LATE WISCONSINAN GLACIATION OF THE WESTERN MOHAWK AND WEST CANADA VALLEYS OF CENTRAL NEW YORK

54th ANNUAL REUNION

FRIENDS OF THE PLEISTOCENE

Herkimer, New York

May 17-19, 1991

Leader: Jack Ridge

Department of Geology
Tufts University
Medford, Massachusetts
02155

DEDICATION

The 54th Annual Reunion of the Friends of the Pleistocene is dedicated to Ernest H. Muller for his long standing dedication to glacial geology in New York State, and his nurturing of numerous students at Syracuse University. He has stimulated our curiosity, fostered the development of new ideas, and skillfully taught by question and suggestion.

For these things we admire and thank him.

ACKNOWLEDGMENTS

Janet Silvano in the Geology Department at Tufts University deserves special thanks for her service to the Friends by making sure mailings were sent out and for her word processing skills in preparation of this guidebook. Several Tufts University students, Andrew Bagley, Brian DesMarais, Doug Hutchinson, James King and Jeff Maxwell deserve thanks for their labor in the field and in handling logistical problems during the conference. Ernest H. Muller and David A. Franzi also deserve thanks for helping with logistics.

Mary Jo Ridge deserves special thanks for her patience over the last three months, and especially because Jack and Mary's 6th wedding anniversary happens to coincide with this years Friends reunion.

TABLE OF CONTENTS

FRIENDS OF THE PLEISTOCENE
54th ANNUAL REUNION
May 17-19, 1991
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TENTATIVE SCHEDULE

<u>Friday</u> (May 17th)

7:00-10:30 P.M.	Welcoming Party - Banquet Room at Rende's Restaurant, 248 N. Main Street, Herkimer. Cash bar will be available.

<u>Saturday</u> (May 18th)

6:45-7:30 A.M.	Breakfast Buffet, Rende's Restaurant.
8:00 A.M.	Field trip leaves from meeting point (Parking area on Rt. 28 North, 3.4 miles north of Rt. 5).
7:00 P.M.	Buffet dinner and gathering at Rende's Restaurant. Cash bar will be available.

<u>Sunday</u> (May 19th) (As many cars as possible should be left in Herkimer where they can be picked up at mid-day).

6:45-7:30 A.M.	Breakfast Buffet, Best Western Motel, downtown Little Falls on Rt. 5.
8:00 A.M.	Field Trip leaves from meeting point (East of Little Falls, 0.9 miles north of Rt. 5 on Rt. 167).
11:30-12:00 A.M.	Approximate time of return to Herkimer area. Trip continues west after collecting vehicles.
3:00-4:00 P.M.	Approximate end of field excursion.

FINAL ANNOUNCEMENT - 54TH ANNUAL (1991) REUNION OF THE FRIENDS OF THE PLEISTOCENE

Dear Friends, **KEEP THIS FLYER!** March 30, 1991

This is the final announcement and registration notice for the 1991 FOP Reunion on May 17-19, 1991 (Friday thru Sunday) at Herkimer, N.Y. (10 miles east of Uitca) in the western Mohawk Valley region. Saturday's field excursion will be in the West Canada Valley north of Herkimer. Sunday's trip will follow a traverse up the axis of the Mohawk Valley from St. Johnsville (east of Little Falls) to Rome at the eastern end of the Ontario basin. Herkimer is at NY State Thruway Exit 30 on the north side of the Mohawk River and NY State Barge Canal. From Exit 30 follow Rt. 28 north into downtown Herkimer. Headquarters for the reunion will be Rende's Restaurant on N. Main St. which is the main N-S street downtown. The nearest air transportation services are at the Oneida County Airport west of Utica and in Syracuse. Arrangements for pickup at these airports can be made by contacting Ernest H. Muller at (315)-443-3848 or (315)-478-5827 by May 6.

Registration will be from 7-10:30 PM on Friday evening at Rende's where a room for socializing will be set up with a cash bar. The registration fee is $60.00 in U.S. funds (by May 3) which includes payment for the Friday meeting place, buffet breakfasts on Saturday and Sunday, lunch on Saturday, a buffet dinner on Saturday, non alcoholic beverages in the field, and a guidebook. Breakfast buffet arrangements have been made because of the difficulty you will have finding breakfast early on Saturday and Sunday in Herkimer and Little Falls. Participants will have to provide their own lodging (see enclosed list) and lunch on Sunday. Lunch for Sunday should be purchased on Saturday evening because we will <u>not</u> be making a special lunch stop to purchase food. Bringing your own small cooler for food on Sunday would be a good idea.

Transportation will be by private vehicles which is the only way to gain access to some parts of the field area. **It would be a tremendous help and greatly appreciated if people from academic institutions (or other outfits) could bring vans in order to consolidate vehicles on Saturday and Sunday morning.**

Some important friendly notices:

1. Other than the lunch stop on Saturday, no bathroom stops are planned. You may have to take advantage of rustic surroundings on field trip stops. On Sunday the field trip has a route which is easy to follow and along which occur several fast food restaurants with bathroom facilities.

2. Weather in central New York in May is unpredictable, but usually OK. Last year in the last week of May it was raining and in the 30's but rebounded into the 80's later in the week. Come prepared with rain gear.

3. At many stops you will encounter muddy conditions on <u>very steep</u> bluff faces where boots with good traction are essential. At a few places we may ask you to ford, cross, or jump over small streams depending on flow conditions. A second pair of rubber boots might be advisable.

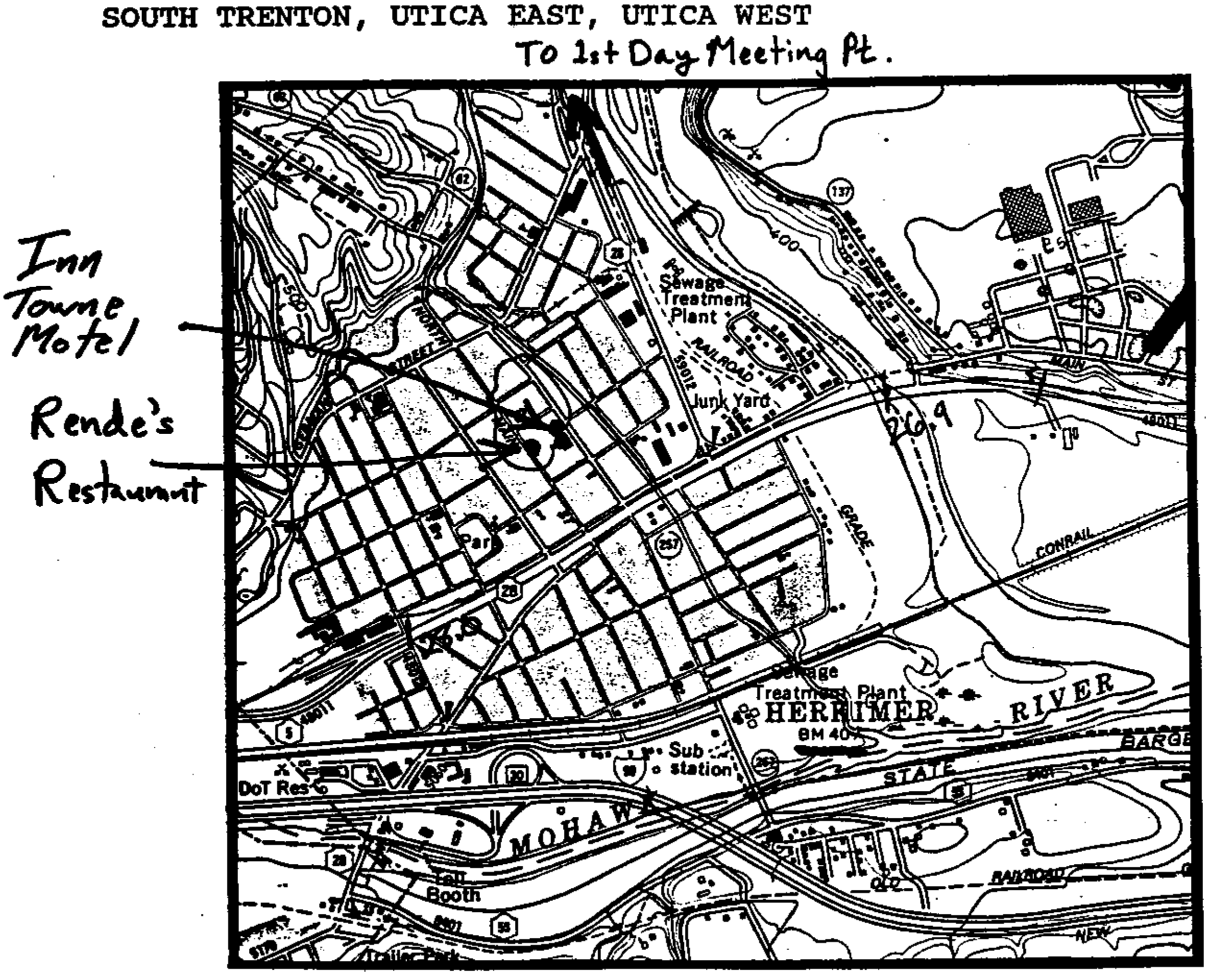
4. The trip will include many exposures of laminated silt and clay as well as extremely compacted diamicton and lacustrine units. The best digging devices for these exposures will be a pick for compact materials and a knife for shaving clay and silt beds. Dirt shovels are almost worthless. An Estwing 26" hoe pick (one flat and one pointed end) is ideal because it can also provide help in climbing slopes.

If you have any questions, contact Jack Ridge at (617)-381-3494.

LOCATION MAP OF HERKIMER

In addition to the location map given below the following is a list of USGS (7.5′ unless otherwise stated) quadrangles relevant to the field excursion. Our Friday and Saturday meeting places are in the Herkimer Quadrangle. Saturday's meeting place is 3.4 mile north of State St. (Rt. 5) at a rest area along the west side of Rt. 28. Saturday's meeting time is 8:00 AM.

FORT PLAIN, HERKIMER, HINCKLEY, ILION, LITTLE FALLS, MIDDLEVILLE, NEWPORT, OHIO (15′), ORISKANY, REMSEN, ROME, SALISBURY, SOUTH TRENTON, UTICA EAST, UTICA WEST



HOUSING IN HERKIMER AREA

The Inn Towne Motel and Rende's Restaurant (their backs face each other) are the headquarters and dinner sites for this years FOP trip. A block of 20 rooms has been set aside for the FOP at the Inn Towne Motel. A list of other accommodations is also provided, all of which are located close to the action. The list gives the motels from closest to furthest from Rende's. Make reservations as early as possible. Costs listed below for motels other than the Inn Towne and Best Western motels are 1-2 years old.

Inn Towne Motel, 227 N. Washington St., Herkimer, NY 13350
(315)-866-1101 Rates: 1 double bed ($38/1 per, $42/2 per);
(Major credit cards) 2 double b. ($48/2 per); each add. person $6, rollaways $4.

The Prospect Motel, 200 N. Prospect St., Herkimer, NY 13350 (1 block from Rende's) (315)-866-4400
(Major credit cards) Rates: single $38, double $42, king $42.

Mohawk Valley Motor Inn, 715 Mohawk St., Herkimer, NY 13350 (at Exit 30 off NY State Thruway) (315)-866-6080
(Major credit card) Rates: single $24, double $30, three $35, add. cots $5.

Herkimer Motel, 100 Marginal Road, Herkimer, NY 13350 (at Exit 30 off NY State Thruway) (315)-866-0490
(Major credit cards) Rates: 1 per. $34-52, 2 per. $48-57, extra per./cot $6.

Glen Ridge Motel, Route 5, Herkimer, NY 13350 (1.5 km east of Herkimer) (315)-866-4149
(Major credit cards) Rates: double 1 $24, double 2 $30, 2 twins $32, 1 doub/1 twin $34, 2 double $39, rollaways $4.

Whiffletree Motel, Route 5s, Ilion, NY 13357 (about 4 km west of NY St. Thruway Exit 30) (315)-895-7777
(Major credit cards) Rates: single $32-38, double $40-46, cot $6, add. person $6.

Best Western Motor Inn, 20 Albany St., Little Falls, NY 13365 (about 10 km east of Herkimer off Rt. 5, close to Sunday Meeting Point) (315)-823-4954 (Major credit cards) Rates: 1P $46, 2P $52, Extra per. $6, cot $4.

CAMPING FACILITIES

Herkimer Diamond KOA, Middleville, NY (315)-891-7355 (10 km north of Herkimer on Rt 28, close to meeting point on Saturday) Camp sites and small cabins available with shower facilities.

ORDER FORM - EXTRA GUIDEBOOKS 1991 FOP

PLEASE PRINT

Return to:

John C. Ridge
Dept. of Geology
Tufts University
Medford, MA 02155

Name: ____

Address: ____

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1991 (54th Annual Reunion) FOP guidebooks - Late Wisconsinan Glaciation of the Western Mohawk and West Canada Valleys of Central New York.

___________ copies X $13.00/copy = ____________________

Cost covers mailing and handling. **Make all checks payable to John C. Ridge.** This price valid through at least 1992.

NOTES

The use of paleomagnetic declination to test correlations of late Wisconsinan glaciolacustrine sediments in central New York

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ABSTRACT

Detrital remanent magnetization (DRM), recorded in laminated glaciolacustrine silt and clay of the western Mohawk Valley of central New York, was used to construct a secular variation record of geomagnetic declination for parts of the late Wisconsinan in the interval 12.5–18 ka B.P. Remanent declination has been used for time-stratigraphic testing of correlations between laminated fine-grained glaciolacustrine sediments at different exposures in the western Mohawk Valley. A discontinuity in the remanent-declination record supports the interpretation that an observed lithostratigraphic discontinuity in the region represents an unconformity. Diamicton units, composed of till and proximal proglacial diamictons, are overlain by laminated clay and silt units that have time-transgressive lower contacts. The clay and silt units exhibit stratigraphic onlap in the direction of ice recession, a characteristic that is recognizable in their paleomagnetic records. The use of a secular variation record of remanent declination has an advantage over lithostratigraphic and morphostratigraphic correlation techniques in that it is time dependent. For a part of the late Pleistocene, it provides a powerful tool for correlating physically disjunct stratigraphic assemblages in New York and New England, where no other dating technique has provided interregional correlations with comparable resolution.

Sampling of different exposures of contemporaneous sediment was used to demonstrate the fidelity of remanent declination as a recorder of geomagnetic declination. The remanent inclination record was not useful for testing correlations because inclinations in strata known to be contemporaneous were different. As compared to remanent inclinations from other contemporaneous lacustrine sequences in the eastern United States, the average remanent inclination of the western Mohawk Valley sediments is at least 11 degrees too shallow. Shallow inclinations may be the result of errors acquired at the time of deposition or compaction resulting from drying of the sediment, consolidation by overriding ice, or lithostatic load of overlying sediment. Subglacial deformation, dewatering, and some outcrop conditions, especially ground-water seepage, were recognized as processes that may cause or facilitate postdepositional disturbance of remanent magnetization.

INTRODUCTION

Glacial units in the Mohawk Valley of central New York (Fig. 1) were deposited during repeated advances and recessions of late Wisconsinan ice lobes. At various times during deglaciation, ice lobes advanced into the western Mohawk Valley from the east (Mohawk Lobe), the west (Ontario Lobe), and across the Adirondacks (inset in Fig. 1; Fullerton, 1971, 1980; Krall, 1977; Ridge, 1985; Muller and others, 1986). The western Mohawk Valley was an area of glacial lake impoundment between the Ontario and Mohawk Lobes, and it also served as an outlet for ice-dammed lakes in the Ontario Basin during several episodes of late Wisconsinan deglaciation. Late Wisconsinan lacustrine sediments of the western Mohawk Valley predate the recession of ice into the Ontario Basin and the formation of Lake Iroquois at about 12,500 yr B.P. (Fullerton, 1980; Muller and Prest, 1985). The lacustrine deposits were formed during ice recession (Ridge, 1985; Muller and others, 1986) and must postdate the maximum extent of late Wisconsinan ice in eastern Pennsylvania (Cotter and others, 1986). Therefore, the western Mohawk Valley glaciolacustrine sediments are younger than 18,000 yr.

Many late Pleistocene glacial sequences, such as the one in the western Mohawk Valley, cannot be dated by numerical dating techniques primarily because glaciolacustrine strata often lack sufficient amounts of organic sediment that is suitable for radiocarbon analysis. Glacial stratigraphers have used conventional lithostratigraphic or morphostratigraphic correlation over long distances as a means of assigning ages to deposits in regions where no numerical dates have been obtained. In areas with complex glacial advance and recession sequences, it is often not possible to determine the relative ages of deposits at separated exposures if lateral tracing cannot be accomplished, or datable material is not available. In the western Mohawk Valley, we have used declination of detrital remanent magnetization (DRM) in fine-grained laminated glaciolacustrine sediments for time-stratigraphic testing of correlations. We believe that additional declination records of long duration will ultimately make interregional correlations of glacial stratigraphic sequences possible. A complete correlation of late Wisconsinan events in New England, the Hudson Valley of eastern New York, and western New York has not yet been established, but we believe that paleomagnetic stratigraphy may lead to that end. The significance of this study is that it demonstrates a means of correlation of complex glaciolacustrine stratigraphic sequences that has not previously been widely used by glacial stratigraphers.

Paleomagnetic correlation has an advantage over lithostratigraphic and morphostratigraphic correlation techniques such as provenance analysis or the tracing of ice-front positions in that it is time-dependent. Provenance may be characteristic, but not necessarily distinctive, of a lithostratigraphic unit and allows only an identification of source, not relative age. Where lithostratigraphic and morphostratigraphic boundaries are time-transgressive, they cannot be used to establish age equivalence. Paleomagnetism constitutes a means of testing the isochroneity or time-transgressive properties of laminated silt and clay units or other stratigraphic units which they bound. This paper addresses (1) problems of recognizing sampling sites in fine-grained lacustrine sediments that pre-

Geological Society of America Bulletin, v. 102, p. 26–44, 14 figs., January 1990.

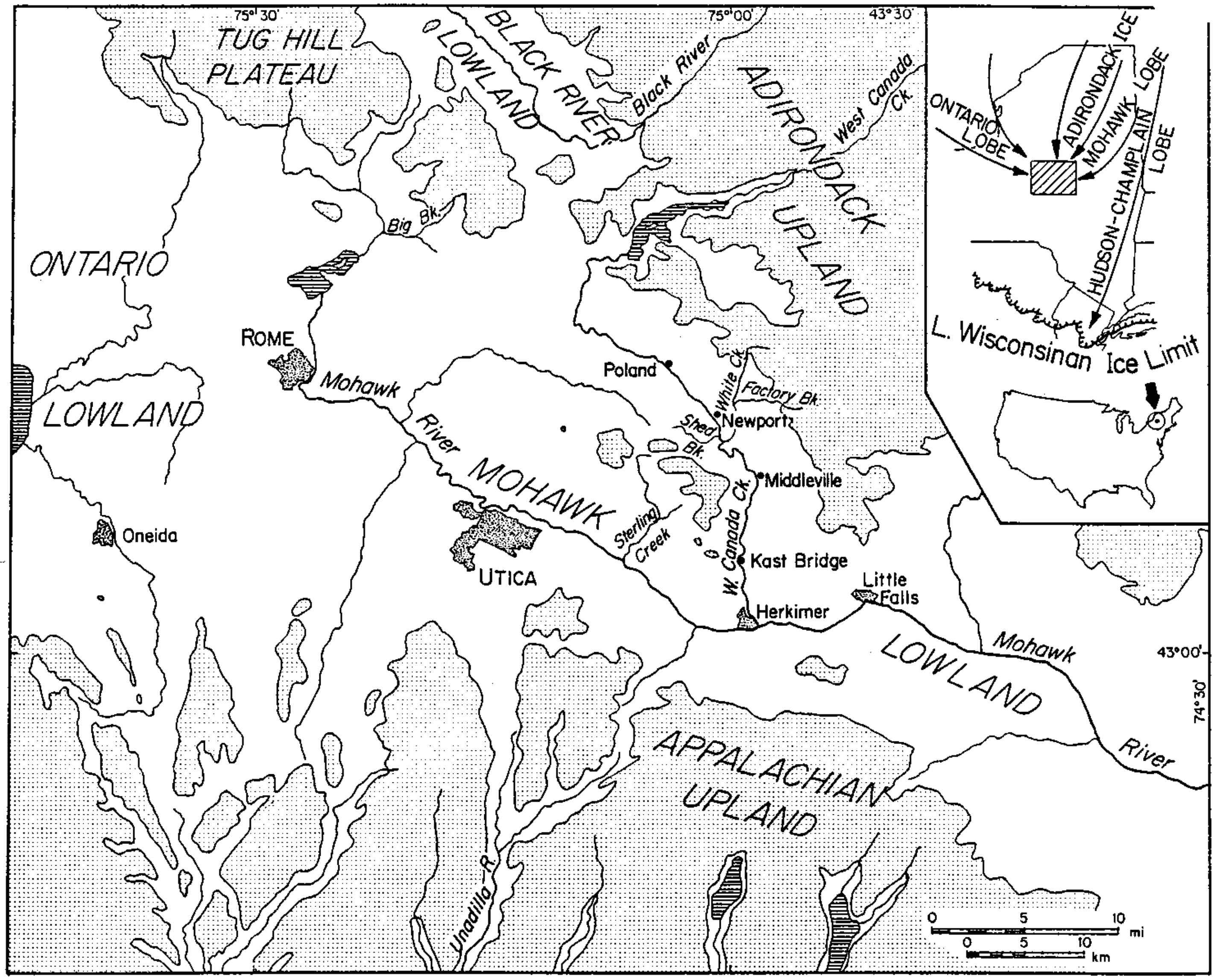


Figure 1. Location map of the western Mohawk Valley region. Patterned areas indicate uplands above an elevation of 400 m.

serve remanent declination from the time of deposition, (2) the application of remanent-declination records to testing correlations and other stratigraphic relationships in the western Mohawk Valley, and (3) the construction of a late Wisconsinan secular variation record of geomagnetic declination for central New York that can be used for correlation with adjacent regions. The purpose of the present study in the Mohawk Valley is not simply to construct a secular variation record of geomagnetic declination, but to use it as a means of correlating glacial sequences.

LATE PLEISTOCENE STRATIGRAPHY: WEST CANADA CREEK VALLEY

The late Pleistocene stratigraphy of the West Canada Creek Valley, a tributary of the Mohawk Valley (Fig. 1), represents a nearly complete record of late Wisconsinan deglaciation and lacustrine impoundments in the western Mohawk Valley region. Formulation of the stratigraphy is much too lengthy for this paper and can be found in Ridge (1985) along with detailed section logs and a surficial map of the lithostratigraphic units. A detailed glacial history of the region that was inferred from the stratigraphy has also been published elsewhere (Ridge, 1985; Muller and others, 1986). Lithostratigraphic units of the West Canada Creek Valley have been traced to the rest of the western Mohawk Valley region and provide an ideal testing ground for paleomagnetic methods for several reasons. The stratigraphic units of the West Canada Creek Valley are well exposed in bluff sections (Fig. 2) where the superposition of deposits is easily determined. Detailed mapping (Ridge, 1985) has revealed that the units are laterally traceable and lithologically distinct, and facies variations within each unit can be recognized in detail. The stratigraphic units of the region include rhythmic, mostly varved, laminated lacustrine silt and clay beds (Fig. 3) that carry a stable and strong magnetic remanence. Fine-grained magnetite, thought to be derived primarily from the crystalline rocks of the Adirondacks and the Canadian Shield, is abundant in the sediments. All of these characteristics of the stratigraphy allow paleomagnetic sampling sites to be placed in chronologic order. The sampling of

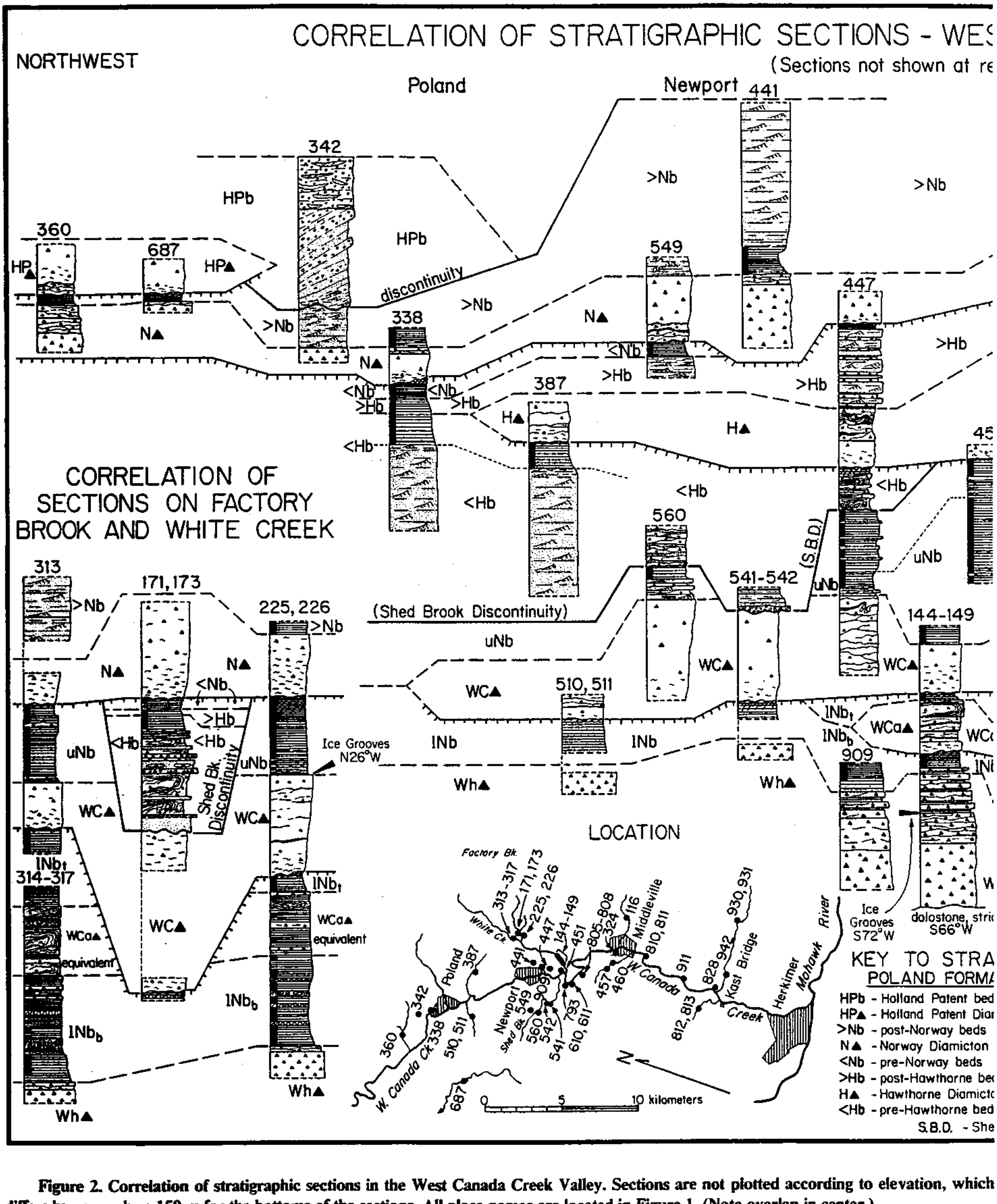


Figure 2. Correlation of stratigraphic sections in the West Canada Creek Valley. Sections are not plotted according to elevation, which differs by as much as 150 m for the bottoms of the sections. All place names are located in Figure 1. (Note overlap in center.)

