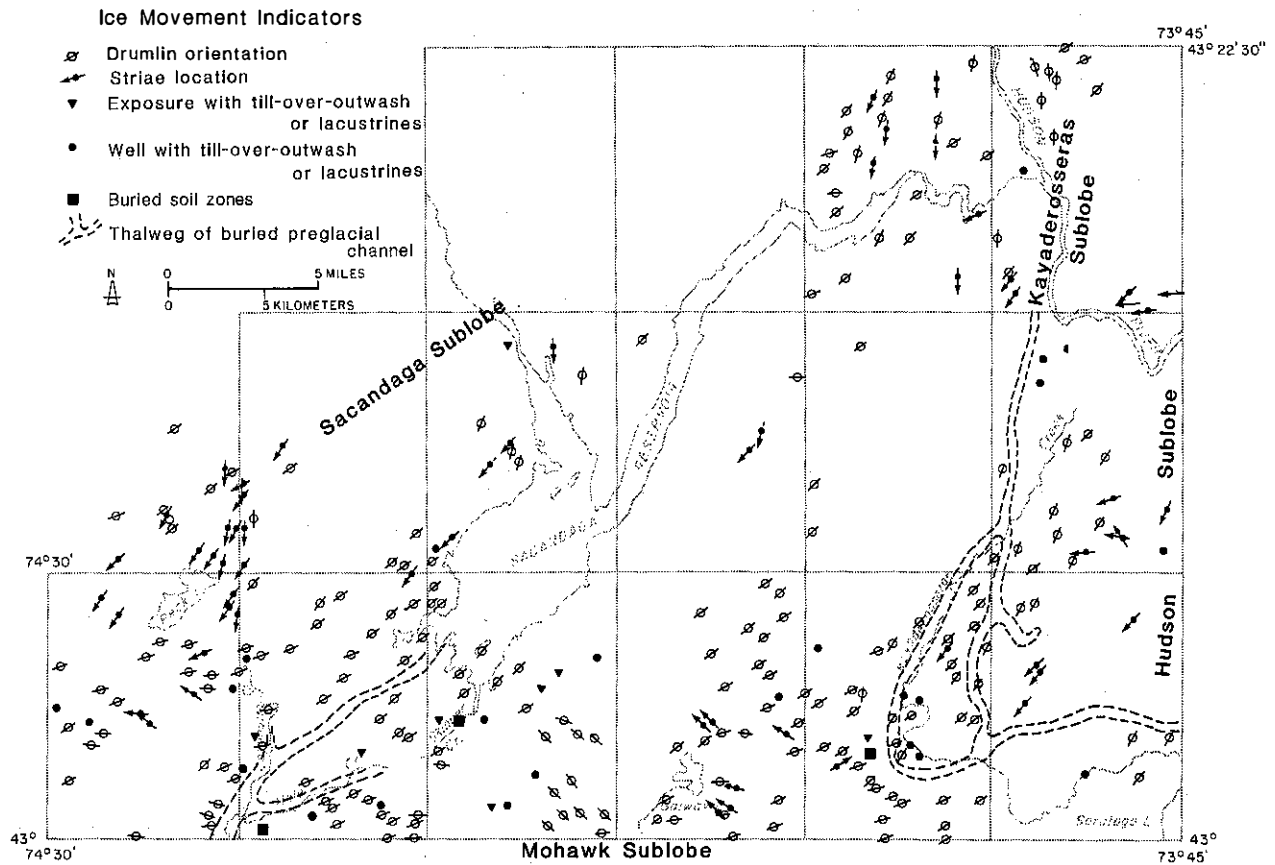


Figure 2. Regional Ice Movement

Figure 2: Ice Movement Indicators. Drumlin orientations are based on airphoto and topographic map interpretation. Striae orientations and localities are from Brigham, 1929, Stoller, 1916, Miller, 1923, and the authors. Wells are from Yatsevitch, 1968, Jeffords, 1950, Arnow, 1951, Heath and others, 1963, and the authors. The trends of the preglacial valleys are inferred from the well data. Exposure data are from Yatsevitch, 1968, the authors, and Connally and Sirkin, 1971.

and east of Gloversville by Yatsevitch (1968) and Dineen (Stop 3). These soil zones imply several thousands of years of weathering between glacial readvances.