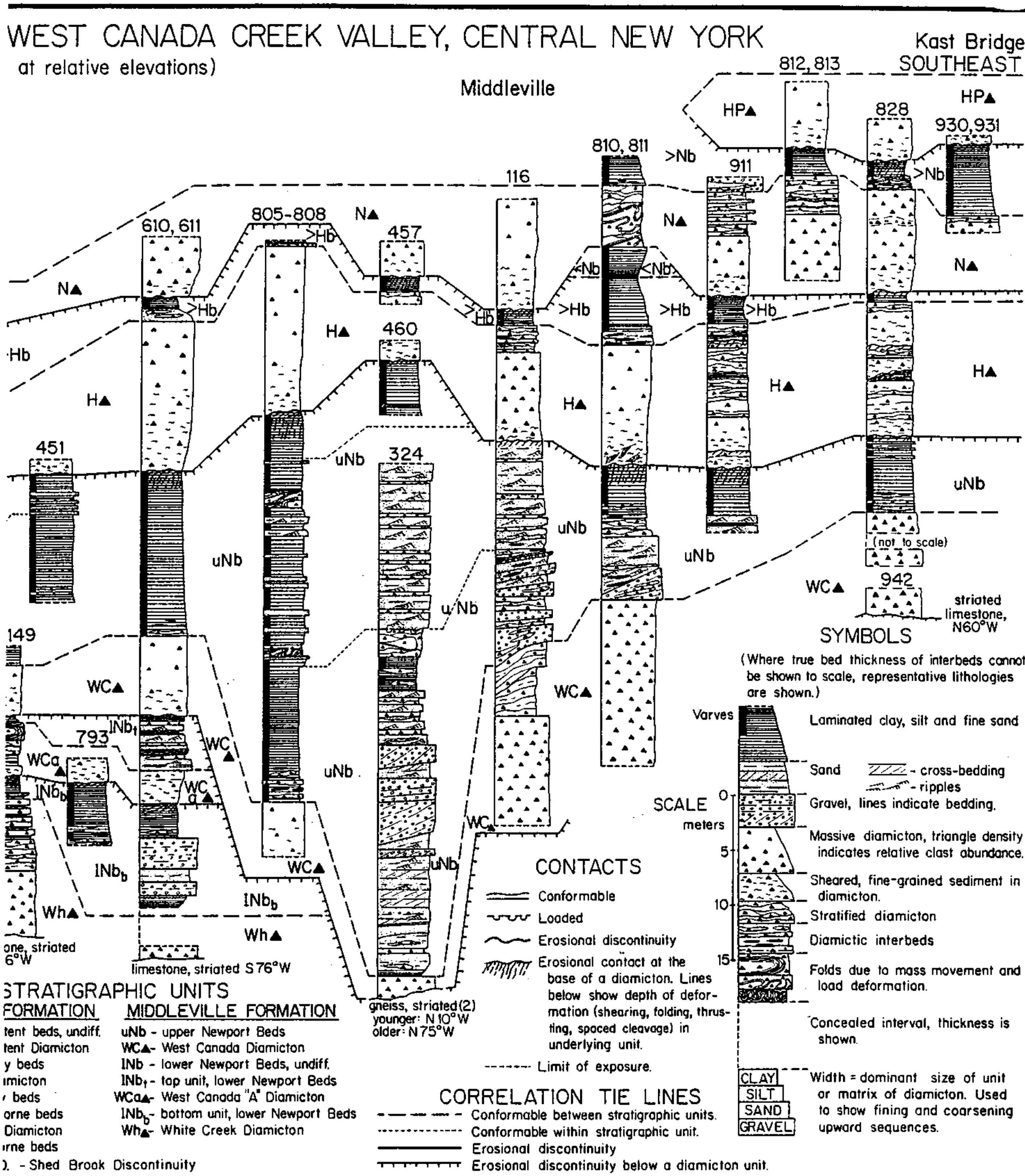
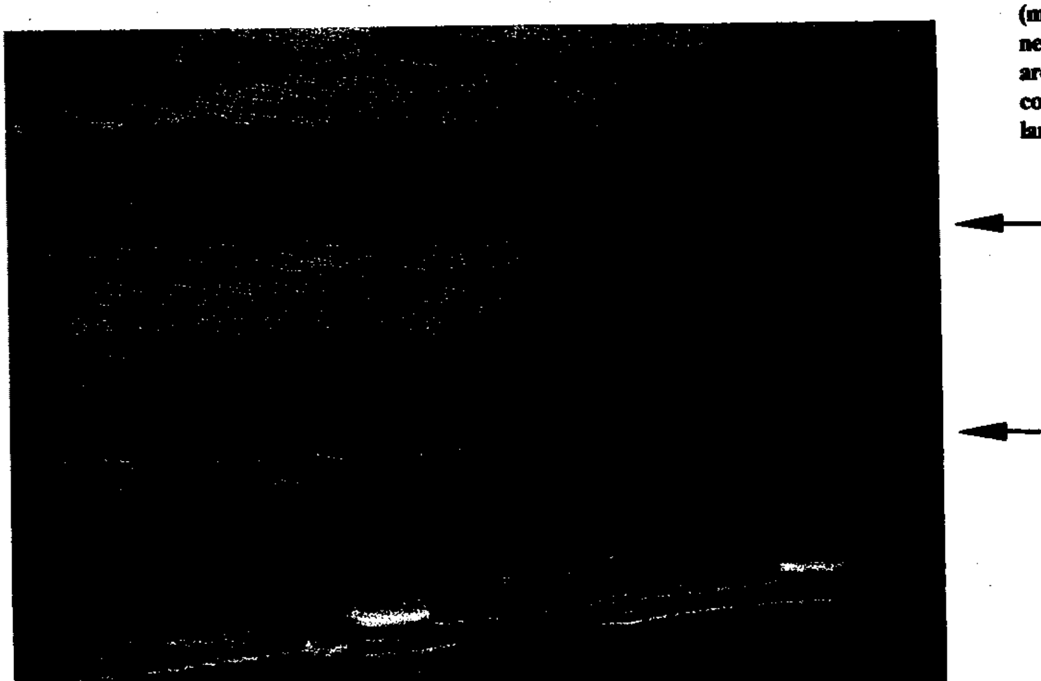


Figure 2. (*Continued*).

A



B

Figure 3. Rhythmic laminated silt and clay beds in the western Mohawk Valley region. Black part of knife handle in both photos is 10 cm. A. Varves of the post-Holland Patent beds in the Big Brook Valley (section 921) northeast of Rome, New York (Fig. 1). Winter beds are dark in color; summer beds are light. Light gray spot in varves is a nonlithified drop clast of silt. B. Laminated clay and clayey to sandy silt of the lower Newport Beds in the West Canada Creek Valley (section 793 on Fig. 2). Thin clay beds (marked by arrows) of uniform thickness (3–5 mm) are winter beds which are separated by summer beds that are composed of multiple, micrograded laminations.

individual parts of each stratigraphic unit at several localities is possible, and the reproduceability of remanent declinations in contemporaneous deposits can be demonstrated.

The stratigraphy of the West Canada Creek Valley has been compiled with strict lithostratigraphic nomenclature that is independent of any genetic interpretations (Fig. 4). The stratigraphy was compiled by section-logging (Fig. 2) and detailed unit and facies mapping, and units were given formal lithostratigraphic names (Ridge, 1985). The stratigraphy is divisible into two distinct units (Poland and Middleville Formations) which are separated by a discontinuity (Shed Brook Discontinuity).

STRATIGRAPHIC RELATIONS AMONG SAMPLING SITES

Relative ages of the sampling sites were determined by superposition, stratigraphic onlap relationships in geographically separated sites, and varve counting. Varve counts were used in the western Mohawk Valley to estimate the absolute number of years separating horizons within single sections. Rhythmites interpreted to be varves consist of couplets of fine sandy to clayey silt and clay beds that differ greatly in thickness and lithology in different stratigraphic units (Fig. 3). Clay beds in couplets have nearly uniform thickness, and silty beds account for nearly all of the variability of couplet thicknesses. The silty beds of each couplet are composed of many micro-graded laminae separated by silt and fine sand partings, and the crawling traces of nematode worms are present upon several different horizons within each couplet. These observations support the interpretation of the couplets as annual sediment layers (Ashley, 1975; Ashley and others, 1985), not as single-event turbidites resulting from storms (surge deposits) or rapidly deposited silt and clay from meltwater plumes (rainout deposits).

Some beds or contacts are essentially isochronous and sufficiently distinctive to be used as time-stratigraphic markers. One example is a thick, graded to massive sand bed that occurs in clay and silt varve sections and can be traced basin-wide at the same stratigraphic position. Such sand beds are thought to be due to floods which occurred when one ice-dammed lake catastrophically drained into another lower lake. Isochronous contacts that mark sudden changes in lake levels brought on by ice advance or recession can also be recognized. These horizons include (1) contacts between rippled lacustrine sand sequences that are conformably and sharply overlain by laminated, varved clay and silt marking a sudden increase in lake level and (2) contacts within units where, over one or two varve couplets, varves more than double in thickness or decrease in thickness by more than one-half. Couplet thickness changes may indicate either rising or falling water levels. The advance and recession of ice margins in the western Mohawk Valley must be considered in order to interpret such thickness changes. Generally, couplets thickened as water levels dropped in the western Mohawk Valley because drainage systems expanded at the expense of lake areas, and tributary streams eroded newly exposed lake-floor sediments around the perimeters of the lakes. More sediment was focused to the deepest parts of lake basins when water levels dropped because the areas over which sediment could be deposited decreased. The reverse was true for rising water levels, but it is important to recognize that bathymetric changes that affected lake currents could have caused deviations from these general rules.

Subaqueous fans and their associated distal sediment facies, deposited from ephemeral positions of a receding ice-front, are also essentially isochronous. The fan deposits consist of coarse gravel to muddy, fine sand and silt that were deposited from an ice-front at one position and can be traced laterally in lacustrine sediments as marker beds. An example is the gravel and sand, which grades laterally into muddy fine sand, that appears in the upper Newport Beds from Middleville to Newport in the West Canada Creek Valley (Figs. 2 and 4). The Middleville deposits are thought to correspond to deposition triggered by a drop in lake level in the wake of a receding Mohawk Lobe (Ridge, 1985). A suddenly lowered lake level would cause rapid drainage of water in the hydrologic system of the Mohawk Lobe. Water would drain from the Mohawk Lobe through subglacial drainage channels, and rapid erosion of exposed lake-bottom sediments along the shores of the lake would then occur. Both of these processes are thought to be responsible for increased input of sediment into the lake. In the West Canada Creek Valley, this period of deposition appears to be represented by a thickening and coarsening of varve couplets.

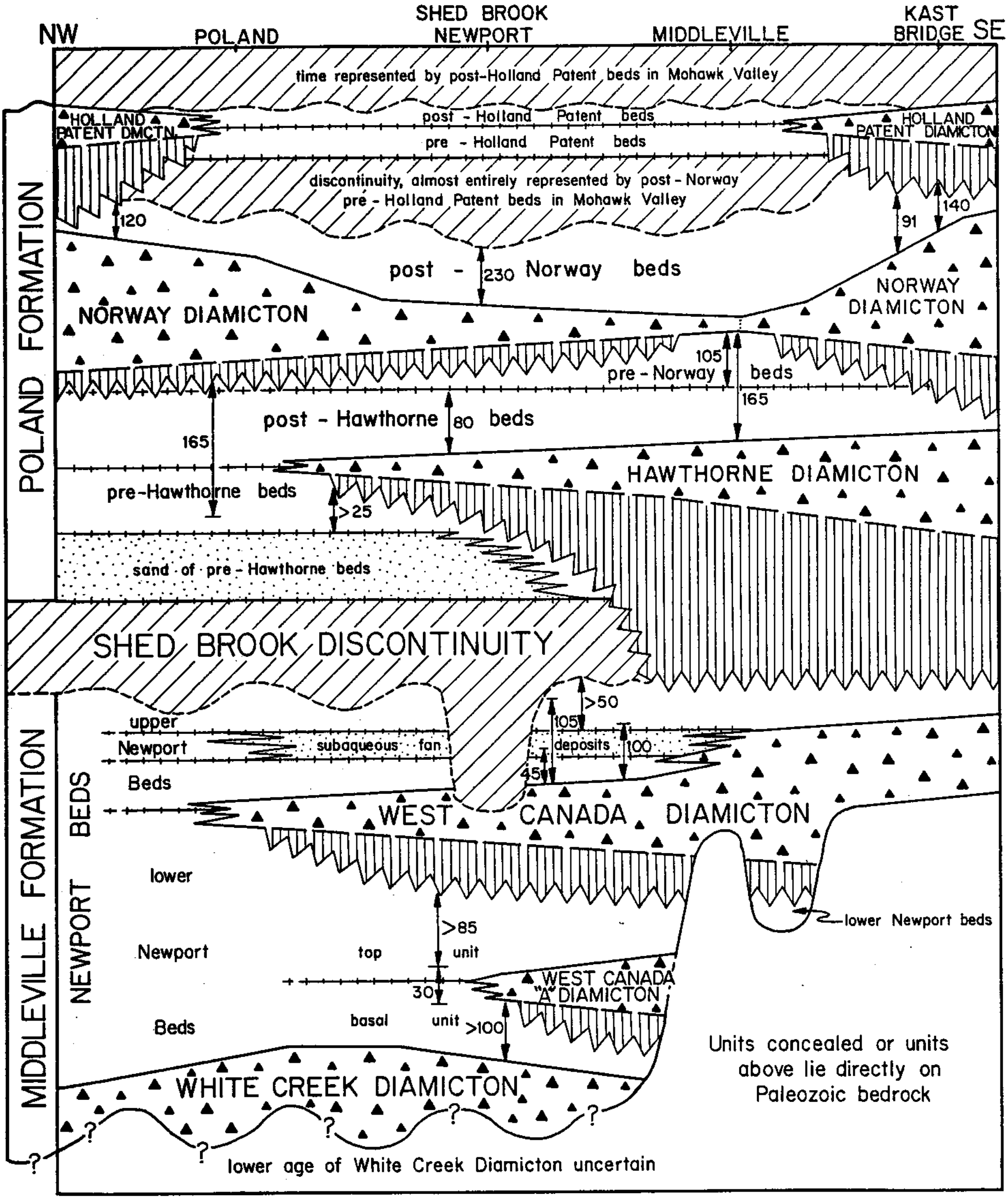
In the West Canada Valley, the contact between the post-Hawthorne and pre-Norway beds is another isochronous horizon that is marked by a sudden basin-wide provenance change within varve sections (Figs. 2 and 4). Varves of the pre-Norway beds contain nonlithified drop sediments (dropclots) that are composed of red clay and red diamicton lithologies, and the clay beds of these varves exhibit faint pink to light gray tones. Varves in the underlying post-Hawthorne beds contain only non-red dropclots, and silt and clay beds of these varves are dark gray in color. The contact between the pre-Norway and post-Hawthorne beds marks the basin-wide appearance of red dropclots and sediments carried by icebergs and bottom waters associated with the advancing Ontario Lobe. This provenance change marks a nearly instantaneous event and is an important time-stratigraphic marker.

The relative ages of sampling sites may also be inferred from their geographic position on the time-transgressive upper contact of a diamicton unit (Fig. 5). Diamicton units in the western Mohawk Valley all include till and were deposited in conjunction with glacial readvances (Ridge, 1985). Their upper surfaces were progressively uncovered in the direction of ice retreat. Varves that conformably overlie diamicton units exhibit a stratigraphic onlap in the direction of ice recession. This relationship alone has been used by Brennan and others (1984) to construct a secular variation record of geomagnetic declination for a period of Ontario Lobe ice recession in western and central New York.

GEOMAGNETIC SECULAR VARIATION RECORDED IN VARVES

Secular variation of the geomagnetic field at a single location is marked by oscillations of inclination, declination, and intensity over hundreds of years (Banerjee, 1983; Verosub, 1988). Over long periods of time (100,000 yr or more), the average declination should be approximately zero degrees, and the average inclination should approximate the expected axial dipole inclination at the latitude under consideration. Secular variation of declination and inclination of the geomagnetic field are known from direct measurement of the geomagnetic field over the past 500 yr (see summaries in Strangway, 1970; and Verosub, 1988). It has also been recorded in the remanent magnetization of many long wet-sediment cores that penetrate both Holocene and Pleistocene sediments of modern lakes (Vitorello and Van der Voo, 1977; Lund and Banerjee, 1979, 1983, 1985a, 1985b; Palmer and others, 1979; Lund, 1981; Barton and McElhinny, 1981; Banerjee, 1983; King and others, 1983; Creer, 1985; Verosub and others, 1986) and cores or outcrop samples from sediments of extinct lakes (Johnson and others, 1948; Verosub, 1979a; Rosenbaum and Larson, 1983). Errors inherent in sediment type (Rosenbaum and Larson, 1983), postdepositional remagnetization of saturated sediments (Palmer and others, 1979; Barton and McElhinny, 1981; Payne and Verosub, 1982), and problems related to wet-sediment piston coring techniques (Brennan and others, 1984), however, have been cited to explain dampened amplitude maxima in declination and inclination records and the inconsistency of secular variation records of multiple cores taken from within some single-lake basins. In such situations, the fidelity of remanent declination or inclination records must be tested by comparing records from separate sections, cores, or lake basins that contain contemporaneous sediment.

Any lacustrine sediment may be used for constructing a secular variation record of the geomagnetic field if it acquires its remanence at the time of deposition, or very shortly thereafter, and if the remanence faithfully records the geomagnetic field direction at the time of deposition. Glaciolacustrine sediments should carry faithful records of the geomagnetic field because their high sedimentation rates favor the rapid compaction and dewatering of sediment necessary to lock magnetic particles into a fixed orientation. Observations from sediment folded shortly after deposition and settling experiments suggest that "lock-in" of magnetic particles and acquisition of remanence occurs shortly after deposition. Remanence di-


NW
POLAND
SHED BROOK
NEWPORT
MIDDLEVILLE
KAST
BRIDGE
SE
time represented by post-Holland Patent beds in Mohawk Valley
HOLLAND
PATENT DMCTN
post - Holland Patent beds
HOLLAND
PATENT DIAMICTON
pre - Holland Patent beds
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MIDDLEVILLE FORMATION
NEWPORT BEDS
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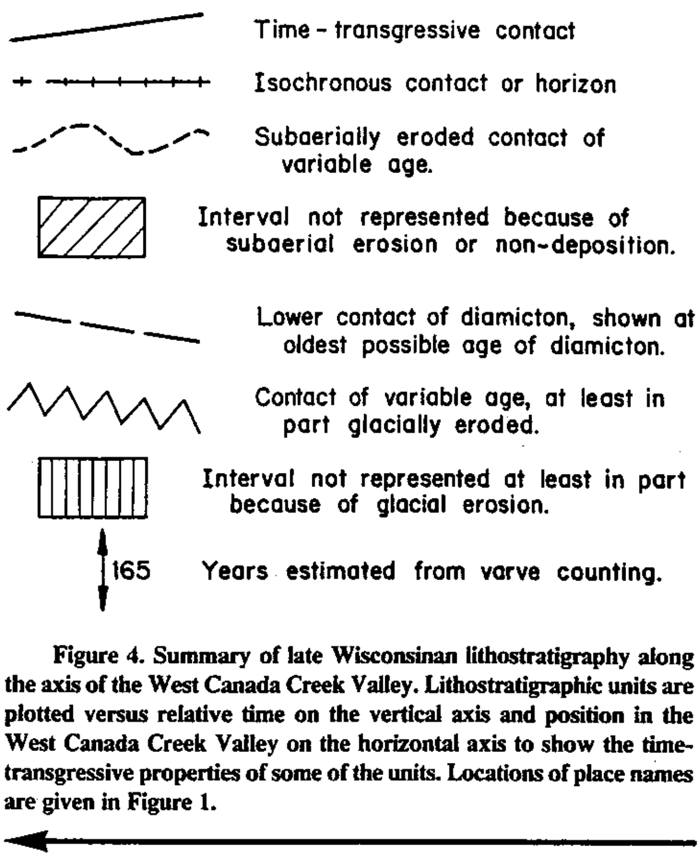


Figure 4. Summary of late Wisconsinan lithostratigraphy along the axis of the West Canada Creek Valley. Lithostratigraphic units are plotted versus relative time on the vertical axis and position in the West Canada Creek Valley on the horizontal axis to show the time-transgressive properties of some of the units. Locations of place names are given in Figure 1.

rections in soft sediment that has been folded several years after deposition are different than those in contemporaneous unfolded sediment (Graham, 1949; Granar, 1958). Estimates of lock-in time based on fold tests from varves range from less than 8 yr (Noel, 1975) to as few as 3 yr (Verosub, 1975). Settling experiments by Johnson and others (1948), showed that remanence directions of rapidly deposited fine-grained sediment are locked in very rapidly. Remanence directions of silt and clay, deposited over a 12-hr period in the presence of a known artificial field, remained unchanged by reorientation of the settling container despite continued deposition of sediment that caused further compaction and dewatering. Similar experiments by Verosub (1979c) indicate that realignment of magnetic particles requires postdepositional disturbance, even in sediments with very high initial water contents. Tucker (1980) found that only 10% of magnetic particles in an artificial sediment experienced postdepositional realignment under changing field conditions. These experiments suggest a geologically nearly instantaneous lock-in time for rapidly deposited glaciolacustrine sediment and provide an experimental basis for concluding that rapidly deposited glaciolacustrine sediment has a very short lock-in time. The varved sediments sampled in the Mohawk Valley have annual couplet thicknesses of 0.6 to 20 cm which represent sedimentation rates conducive to a short lock-in time.

Several problems that may exist with remanence directions in varves and other clastic sediments have been discussed by Verosub (1977). Particularly troublesome in the case of varved sediments is the problem of remanent inclinations which may be shallower than the geomagnetic field at the time of deposition. Shallow remanent inclinations have been observed in varves by Granar (1958), King and others (1983), and Brennan and others (1984). Experiments by Johnson and others (1948) showed that varve sediment, when disaggregated and resettled under known field conditions, can have an inherent inclination error of as much as 20 degrees depending on the strength of the artificial field used in the experiment. Resedimentation experiments by King (1955), Griffiths and others (1960), and Hamilton and King (1964) have also produced sediments with inclinations that are as much as 20 degrees too shallow. Granar (1958) and

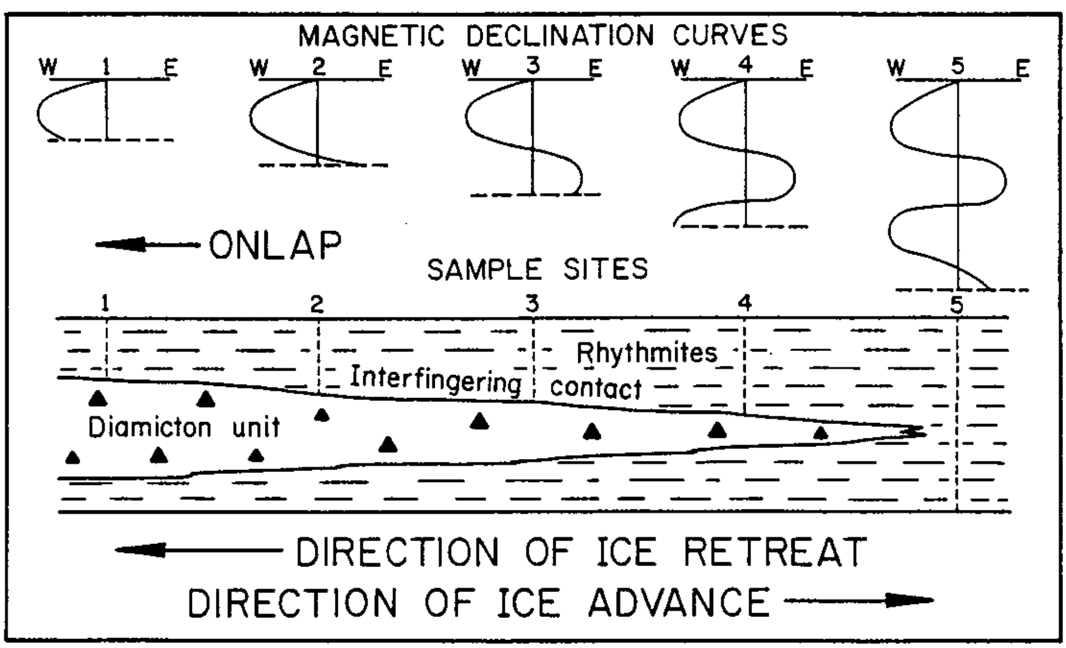


Figure 5. Stratigraphic onlap of lacustrine sediments on the upper surface of a diamicton unit deposited by a glacial readvance. Basal lacustrine sediments immediately above the diamicton are progressively younger to the left in the direction of ice recession. Records of remanent declination have progressively younger starting times to the left.

Griffiths and others (1960) have shown that silty summer beds of varve couplets have shallower remanent inclinations than do clayey winter beds. Experiments by Barton and McElhinny (1979) and Barton and others (1980), however, have shown that no significant inclination error was produced by laboratory deposition of muds at rates of 2 m/yr. The sediment they studied also exhibited a lock-in time of less than 2 days after completion of sedimentation. Inclination error in natural sediments has most often been found to be less than 10 degrees (Johnson and others, 1948; King, 1955; Granar, 1958; Griffiths and others, 1960; Lund and Banerjee, 1985b). A comparison of remanent inclination of Holocene clastic sediment of Fish Lake in Oregon with both remanent inclinations of contemporaneous pyroclastic rocks and historic inclination measurements indicate that the lake sediments have remanent inclinations that are as much as 5 degrees too shallow (Verosub and others, 1986; Verosub, 1988). Both experimental results and measurements of natural sediments seem to indicate that most natural sediments are unlikely to have inclination errors of as much as 10–20 degrees. Without independent records of ancient geomagnetic inclination, however, it may be incorrect to assume that inclination error is insignificant. Compaction (Blow and Hamilton, 1978; Anson and Kodama, 1987) and desiccation (Henshaw and Merrill, 1979) have also been recognized as possible postdepositional causes of shallow remanent inclination. The processes outlined above do not appear to affect remanent declination.

Two processes that have been suggested as causes of shallow remanent inclinations and systematic errors in remanent declination are (1) deposition on a sloping surface (Griffiths, 1955; King, 1955; Griffiths and others, 1960; Hamilton and King, 1964) and (2) deposition in the presence of a current (Rees, 1961, 1964; Rees and Woodall, 1975). Sloping bed experiments by King (1955) and Rees (1965) produced bedding errors in remanent inclination of as much as 25 degrees.

There are both advantages and disadvantages to obtaining paleomagnetic secular variation records from subaerially exposed outcrops of Pleistocene glacial varve sediments as opposed to obtaining them from long wet-sediment cores. One important advantage is that postdepositional remanence (pDRM; Payne and Verosub, 1982), sometimes observed in wet sediments that may have had slurry-like consistencies through the Holocene, should not be prevalent in varve sediments that were deposited and compacted quickly, and survived the Holocene in a dewatered and compacted state. Other advantages are that glacial varve sequences are usually well laminated and were deposited with high sedimentation rates. For these reasons, glacial varves are more mechanically stable than most other lacustrine sediments and have not had remanence altered by bioturbation, which is common in slowly deposited sediment (Verosub, 1977). High sedimentation rates with a lack of bioturbation also make glaciolacustrine varves favorable for obtaining high-resolution secular variation records (Verosub, 1979b). In addition, orientation of samples is unequivocal, and sampling of sediment that shows evidence of postdepositional disturbance such as slumping or folding can be selectively avoided (Brennan and others, 1984). Outcrop-sampling techniques may also avoid the problems of coring-induced mechanical reorientation of remanence by some long wet-sediment coring methods (Morris and Carmichael, 1984).

One important disadvantage of sampling varves from outcrop is that individual varve sections span relatively short time intervals (usually less than 500 yr). Thus, several overlapping varve sections must be sampled to obtain a secular variation record for a time interval comparable to that obtained from a typical long wet-sediment core. A varve chronology (Antevs, 1922) has been used to place samples from varves of Lake Hitchcock in New England in chronological order for construction of a secular variation record (McNish and Johnson, 1938; Johnson and others, 1948; Verosub, 1979a, 1979b). Such varve chronologies, however, are seldom available, and it is usually not possible to accurately determine the absolute ages of varve sequences which generally lack significant datable material. If isochronous beds or horizons cannot be found, correlation of varve sections is difficult. In spite of these problems, varves often represent the only available sediments from which Pleistocene secular variation records for a particular place and time interval can be constructed.

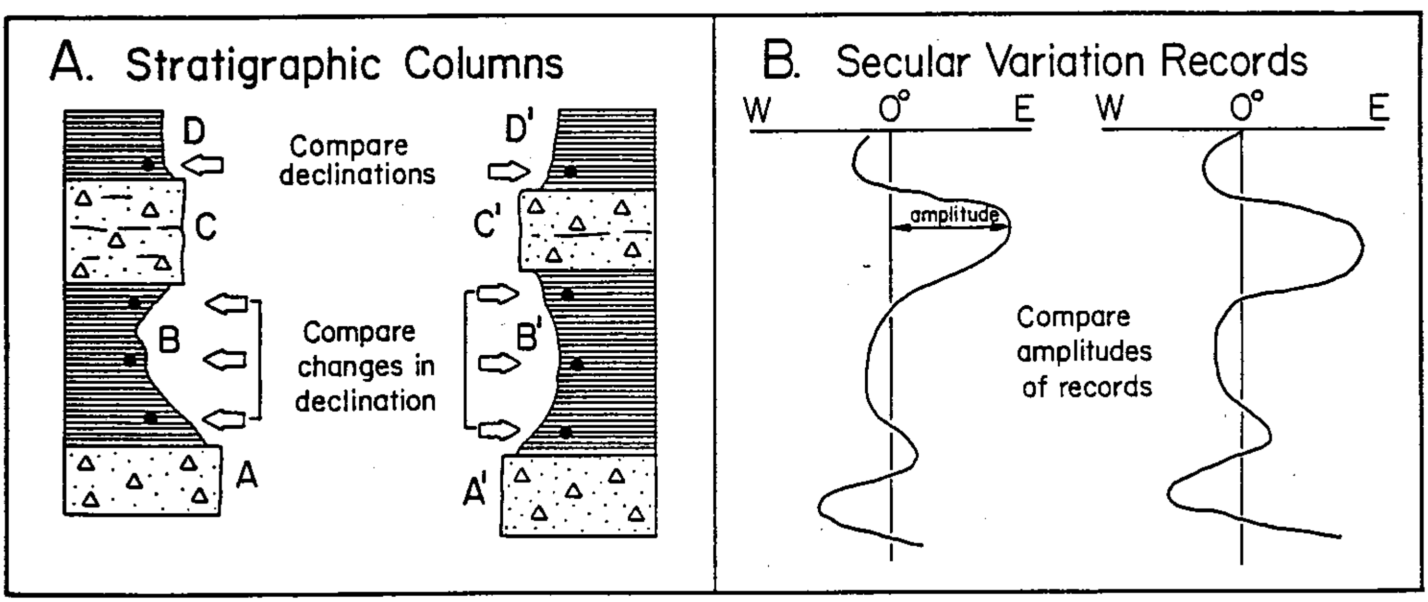


Figure 6. Time-stratigraphic tests of correlation using remanent declination. A. Comparisons of remanent declinations and temporal changes in remanent declination measured in sections containing varved lacustrine sediments. B. Comparison of declination maxima of records from two different stratigraphic sequences.

TESTING CORRELATIONS WITH SECULAR VARIATION RECORDS

Remanent declination has been used for time-stratigraphic testing of correlations between glacial units. The simplest test involves two sampling sites in units that are thought to be contemporaneous (Units D and D′, Fig. 6A). If the remanent declinations at the two sites differ significantly, the two sites are not contemporaneous. If remanent declinations are the same, the two sample sites may be contemporaneous, but the test does not prove this relationship because of the periodicity of geomagnetic declination.

A second, more powerful test of contemporaneity involves the remanent-declination values and temporal changes in these values in sections thought to represent the same interval of time (Units B and B′, Fig. 6A). If both varve sections record the same declination values and the same temporal changes in declination, the two sample sites may be contemporaneous. Again correlations can be conclusively disproved, but similar declinations in two sections can only provide supporting evidence for time-equivalence.

Physically unconnected stratigraphic sequences may be correlated by matching several consecutive amplitude maxima of their remanent-declination records (Fig. 6B). Whenever possible, independent stratigraphic controls should be used to test paleomagnetic correlations. Time correlation can be accomplished provided that the distance separating two stratigraphic sequences is not great enough that a significant delay caused by drift of the non-dipole component of the geomagnetic field exists (Bullard and others, 1950; Nagata, 1965; Skiles, 1970; Dodson, 1979). At a latitude of 40°–50°, a non-dipole field drift rate of 0.11°/yr, as has been estimated for the late Wisconsinan in the eastern United States (Lund and Banerjee, 1985b), would cause a delay of 55 yr over an east-west distance of about 500 km. This time error is smaller than the precision of radiocarbon dating. Westward drift of the non-dipole field at its modern rate of about 0.2°/yr (Yukutake, 1968) would produce a delay of only about 30 yr over a distance of 500 km (King and others, 1983).

Discontinuities which represent unconformities in a stratigraphic section may also be recognized using remanent-declination records. Abrupt change in remanent declination across a discontinuity indicates the presence of an unconformity. A diastem of 100 yr or more can be recognized by a discontinuity in a declination record. It is unlikely, although possible, that an unconformity representing a substantial interval of time might go unrecognized because of the periodicity of geomagnetic declination.

SAMPLING AND LABORATORY METHODOLOGY

Approximately 1,250 individual specimens (cut blocks or cylindrical cores) were collected from 119 sampling sites in 80 different sections where fine-grained laminated glaciolacustrine sediments are exposed in the western Mohawk Valley. It should be noted that for this study a sampling site is a short stratigraphic interval in a single section from which a group of specimens has been taken. Sections are geographic localities where the stratigraphy has been logged in detail, and individual sections may have several sampling sites within them. Multiple sampling sites in one section may be in one or more stratigraphic units. The precise locations, logged sections, and stratigraphic positions from which all paleomagnetic samples were obtained are given in Ridge (1985). Most of the sampling sites are in sections in the West Canada Creek Valley (Fig. 1), some of which are shown in Figure 2. Specific sampling sites within sections were chosen rather than complete vertical sampling of varved units because at many sections some intervals were sedimentologically inappropriate for paleomagnetic analysis, or they exhibited evidence of postdepositional disturbance. Only sediments that exhibited planar bedding with less than 5 degrees dip (in almost all cases dip was less than 2 degrees), that were not visibly deformed by soft-sediment or other mechanical disturbances, that were not oxidized, and that were not soft or sensitive as a result of pore water or seasonal ground-water seepage were sampled for stratigraphic purposes. Some additional exposures in which mechanical deformation was present, or that were soft as a result of ground-water seepage or wetting and drying were sampled to gauge the effects of these phenomena on remanent magnetization.

At each sampling site, an attempt was made to collect at least 10 individual oriented specimens from 5 horizons (2/horizon) which spanned no more than 20 varve years. Individual specimens were 2.5 × 2.5 cm cylinders that were trimmed from cut blocks to fit in plastic tubes or that were obtained directly using an aluminum coring tube. The coring tube was used only at sampling sites where the sediments were compact and would not become disturbed by coring. No differences in remanent declination or inclination were recognized among samples from sites where both block and core sampling techniques were used. Statistical parameters (alpha-95 and precision parameter) were calculated for the specimens from each sampling site and provided a determination of the precision of remanence directions for the sampling interval at each site. The rationale for the sampling and statistical analysis of several different horizons at each site is that previous studies (McNish and Johnson, 1938; Johnson and others, 1948; Verosub, 1979b; Brennan and others, 1984) have shown that remanence directions in varves vary, not only within single beds, but between adjacent beds.

Natural remanent magnetization (NRM) was measured on a PAR SM-2 spinner magnetometer at the Department of Geological Sciences at the State University of New York College at Geneseo. All of the ~1,250 specimens were subjected to progressive alternating field demagnetization (Zijderveld, 1967) at peak fields of 10, 20, 30, and in some cases as much as 40 mT. A small number of samples, representing different lithologies, were subjected to additional AF demagnetization to peak fields of 60, 80, and 120 mT (Fig. 7). A complete tabulation of all paleomagnetic data that includes remanence directions and intensities for all individual cores, including NRM and all AF demagnetization steps, are given in Ridge (1985). Remanent directions did not change significantly after AF demagnetization in peak fields of 20 mT or higher. Shifts of less than 5 degrees in remanent directions observed in some samples at AF demagnetization of 20 mT or less (Fig. 7) are attributed to the removal of a viscous remanent magnetization (VRM). The median destructive field for all samples was between 30 and 40 mT and provides evidence of the high stability of the samples. Less than 10% of original NRM remained in all samples demagnetized to 120 mT. Very high intensities between .08 and 1.0 A/m after AF demagnetization to 30 mT is consistent with the presence of abundant, fine-grained magnetite.

Because no visible evidence of oxidation or organic material has been found in the Mohawk Valley sediment, we have concluded that no chemical remanent magnetization (CRM) has occurred. Some samples, however, were tested for their rock magnetic properties (Ridge, 1985). In all samples tested, except one laminated silty clay with red pigment, saturation isothermal remanent magnetization (sIRM) was achieved in peak fields of between 200 and 300 mT, which is consistent with single-domain magnetite as the dominant magnetic mineral phase. The one sample that did not saturate in peak fields less than 300 mT acquired an additional 10% of IRM in peak fields of up to 700 mT. This sample may contain some hematite (Evans and others, 1968; Dunlop, 1972), as is also suggested by its red color. Because more than 90% of the NRM of this sample was removed by AF demagnetization at a peak field of 120 mT, hematite is probably not a significant remanence carrier. Only three sites with red-colored sediment from the westernmost part of the study area were

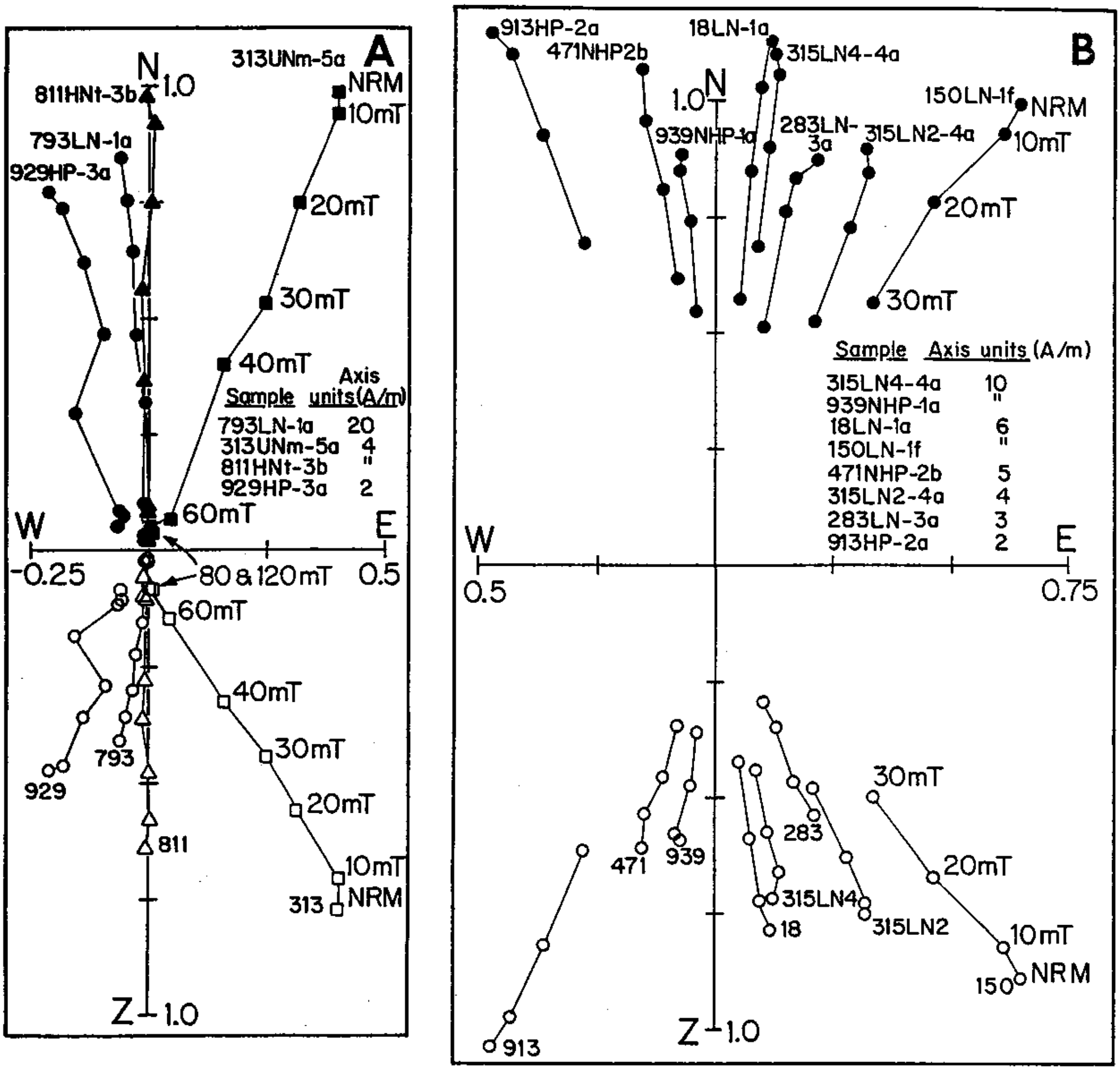


Figure 7. AF demagnetization of representative samples from the western Mohawk Valley region using the method of Zijderveld (1967). Remanent magnetization directions remain essentially unchanged by demagnetization. A. Results of progressive AF demagnetization to 120 mT on selected specimens. B. Results from some specimens that were progressively AF demagnetized to 30 mT.

sampled. Red clay and silt in these samples are derived from glacial erosion of red beds of the Vernon Shale, a Silurian formation that underlies the Ontario Lowland (Fig. 1) immediately west of the Mohawk Valley.

Additional tests using the method of Lowrie and Fuller (1971), as modified by Johnson and others (1975), were performed on the samples that showed no evidence of hematite. Resistance of anhysteretic remanent magnetization (ARM) to AF demagnetization which is inversely related to the magnitude of biasing field (0.2 and 2 mT) is consistent with remanence carried by single- and pseudo-single-domain magnetite. In addition, sIRM was found to be less resistant to AF demagnetization than was ARM.

RECOGNITION OF POSTDEPOSITIONAL REMANENT MAGNETIZATION

Before a secular variation record of the geomagnetic field can be constructed from remanence in lacustrine sediment, it must be established that the remanence is a faithful record of the geomagnetic field at the time and place of deposition and has not been disturbed since deposition. Postdepositional reorientation of remanence may result from mechanical deformation or grain rotation. Mechanical deformation observed in the Mohawk Valley sediment has been attributed to load deformation and also to shearing and compaction at sites which were overridden by grounded ice. Folding and shearing of sediment immediately beneath till is common (Fig. 8), and such sediment is obviously disturbed as compared to undeformed sediments (Fig. 3). Forced dewatering of sediment as a result of loading by readvancing ice appears to have been responsible for vertical *en echelon* fractures (spaced cleavage) which extend as much as several meters into sediments underlying till (Fig. 9). In sediments underlying till, subglacial shearing may be responsible for mechanical realignment of remanence. For example, within the upper 1.5 m of laminated clay and silt of the lower Newport Beds, which are overlain by till of the West Canada Diamicton (sites 313LNt and 313LNm in Fig. 10; section 313 in Fig. 2), remanent declination varies greatly from bed to bed. In the uppermost 0.5 m of the lower Newport Beds, remanent declination and inclination ap-

Figure 8. Nappe-like folding in glacially overridden, laminated fine sand, silt, and clay of the lower Newport Beds in section 145 (Fig. 2).

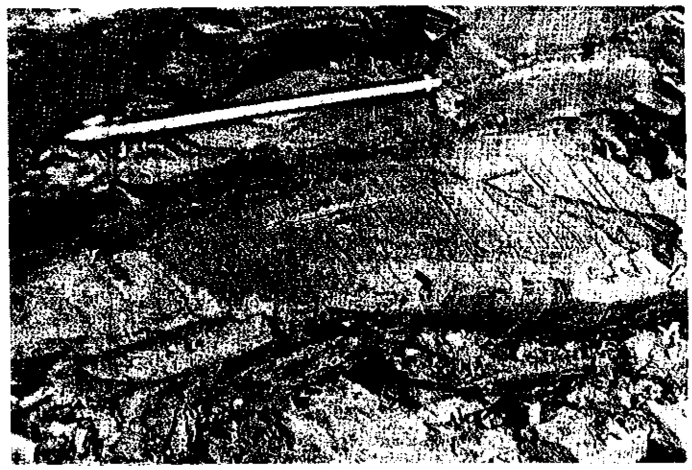


Figure 9. Bedding-plane traces of *en echelon* vertical fractures (spaced cleavage) in laminated silt and clay of the post-Hawthorne beds in section 828 (Fig. 2). These features are believed to be the result of forced dewatering by overriding ice.

pear to be progressively shifted, possibly as a result of subglacial shearing. Magnetic mineral grains in such deformed sediment may have been rotated mechanically, but it is not known if this process is responsible for the reorientation observed. It is clear, however, that directions of remanence in sediment deformed by overriding ice are different from the directions in sediment which is more than 2 m below the West Canada Diamicton (site 315LN2 in Fig. 10, sections 314–317 in Fig. 2) and apparently below the influence of overriding ice. Mechanical disturbances usually have some macroscopic expression, and sediments which display these features should not be used to establish secular variation records.

Seepage faces, seasonal wetting and desiccation, freeze-thaw activity, exfoliation, and swelling of overconsolidated sediments may alter the original DRM of clayey and silty sediments by allowing realignment of magnetic particles. In general, contemporaneous sections that show evidence of these types of disturbance do not have the same values of remanent declination. These sections also do not have the same declinations as contemporaneous sections that show no evidence of postdepositional disturbance. A comparison of soft, wet sediments that have lost some degree of consolidation due to ground-water seepage (section 922HP in Fig. 11), and sediments that are firm and therefore probably retain their consolidation (section 923HP in Fig. 11), shows that remanent declinations and inclinations are different despite the fact that the sediments are known to be contemporaneous. Thus, the remanence of at least one of the two sections is not a faithful record of the geomagnetic field. At section 923HP, the remanent declinations are similar to those at contemporaneous sections (other than 922HP) that exhibit no evidence of postdepositional disturbance. The remanent declinations for each sample site in section 923HP exhibit tight clustering, and declination changes smoothly up section. We thus conclude that the remanent declination at section 923HP is probably a faithful record of the geomagnetic field at the time of deposition. The influences of postdepositional disturbance associated with wet exposures cannot be removed by AF demagnetization and cannot always be recognized at the outcrop, but they must be avoided whenever possible. The results described above are similar to those recognized by McNish and Johnson (1938), who observed different remanence directions in silt and clay beds within single varve couplets from glacial Lake Hitchcock in New England. They attributed a shift in remanent declination toward the direc-

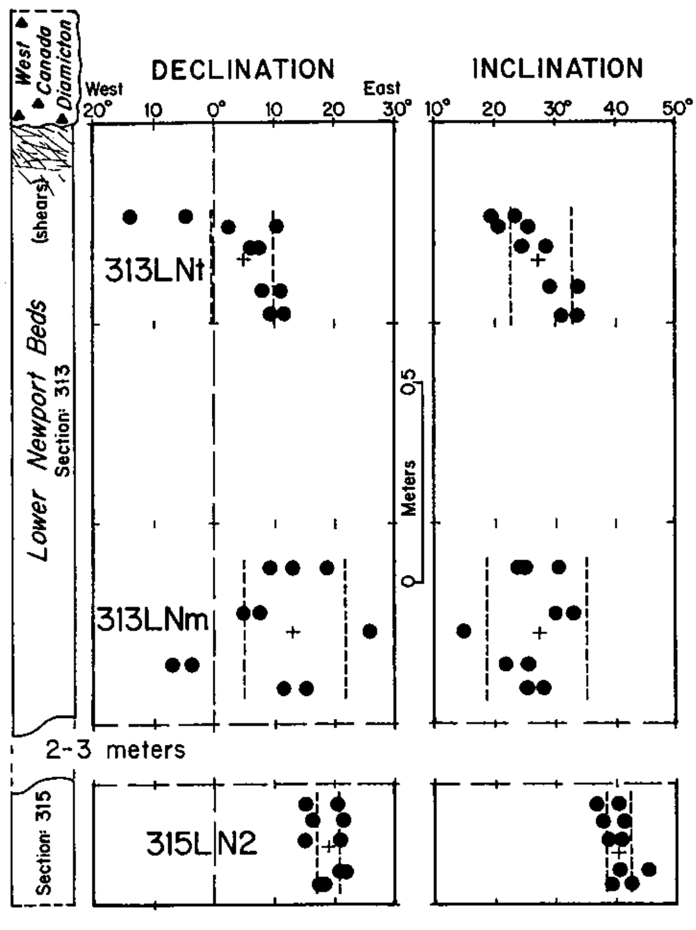


Figure 10. Remanence directions in sediment below the West Canada Diamicton (sites 313LNm and 313LNt) showing the effects of subglacial deformation less than 1.5 m below the diamicton. Remanence directions of undisturbed beds more than 2 m below the diamicton are from site 315LN2. Remanence directions of individual specimens are shown with small circles; dashed lines represent confidence intervals (alpha 95) about means calculated for sampling sites. All remanence directions are after AF demagnetization to 30 mT. Sections 313 and 315 are located in Figure 2.

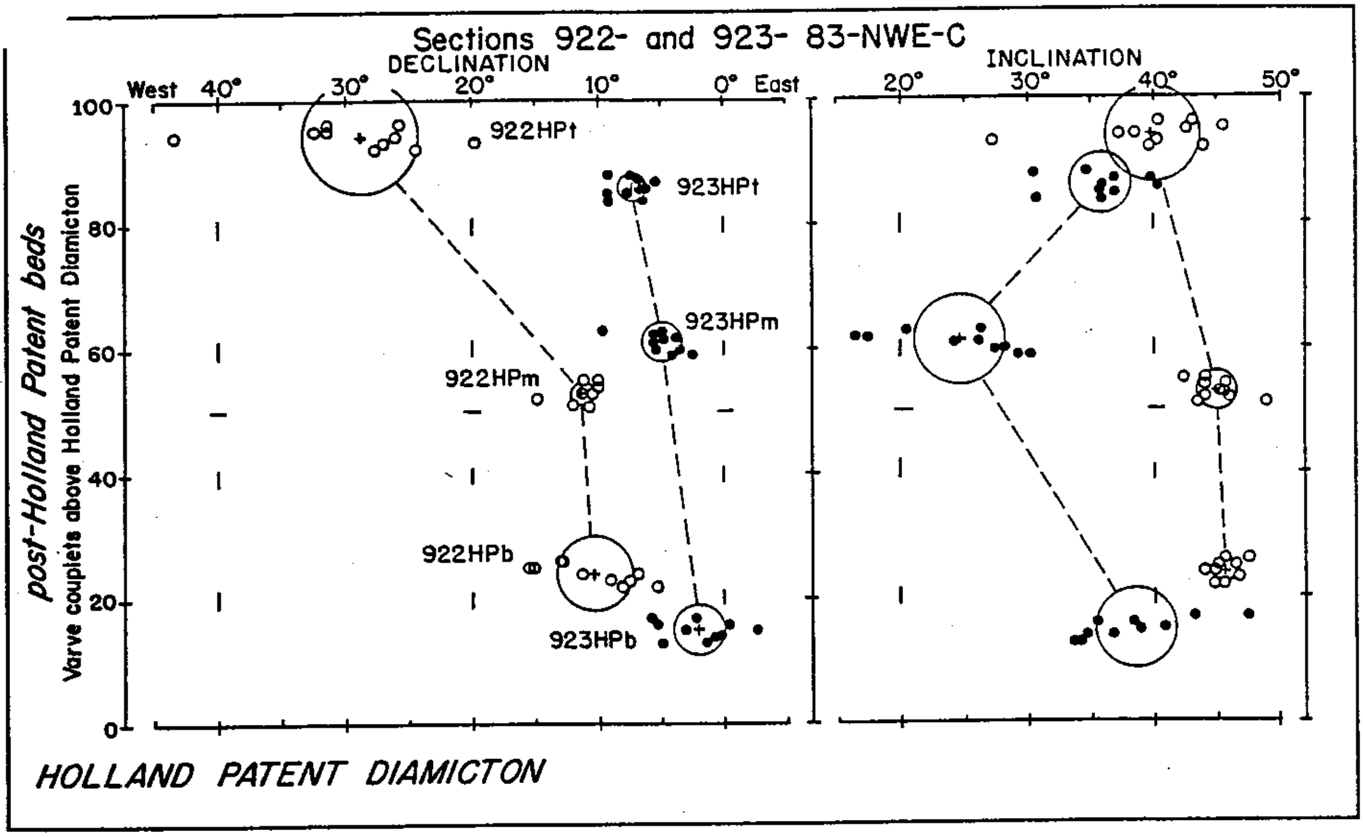


Figure 11. Remanent declination and inclination, after AF demagnetization to 30 mT, in varves of the post–Holland Patent beds at two contemporaneous sections (922HP and 923HP) in the Big Brook Valley northeast of Rome, New York (Fig. 1). Small circles represent remanence directions of individual specimens, and large circles represent 95% confidence intervals about means of declination and inclination for sampling sites. Section 922HP (small open circles) exhibits evidence of postdepositional disturbance, possibly the result of ground-water seepage, whereas section 923HP (small dark circles) shows no evidence of postdepositional disturbance. Neither of the sections has been overridden by ice. At least one of the sections must have remanence that is not a faithful record of the geomagnetic field at the time of deposition.

tion of the modern geomagnetic field in more permeable silt beds to seepage of ground water. Low within-site scatter, site-to-site reproducibility in contemporaneous sections, and stability under AF demagnetization must be demonstrated before remanent declination can be used to infer the declination of the geomagnetic field.