Glacial Deposits

The surficial geology is summarized on Figure 4. This map is based on the 1:60,000 and 1:250,000 reconnaissance glacial maps that were prepared for the Surficial Map Project of the NYSGS. Several units are identified on Figure 4.

Meltwater channels are scoured channels and outwash trains, the arrow-head points in flow direction. Upper end of arrows mark heads-of-outwash and ice margin positions.

Several large, extensive moraines occur in the area:

The Jackson Summit Moraine Complex dominates the northwestern portion of the map. It borders Peck Lake, wraps around the heights of the Jackson Summit Mountain Range, and extends southwestward to the Noses. Several major valley trains originate at this recessional moraine. They grade downstream into proglacial lake sands south of Caroga Lake (Fig. 4).

The Woodward Lake Moraine Complex lies along the foot of the Jackson Summit Mountain Range. It is named for a lake west of Northville, where it is very well developed. It is predominantly a kame moraine with large quantities of stratified drift. Many gravel pits document water flow from the adjacent uplands into the glacier. This is a recessional moraine, built primarily against the Sacandaga sublobe, and is contemporaneous with the Broadalbin Moraine Complex (below).

The Broadalbin Moraine Complex is an extensive interlobate moraine that extends east 23 km (15 mi) from Gloversville to beyond Broadalbin. This moraine was deposited between the Sacandaga and Mohawk lobes. It is 30 to 100 m (100 to 300 ft) high on 0.5 to 6 km (0.25 to 4 mi) wide. It is comprised of ice-contact trough-crossbedded gravelly sand, with interbeds of till. It is coarser-grained to the east, where it also contains numerous flow tills. Brigham (1929) called it "the Interlobate Moraine" and noted that it was primarily waterlaid. Yatsevitch (1968) named it the Gloversville Kame Complex, and also noted its water-washed character. He considered it to have been deposited in a "fluvial-lacustrine" environment over and around older sandy till drumlins. Crossbeds show that it was deposited by water flowing from southwest to northeast (Stops 3 and 4).

Brigham (1929) inferred that a Mohawk lobe readvance deposited the till veneer on the southern edge of the complex, and created the subdued topography south of "the Interlobate Moraine". Yatsevitch (1968) also noted the subdued topography and till veneer. He correlated them with a till moraine at an elevation of 213 m (700 ft) along the base of the Noses Escarpment. According to Yatsevitch (1968) these features were emplaced by the Yost Readvance, a "weak readvance" of the Mohawk Lobe. Additional evidence for the Yost Readvance can be observed at Stops 2 and 3.