MAGNETIC STRATIGRAPHY OF THE WESTERN MOHAWK VALLEY SEDIMENTS

Remanent-Declination Record

Records of remanent declination and inclination for sampling sites in the western Mohawk Valley region are given in Figure 12. Although most sampling sites could be arranged chronologically with confidence, there were some exceptions. A bar graph illustrates the relative age determinations and the possible overlap in ages of the sites (right column in Fig. 12). All sample groups (sites) bearing the same sample number are from the same section, and their relative ages are known from superposition. Varve counts (in varve years) for the sampling intervals from single measured sections are plotted versus relative time. Because the samples are simply plotted in order of relative age, the vertical scale is variable in terms of years. For almost every part of the remanence record, several nearly contemporaneous sample sites (several within 100-yr intervals) have been compared to test the reproducibility of the remanence directions. Remanence from sites showing no physical evidence of postdepositional disturbance (solid circles) and from sites showing evidence of postdepositional disturbance (open circles) were both plotted for comparison.

Sampling sites with no evidence of postdepositional disturbance show smooth temporal changes in remanent declination and overlapping confidence intervals for nearly contemporaneous sites (Fig. 12). Contemporaneous sampling sites which exhibit evidence of postdepositional disturbance generally exhibit different remanent declinations. Using data from sampling sites which exhibit no evidence of postdepositional disturbance, a smooth declination curve can be constructed for the intervals of time represented by the Middleville and Poland Formations.

The earliest units of the lower Newport Beds have a remanent declination of 5°W (Fig. 12). The declination shifted to 30°E by the time the upper Newport Beds were deposited, a period of at least 300 yr. From this time to the break marked by the Shed Brook Discontinuity, there was a westward swing in declination to about 20°E over a period of at least 200 yr.

The Shed Brook Discontinuity appears to represent a significant amount of time because there is an abrupt change in declination of about 12 degrees (20°E to 8°E) across the discontinuity (Fig. 12). Based on sedimentologic and stratigraphic evidence in the White Creek, West Canada Creek, Shed Brook, and Sterling Creek Valleys (Fig. 1), the discontinuity appears to represent a period of subaerial erosion and nondeposition (Ridge, 1985), a conclusion supported by the declination record.

The pre-Hawthorne beds of the Poland Formation have a remanent declination of 8°E, and by the post-Hawthorne/pre-Norway transition (more than 100 yr later), the declination had shifted to about 3°E (Fig. 12). By the time the post-Norway beds were deposited 105 yr later, a point marked by a short gap in the remanence record and deposition of the Norway Diamicton (section 811 in Fig. 2; Fig. 4), the declination had shifted to about 2°W. During deposition of the post-Norway beds, a period of at least 525 yr, declination shifted westward to about 10°W–15°W after which it began to shift back to the east. The period of time marked by the upper part of the post-Norway beds is incompletely represented by paleomagnetic samples, and reproducibility of remanence directions between contemporaneous sections was not completely tested. Similar field conditions as those in the post-Norway beds, however, are present at outcrops of other stratigraphic units in which remanent declinations faithfully record the geomagnetic field. We therefore conclude that remanent declination in the upper part of the post-Norway beds probably records geomagnetic declination. Declination shifted to about 15°E–20°E during deposition of the pre–Holland Patent beds. Deposition of the post–Holland Patent beds continued while declination underwent a westward swing of 50 degrees to 30°W.

The two gaps in the portion of the paleomagnetic record obtained from the Poland Formation are thought to be only minor time breaks of less than 250 yr. Both gaps span periods represented by coarse stratified deposits in the Mohawk Valley (post-Norway to pre–Holland Patent beds) or a diamicton unit (Norway Diamicton between the pre- and post-Norway beds) and they are not represented everywhere by a discontinuity in the lithostratigraphy (Ridge, 1985). The same statement cannot be made for the Shed Brook Discontinuity, which is a basin-wide break in the lithostratigraphy (Figs. 2 and 4). The declination record of the Poland Formation appears to be continuous across both unsampled intervals in that unit as would be expected if the gaps in the magnetic record represented only diastems.

Confirmation of the time-transgressive character of the upper contact of a diamicton unit, a stratigraphic onlap (Fig. 5), can be seen by examining remanent declination in sediments directly overlying the Hawthorne Diamicton. The Hawthorne Diamicton is a unit composed of till and proglacial lacustrine diamictons that were deposited in conjunction with a readvance of the Mohawk Lobe from the east (Ridge, 1985; Muller and others, 1986). The diamicton has an upper contact that becomes progressively younger to the east in the direction of recession of the Mohawk Lobe. The basal varves deposited on the surface of the Hawthorne Diamicton are progressively younger to the east in the direction of ice recession. A secular variation record of remanent declination was obtained by sampling the basal varves across the surface of the Hawthorne Diamicton from west to east in the direction of ice retreat. Sampling sites were placed in chronologic order by their location with respect to ice-retreatal positions of the Mohawk Lobe (Fig. 13). A time-equivalent remanence record was also obtained by vertical sampling of 160 varve couplets on top of the diamicton at one location in the West Canada Valley (section 811, Figs. 2 and 13). Both remanence records exhibit the same temporal changes in declination upward in time, as would be expected for records spanning the same time interval. Varve counting, coupled with the paleomagnetic record, indicates that glacial recession of 40 km took place in less than 150 yr, giving an ice-recession rate for the Mohawk Lobe of at least 0.27 km/yr.

The effects of postdepositional disturbance on remanence can be seen in the remanent declinations of some sites in the upper Newport Beds (Fig. 12). Sampling sites which exhibit postdepositional disturbance have remanent declinations west of those at sites where no evidence of postdepositional disturbance was present. At the time of deposition of the upper Newport Beds, the geomagnetic declination was at an eastward maximum (25°E–30°E). Later periods of postdepositional disturbance, and realignment of remanent declination, had a much greater probability of occurring at times when the geomagnetic declination was west of, rather than east of, this eastward maximum. Postdepositional disturbances, therefore, are likely to have caused only a westward shift in remanent declination.

Remanent Inclination

Although remanent declination proved to be a useful means of testing time-stratigraphic correlations, remanent inclination could not be used because inclinations in sediments known to be contemporaneous were almost always different. Remanent inclinations from contemporaneous sites showing no evidence of postdepositional disturbance (solid circles on Fig. 12) differed by as much as 20 degrees, much more than can be introduced by sampling errors. Sites that did not exhibit evidence of postdepositional disturbance (solid circles on Fig. 12) did not exhibit discernible trends in remanent inclination up or down section that might be expected in a secular variation record of the geomagnetic field. It cannot be determined which, if any, of the remanent inclinations are faithful records of the geomagnetic field at the time of deposition.

Low values of both remanent inclination (all are between 17° and 47° except for one) and average remanent inclination (34°) of the Mohawk Valley sediments (Fig. 12) may be partly the result of deposition during an interval when the average dipole inclination was much lower than the presently expected axial dipole value (62° at latitude 43°N). Low remanent inclination results have been obtained from other late Wisconsinan sediments and rocks at mid-latitudes (see summary by Lund and Banerjee, 1985b). One cannot conclude, however, that the average geomagnetic inclination for intervals represented by the Mohawk Valley sediment (12,500–18,000 yr B.P.) was 34° given the higher remanent inclinations of other late Pleistocene records from the eastern United States. For example, the remanent inclination for late Pleistocene sediments of the period 12,000–15,000 yr B.P. from Kylen Lake, Minnesota (latitude, 47°N), is 45°–70° (Lund, 1981; Lund and Banerjee, 1985a), and exceeds the *average* remanent inclination of the Mohawk Valley (latitude, 43°N) sediments by at least 11 degrees. Remanent inclinations from sediments dated at 12.5–21 ka yr B.P. from Anderson Pond in Tennessee (latitude, 36°N) range from 30° to 65° and have an average value of about 50° (Lund, 1981; Lund and Banerjee, 1985b). The average remanent inclination at Anderson Pond is greater than the average Mohawk Valley inclination by 15 degrees. Sediments of glacial Lake Hitchcock in the Connecticut Valley of New England (42°N), that may be in part contemporaneous with the Mohawk Valley sediments, have inclinations of 30° to 65° and an average value of 45°–50° (Johnson and others, 1948; Verosub, 1979a). The average remanent inclination of the Lake Hitchcock sediment is greater than that of the Mohawk Valley by 11–16 degrees. These comparisons make it difficult to conclude that the Mohawk Valley sediments have remanent inclinations that faithfully record the late Pleistocene geomagnetic field. What seems more likely is that remanent inclinations in western Mohawk Valley sediments have been either flattened by postdepositional processes or are the result of a large error acquired at the time of deposition. Comparisons of remanence directions obtained from cores of Fish Lake in Oregon (Verosub and others, 1986; Verosub, 1988) with contemporaneous historic geomagnetic field records and remanence directions obtained from volcanic rocks indicate that lake sediments can have a remanent declination that faithfully records the geomagnetic field, but remanent inclination is too shallow.

Shallow remanent inclinations of the Mohawk Valley sediments may be the result of several processes that have been outlined above in this paper. Among these processes, inclination error that is common in rapidly deposited clastic sediment or the effects of currents may be responsible for shallow remanent inclinations at the time of deposition. Compaction and drying of the sediments may have been responsible for postdepositional flattening of remanent inclination. The Mohawk Valley sediments may have shallow remanent inclinations for one or several of the reasons listed above.

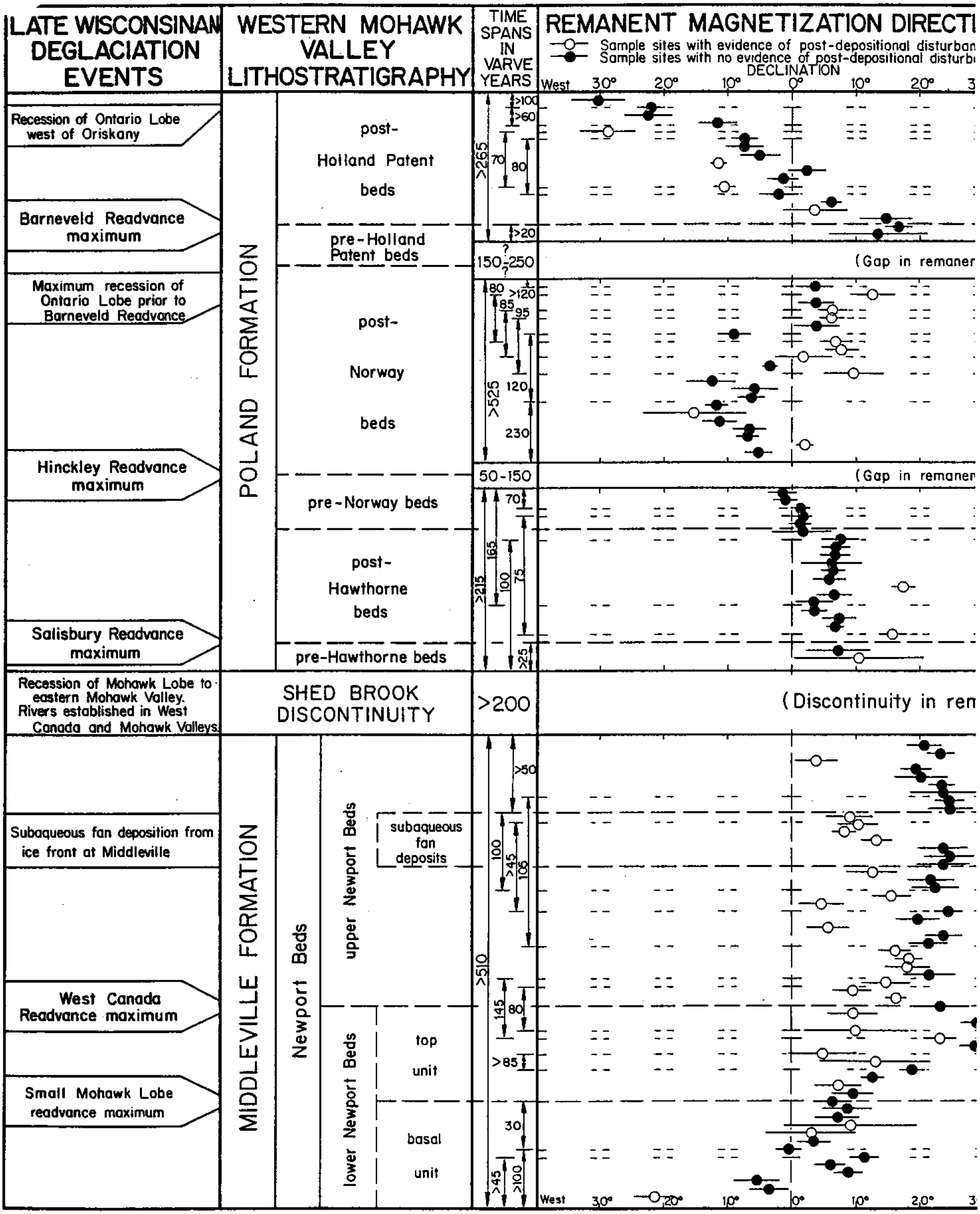
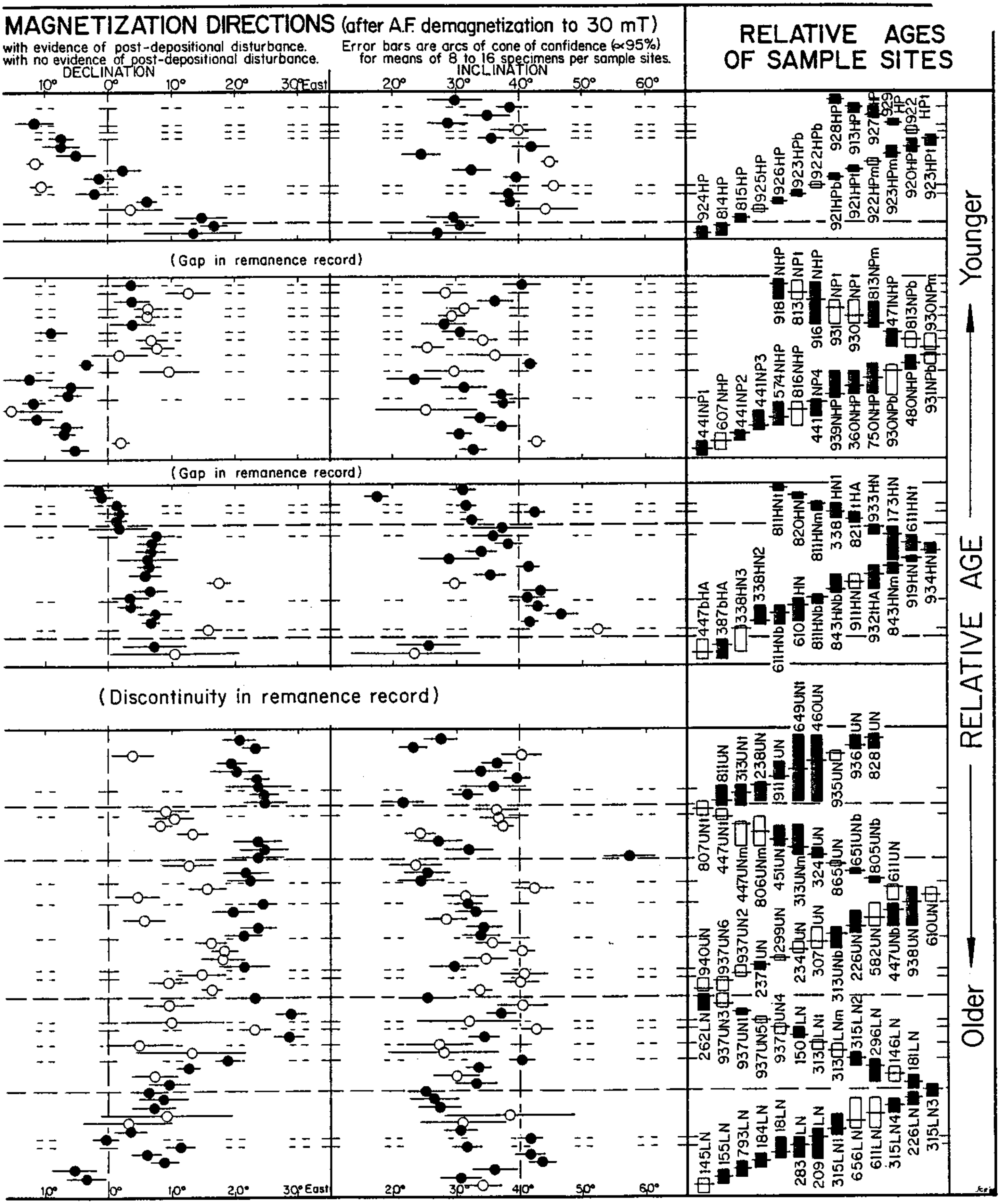


Figure 12. Plot of mean of remanent declination and inclination for sampling sites (8–16 individual specimens) versus relative age for the western Mohawk Valley region. All remanence directions are after AF demagnetization to 30 mT. Error bars are confidence intervals (alpha 95) about sample-site means. Sampling sites have numbers that indicate the measured section where the site is located; the letters after the numbers



indicate the units and stratigraphic horizons sampled at each site. Sites with the same number are from the same measured section. Some of the sections are shown in Figure 2, and the precise locations of all sampling sites are given in Ridge (1985). The possible overlap of relative ages of sampling sites are shown with a bar graph on the right side of the diagram. (Notice overlap in center.)

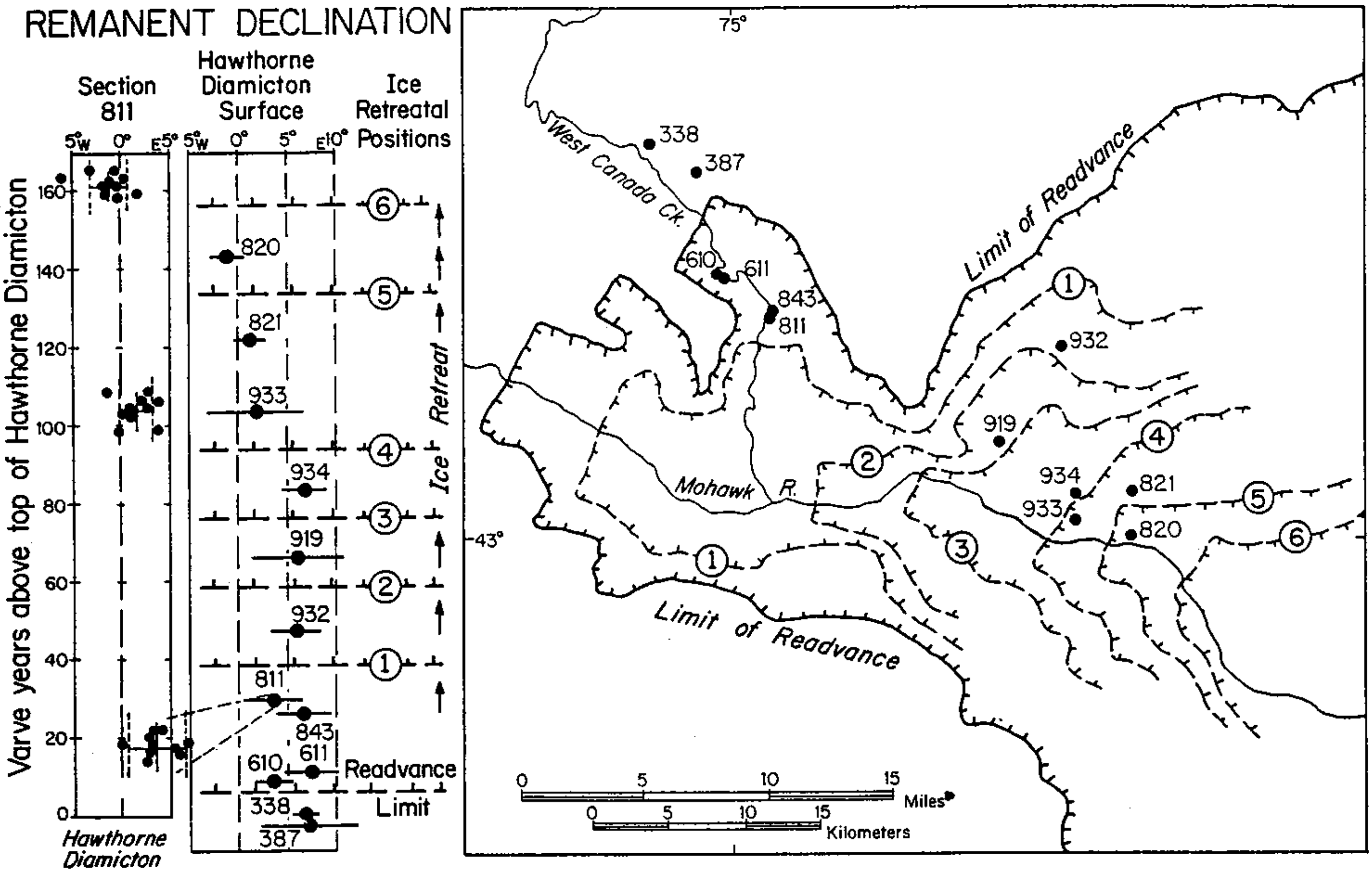


Figure 13. Remanent declination after AF demagnetization to 30 mT of varves overlying the Hawthorne Diamicton which was deposited by a Mohawk Lobe readvance. Only section numbers are used to identify sampling sites. Vertical sampling of stratigraphy was done at section 811 (Fig. 2). Relative ages of sampling sites in basal varves on the surface of the Hawthorne Diamicton are inferred from the positions of sites relative to ice-retreatal positions (1–6) and the limit of readvance of the Mohawk Lobe, which retreated from west to east. Confidence intervals (alpha 95) about mean remanent declinations of sites in section 811 are indicated with vertical dashed lines. The same secular variation record was obtained from the vertical sampling of varves at section 811 as was obtained from sites sampled from west to east across the time-transgressive upper surface of the Hawthorne Diamicton.

Compaction of the Mohawk Valley sediments was extreme because of the application of high lithostatic loads from thick, younger sediment and/or the weight of overriding ice. These characteristics make the Mohawk Valley sediments different from the sediments of modern lakes from which long piston cores have been taken to study secular variation. Extreme compaction may explain the anomalously shallow inclination of the Mohawk Valley sediments as compared to sediments from other localities. Because remanent declinations at contemporaneous sampling sites in the Mohawk Valley are in agreement, despite different degrees of compaction, compaction does not appear to have significantly altered remanent declination. Compaction experiments by Anson and Kodama (1987) indicate that compaction can cause significant flattening of inclination without significant reorientation of declination.

Current features, such as parting lineations and rib and furrow structures on bedding planes, are abundant in the Mohawk Valley sediments, which suggests that remanent inclinations may be shallow because of current activity. Although current activity may be responsible for some shallowing of inclination, it is clear from comparisons of contemporaneous sampling sites, where current direction indicators exhibit different orientations, that declinations are in agreement. Therefore, remanent declinations do not appear to be significantly affected by current activity. Because it has not been possible to isolate the effects of each potential cause of shallow remanent inclination in the Mohawk Valley sediments, and in most other natural sediments, it has not been possible to determine which potential cause or causes may have been responsible.

POSSIBLE CORRELATION WITH NEW ENGLAND

In the northeastern United States, late Pleistocene secular variation records of geomagnetic declination have been obtained in the northern Genesee Valley in western New York (Brennan and others, 1984) and from sediments of glacial Lake Hitchcock in New England (Johnson and others, 1948; Verosub, 1979a). Unfortunately, the record for the western Mohawk Valley is older than the Genesee Valley record. If one assumes that the assignment of relative ages of sampling sites based on the varve chronology for Lake Hitchcock (Antevs, 1922) is correct, a correlation may exist between the remanent-declination records for Lake Hitchcock and the western Mohawk Valley. Two declination maxima on the Hitchcock record may correspond to maxima of similar amplitude in the post-Norway beds (10°W–15°W) and the pre-Holland Patent beds (15°–20°E) of the Poland Formation (see tie lines A and B in Fig. 14). If the two remanence records do overlap in time, the proposed correlation is the only way in which the sediments can be correlated based on the amplitude maxima of their remanent-declination records. As far as it is

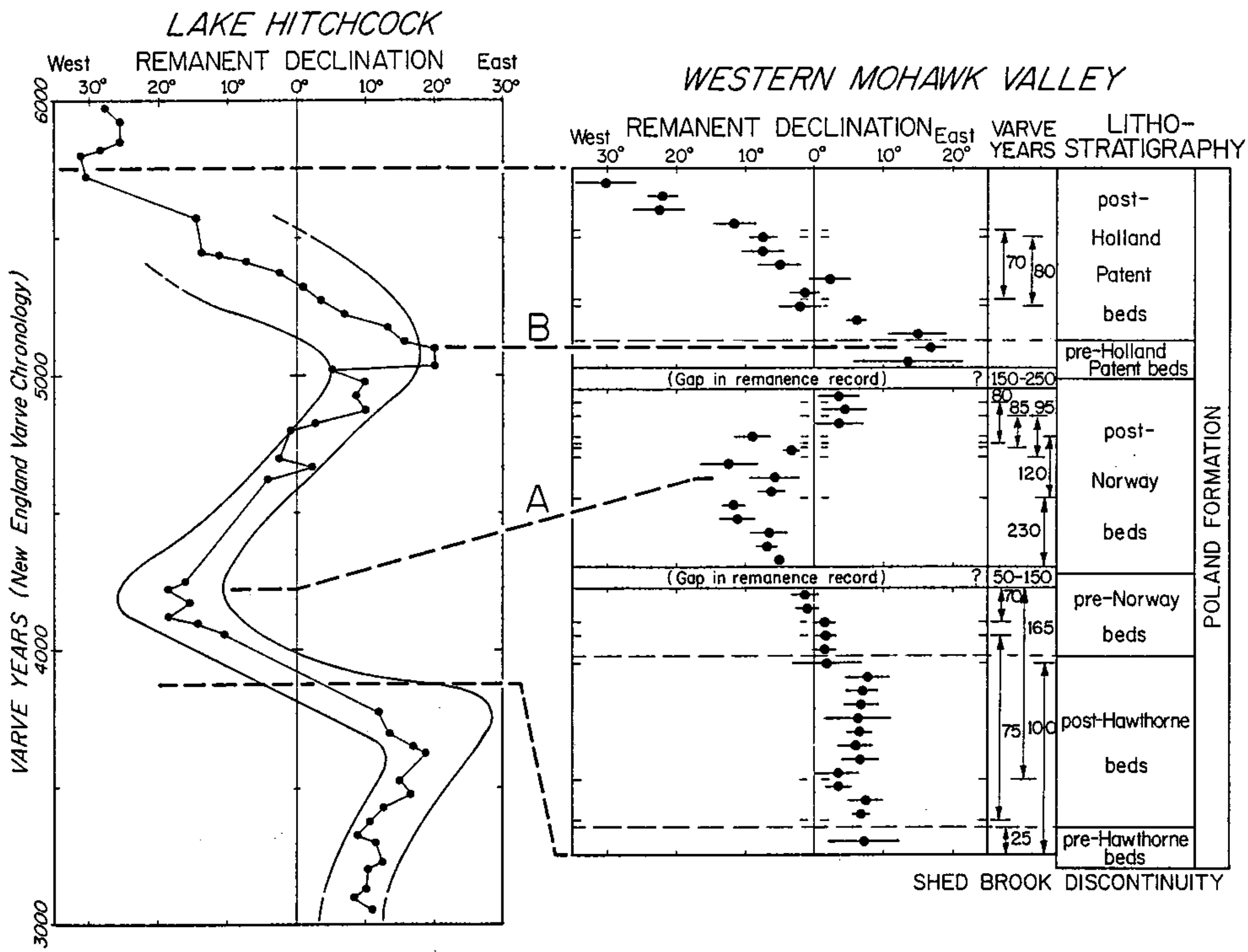


Figure 14. Partial remanent-declination record from the western Mohawk Valley versus declination record from varves of glacial Lake Hitchcock in the Connecticut Valley of New England. Only sites from the western Mohawk Valley that exhibit no evidence of postdepositional disturbance (Fig. 12) are shown. Confidence intervals (alpha 95) are shown with error bars. On the Lake Hitchcock record, solid dots connected by thin lines are natural remanent-magnetization results of Johnson and others (1948). The area between the two smooth curves on the Lake Hitchcock record represents the region within which geomagnetic declination lies (Verosub, 1979a) as compiled from Johnson and others (1948) and additional demagnetized (17.5–20 mT) results of Verosub (1979a). The vertical axis on the Lake Hitchcock record is time recorded in varve years of the New England varve chronology that arbitrarily begins at year 3000 (Antevs, 1922). Tie lines A and B show correlations based on the declination maxima.

possible to determine, the intervals of time recorded by the two remanent-declination records are similar. Correlative portions of the records do not show rates of declination change that are different. Intervals represented by the post-Hawthorne, pre-Norway, and post–Holland Patent beds are characterized by more rapid changes in declination than the interval represented by the post-Norway beds (Figs. 13 and 14), and correlative parts of the Lake Hitchcock record show these same relationships. Confidence in the Antevs varve chronology, as well as either radiocarbon dates or a better understanding of the relative ages of glacial events in New England and New York, will be needed to more definitively test the possible correlation of remanent-declination records from the western Mohawk Valley and Lake Hitchcock. At present, the interpretation of radiocarbon dates that bracket the age of Lake Hitchcock (Flint, 1956) and the number of years represented by the Lake Hitchcock varve chronology are in conflict (Schafer and Hartshorn, 1965). As pointed out by Verosub (1979a, p. 245), however, "in no case has the varve chronology itself ever been shown to be incorrect" and "in all cases varve sequences at [eleven] new sites [not seen by Antevs] could be matched completely, varve for varve, with the master chronology." The eastern Mohawk Valley, the Hudson-Champlain Valley and southwestern New York (Braun and others, 1984, 1985) are areas where secular variation records of geomagnetic declination may be obtained from glaciolacustrine sediments that are contemporaneous with sediments of the western Mohawk Valley. Correlation of such remanent-declination records should ultimately provide a time-stratigraphic framework of glacial sediments and events in these regions.