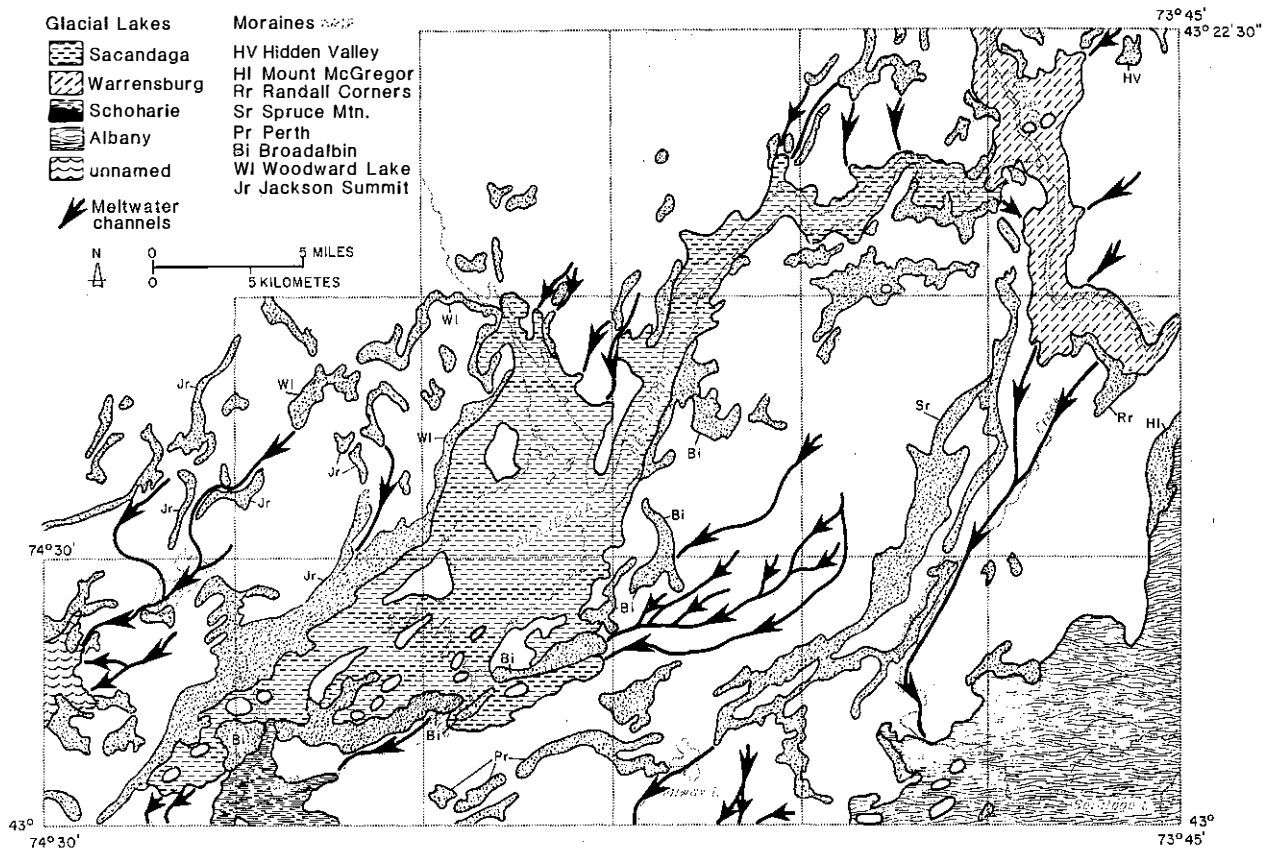


Figure 4. Surficial Geology of the Sacandaga Area

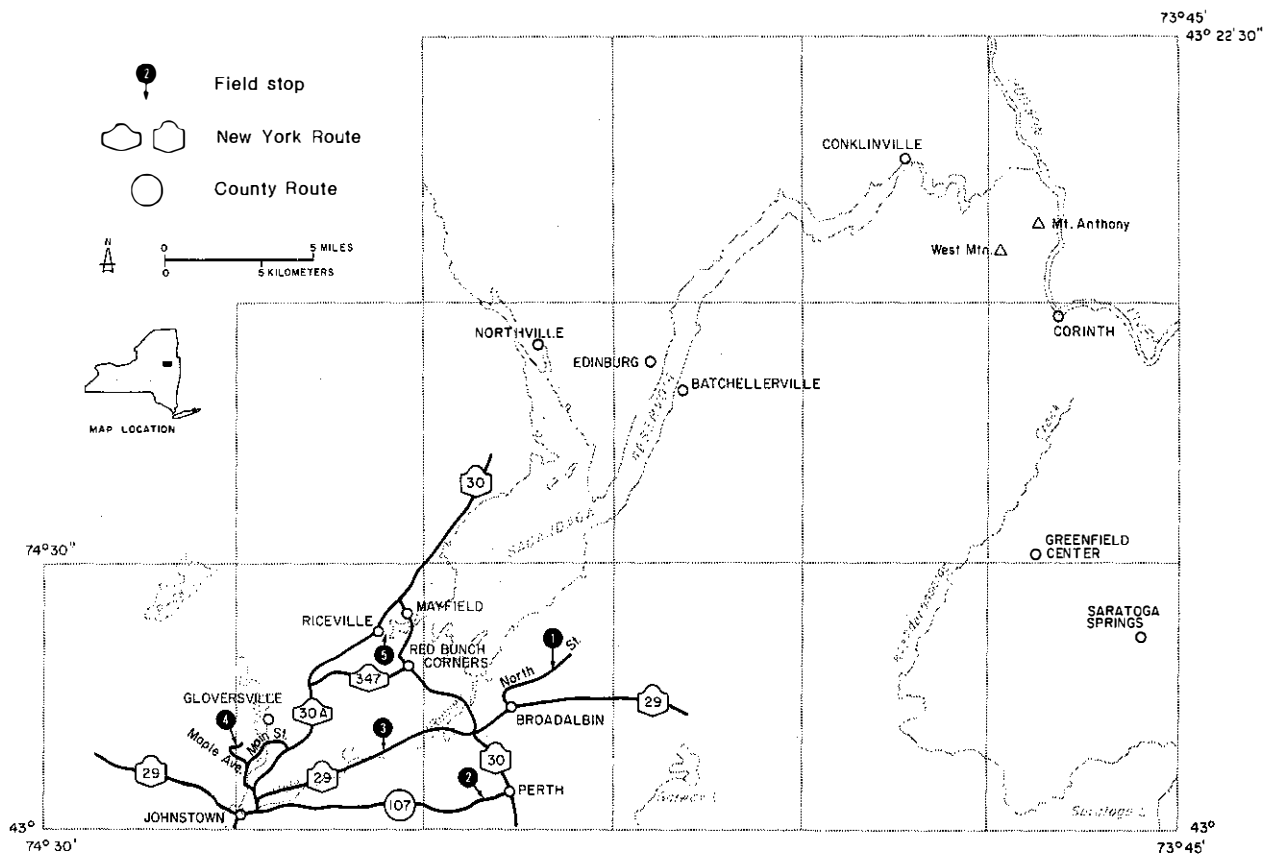


Figure 5. Field Trip Stops

The moraine was deposited during several episodes of sedimentation - a soil zone is developed on the sediments below the Yosts till (Stop 3). The moraine was originally deposited by meltwater flowing between the Sacandaga and Mohawk lobes, and was modified by the Yosts Readvance after a relatively long period of subareal exposure.

The Perth Moraine is a high (40 to 50 m, 120 to 150 ft) platform of till- and-stratified drift that is south of the Broadalbin Moraine. The platform has a low (3 to 6 m, 10 to 30 ft high) recessional moraine near its southern edge, shown as the Perth Recessional Moraine. The platform is capped with massive (unbedded) sand north of the recessional moraine, and till south of it. An exposure at Perth (Stop 2) shows silty till that is interbedded with fluviially-crossbedded sand and gravel. Some outwash channels extend northwest from the moraine. The Perth Moraine appears to grade eastward into the Galway and Spruce Mountain moraine systems.

The Randall Corners Recessional Moraine lies at the head of the Kayaderosseras Valley. It is mostly bouldery kame gravels and was originally described by Stoller (1916) as being lobate and forming a head of outwash.

The McGregor Moraine was mapped by Stoller (1916) at the base of Mt. McGregor as the Kings Station kame terrace. Connally and Sirkin (1971) renamed this feature and correlated it with the Luzerne Readvance.

The Hidden Valley Moraine, in the Lake Luzerne quadrangle is a till moraine that Connally and Sirkin (1971) also correlated with the Luzerne Readvance.

Glacial Lakes: We have correlated lake levels using the elevations of delta tops and sand or clay plains. The existence and extent of glacial lakes is indicated by extensive, low-relief areas underlain by laminated sand, rhythmic silt and clays, and by beach terraces. Most of the lake-bottom deposits north of the Broadalbin Moraine are very sandy, whereas silt and clay characterize lake-bottom sediment south of the moraine.

Glacial Lake Gloversville occupied a re-entrant between the Broadalbin and Woodward Lake moraines of the Mohawk and Sacandaga Lobes. It is recorded by an 265 m (870 ft) kame delta-and-sandplain that lies along the foot of the Jackson Summit Mountain Range between Gloversville and Mayfield. It drained southwest, along the base of the Noses Escarpment, and formed as the Sacandaga sublobe retreated from the Broadalbin Moraine.

Glacial Lake Sacandaga was a large, relatively long-lived proglacial lake that was dammed between the retreating Sacandaga Sublobe and the Broadalbin Moraine (Brigham, 1929; Yatsevitch, 1968; LaFleur, 1961, 1965, 1969). Several lake levels are recorded by deltas, beaches, and sandplains at 262 m (860 ft), 250 m (820 ft), 244 m (800 ft), and 238 m (780 ft). Locally, eskers grade southward into wedges of gravelly sand (Stop 5), while other ice-marginal deposits include a kame delta and moraine at Northville (Brigham, 1929), and kame deltas and moraines at Edinburg and Batchellerville.