CONCLUSIONS

The principal result of this study is the construction of a secular variation record of geomagnetic declination that has been used for stratigraphic testing and correlation in undated late Wisconsinan glaciolacustrine sediments of the western Mohawk Valley. The secular variation record of geomagnetic declination has been used to test the contemporaneity or time-transgressive relationships of laminated clay and silt deposits, and it has been used to identify an unconformity (Shed Brook Discontinuity) in the late Wisconsinan glacial stratigraphy. The declination record has been particularly useful in defining the upper Newport Beds, which were deposited during an interval when the declination was 20°E–30°E. This range of declination did not reoccur during the intervals of deposition of the other glacial units of the western Mohawk Valley.

In a more general sense, paleomagnetic secular variation methodology can provide a useful means of reconstructing lateral facies assemblages in glaciolacustrine deposits with an unparalleled resolution of time equivalence. When combined with varve counts, the rates of recession for retreating ice masses may also be estimated.

There are limitations to the application of paleomagnetic secular variation methodology to glacial stratigraphic assemblages. The western Mohawk Valley region, and in particular the West Canada Creek Valley, is unusual in that exposures of single stratigraphic units are abundant, and nearly all of the interval of glacial recession in the region is represented by varved silt and clay suitable for paleomagnetic analysis.

ACKNOWLEDGMENTS

This study was funded by grants from the Geological Society of America, Sigma Xi, and the Senate Research Committee of Syracuse University. Field support was provided by the Geology Department of Syracuse University and the New York State Geological Survey. Special thanks go to the Department of Geological Sciences of the SUNY College at Geneseo for providing the laboratory facilities necessary for paleomagnetic measurements. Computer facilities were provided by the Academic Computing Center of Syracuse University. Critical field discussions with David Franzi on the interpretations of stratigraphic sections should never go unrecognized, and for his assistance we thank him. We also thank Gail M. Ashley and two anonymous GSA reviewers for their constructive comments.

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Manuscript Received by the Society May 14, 1989
Revised Manuscript Received June 12, 1989
Manuscript Accepted June 14, 1989

Printed in U.S.A.

LATE WISCONSINAN, PRE-VALLEY HEADS GLACIATION IN THE WESTERN MOHAWK VALLEY, CENTRAL NEW YORK AND ITS REGIONAL IMPLICATIONS

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ABSTRACT

The history of late Wisconsinan, pre-Valley Heads glaciation (about 18-15.5 ka) implies that major glaciological controls, as well as overall climatic warming, influenced the pattern of deglaciation in the western Mohawk Valley. The Middleville Formation in the West Canada Valley contains the most complete record of pre-Valley Heads ice recession in central New York. The lithostratigraphic succession was determined through detailed mapping and logging of measured sections, provenance study of diamicton units, and the analysis of declination of detrital remanent magnetization (DRM) in laminated lacustrine silt and clay. The initial recession of southwest-flowing ice from the Adirondacks and at least two glacial readvances of the Mohawk Lobe are recorded in these units. Glacial Lake Newport, impounded in the West Canada Valley during ice recession, attained levels that required ice-damming by coalescent Ontario and Mohawk lobes and a subglacial outlet across the Mohawk Valley to the Susquehanna drainage basin. Initial ice recession in the Mohawk Valley was mostly by calving of active valley lobes in deep water (up to 350 m) embayments and not by regional stagnation and simple downwasting. A shift of ice flow from the Adirondacks to ice flow from the Mohawk Lobe marks the development of lowland lobes during pre-Valley Heads time before the complete uncovering of the Adirondacks. The later dominance of the Ontario Lobe in Valley Heads time may have been the result of (1) a reduced supply of ice to the Mohawk Lobe from a diminished Adirondack ice dome, (2) changing ice-flow conditions in Quebec associated with an eastern St. Lawrence ice stream and calving bay, and (3) non synchronous surging of the Mohawk and Ontario lobes as these lobes became fronted by deep lacustrine waters at different times.

INTRODUCTION

Regional syntheses of late Wisconsinan glacial history have been attempted for the northeastern United States (Fullerton, 1980; Mayewski and others, 1981; Mickelson and others, 1983; Hughes and others, 1985; Dyke and Prest, 1987a, 1987b; Hughes, 1987; Teller, 1987; Gadd, 1988), but local details have not been adequately known to completely test these models. An understanding of Late Wisconsinan glaciation in the Mohawk Valley of central New York is necessary for a correct evaluation of the contemporaneity of glacial events from the Midwest to New England. Until recently, the late Wisconsinan glacial stratigraphy and chronology of the Mohawk Valley had been incompletely

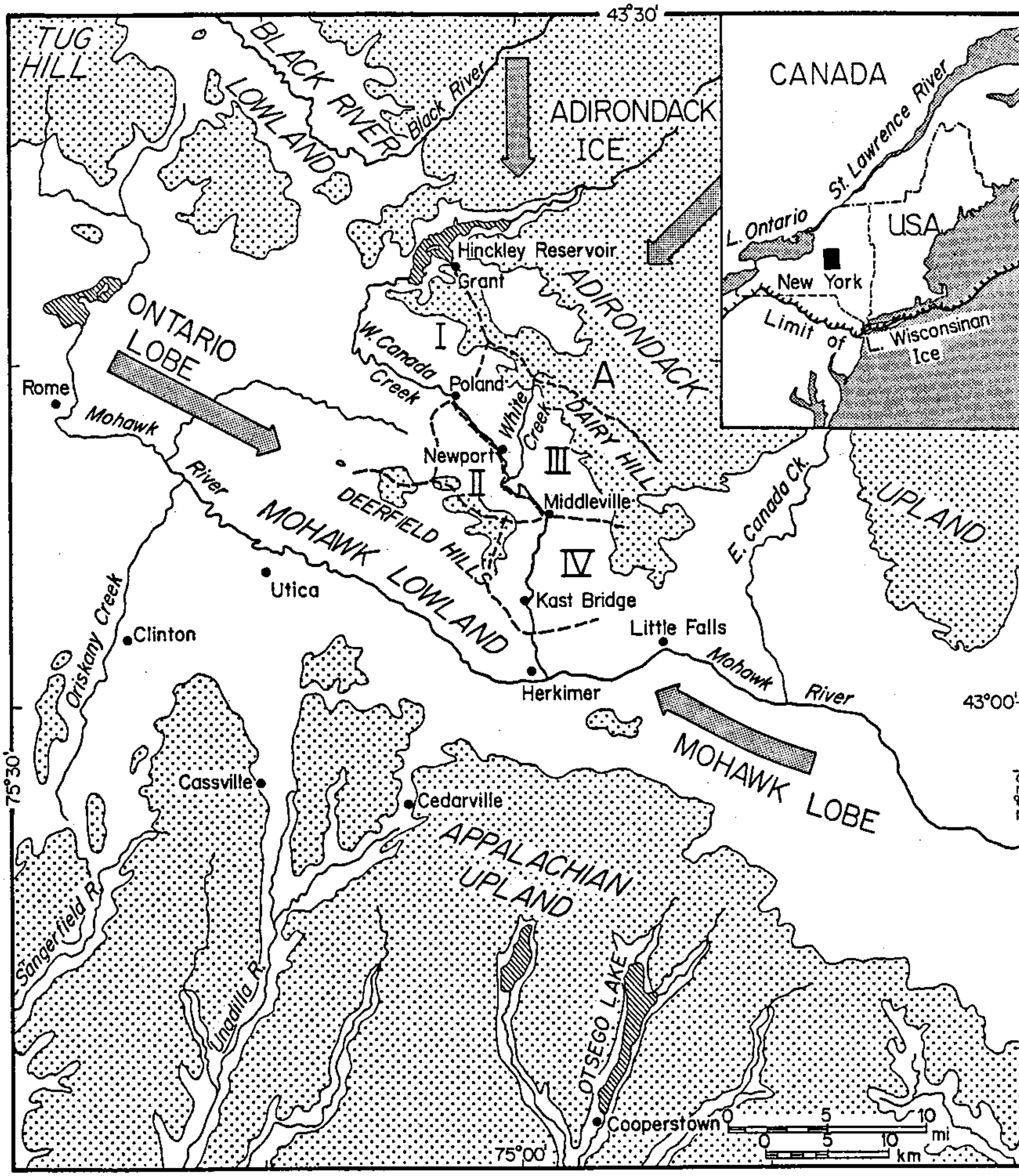


Figure 1. Location map of the western Mohawk Valley region. Shaded areas are above 400 m. The Mohawk River at Herkimer is at an elevation of 115 m, and West Canada Creek at Poland has an elevation of 207 m. Areas I thru IV are regions within which pebble provenance comparisons were made. Area A is the area covered by the Adirondack facies of the White Creek Diamicton. The directions of flow of ice lobes in the region are indicated by large arrows. Note that Adirondack ice entered the area from several different directions at various times during late Wisconsinan, pre-Valley Heads glaciation. Inset map shows the location of Figure 1 and the late Wisconsinan ice limit in the northeastern United States and adjacent Canada.

documented, despite observations in the area prior to the general acceptance of The Glacial Theory (Vanuxem, 1842). Glacial readvances in the Mohawk Valley have regional significance because they controlled the release of glacially impounded waters in the eastern Great Lakes region (Dreimanis and Karrow, 1972; Dreimanis and Goldthwait, 1973; Morner and Dreimanis, 1973; Calkin and Feenstra, 1985; Muller and Prest, 1985; Teller, 1987, 1990). An improved understanding of deglaciation in the Mohawk Valley provides insight into the influence of general climatic warming and glaciological controls on deglaciation.

A complete study of late Wisconsinan ice recession in the western Mohawk Valley is difficult because the analysis of glacial landforms of pre-Valley Heads age (>15.5 ka) is not usually possible. A study of pre-Valley Heads glaciation must rely on the interpretation of lithostratigraphy buried by later Valley Heads Drift (Mickelson and others, 1983). This paper presents the results of an investigation of a complex pre-Valley Heads lithostratigraphy in the West Canada Creek valley (Figs. 1, 2 and 3) that is the most complete record of pre-Valley Heads glaciation and lake impoundment in central New York.

HISTORICAL PERSPECTIVE

Early workers recognized both eastward (Ontario Lobe) and westward (Mohawk Lobe) flow of ice in the Mohawk Valley (Fig. 1; Dana, 1863; Chamberlin, 1883, 1888; Brigham, 1898, 1908; Cushing, 1905). Ice-flow indicators also record flow parallel to the trend of lowlands west and south of the Adirondacks (Miller, 1909), which were thought to have impeded continental ice flow during deglaciation. Fairchild's (1912) reconstruction of deglaciation showed the Adirondacks as a large nunatak entirely surrounded by receding ice in the lowlands. A lack of thick deposits and end moraines in the Mohawk Valley led Cushing (1905), Brigham (1911, 1929), and Fairchild (1912) to believe that ice in the lowlands receded by stagnation and downwasting rather than by the backwasting of an active ice margin. Fullerton (1971) and Krall (1977, 1984), however, provided evidence of Late Wisconsinan Ontario and Mohawk lobe readvances. Local Adirondack ice sources, too, may have nourished active valley lobes during deglaciation (Coates and Kirkland, 1974; Craft, 1975; Hughes and others, 1985; Gadd, 1988). Fairchild (1912) inferred that deep glacial lakes which drained southward across the Appalachian Uplands were impounded between the Mohawk and Ontario lobes during deglaciation. Brigham (1911, 1929) opposed the idea of large regional lakes based on a scarcity of lacustrine sediments above 200 m.

STRATIGRAPHIC NOMENCLATURE AND ANALYSIS

Lithostratigraphic Names and Genetic Terminology

Detailed mapping, section logs (Fig. 2) and provenance analysis have provided the information necessary to define lithostratigraphic units in the West Canada Valley (Fig. 3; Ridge and others, 1984; Ridge, 1985; Muller and others, 1986). Continuous packages of sediment bounded by discontinuities are defined as formations subdivided into members which include stratified units (signified as "beds") that range from silt and clay to gravel, and diamicton units.

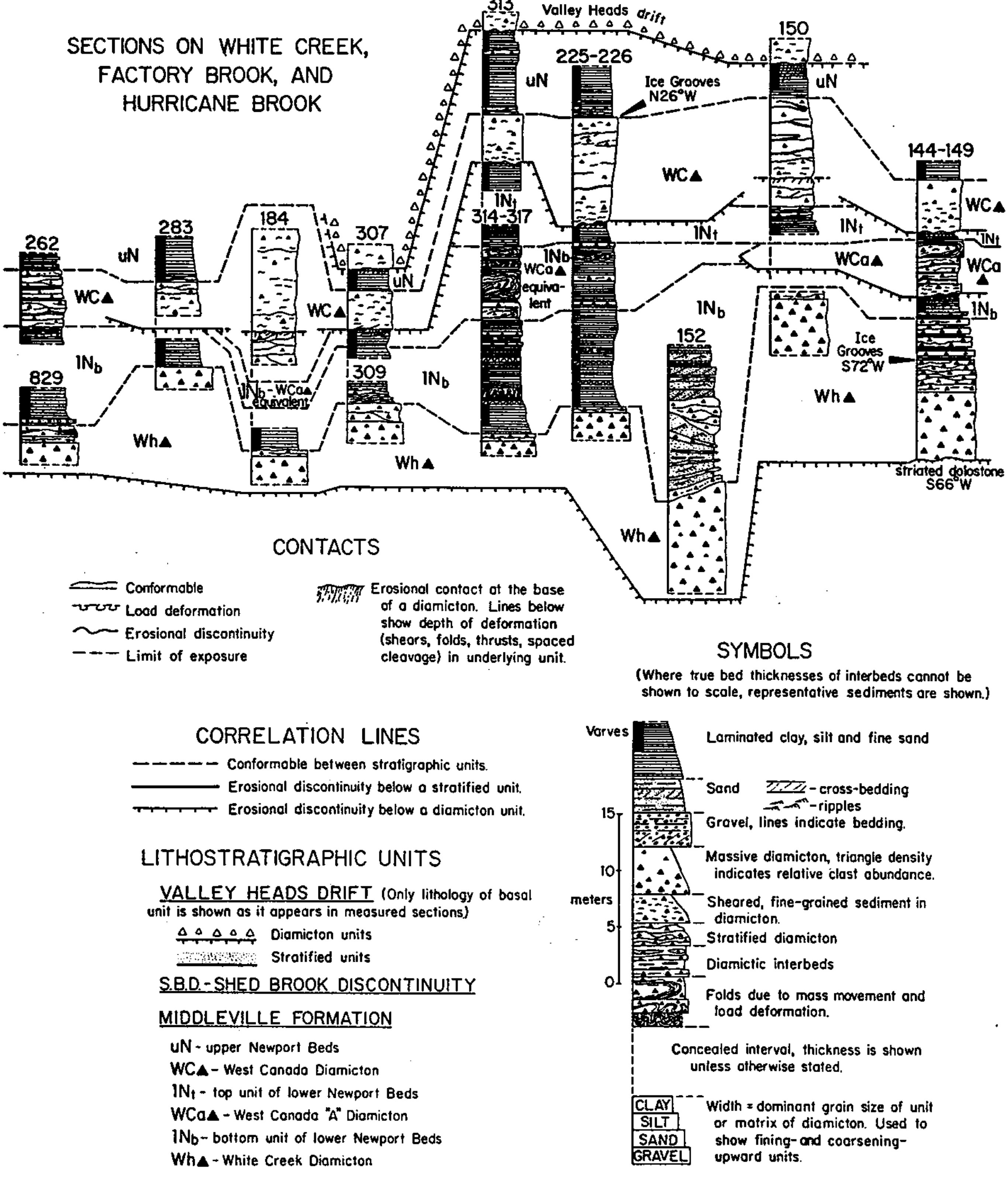
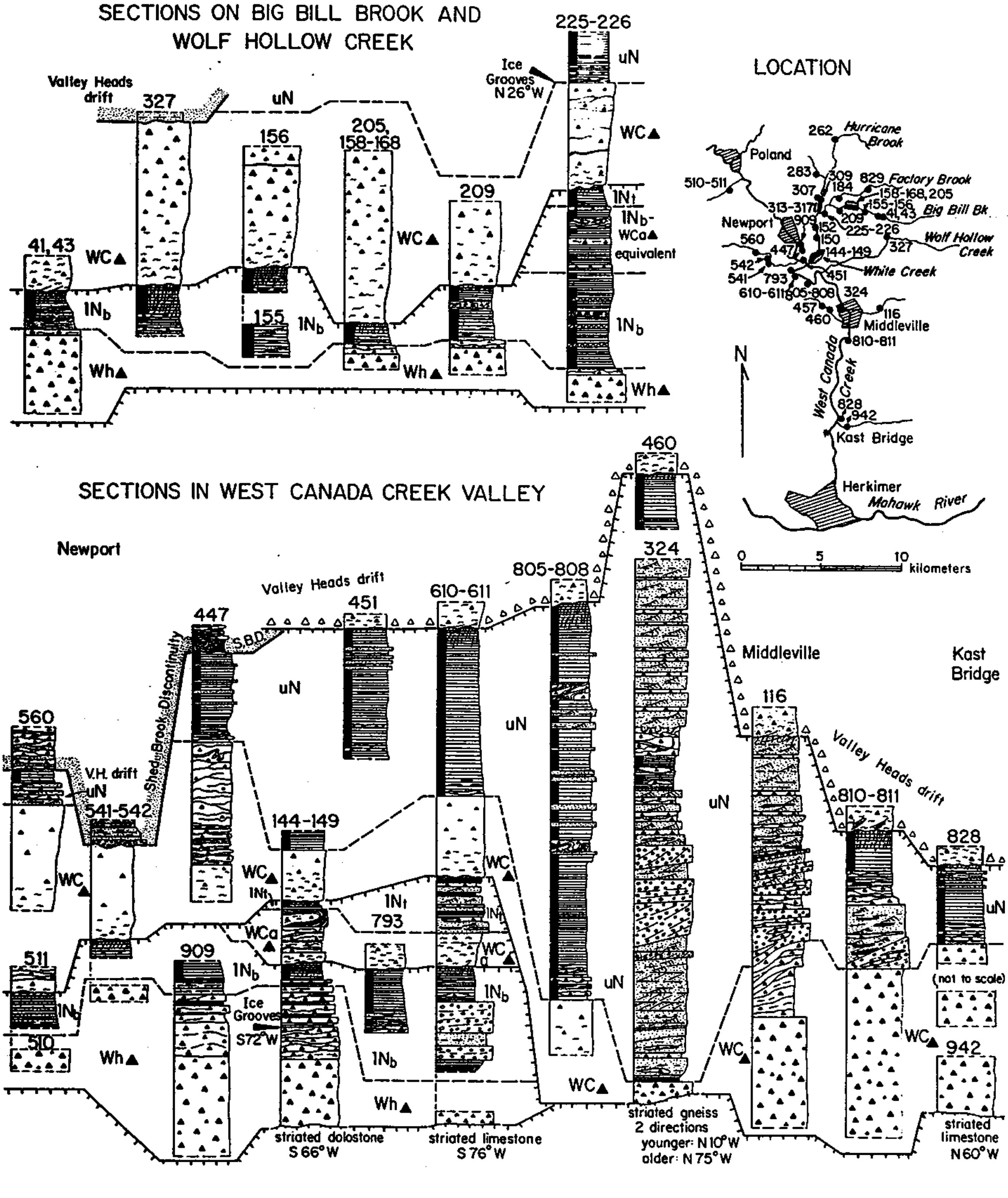


Figure 2. Representative measured sections of pre-Valley Heads deposits in the West Canada Valley and their correlation.



SECTIONS ON BIG BILL BROOK AND WOLF HOLLOW CREEK
Valley Heads drift
327
uN
156
205, 158-168
209
225-226
Ice Grooves N 26° W
WC▲
INt
INb-WCa▲ equivalent
41,43
WC▲
INb
155
INb
Wh▲
Wh▲
Wh▲
LOCATION
262 Hurricane Brook
Poland
283
309
829 Factory Brook
510-511
307
184
158-168, 205
313-317
155-156
Big Bill Bk
Newport
909
41,43
152
225-226
209
Wolf Hollow Creek
560
150
327
447
144-149
542
White Creek
541
793
451
610-611
805-808
324
457
116
460
Middleville
810-811
N
West Canada Creek
828
942
Kast Bridge
Herkimer
Mohawk River
0 5 10 kilometers
SECTIONS IN WEST CANADA CREEK VALLEY
Newport
Valley Heads drift
460
324
805-808
610-611
451
447
S.B.D.
Shed Brook Discontinuity
560
V.H. drift
uN
541-542
uN
uN
uN
Middleville
Kast Bridge
116
Valley Heads drift
810-811
828
144-149
WC▲
WC▲
INt
INt
793
WCa▲
INt
WC a▲
511
909
INb
INb
INb
Ice Grooves S72°W
510
Wh▲
INb
Wh▲
WC▲
WC▲
WC▲
uN
(not to scale)
942
striated dolostone S 66° W
striated limestone S 76° W
striated gneiss 2 directions younger: N 10° W older: N 75° W
striated limestone N 60° W

This nongenetic lithostratigraphy (Fig. 3) is here used as a basis for the interpretation of paleoenvironments, glacial events, and lake levels during Late Wisconsinan deglaciation.

The nongenetic term "diamicton" has been chosen for lithostratigraphic names, instead of "till", because it appropriately describes the stratigraphic units. Our use of the term "diamicton" follows that of Frakes (1978) for a nonlithified, poorly sorted mixture of clay to boulders. Formal names are given to diamicton units only if they extend over a distance of at least 2 km and if nearly complete exposures of the units have been found.

Diamicton Units and Ice-Flow Analysis

Diamicton units in the West Canada Valley include subglacial till, and rain-out and sediment-flow deposits (Ridge, 1985). The term "till" is restricted to "sediment, deposited directly from glacier ice, which has not undergone subsequent disaggregation and resedimentation" (Lawson, 1979, p.28). Rain-out deposits (Eyles and Eyles, 1983; Eyles and others, 1983a, 1983b) are formed by rapid settling of sand, silt, and clay from suspension in meltwater plumes and by the dropping of sediment from floating ice. Based upon the general sparsity of clasts (stones and sediment pellets) and the muddy character of most of these deposits in the West Canada Valley, suspension settling dominated over dropping of ice-rafted debris. Sediment-flow diamictons were formed by mass movement of lacustrine deposits or glacial debris in subaqueous environments (Evenson and others, 1977) in ways that are analogous to sediment flows in subaerial environments (Hartshorn, 1958; Boulton, 1968; Lawson, 1979, 1982).

The differentiation of diamicton units in the West Canada Valley, based solely on provenance, is difficult because diamictons are not derived from unique sources, and local bedrock usually dominates in pebble counts. Most of the diamicton units are calcareous, dark to medium gray, and are derived primarily from beds of carbonate rocks and shale in the West Canada Valley region (Table 1)p.B10. Mixing of source material by the reworking of previously deposited glacial units also makes distinctions between diamicton units difficult.

In the West Canada Valley from Poland to Kast Bridge, the differences in pebble composition of diamicton units are subtle (Fig. 4). Differences in provenance are based on ice-flow indicators associated with diamicton units (Fullerton, 1971; Ridge, 1985) and changes in diamicton pebble types where ice crossed contacts between different bedrock types. Ice-flow directions were inferred from rat-tailed striations, subglacial grooving on till surfaces, and the sense of displacement on thrusts, overturned folds, and slickensides in sub-till sediment that was deformed by overriding ice. Horizontal (2-D) clast fabrics in till provided additional evidence for ice-flow interpretations. The fabrics were obtained by measuring the long-axis orientation of 50 stones with long axes of 1.5 to 25 cm and a long- to intermediate-axis ratio of at least 1.5:1.