Borings into tills that underlie fine sands in the Broadalbin area suggest that the Sacandaga ice tongue readvanced into Glacial Lake Sacandaga (or its predecessor). The southern shore of the lake consists of fans

projecting from the Broadalbin Interlobate Moraine, built into the lake by outwash from the Yosts Readvance.

Some controversy surrounds the outlet of the lake. Brigham (1929) placed the outlet along Cayadutta Creek, an underfit stream that occupies a boggy channel with well-developed boulder pavements, with a spillway at 238 m (780 ft). LaFleur (1965) disagreed, and drained the lake north through the Conklinville area. We place the spillway for the early phases of the lake across the swampy, 244 m (800 ft) divide between Skinner and Hale Creeks (Fig. 4); Hale Creek was the lake outlet. It occupies a well-scoured valley (Stop 3) and is a tributary to Cayadutta Creek. Additional, temporary spillways lie west of Johnstown. These outlets controlled the 262 m through 244 m lakes, while the 238 m lake was controlled by 229 m (750 ft), rock-floored spillways between West Mountain and Mount Anthony near Conklinville, 24 km (15 mi) north of Broadalbin. This outlet could not have controlled the higher level lakes. It was at least 10.5 m too low during glacial times, based on a rebound rate of 2.5 ft/mi (LaFleur, 1965), and was blocked by the Sacandaga Lobe.

Lake Sacandaga existed while a series of kame deltas, ice-free deltas, and outwash terraces were formed along Hale Creek by the falling levels of Lakes Schoharie and Amsterdam in the Mohawk Valley. Lake Sacandaga briefly drained into early Lake Warrensburg in the Corinth area via the Mt. Anthony Channel (Fig. 5).

Lake Schoharie originally was defined as a circum-Adirondack 335 m (1100 ft) lake level (Fairchild, 1912). Brigham (1929) demonstrated that the water plane was by no means continuous, and redefined it as a 262 to 253 m (860 to 830 ft) proglacial lake in the Schoharie Valley, controlled by the Delanson outlet. LaFleur (1965, 1969) redefined Lake Schoharie as a 262 m (860 ft) lake that was confined to the Schoharie Valley by the Yosts Readvance. We define Lake Schoharie by a series of sandplains, clay plains, and deltas in the Mohawk and Schoharie Valleys that range from 256 to 213 m (840 to 700 ft). It received large quantities of sand from Lake Sacandaga via Hale Creek, and outwash from an ice margin at Galway Lake via Chuctanunda Creek (Fig. 4). Lake Sacandaga was dammed by retreating ice in the Mohawk Valley.

Lake Amsterdam is represented in the Mohawk Valley by sandplains at 183 to 122 m (600 to 400 ft). They extend from Fonda to Schenectady. Brigham (1929) and LaFleur (1961, 1965, 1969) believed that the lake was dammed by stagnant ice at Schenectady. Yatsevitch (1968) thought that the Fonda sandplain represented outwash. The Fonda sandplain coarsens and grades up towards the north, along Cayadutta Creek. It received the overflow of Lake Sacandaga through a dry valley between Johnstown and Fonda that contains Sammons Cemetery and Rt. 30A (see the Randall 7-1/2 minute quadrangle). The Fonda sand plain was redeposited Glacial Lake Sacandaga sand and was subsequently scoured by catastrophic floods from the upper Mohawk Valley.

Glacial Lake Warrensburg was a glacial lake at 213 m (700 ft) in the Hudson Valley north of Corinth (Miller, 1923, 1925). It was dammed by the Randall Corners Recessional Moraine (Stoller, 1916). The lake drained south through the Kayaderosseras Valley and was responsible for the high outwash terraces along that valley (Stoller, 1916). Connally and Sirkin (1971) were able to

show that this lake was contemporaneous with the Luzerne Readvance and noted that many ice blocks occupied the lake. Our mapping indicates that Lake Sacandaga briefly drained into ice-marginal Lake Warrensburg via the Mt. Anthony spillways. Lake Warrensburg expanded as the Kayaderosseras sublobe retreated north. Till-over-lacustrine deposits along the Glens Falls to Luzerne road (Hansen and others, 1961; Connally and Sirkin, 1971), and in borings near Hadley suggest a readvance into this area. Unfortunately, sub-surface data is lacking to determine whether the Hidden Valley Moraine and Sheaffers Brook outwash are recessional or readvance features.