Analysis of the pebble types in diamictons is useful for differentiating drift provenance from the Ontario or Mohawk lobe, or ice that flowed across the Adirondacks (Fig. 1). The technique is

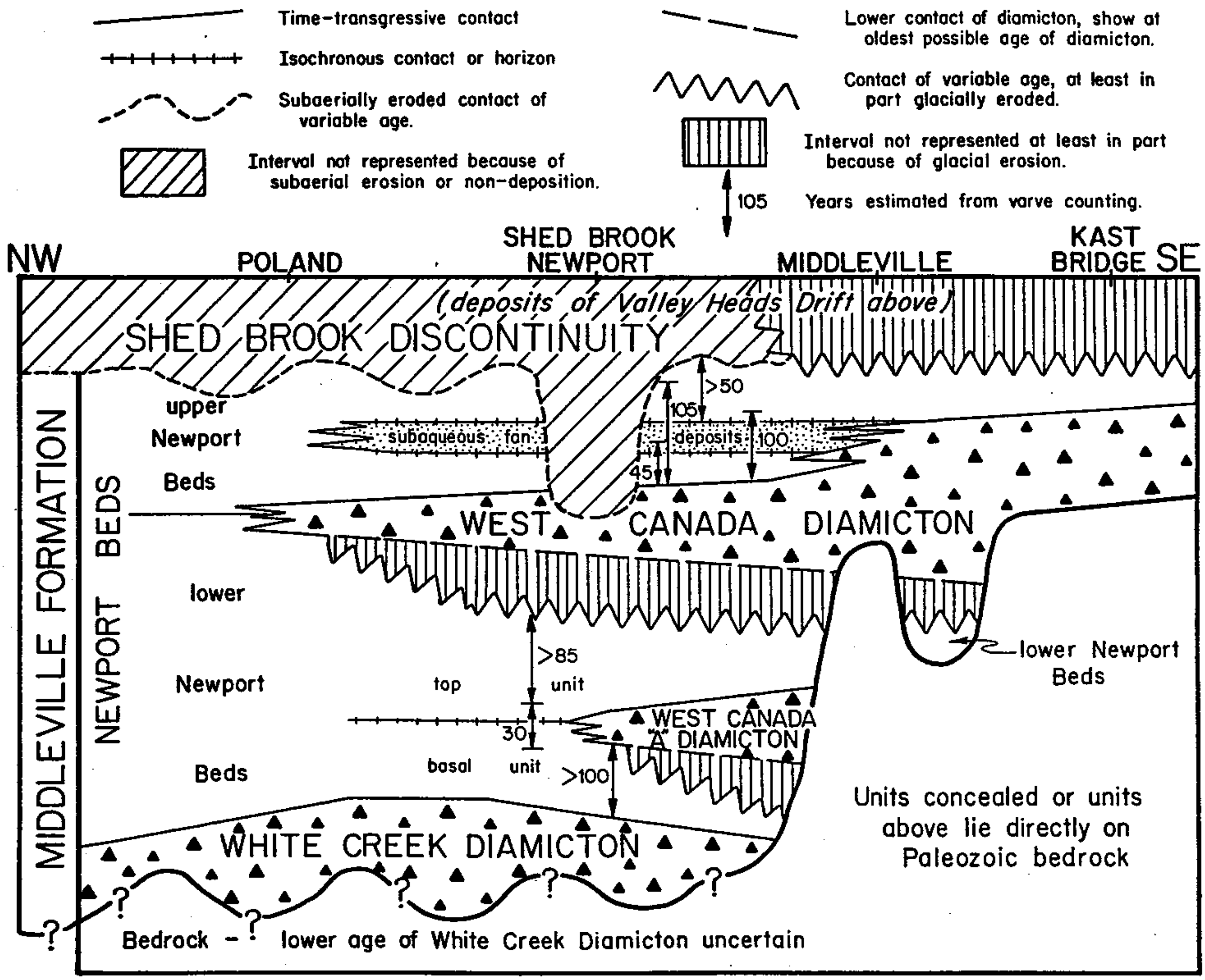


Figure 3. Time (relative)-distance plot of pre-Valley Heads (late Wisconsinan and >15.5 ka) lithostratigraphic units in the West Canada Valley. Places are located on Figures 1 and 2.

reliable only within restricted regions because of the regional variability of individual units. The West Canada Valley has been subdivided into four regions for the purposes of provenance analysis (Regions I thru IV in Figs. 1 and 4). Because no Ontario Lobe deposits of pre-Valley Heads age occur in the West Canada Valley, data for Ontario Lobe units of Valley Heads age are reported for comparison. In general, diamicton of Adirondack provenance (valley facies of the White Creek Diamicton) is sandier and has more metamorphic and fewer clastic pebbles than do other diamictons (Regions I and III in Fig. 4). This general rule does not apply where Adirondack ice crossed several kilometers of sedimentary rock and diamicton is dominated by local carbonate rocks and shale. Locally derived dolostone and light gray limestone are abundant in Region II south of West Canada Creek where the White Creek Diamicton lies directly on these carbonate bedrock types (Region II bar graph in Fig. 4).

Mohawk Lobe diamictons are generally more calcareous than are Ontario Lobe diamictons because of greater abundances of calcareous black shale and dark gray limestone of the Trenton Group (Table 1). South of Middleville (Region IV in Fig. 4), Mohawk Lobe diamicton (West Canada Diamicton) contains very few non calcareous shale pebbles derived from the Lorraine Group in the Deerfield Hills (Table 1). In all regions, Ontario Lobe diamicton contains more coarse clastic, siltstone, and non calcareous shale pebbles derived from the Deerfield Hills and western sources which were crossed by the Ontario Lobe prior to its flow into the West Canada Valley. Adirondack and Mohawk diamictons are derived from ice that did not cross nearby clastic rock outcrops, but these rock types occur in the diamictons although with lower abundances than in Ontario Lobe deposits.

Stratified Units

Coarse-grained stratified deposits in the West Canada Valley are mostly ice-contact deltaic and subaqueous fan sediments such as those described by Rust and Romanelli (1975), Burbridge and Rust (1988), Rust (1988), and Sharpe (1988). Stratified silt and clay include turbidites, underflow deposits (Ashley, 1975; Smith and Ashley, 1985), deposits produced by pelagic settling, and varves. All of the silt and clay deposits contain clasts (pellets, angular fragments, and flakes) of clay, silt, and diamicton. Most of the sediment clasts have shapes similar to "till pellets" described by Ovenshine (1970), which are dropped from icebergs. Turbidites and deposits produced by rapid settling of mud from suspension have faint laminations and differ from varves in that they do not contain beds of almost pure clay. Faintly laminated beds produced by settling of mud from suspension contain sediment clasts of several types, but turbidites are usually subtly graded and have sediment clasts of a single or dominant type which may indicate the scour of beds up slope.

Rhythmic beds of nearly pure clay coupled with fine sand to clayey silt in multiple micrograded beds are interpreted as varves. Ridge and others (1990) substantiated their usefulness in estimating time durations. The clay (winter) layers have a relatively uniform thickness as compared to coarser micrograded (non-winter) layers. Nematode worm trails on several different bedding planes within a single couplet, along with the multiple graded character of couplets,

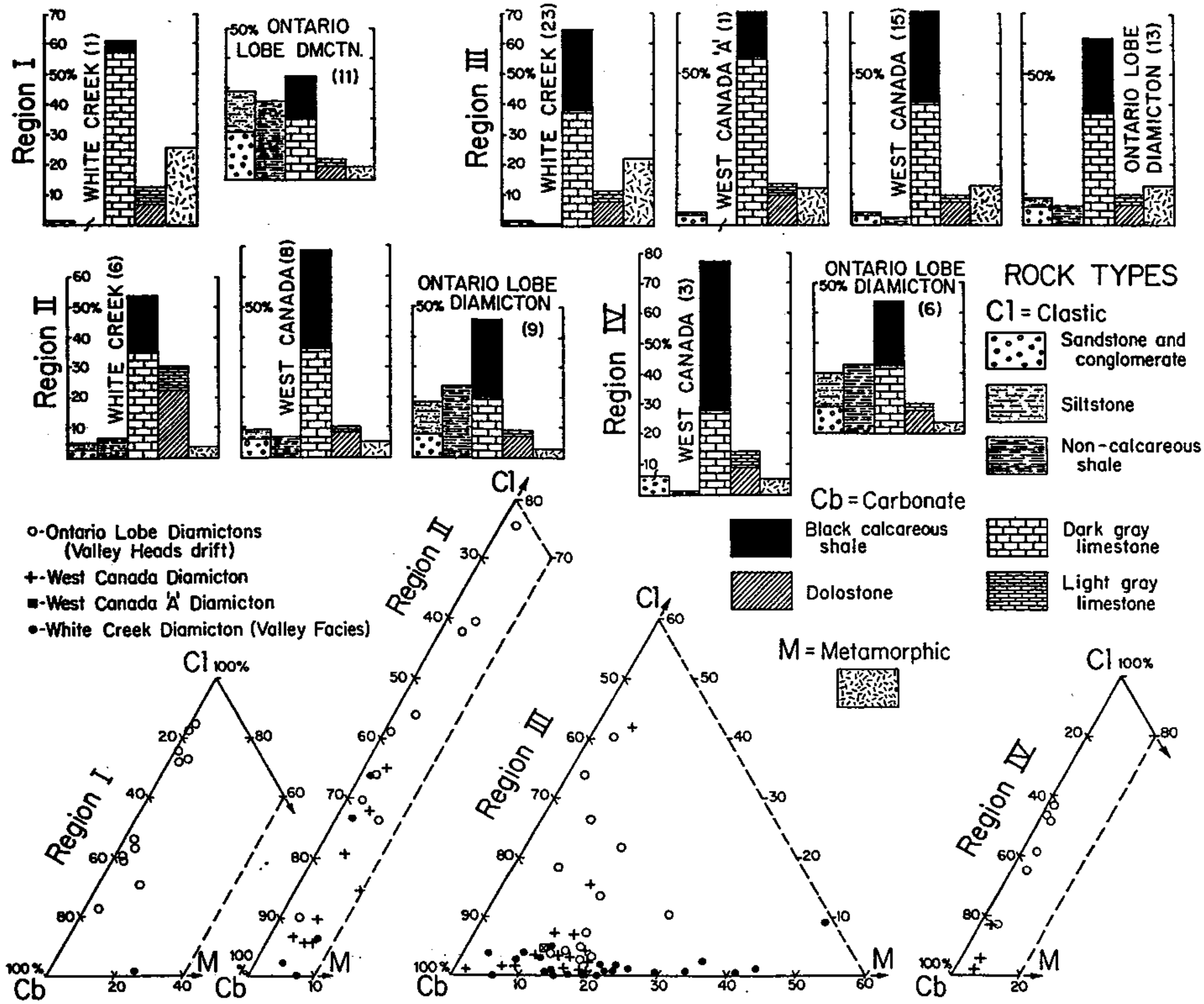


Figure 4. Pebble count data for diamicton units in the West Canada Valley. Pebble types, their sources, and ages are given in Table 1. Histograms are for mean percentages of diamicton units in four regions of comparison (regions I-IV in Fig. 1). Numbers in parentheses in each histogram indicate the number of sites used to calculate means. At each site, 150-300 pebbles were counted. The West Canada Diamicton does not occur in region I, and exposures of the White Creek Diamicton have not been found in region IV. Only one exposure of the West Canada "A" Diamicton (region III) has a sufficient number of pebbles for analysis. Triangular plots are of individual sample sites in each region of comparison. On the triangular plots, Cl = sedimentary clastic rock types, Cb = sedimentary carbonate rock types, and M = metamorphic rock types. Note that triangular plots for regions II and III are at twice the scale as those for regions I and IV.

TABLE 1. ROCK TYPES AND SOURCES OF PEBBLES IN DIAMICTON UNITS OF THE WESTERN MOHAWK VALLEY

Rock type	Source
CLASTIC SEDIMENTARY	(Cambrian through Silurian age)
Sandstone and conglomerate	Potsdam Formation flanking the northern half of the Adirondacks and the Lorraine and Medina Groups of the Tug Hill.
Siltstone	Lorraine Group of the Deerfield Hills and Tug Hill to the west and northwest.
Non calcareous shale	Lorraine Group and some beds of the upper Utica Shale in the Deerfield Hills.
CARBONATE SEDIMENTARY	(Cambrian through Ordovician age)
Black calcareous shale	Utica Shale and upper limestone units of the Trenton Group in and surrounding the West Canada Creek Valley.
Dark gray limestone	Limestone units of the Trenton Group in and surrounding the West Canada Creek Valley.
Light gray limestone	Limestone units of the Black River Group in the West Canada Creek Valley, in valleys to the east, and flanking the Adirondacks.
Dolostone and dolomitic units	Dolostone units of the Beekmantown Group in the West Canada Creek Valley, in valleys to the east, and flanking the Adirondacks.
METAMORPHIC	(Precambrian - the Adirondacks and also minor amounts from Canada)
Light-colored gneiss	Mostly granitic and syenitic gneisses of the Adirondacks.
Dark-colored gneiss	Mostly charnockitic gneiss and amphibolite of the Adirondacks.
Garnetiferous rocks	Red and lavender garnet-bearing gneisses and quartzites of the Adirondacks.
Other metamorphic rock types	Includes mostly quartzite with minor amounts of marble and schist from the Adirondacks.

support an interpretation as annual beds rather than single-event deposits (Ashley, 1975; Smith and Ashley, 1985). Sediment clasts in the varves are several sediment types and are almost exclusively drop sediment.

There are some general provenance differences which can be recognized in the laminated clay, silt, and fine-sand units of the West Canada Valley. Fine-grained deposits of Adirondack provenance are generally sandier than those of Ontario or Mohawk provenance, and they may contain mica, green or blue clay, and green or blue sediment clasts. Clay and silt of Ontario Lobe provenance (Valley Heads Drift) are generally medium gray with faint pink to red tones and contain red and pink sediment clasts. Clay and silt of Mohawk provenance are dark to medium gray and contain only light to dark gray sediment clasts. The declination of detrital remanent magnetization of laminated silt and clay has also been used to categorize stratigraphic units and test correlations (Ridge and others, 1990).

LITHOSTRATIGRAPHY OF THE WEST CANADA CREEK VALLEY

A summary and interpretation of each pre-Valley Heads unit in the West Canada Valley are given below. Appendix 1 includes a detailed written description and facies map of each stratigraphic unit in the West Canada Valley field area that documents (1) all exposures of the units, (2) provenance sample sites, (3) textural facies, (4) the locations and directions of ice flow indicators, and (5) the locations and directions of paleocurrent indicators associated with each unit.*

The Middleville Formation is here defined as all of the pre-Valley Heads deposits currently identified in the West Canada Valley (Fig. 3). It is bounded above by unconformities; its base, where exposed, lies directly on bedrock. Along the axis of the West Canada Valley south of Middleville (Figs. 2 and 3), the top of the Middleville Formation is glaciotectonically deformed and unconformably overlain by a diamicton unit of the Valley Heads Drift (see Table 1-1 of Mickelson and others, 1983). Northwest of Middleville, the top of the Middleville Formation is unconformably overlain by either diamicton of the Valley Heads Drift along a glaciotectonically deformed contact, or glaciolacustrine stratified units of the Valley Heads Drift. The <u>stratified</u> units of the Valley Heads Drift are separated from the Middleville Formation along a highly irregular surface defined as the "Shed Brook Discontinuity" (Ridge, 1985; Ridge and others, 1990). In no place in the West Canada Valley is the Valley Heads Drift conformable with the Middleville Formation.

The Valley Heads Drift (15.5-12.9 ka; Mickelson and others, 1983) has tentatively been assigned to the Port Bruce and Port Huron Stadials (Fullerton, 1980; Franzi, 1984; Muller and Prest, 1985; Ridge, 1985; Muller and others, 1986). The Shed Brook Discontinuity may represent ice recession, lake drainage, and subaerial erosion during the Erie Interstade (Ridge, 1985; Ridge and others, 1990), when lacustrine waters in the Ontario Basin drained east through the Mohawk Valley (Morner and Dreimanis, 1973). If these correlations are correct, the Middleville Formation is at least as old (>15.5 ka) as the Nissouri Stadial (Dreimanis and Karrow, 1972; Dreimanis and Goldthwait, 1973).

*Appendix 1 is Article C this guidebook

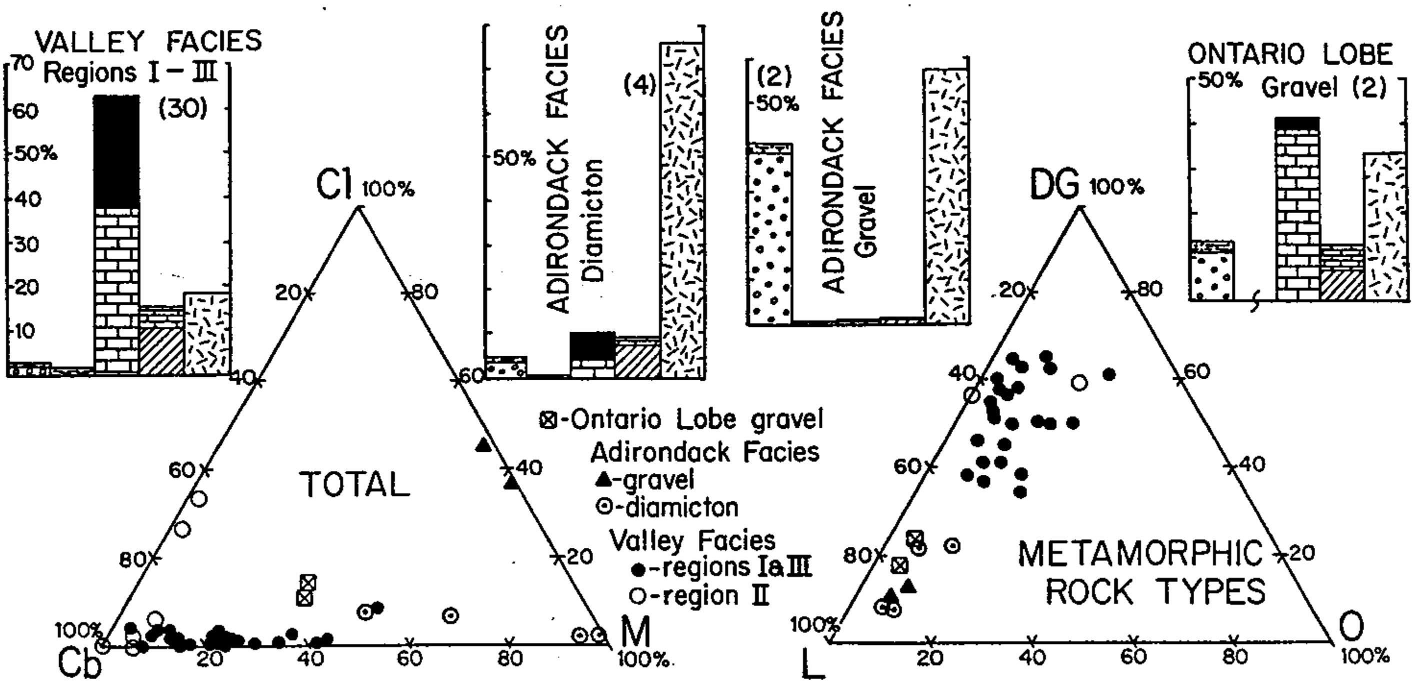


Figure 5. Pebble count data for the valley and Adirondack facies of the White Creek Diamicton. Counts from gravels of the Adirondack facies and for Ontario Lobe gravels of Valley Heads age that occur near the limit of the Adirondack facies are shown for comparison. Histograms of means of pebble counts and triangular plots of total rock types (Table 1) have the same symbols as in Figure 4. The triangular plot of metamorphic rock types (Table 1) shows a comparison of dark-colored gneisses, including charnockitic and garnet-bearing gneisses (DG), with light-colored, mostly granitic gneisses (L), and other metamorphic rock types (O).

The White Creek Diamicton (Valley and Adirondack Facies)

The oldest Pleistocene stratigraphic unit identified in the West Canada Creek Valley is the White Creek Diamicton, which is named for type sections along White Creek (sections 144-149 in Fig. 2). Two distinct facies of the White Creek Diamicton are recognized, the valley and Adirondack facies. The valley facies covers the lower West Canada Valley and the highest elevations of Dairy Hill and the Deerfield Hills (Fig. 1). It has been found only directly overlying bedrock and has an Adirondack provenance that has been diluted by local carbonate rock types (Figs. 4 and 5). Ice-flow indicators associated with the valley facies record early southwest flow followed by south to southeast flow which developed during deglaciation. The Adirondack facies of the White Creek Diamicton occurs northeast of Dairy Hill (Fig. 1) and is composed almost entirely of Adirondack-derived metamorphic rocks and minor sandstone clasts from the north and northeast perimeter of the Adirondacks (Fig. 5). The Adirondack facies is associated with southwest ice-flow indicators, and its limit along the northeastern flank of Dairy Hill is marked by ice-marginal sand and gravel deposits. The boundary between the Adirondack and valley facies of the White Creek Diamicton is represented by an abrupt change in diamicton texture and metamorphic rock types (Fig. 5). In the basal parts of bluff exposures at the Hinckley Reservoir, the Adirondack facies occurs beneath lake beds that have been correlated with the top unit of the lower Newport Beds. The Adirondack facies may represent an Adirondack ice readvance that was synchronous with deposition of the West Canada "A" Diamicton at Newport (Figs. 2 and 3).

The Lower Newport Beds and West Canada "A" Diamicton

The lower Newport Beds are defined as a sequence that consists primarily of laminated silt and clay in the West Canada Valley overlying the White Creek Diamicton (valley facies) and underlying the West Canada Diamicton (Fig. 3). In the West Canada Valley near Newport the West Canada "A" Diamicton occurs between the basal and top units of the lower Newport Beds (Figs. 2 and 3). The basal unit contains paleocurrent indicators that record a change from southeast to northwest flow over time, combined with a provenance change which records an upward transition from an Adirondack ice source to a Mohawk Lobe source. The West Canada "A" Diamicton of Mohawk Lobe provenance is associated with ice flow to the north-northwest (see Fig. 8 of Ridge and others, 1990). The West Canada "A" Diamicton grades laterally to the northwest from a unit with till (sections 144-149, 610-611, and 793 in Fig. 2) to one with only subaqueous diamicton and interbeds of laminated silt and clay of the lower Newport Beds (sections 225-226 and 314-317 in Fig. 2). The top unit of the lower Newport Beds has a Mohawk Lobe provenance and northwest paleocurrent indicators.

West Canada Diamicton and Upper Newport Beds

The West Canada Diamicton has a Mohawk Lobe provenance and is associated with northwest ice-flow indicators defining an extensive Mohawk Lobe readvance. The upper Newport Beds consist predominantly of varves and turbidites with northwest paleocurrent indicators deposited during recession of the Mohawk Lobe. A sequence of sand and gravel with intercalated diamicton beds in the upper Newport Beds at

Figure 6. The Newport Beds at bluff exposures along the southwestern shore of the Hinckley Reservoir (Fig. 1). Dashed lines show contacts between a middle calcareous unit of Mohawk lobe provenance and units above and below which are less calcareous and have a dominantly Adirondack source. Curved contact lines at right show slump scarps draped by younger beds. Beds beneath the scarps are warped due to slight displacement, loading, and compaction beneath beds infilling the scarps. The top of the bluff is a terrace capped by 1-2 m of fluvial pebbly sand of Valley Heads age or younger which sits on an erosion surface cut into the upper Newport Beds.

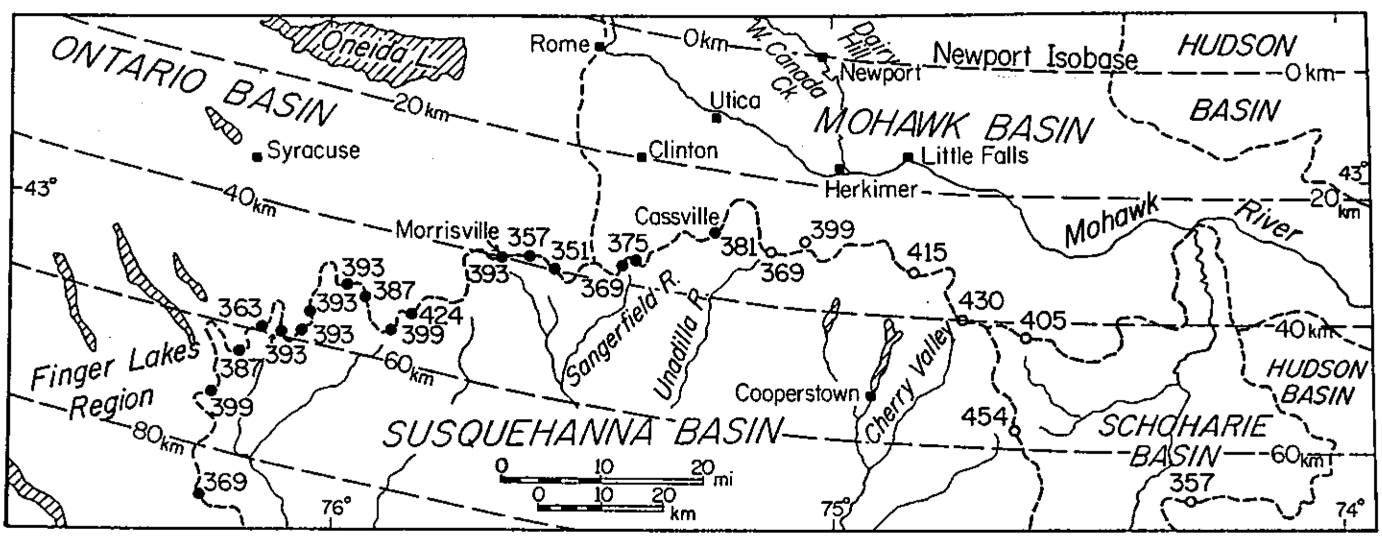


Figure 7. Cols south of the Schoharie, Mohawk, and Ontario basins in central New York. All elevations are given for the present day land surface in meters as converted from feet in U.S. Geological Survey 1:24,000-scale topographic maps. Cols known to be filled with Valley Heads Drift (Randall and others, 1988) are indicated with solid symbols. Inferred isobase trends are shown with isobases spaced 20 km apart, starting in the north with an isobase through Newport. Projections of water planes shown in Figure 8 are perpendicular to inferred isobases.

Middleville (sections 116 and 324 in Fig. 2) represents an esker-subaqueous fan sequence deposited at an ice-recessional position of the Mohawk Lobe. Similar sequences occur in ice-marginal deposits of the Champlain Sea (Sharpe, 1988).

The Newport Beds at the Hinckley Reservoir (Fig. 6) are represented by about 300 varve couplets that span the deposition of the top unit of the lower Newport Beds, the West Canada Diamicton, and the upper Newport Beds in the lower West Canada Valley. This correlation is supported by similar paleomagnetic declinations in both areas (Ridge and others, 1990). The Hinckley Reservoir section records a bottom to top change from Adirondack to Mohawk and back to Adirondack provenance. The changing provenance of the Newport Beds records an oscillation of the Mohawk Lobe, which approached the Hinckley Reservoir area from the south and caused bathymetric changes in the lake basin.

RECONSTRUCTING GLACIAL READVANCES AND LAKES

The limits of pre-Valley Heads glacial readvances in the Mohawk Valley are not delineated by continuous landforms such as end moraines and ice-marginal stratified deposits near the distal margins of diamicton units. Instead, the limits of till, glaciotectonic features, and erosion of lacustrine units by overriding ice in stratigraphic sections (Ridge, 1985) were used to infer the limits of glacial readvances. Deep water (>75 m) ice margins crossing the Mohawk and West Canada valleys were reconstructed as embayed or straight, calving margins and not as lobate ice fronts. The reconstruction of glacial lakes and their outlets at various times is based upon the elevation and areal distribution of lacustrine deposits and estimates of postglacial isostatic tilting. Lake levels inferred from the Newport Beds are minimum estimates because the deposits are subaqueous and no unequivocal pre-Valley Heads strandline features have been identified. The exact elevations of bedrock thresholds along the Appalachian Upland (Fig. 7) that may have served as spillways for lakes in pre-Valley Heads time are uncertain, because the elevations of most cols were topographically lower than their present elevations due to later infilling with Valley Heads Drift (Randall and others, 1988).

The gradient of postglacial isostatic tilting of pre-Valley Heads water planes is not known, but it has to be steeper than the gradient of the Lake Iroquois water plane in the southern Ontario Basin, which post-dates the initiation of isostatic uplift. The southern Lake Iroquois gradient of 0.35-0.4 m/km (Fairchild, 1916, 1917) was measured on post-Valley Heads (<13 ka) features (Fullerton, 1980; Muller and others, 1986) which post-date the Newport Beds by at least 2,500 yr. Water planes in the eastern United States that are younger than, or in part contemporaneous with, the Newport Beds and are at about the same position relative to the edge of the Laurentide ice sheet, have gradients of about 0.7-0.95 m/km (Chapman, 1937; Flint, 1971, p. 360; Denny, 1974; Koteff and Larsen, 1989). Preliminary map analysis of deltas and spillway elevations of glacial Lake Miller (unpub. data), a Valley Heads age lake in the Hinckley Reservoir area (Fullerton, 1971), indicates that tilting since Valley Heads time is 0.74-0.93 m/km. It seems reasonable, therefore, to assume that pre-Valley Heads water planes in the Mohawk Valley should have a tilt of at least 0.74 m/km. Tilting of greater than 1.0 m/km has been inferred northwest of the Adirondacks (Pair, 1986).

The direction of isobases in the western Mohawk Valley is not known, but the valley lies between the Ontario Basin, where initial post-glacial tilting was up to the north-northeast (Fairchild, 1916, 1917; Pair, 1986; Pair and others, 1988), and the Hudson, Champlain, and Connecticut Valleys, where tilting was up to the north-northwest (Chapman, 1937; Flint, 1971; Koteff and Larsen, 1989). A direction of tilting in the western Mohawk Valley, intermediate between those of adjacent areas, is assumed for isobases in Figure 7.

Potential spillways for lakes were identified by projection of the minimum water plane estimates, based on the Newport Beds, perpendicular to the inferred trend of isobases in the Mohawk Valley (Fig. 8). Limits of postglacial tilting were assumed to be 0.7-1.2 m/km in order to compensate for errors in estimating the direction and degree of tilting of hypothetical isobase lines. We were not able to evaluate warping or uplift due to neotectonic activity surrounding the Adirondacks, but existing data seem to indicate that this activity did not cause post-glacial tilting to deviate from 0.7-1.2 m/km.

Projection of the steepest water planes southward from Newport requires the impoundment of lakes in the West Canada Valley by ice in the Mohawk Valley, and subglacial drainage of lakes. Supraglacial drainage of lakes is considered implausible because it would have caused flotation and rapid calving of deep-water margins of ice masses which impounded lakes. Subglacial tunnels would have been outlets that could maintain only transient lake levels, and no evidence has been found for persistent lake levels in the West Canada Valley.

PRE-VALLEY HEADS GLACIATION

The Late Wisconsinan Age of the Middleville Formation

The Terminal Moraine in Pennsylvania (Lewis, 1884; Crowl and Sevon, 1980) represents the limit of late Wisconsinan ice (Sevon, 1974; Berg, 1975; Berg and others, 1977; Marchand, 1978; Berg, 1980; Crowl, 1980; Cotter, 1983; Cotter and others, 1986). Late Wisconsinan ice with even a very low profile, therefore, would have covered the highest elevations of the Mohawk Valley region. The White Creek Diamicton is the oldest glacial unit that has been identified in the western Mohawk Valley, and it is the only unit identified thus far that could represent the advance and initial recession of ice that reached the Terminal Moraine in Pennsylvania. The diamicton is found at the base of thick stratigraphic sections in valley bottoms, and it is surficially exposed at higher elevations. It also lies on striated bedrock that records ice flow across the topographic grain of the region and widespread scour of pre-existing deposits. All younger diamicton units are, by contrast, associated only with ice-flow indicators that delineate local topographic control of ice flow. The younger diamictons are spatially restricted to lowland regions where they terminate, thus indicating glacial readvances of limited extent.

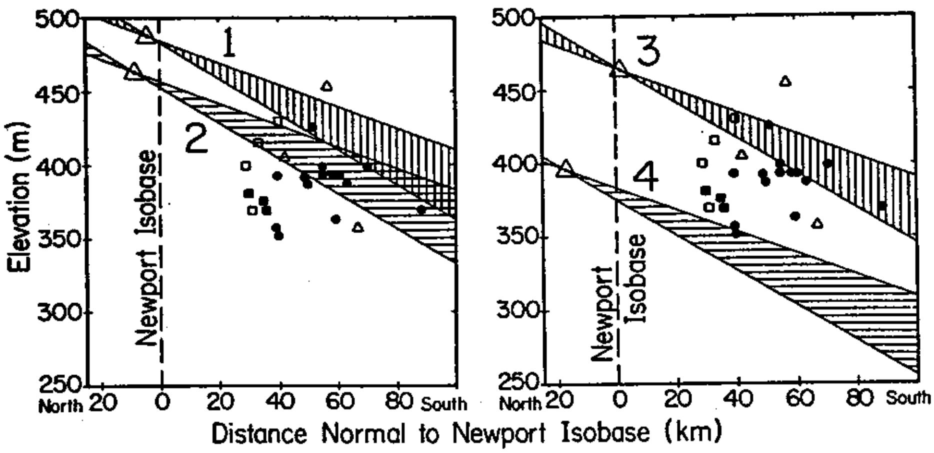


Figure 8. Projected water planes of minimum levels of Lake Newport at four times during pre-Valley Heads deglaciation. The time periods are: (1) during "early" late Wisconsinan ice recession on Dairy Hill (Fig. 9), (2) during the first Mohawk Lobe readvance which deposited the West Canada "A" Diamicton (Fig. 10), (3) during the West Canada Readvance maximum (Fig. 11), and (4) during final pre-Valley Heads recession of the Mohawk Lobe when subaerial drainage of Lake Newport was established across the Appalachian Upland (Fig. 12). Minimum elevations for lakes in the West Canada Valley area are the highest occurrences of subaqueous sediments (large triangles) deposited at times 1 thru 4. Water planes are projected perpendicular to inferred isobases (Fig. 7). Minimum water plane envelopes have assumed gradients of 0.7 m/km (less steep) to 1.2 m/km (steeper line). Positions and lowest elevations of cols on the Appalachian Upland are plotted (circles = cols between Ontario and Susquehanna basins; squares = cols between Mohawk and Susquehanna basins; small triangles = cols between the Schoharie and other basins). Solid symbols indicate cols known to be filled with an uncertain thickness of Valley Heads Drift (Randall and others, 1988).

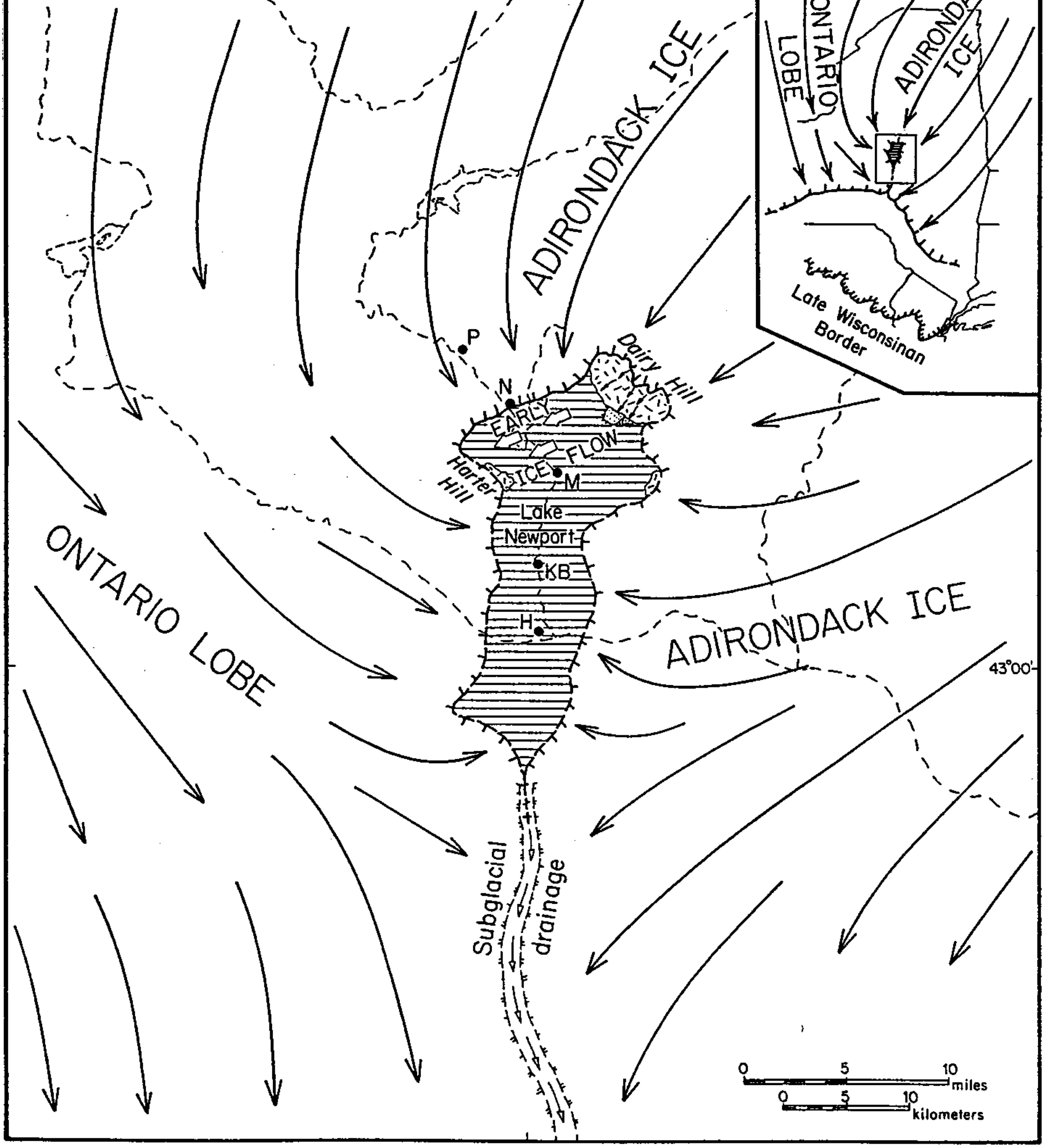


Figure 9. "Early" late Wisconsinan deglaciation. An inferred reconstruction of ice lobes, ice-flow directions, and approximate shorelines and an outflow stream of Lake Newport during the initial late Wisconsinan deglaciation of the western Mohawk Valley. The deposition of the basal unit of the lower Newport Beds occurred in the West Canada Valley at this time. The exact position of contemporaneous ice lobes during ice recession is not known. The direction of earlier overflow by Adirondack ice as indicated by ice flow indicators in the lower White Creek valley is shown with large open arrows. Small arrows on Dairy Hill show meltwater channels. Area shown is the same as in Figure 1. Place names in the West Canada Valley are abbreviated (H = Herkimer, KB = Kast Bridge, M = Middleville, N = Newport, and P = Poland).

The White Creek Diamicton is the youngest diamicton that could represent a more extensive glaciation than a readvance that terminated in the West Canada Valley. Because it is surficially exposed at the highest elevations in the western Mohawk Valley region which was completely covered by late Wisconsinan ice, the White Creek Diamicton must be late Wisconsinan in age. The White Creek Diamicton represents either deposition by late Wisconsinan ice that advanced to the Terminal Moraine or deposition during early recession. Units tentatively assigned to middle or early Wisconsinan events (Fullerton, 1971) are here recognized as part of the late Wisconsinan Middleville Formation.

Initial Late Wisconsinan Recession of Adirondack Ice

The oldest record of late Wisconsinan ice flow across the West Canada Valley (Fig. 9) is southwest-trending striations at the base of the White Creek Diamicton near Newport (sections 144-149 and 610-611 in Fig. 2). Initial thinning of ice is recorded by ice-stagnation deposits and meltwater channels that carried water to the southwest across the top of Dairy Hill. Locally controlled south-to-southeast ice flow first developed in the West Canada Valley as Dairy Hill impeded southwest flow from the Adirondacks, and the emerging Tug Hill and Deerfield Hills channelized ice into adjacent lowlands. Deposition of lake bottom deposits of the basal unit of the lower Newport Beds, into what is here named "Lake Newport", first occurred in the West Canada Valley near White Creek (bottom of unit 1Nb in Fig. 2) and followed northward ice recession. Any controlling bedrock threshold for Lake Newport would have been as high as lacustrine sand on Dairy Hill at 488 m (Fig. 9), which represents a minimum level of Lake Newport. Projected minimum water level estimates for Lake Newport (time 1 in Fig. 8) lie above all but three cols on the Appalachian Upland. Two of these cols in the eastern Finger Lakes region are presently filled with Valley Heads deposits (Randall and others, 1988) and were too low to have served as spillways for Lake Newport. They would, also, have been blocked by ice that prevented drainage through adjacent cols which were too low to have controlled the level of Lake Newport. Mohawk ice, which must have blocked cols that were otherwise too low to have controlled the level of Lake Newport, would also have blocked the third col between the Schoharie and Susquehanna Basins. Drainage of Lake Newport to the Susquehanna Basin, therefore, must have been beneath ice in the Mohawk Valley. The extent of ice recession in the lower West Canada Valley prior to any readvances is not known because of the limited exposure of the basal unit of the lower Newport Beds, but ice receded at least to Middleville.

The First Mohawk Lobe Readvance and Adirondack Ice Recession

The first Mohawk Lobe readvance in the West Canada Valley deposited the West Canada "A" Diamicton (Fig. 10). This readvance may have been only a minor oscillation, because exposures of till and deformed lacustrine sediments of the basal unit of the lower Newport Beds are limited to an area between Middleville and Newport. Deposition of the Adirondack facies of the White Creek Diamicton by southwest-flowing Adirondack ice northeast of Dairy Hill coincided with deposition of the lower Newport Beds and probably the West Canada "A" Diamicton (Fig. 3). Deposition of the Adirondack facies represents at least a change in flow direction, if not a readvance of

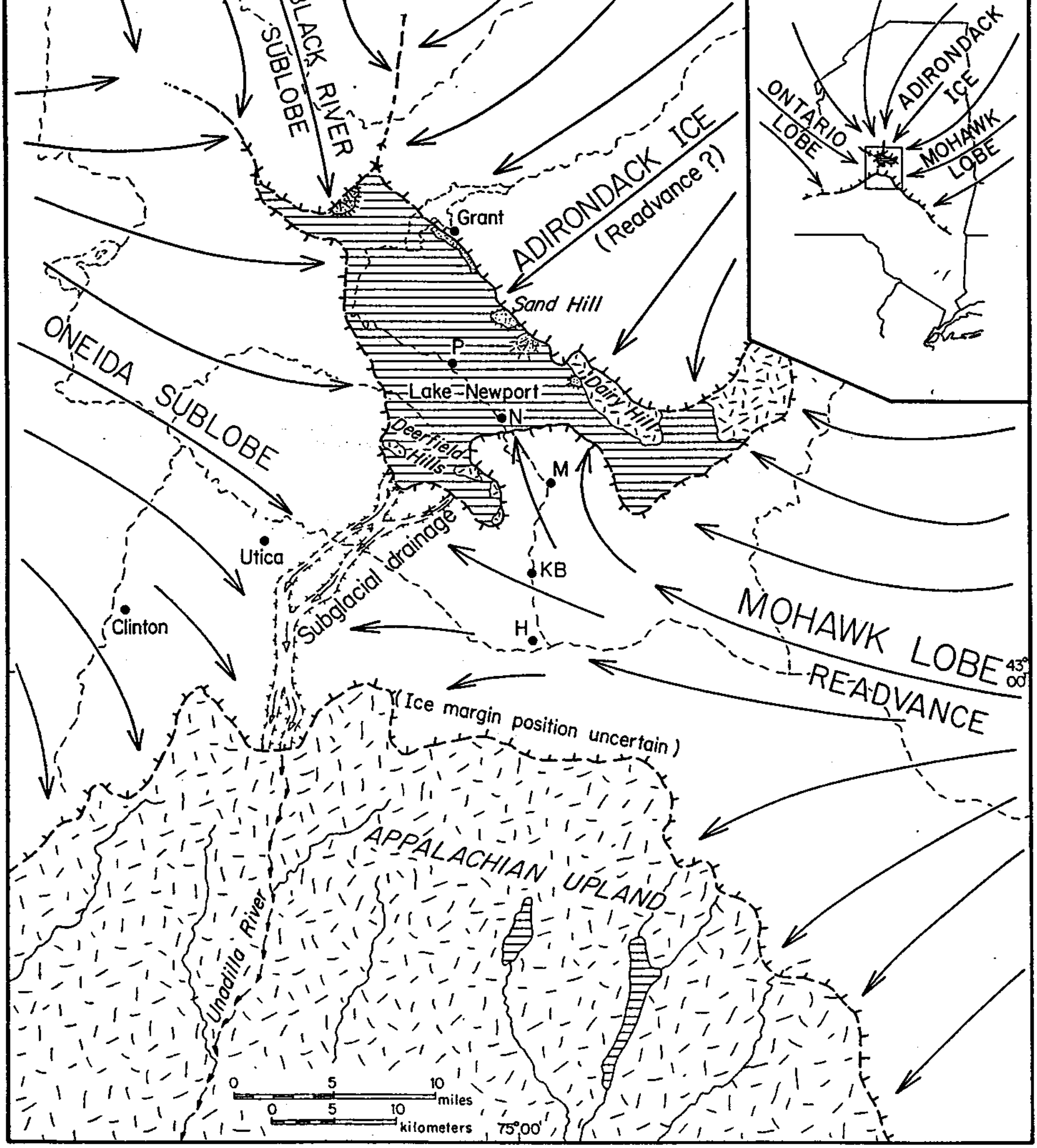


Figure 10. **First readvance of the Mohawk Lobe.** An inferred reconstruction of ice lobes, ice flow directions, and approximate shorelines and an outflow stream of Lake Newport during a small readvance of the Mohawk Lobe which deposited the West Canada "A" Diamicton. Adirondack ice is covering the Adirondack facies of the White Creek Diamicton. Ice-contact deltas northwest of the Hinckley Reservoir mark a possible position of the Black River Sublobe. The exact positions of the Oneida Sublobe and ice along the Appalachian Upland are not accurately known. Area shown is the same as on Figure 1.

Place names in the West Canada Valley are abbreviated as on Figure 9.

Adirondack ice. The limit of the Adirondack facies coincides with ice-marginal, sand and gravel deposits of Adirondack provenance that extend from Dairy Hill to the Hinckley Reservoir at Grant and reach an elevation of 463 m (Fig. 10; Franzi, 1984). These deposits are subaqueous and are the basis for minimum lake-level reconstruction. The Black River Sublobe may have occupied or readvanced to an ice-contact position delineated by deltaic gravels northwest of the Hinckley Reservoir which are at about the same elevation as subaqueous stratified deposits at the margin of Adirondack ice (Fig. 10; Franzi, 1984). At the front of the Mohawk Lobe at Newport, water depths were at least 240 m. Several cols on the Appalachian Upland fall in the range of water planes projected from Dairy Hill perpendicular to assumed isobases (time 2 in Fig. 8). Cols high enough to serve as spillways leading from the Schoharie and Mohawk Basins into the Susquehanna or Hudson Basins were blocked by the Mohawk Lobe. Presence of the Mohawk Lobe was required to prevent drainage through cols that were too low to serve as spillways for Lake Newport. Ice was also required to block outlets from the Ontario Basin at Morrisville and sites to the east that were too low to serve as spillways for Lake Newport. Lake Newport probably drained subglacially to the Susquehanna Basin (Fig. 10), because it is unlikely that the Ontario Lobe receded enough to allow drainage over cols west of Morrisville. This latter possibility cannot be eliminated, however, because of the uncertain positions of the Mohawk and Ontario lobes in the Mohawk Valley. The extent of withdrawal of the Mohawk Lobe following readvance is not known, but it is marked by the deposition of the top unit of the lower Newport Beds as far south as Middleville (unit 1Nt in Fig. 2 and 3). Recession of the Mohawk Lobe may have allowed Lake Newport to temporarily drain to a lower level.

The West Canada Readvance

A second larger Mohawk Lobe readvance deposited the West Canada Diamicton from south of Middleville to northwest of Newport and is here named the "West Canada Readvance" (Fig. 11). The limit of the readvance is partially marked by end moraines and ice-contact, subaqueous sand and gravel at the south end of Dairy Hill. This ice-front position appears to be continuous with ice-contact sand and gravel deposits that reach an elevation of 469 m and extend east to the Adirondacks. A continuous sequence of the lower and upper Newport Beds at the Hinckley Reservoir indicates that Adirondack ice did not cover that area during the West Canada Readvance.

The Cassville-Cooperstown Moraine south of the Mohawk Valley (Krall, 1977; Fleisher, 1986) is tentatively correlated to the West Canada Readvance (Fig. 11). This correlation is based upon the southward projection of the elevations of ice-marginal deposits at Dairy Hill along the inferred isostatic rebound gradients (0.7-1.2 m/km) and the fact that the Cassville-Cooperstown Moraine has been inferred to represent the limit of a glacial readvance (Fleisher, 1986). The West Canada Readvance is the most extensive Mohawk Lobe readvance in the West Canada Valley, and thus the Mohawk Lobe may have also extended farther west in the Mohawk Valley than at any other time unless it was blocked by the Ontario Lobe. Till with Mohawk

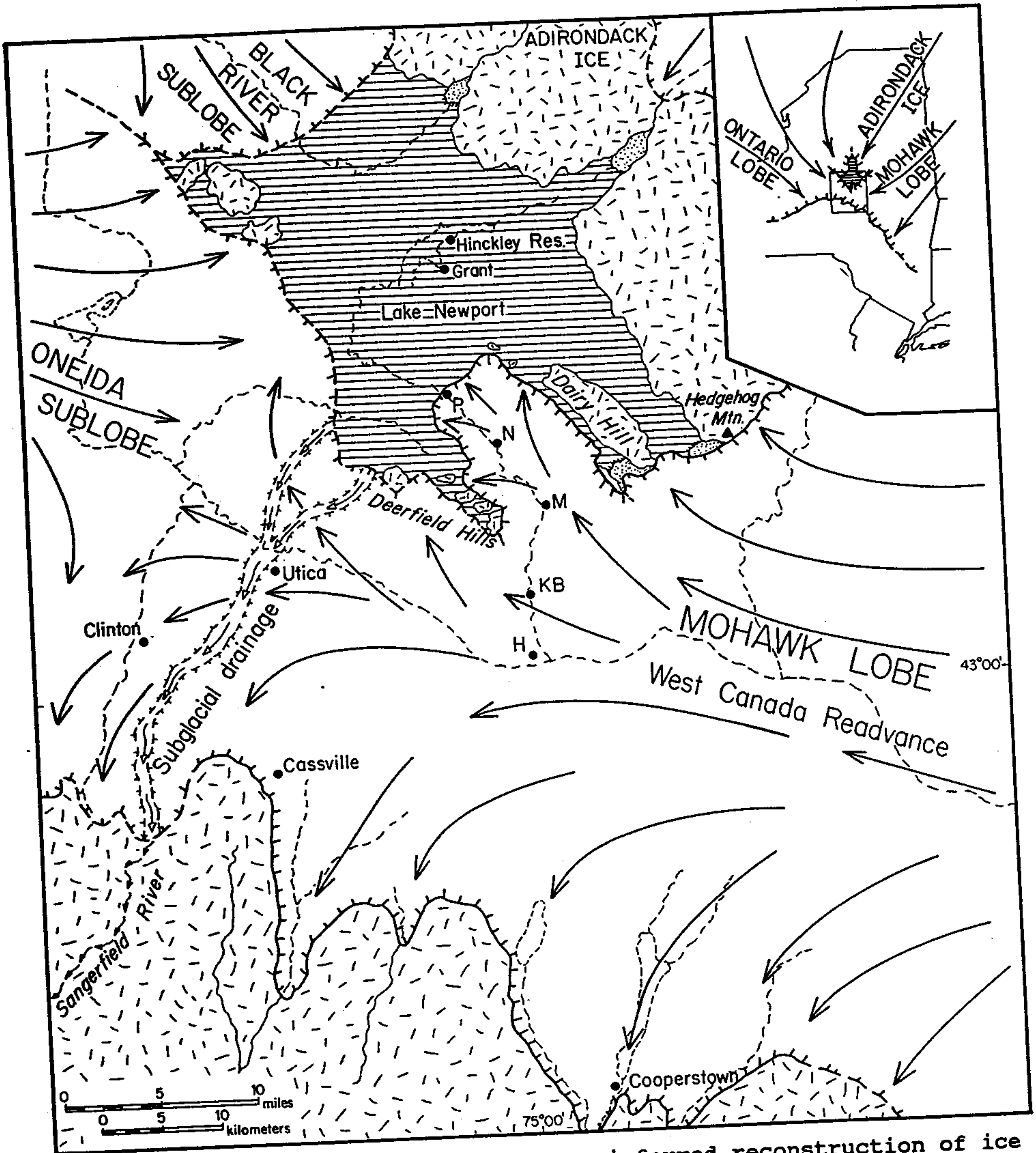


Figure 11. West Canada Readvance. An inferred reconstruction of ice lobes, ice-flow directions, and approximate shorelines and an outflow stream of Lake Newport at the maximum extent of the West Canada Readvance. The margin of the Mohawk Lobe along the Appalachian Upland is inferred to be the Cassville-Cooperstown Moraine (Krall, 1977; Fleisher, 1986). The exact positions of the Black River and Oneida Sublobes are not known. Area shown is the same as in Figure 1. Place names in the West Canada Valley are abbreviated as in Figure 9.

provenance in the Oriskany Valley (Fig. 11) records the last penetration of southwest-flowing ice as far west as Clinton (Krall, 1977, 1984) no later than the West Canada Readvance.

Lake Newport was impounded to at least 463 m at the maximum extent of the West Canada Readvance as recorded by deltaic sand at the south end of Dairy Hill (Fig. 11). Water depths at Newport would have been at least 220 m. Projected water planes (time 3 in Fig. 8) indicate that four cols on the Susquehanna drainage divide are high enough to have served as outlets for Lake Newport. All of these cols were blocked by ice required to block cols that were too low to have been spillways for Lake Newport. The cols on the eastern portion of the divide were blocked by the Mohawk Lobe, which is inferred to have reached its southwestern limit at the Cassville-Cooperstown Moraine (Krall, 1977; Fleisher, 1986). The cols west of the inferred maximum extent of the Mohawk Lobe would have been blocked by the Ontario Lobe. The terminal margins of the Mohawk and Ontario Lobes probably coalesced somewhere near Clinton (Fig. 11) where drainage of Lake Newport probably occurred through subglacial channels. A lack of conspicuous strandline features from Lake Newport north of the ice dam is consistent with the unstable nature of subglacial lake drainage.

The eastern extent of the Ontario Lobe at the time of the West Canada Readvance is constrained by the paleogeography of Lake Newport and the position of the Mohawk Lobe as discussed above. The Ontario Lobe did not extend as far east as during later Valley Heads events when it advanced unrestricted by the Mohawk Lobe to positions east of Little Falls and into the West Canada Valley (Fig. 1; Fullerton, 1971; 1980; Franzi, 1984; Ridge, 1985; Muller and others, 1986).

Final Pre-Valley Heads Mohawk Lobe Recession

Recession of the Mohawk Lobe from the West Canada Valley is recorded by deposition of the upper Newport Beds. Lake Newport lasted for at least 150 yr after the onset of recession of the Mohawk Lobe (Fig. 3), during which time it remained with a surface elevation of at least 396 m at the Hinckley Reservoir. Minimum water plane elevations projected from the Hinckley Reservoir (time 4 in Fig. 8) indicate that ice recession could have allowed Lake Newport to drain into the Susquehanna Basin over one of a number of cols on the Appalachian Upland. The initial subaerial drainage of Lake Newport is hypothetically shown over a col into the Sangerfield River (Fig. 12) because this col would have been close to the position of lowest ice elevation at the coalescent margins of the Ontario and Mohawk Lobes. The exact position of this drainage remains unknown because of uncertainties in the position of the Mohawk Lobe during recession, the exact amount of isostatic tilting, and the elevations of bedrock thresholds presently filled with Valley Heads Drift.