The lower Kayaderosseras Valley outwash trains are graded downstream to the Milton sandplain at 152 to 158 m (500 to 520 ft). The Milton sandplain drops southward to 122 m (400 ft) at Ballston Spa (Stoller, 1911, 1916) suggesting that ice-marginal Lakes Alplaus and Milton were contemporaneous with Lake Warrensburg.

The water levels fell to Lake Corinth in the Upper Hudson Valley as the spillway at South Corinth was scoured to 201 m (660 ft) (Miller, 1923; Stoller, 1916). Lake Corinth deposits were later scoured by meltwater from upland glaciers.

The lower Hudson Valley lakes fell to the 110 m (360 ft) level of Lake Albany, as recorded by a large delta at Saratoga Springs. Lake Albany levels fell farther, to the 101 m (330 ft) level of Lake Quaker Springs. The large Quaker Springs delta at Saratoga Springs suggests that an immense quantity of sand was still coming from the Kayaderosseras Valley (from Lake Glacial Corinth drainage?). Late fluvial terraces were carved by catastrophic floods from the Mohawk Valley (Stoller, 1922, Hanson, 1977).

CONCLUSIONS

The exposures in the Sacandaga and Mohawk valleys record two glacial readvances. An early readvance is suggested by the lower, sandy till at Hadley, the weathered ice-contact stratified drift at Gloversville (Stop 3), the lower till at West Milton (Mack and others, 1964), and at Hell Hollow (LaFleur, 1983). We correlate the soil surfaces and eroded contacts in the study area with the "Free Drainage" episode of Ridge and others (1984), and correlate the tills to their West Canada Creek Till (Table I).

The lacustrine sands and outwash that overlie the weathered till were deposited in proglacial lakes in front of an advancing glacier that emplaced another till sheet. This second readvance was widespread; except for the deposits of the interlobate moraine, ice marginal deposits related to the readvance were not found within the study area. We suggest that these tills are equivalent to the basal part of the Mohawk I Till at Hell Hollow (LaFleur, 1983) and the Hawthorne Till in the western Mohawk (Ridge and others, 1984). The tills were deposited by the Middleburg Readvance (Table I).

As the glacier retreated again, proglacial lakes formed in the Mohawk, Sacandaga, Kayaderosseras, and Hudson Valleys (Table I). Lake Sacandaga drained south, through Hales Creek, into the Mohawk Valley. Glacial retreat was short-lived, however, and the Mohawk ice again readvanced into the area.

The Yosts Readvance went only as far west as the Noses, and built the 213 m (700 ft) moraine at Yosts (Yatsevitch, 1968), emplaced the upper till at Hadley, West Milton, and along the southern margin of the Broadalbin Moraine (Stop 3), and smoothed the topography between the Broadalbin and the Mohawk River (Stop 1 and Brigham, 1929). This is probably the same readvance that streamlined lake clays at South Amsterdam (LaFleur, 1979, p. 329) and deposited the New Salem Moraine in the Hudson Valley (Dineen and Rogers, 1979).

As the ice retreated from the Mohawk Valley for the last time, Lake Sacandaga expanded and spilled once more through the Hale and Cayadutta Creeks into Lake Schoharie, whose falling lake levels in the Mohawk Valley later stabilized at Lake Amsterdam, while recessional moraines were successively built at Perth, Galway, and Randall Corners (Table I).

Eventually, the retreating Sacandaga lobe uncovered a lake outlet at West Mountain, allowing rapidly falling Lake Sacandaga to drain into proglacial Lake Warrnesburg (Table I). This process might have been briefly interrupted by the Luzerne Readvance (Connally and Sirkin, 1971). Lake Sacandaga soon became extinct as the Kayaderosseras lobe retreated up the Hudson Valley, away from Mount Anthony, and Lakes Warrensburg and Corinth came into existence. Connally and Sirkin (1971) suggest that this happened 12,800 years ago. The ice then retreated from the Hudson Lowlands and postglacial time began in eastern New York.

There is a distinct difference between the ice-marginal environments north and south of the interlobate moraine. To the north are short eskers that terminate in subaqueous fans and kame deltas. These proglacial lake deposits are surrounded by lake sand. Kame deltas along the valley side show that meltwater also came from the adjacent uplands. An ice margin is suggested along the present shoreline of the Great Sacandaga Lake. Brigham (1929) thought that an ice tongue persisted in the area north of Broadalbin, based on the "mega-" kettle hole that formed the now-drowned Vly. All these features indicate that the Sacandaga lobe retreated from the interlobate moraine to Conklinville with few, if any, readvances.

The story south of the moraine is different. Here, multiple lake sand-outwash-till sequences, sometimes separated by soil zones, tell us that the Mohawk lobe was more active than the Sacandaga. At least two readvances can be documented in several pits along the southern flank of the moraine.

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Ridge et al 1983 (in press)	LaFleur 1983	Mohawk	Sacandaga	Luzerne-Kayaderosseras	Hudson (Dineen, Hanson, Waller, 1983)
Holland Patent till	catastrophic floods	Scotia gravels		distal outwash	Lake Quaker Springs
	Fonda gravel			Lake Corinth	Lake Albany
				Lake Warrensburg	Lake Milton
		Fonda sand plain	Lake Sacandaga	Lake Albany	Lake Albany
		Lake Amsterdam	760	upper sandy till at Hadley & W. Milton	Lake Quaker Springs
		Lake Schoharie	800	lakes at Hadley & W. Milton	Lake Albany
		Lake Amsterdam	860		Lake Albany
		Yosts readvance	Perth recessional moraine		Lake Albany
		Lake Schoharie			Lake Albany
		Yosts readvance			Lake Albany
		upper Yosts till			Lake Albany
		sand & gravel			Lake Albany
					Lake Albany
Hawthorne till	Mohawk till	Middleburg readvance	Broadalbin moraine	upper clayey till at Hadley	Middleburg readvance
		middle Yosts till	till over lake sand	middle lake sand at Hadley	till over gravels at Duanesburg
free drainage	soil zone weathered till	soil zone weathered till	soil zone (weathered i. c. s. d.)	soil zone (weathered till at Hadley)	gravels at Duanesburg
West Canada till	Hell Hollow till	lower Yosts till	early Broadalbin moraine	lower till at Hadley	retreat of Hudson Valley ice ?
					weathered clay at Niskayuna (Hanson, 1978)

* from the East i. c. s. d. ice-contact stratified drift ◀ drainage direction ~ erosional interval << readvance >> interbedding

Table 1. Stratigraphic Correlation in the Mohawk Valley

FIELD LOG - FIGURE 5

<u>Miles from Start</u>	<u>Miles from Last Stop</u>	
0.0	0.0	Mileage starts at the intersection of N.Y. Routes 50 and 29 in Saratoga Springs. You are on the Quaker Springs delta. Proceed west on NY 29.
6.5	6.5	Kame moraine.
17.1	10.6	East Broad St. Turn right (north) and go into the Village of Broadalbin.
18.0	0.9	North Street, veer right, follow North St. through village.
18.3	0.3	Follow North Street to the right (northeast), along south edge of Interlobate Moraine.
19.3	1.0	Town of Broadalbin Landfill (left side of road).
<u>Stop 1: Broadalbin Town Landfill</u>		
This pit reveals the products of the ice-marginal environment. Here, the Yosts Readvance reached its maximum extent. The massive basal sands contain de-watering features (flame, dish, ball-and-pillow structures). These basal sands are sharply truncated, and overlain by fluvial sand with gravel that contains many reverse graded diamictons (flowtills).		
Another pit, 0.4 m (0.7 km) west of Stop 1 shows evidence of more active ice. At this pit, a sequence of trough corssbedded sand is shared and overlain by a thick (1 to 3 m) diamicton.		
21.5	2.2	Retrace path to NY Rte. 29.
22.9	1.4	Turn right (west). Proceed along Lake Sacandaga sands to the intersection of NY Routes 29 and 30. Turn left (south) on NY Rte. 30.
25.1	2.2	Proceed on 30 to Perth, and Fulton County Route 107 (at Stoplight). The upland that we drove over is the broad platform of the Perth Moraine. The low rise that we cross just before the stoplight is the Perth Recessional Moraine. Turn right (west) onto County Route 107.
26.0	0.9	Go 0.9 mile to a small access road on the right (north) side of the road.

Stop 2: Perth Pit

We are on the Perth moraine, in a pit that cuts into the Perth Recessional Moraine. The base of the pit is trough-crossbedded outwash, overlain by 3 m of sand-matrix-supported diamicton. This till is overlain by trough-cross-laminated outwash sand and gravel. Wells nearby indicate that the pit is underlain by 30 to 40 m of interbedded till and sand. The till in this pit probably was deposited by the Yosts Readvance.

Leave pit, retrace path north to the intersection of NY Routes 29 and 30.

- | | | |
|------|-----|---|
| 29.1 | 3.1 | Turn left (west) on NY 29. Follow the outlet of Lake Sacandaga to the long access road at the next Stop. The Interlobate Moraine is on the right. |
| 32.9 | 3.8 | Turn right on access road, cut across the Hale Creek spillway of Lake Sacandaga. |

Stop 3: Rex Excavating

This exceptional pit has many instructive exposures. The base of the pit is bluish-gray clayey Mohawk till, overlain by 5 m of laminated fine sand, cut by trough-cross bedded sand and gravel. The sand and gravel is capped by 2 m of weathered till that is overlain by another sequence of lacustrine sand and prograding outwash. Till overlies this outwash, and is interbedded with lacustrine sand.

The multiple tills are the products of at least two readvances. The soil zone between the major sequences suggest several thousand years separated the two advances. Both sequences involved glacial ice overriding proglacial lacustrine and outwash deposits. The several tills above the soil zone probably were mudflows and lodgement tills of the Yosts Readvance. A similar exposure lies 1.1 miles to the east.

We leave, with regret, the Rex Pits, and continue west along Hale Creek outlet on NY 29, to stoplight in Johnstown.

- | | | |
|------|-----|--|
| 37.0 | 4.1 | Intersection of Routes 30A and 29, turn right (north). |
| 38.0 | 1.0 | Intersection with Townsend Road at Stoplight. Turn left (west) onto Townsend Road, cross the Cayadutta Spillway. |
| 38.1 | 0.1 | Turn right (north) onto Main Street. |
| 38.2 | 0.1 | Turn left (west) on Maple Avenue. |
| 39.0 | 0.8 | Large exposure on right. |

Stop 4: Twin Cities Sand and Gravel

This immense pit is over 300 m long and 7 m high. It is the distal portion of the Interlobate Moraine, and contains distinct deltaic features. Both thrust and gravity faults are common, especially on the eastern end of the pit. A sandy diamicton caps the sandy deltaic sequence. Aeolian sand unconformably overlies the sandy till on the eastern end of the pit.

Leave pit, retrace road to NY Rte. 30A.

- | | | |
|------|-----|--|
| 40.0 | 1.0 | Turn left (north) onto NY 30A. Drive up ice-contact slope of the Interlobate Moraine and onto the Lake Gloversville delta. |
| 45.8 | 5.8 | Nice drumlins to the west, the Interlobate Moraine dominates the skyline to the southeast. |
| 47.7 | 1.9 | Intersection of NY Routes 30 and 30A. Turn right (east) on 30. |
| 47.9 | 0.2 | Turn onto access road on left side of Rte. 30. |

Stop 5: Mayfield Pits

This complex of pits is developed in an esker that drained the Sacandaga ice tongue. A subaqueous sand and gravel fan lies at the mouth of this esker. It was built by meltwater flowing in an ice tunnel into Lake Sacandaga. The esker is interbedded with lake sand.

To get home from this stop, you can retrace your drive to Rte. 30A, turn left, and follow 30A to the NYS Thruway at Fonda. Or, you can turn left and proceed down Rte. 30 to the NYS Thruway at Amsterdam. This route will also take you back to the intersection of 30 and 29. Turn left on 29 to get back to Saratoga Springs. Have a good trip home!

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Handwritten notes or scribbles in the middle of the page, possibly including a date or initials.