Ice-marginal subaqueous fan deposits in the base of the upper Newport Beds at Middleville (sections 116 and 324 in Fig. 2) represent either a stillstand of the receding ice front that stabilized against a dolostone high, or stabilization brought on by a drop in lake level. A drop of at least 75 m in the level of Lake Newport at the initiation of subaerial drainage across the Appalachian Upland would have caused a sudden steepening of subglacial hydraulic gradients of the Mohawk Lobe. Steepening of hydraulic gradients may have caused enormous

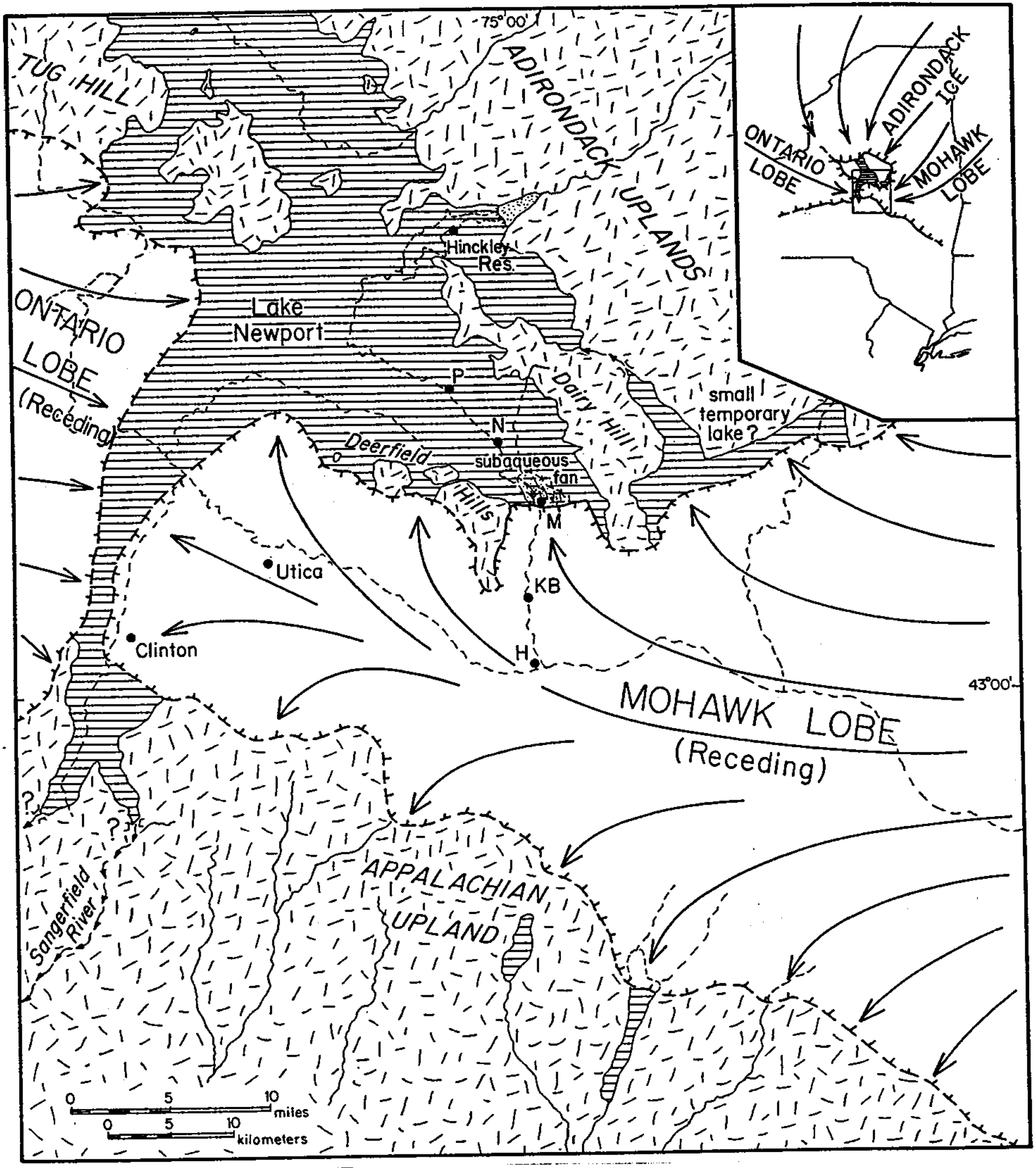


Figure 12. **Recession following the West Canada Readvance.** An inferred reconstruction of ice lobes, ice-flow directions, and approximate shorelines and an outflow stream of Lake Newport during recession of the Mohawk Lobe from the West Canada Readvance limit. A large subaqueous fan in the upper Newport Beds, deposited at the margin of the Mohawk Lobe in the West Canada Valley, may represent subglacial meltwater discharges associated with a sudden drop in lake level and ice-front grounding when subaerial drainage of Lake Newport was established over cols on the Appalachian Upland. The exact positions of the Ontario Mohawk lobes along the Appalachian Upland are uncertain. Area shown is the same as in Figure 1. Place names in the West Canada Valley are abbreviated as on Figure 9.

subglacial meltwater discharges from the Mohawk Lobe that produced the subaqueous fan at Middleville (Fig. 12). It has been suggested that similar fan deposits from the Champlain Sea (Sharpe, 1988) and glacial Lake Agassiz (Sharpe, 1990) may be the result of large meltwater discharges associated with surges. Further recession of the Mohawk and Ontario Lobes caused drops in the level of Lake Newport as lower cols on the Appalachian Upland became uncovered. Subaerial erosion recorded by the Shed Brook Discontinuity occurred after lake drainage in the West Canada Valley (Ridge, 1985; Ridge and others, 1990).

CONCLUSIONS

During pre-Valley Heads deglaciation, southwest flow of ice across the Adirondacks and into the Mohawk Valley gave way to topographically controlled south-southeast-flowing ice from the Adirondacks and the Black River Lowland. Northward recession of ice in the West Canada Valley was followed by Mohawk Lobe readvances and continued southwest flow of Adirondack ice into the upper West Canada Valley. Lake Newport was impounded in the West Canada Valley and initially drained through subglacial channels beneath ice in the Mohawk Valley. Final Mohawk Lobe recession in pre-Valley Heads time allowed subaerial drainage of Lake Newport across cols on the Appalachian Upland.

Several aspects of the style of deglaciation of the western Mohawk Valley can be deduced from the data gathered in this study. The Adirondacks emerged from Laurentide ice after initial deglaciation of adjacent lowlands. The flow of Adirondack ice into the upper West Canada Valley continued well after the formation of proglacial lakes and lowland ice lobes in the West Canada and Mohawk Valleys. Either the Adirondacks did not prevent overflow of Laurentide ice, or an Adirondack ice dome formed during deglaciation. At least two oscillations of the Mohawk Lobe demonstrate that it was active during deglaciation. Deglaciation of the lowlands southwest of the Adirondacks was predominantly by the calving of active ice rather than by downwasting and regional stagnation. As deep lakes (up to 350 m) developed at the margins of the Mohawk and Ontario Lobes, a calving embayment may have triggered surging and drawdown of interior ice leading to rapid ice recession prior to Valley Heads readvances. Possible surging of receding ice in the western Mohawk Valley is consistent with the overall rapid recession and oscillation of the Mohawk Lobe during pre-Valley Heads deglaciation.

Although Adirondack ice dominated early pre-Valley Heads deglaciation in the West Canada Valley, it eventually gave way to dominance by the Mohawk Lobe. Significant readvances of the Ontario Lobe did not penetrate the Mohawk Valley until Valley Heads time, when they were no longer impeded by the Mohawk Lobe. The Mohawk and Ontario Lobes shared a common source but may have been differently affected by ice flow from the Adirondacks. Although no conclusive field evidence demonstrates the existence of an Adirondack ice dome, a dome has been inferred in several glaciation models (Coates and Kirkland, 1974; Denton and Hughes, 1981; Hughes and others, 1985; Hughes, 1987; Gadd, 1988). The change in dominance from eastern to western ice lobes from pre-Valley Heads to Valley Heads deglaciation may reflect a diminished Adirondack ice dome that fed the Mohawk Lobe or changing ice-flow conditions in the eastern St. Lawrence Lowland. Development of a calving bay in the eastern St. Lawrence before 14 ka (Denton and Hughes, 1981; Hughes and others, 1985; Hughes, 1987) may have diminished ice supply to the Hudson-Champlain and Mohawk Lobes starting in early Valley Heads time. Development of an ice saddle in the St. Lawrence, caused by drawdown to a marine calving embayment to the east, and surging of an Ontario lobe ice stream in response to development of a deep water lacustrine margin may account for the extensive Valley Heads Readvances of the Ontario Lobe (Hughes and others, 1985; Hughes, 1987).

Although climatic warming probably triggered the overall recession of ice from the late Wisconsinan maximum position, non climatic glaciological changes may better account for the oscillatory pattern and mode of ice recession during pre-Valley Heads deglaciation. The placement of Mohawk Lobe events into the stadial-interstadial framework for the Erie and Ontario Basins (Dreimanis and Karrow, 1972; Dreimanis and Goldthwait, 1973) may not be justified. Such correlation implies a synchronous climatic control on glacial oscillations of the Mohawk and Ontario lobes that underemphasizes the influence of non synchronous glaciological controls on the readvances of different ice lobes. Oscillations of glaciers terminating at terrestrial ice margins are more closely controlled by climatic change than are oscillations of glaciers with marine-ice margins (Hughes and others, 1985; Hughes, 1987). Deep ice-marginal lakes, like those in central New York during late Wisconsinan ice recession, may have influenced ice-sheet dynamics much as do marine margins, particularly as they relate to calving, drawdown, and surging during ice recession (Denton and Hughes, 1981; Hughes, 1987; Mickelson, 1987; Teller, 1987). The rapid readvances which occurred in the Mohawk Valley and in other areas with deep ice-marginal lakes are more likely to be functions of rapid glaciological changes than of oscillatory climatic change.

ACKNOWLEDGMENTS

This study was funded in part by grants from the Geological Society of America, Sigma Xi, and the Senate Research Committee of Syracuse University. Field support was provided by the Department of Geology at Syracuse University and the New York State Geological Survey. Computer facilities were provided by the Academic Computing Center at Syracuse University and by Tufts University. We thank Parker E. Calkin and G. Gordon Connally for critical field discussions. Gail M. Ashley, Donald H. Cadwell, and Edward B. Evenson deserve special thanks for reviews which led to significant improvements.

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MANUSCRIPT RECEIVED BY SOCIETY FEBRUARY 9, 1990
REVISED MANUSCRIPT RECEIVED JANUARY 17, 1991
MANUSCRIPT ACCEPTED JANUARY 21, 1991

APPENDIX 1

Detailed descriptions and data from lithostratigraphic units of the Middleville Formation (Late Wisconsinan) in the West Canada Valley of central New York.

INTRODUCTION

This appendix gives complete descriptions and data sets for each of the diamicton and stratified units of the Middleville Formation in more detail than is possible in the associated journal article (Article 6). Figures and the table in the main article are referred to by number and figures of this appendix have numbers preceded with an "A" (e.g. Figs. A1, A2, etc.).

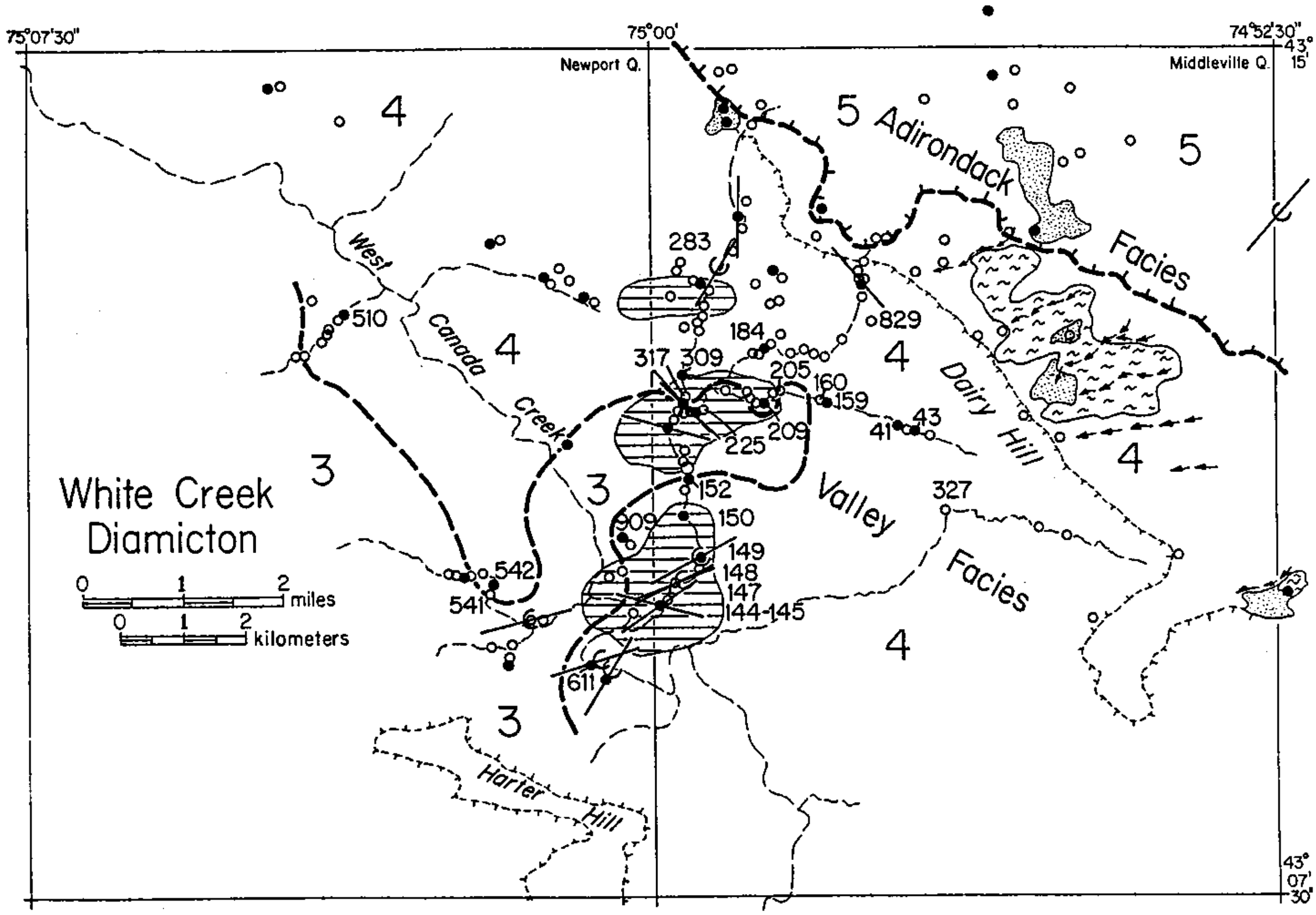
For each stratigraphic unit of the Middleville Formation a figure has been prepared that consists of a reduced map of the Middleville, Newport, and parts of the Herkimer, NY 7.5-minute quadrangles (U.S. Geological Survey, 1:24,000-scale) showing all of the data that is summarized and used to make interpretations in the journal article. Maps for all the units show the locations of exposures and numbered stratigraphic sections on Figure 2. Maps of diamicton units include textural facies, ice flow indicators, and special features associated with diamictons such as areas of topographic relief on a diamicton surface, morainic topography, meltwater channels, and ice-marginal sand and gravel deposits. Two-dimensional clast fabrics were obtained by measuring the long-axis trend of at least 50 stones with long-axes of 1.5 to 25 cm and a long- to intermediate-axis ratio of at least 1.5:1. The two-dimensional vector analysis of Curray (1956), that has also been used by Krall (1977) in the Mohawk Valley, was employed for 10-degree increments to determine the mean orientation of clasts. Maps of stratified units include areas of sand and gravel facies, paleocurrent data, and the approximate outlines of inferred minimum lake levels.

THE WHITE CREEK DIAMICTON

The oldest Pleistocene stratigraphic unit that has been identified in the West Canada Valley is the White Creek Diamicton (Fig. 3) which is named for type exposures along White Creek (sections 144-149 in Figs. 2 and A1). Two distinct facies of the White Creek Diamicton are recognized, the valley and Adirondack facies.

Valley Facies of White Creek Diamicton

The valley facies is a moderately to very stony diamicton with a clayey silty sand to sandy clayey silt matrix (Figs. 2, 3, and A1). The valley facies is exposed in the West Canada Valley from the area of White Creek, where it is as thick as 25 m, to west of Poland. The valley facies is surficially exposed on Dairy Hill, where it has associated ice stagnation deposits, and on Harter Hill. South of Middleville, diamicton units that are at least in part younger than



75°07'30"
75°00'
74°52'30"
43° 15'
43° 07' 30"
Newport Q.
Middleville Q.
Adirondack Facies
Dairy Hill
Valley Facies
West Canada Creek
Harter Hill
White Creek Diamicton
0 1 2 miles
0 1 2 kilometers
3
4
5
283
510
184
317
309
205
160
159
829
43
41
225
209
152
327
150
909
149
148
147
144-145
542
541
6
611

EXPLANATION

EXPOSURES AND DIRECTIONAL DATA

○ ● - sites of detailed field description (dark circle = pebble count site).

283 - measured section number (Fig. 2).

- trend of pebble fabric.

- azimuth of bedrock striations or grooves on diamicton surface.

DIAMICTON TEXTURE

- approximate boundaries of textures.

- southwestern limit of Adirondack facies and texture 5.

3 - moderately stony with sandy, clayey silt matrix.

4 - moderately to very stony with sandy silt matrix.

5 - very stony with sand matrix.

OTHER FEATURES

(covered) - limit of cover of White Creek by younger diamicton units.

- areas of more than 10 m of relief on diamicton surface.

- ice stagnation and morainic topography.

- sand and gravel.

- meltwater channel.

Figure A1. Distribution of exposures, and textural and directional data for the White Creek Diamicton in the West Canada Valley. Shown are both the valley and Adirondack facies of the unit. Numbered sections are shown in Figure 2.

the White Creek Diamicton were found overlying striated bedrock (section 942 in Fig. 2) and in this area the White Creek Diamicton may have been removed by later readvances.

The basal portion of the valley facies is massive, generally very stony, shows no evidence of incorporation of older stratified clay and silt beds, and is interpreted as subglacial till. The upper portion of the valley facies may be composed of up to 10 m of proglacial diamicton beds which grade into the lower Newport Beds (sections 144-149 in Fig. 2). The valley facies is the sandiest, has the highest percentages of metamorphic pebbles and has the lowest percentages of coarse clastic and non-calcareous shale pebbles of all diamictons in the lower West Canada Valley (Fig. 4). Metamorphic pebbles in the valley facies show a decrease in abundance from north to south. The unit also has the highest percentages of dolostone pebbles derived from rock units exposed along the axis of the West Canada Valley and along the perimeter of the Adirondacks. Diamictons deposited during later ice advances have less dolostone because the White Creek Diamicton covers most dolostone exposures. Abundant metamorphic pebbles (Figs. 4 and 5), the sandy and stony character of the diamicton and south-southeast to southwest ice striation directions at the base of the unit (Fig. A1) all indicate an Adirondack source.

The valley facies has only been found overlying bedrock which indicates that ice scour was probably extensive prior to deposition. Ice flow indicators including pebble fabrics in the massive diamicton which are approximately parallel to ice striations (S68W at section 144 in Fig. 2) and grooving on the surface of till (S72W at section 145 in Fig. 2) indicate southwest flow from the Adirondacks across the grain of the topography in the lower White Creek valley during ice recession. South-southeast fabrics and striations associated with the White Creek Diamicton in the upper White Creek valley indicate topographically controlled ice flow from the Black River Lowland and western Adirondacks that developed during a later phase of ice recession.

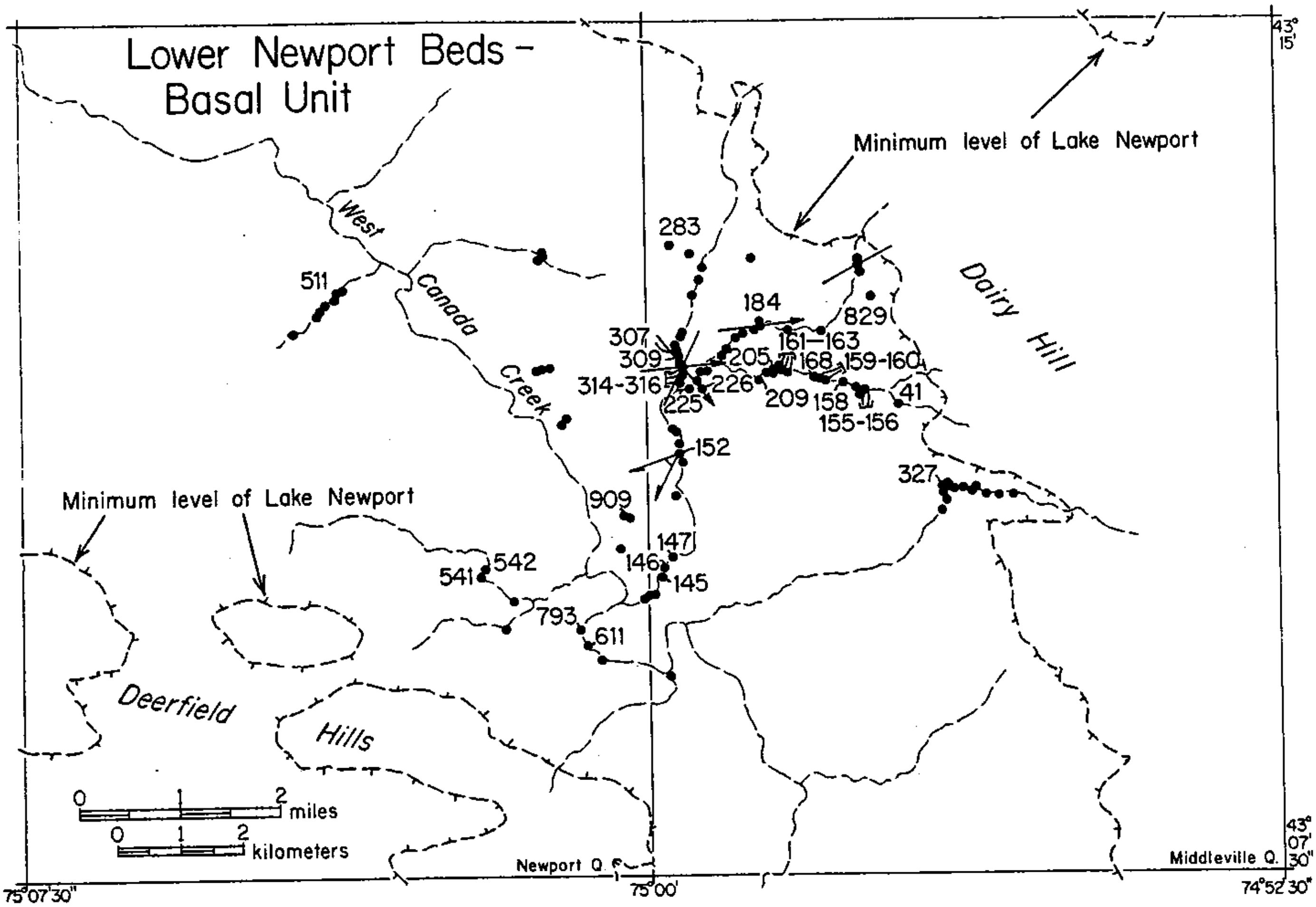
In some areas, the upper surface of the valley facies in the White Creek valley has a relief of more than 15 m over distances of less than 50 m (Fig. A1). The upper surface of the unit in these areas has the form of elongate hills that are separated by basins in which lacustrine ponding is recorded by sand, silt, and clay of the lower Newport Beds. The hills are composed of massive diamicton, are elongate transverse to ice flow indicators, and are interpreted to be subglacial till ridges.

Adirondack Facies of the White Creek Diamicton

The Adirondack facies occurs on the northeast flank of Dairy Hill (Fig. A1) and is a stony, sandy diamicton. The Adirondack facies has mostly Adirondack-derived metamorphic pebbles (Fig. 5) and generally less than 5% mud in its matrix. Striated bedrock at several sites associated with the Adirondack facies (eastern border of the Middleville Quadrangle in Fig. A1 and others further east and northeast in the Adirondacks) indicate southwest ice flow which is perpendicular to the boundary between the valley and Adirondack facies. The distinct boundary between the valley and Adirondack facies suggests that they are separate units, but no stratigraphic section has been found that clearly demonstrates the superposition of the two facies. Ice-contact deltaic deposits occur along the Adirondack facies margin (Fig. A1). There is an abrupt change in matrix grain size, overall pebble types, and metamorphic pebble types across the facies boundary (Fig. 5). Metamorphic pebbles in the Adirondack facies are dominated by 60-90% light-colored, granitic gneisses, and the valley facies has less than 60% light-colored gneisses and 30-70% garnetiferous and dark charnockitic gneisses. Pebbles in the Adirondack facies indicate a source in the Adirondacks immediately adjacent to Dairy Hill. Pebbles in the valley facies indicate a source in the western Adirondacks north to northwest of the Hinckley Reservoir (Fig. 1).

Ice-marginal stratified deposits at the limit of the Adirondack facies (Adirondack facies gravel in Fig. 5) contain almost exclusively coarse clastic and metamorphic pebbles. The low percentages of carbonate pebbles (<5%) in these deposits are mostly dolostone which crops out along the southwest perimeter of the Adirondacks. Less than 1% of all pebbles are limestone and calcareous shale. Metamorphic pebbles in the stratified deposits are similar to those in the Adirondack facies diamicton. Ontario Lobe gravels of Valley Heads age near the Adirondack facies limit also contain coarse clastic pebbles but much lower percentages of metamorphic pebbles and abundant dark gray limestone pebbles derived from the Trenton Group to the west (Table 1; Ontario Lobe gravel in Fig. 5). Abundant metamorphic and scarce limestone and calcareous shale pebbles in the stratified deposits at the Adirondack facies boundary indicate that these deposits must have been derived from an Adirondack rather than an Ontario ice source. The coarse clastic rocks in the deposits are derived from sandstone outcrops on the north and northeast sides of the Adirondacks and not from Paleozoic rocks to the west. Regional overflow of ice across the Adirondacks or subglacial fluvial activity may have transported the clastic rock types to the southwestern corner of the Adirondacks. Metamorphic pebbles in Ontario Lobe gravels are the same types as in the Adirondack facies diamicton and gravel and they are probably derived from the reworking of Adirondack deposits northwest of Dairy Hill along a Valley Heads readvance limit (Indian Castle Readvance of Fullerton, 1971).

The Adirondack facies of the White Creek Diamicton cannot be younger than the top unit of the lower Newport Beds which is exposed north-northwest of Dairy Hill at the eastern end of the Hinckley Reservoir and was not overridden by ice (Franzi, 1984). The eastern Hinckley Reservoir area would have been covered by ice that deposited the Adirondack facies at Dairy Hill. The base of the top unit of the lower Newport Beds at the Hinckley Reservoir overlies a sandy diamicton of Adirondack provenance which is interpreted to be the Adirondack facies. The Adirondack facies is probably contemporaneous with the West Canada "A" Diamicton or some part of the basal unit of the lower Newport Beds in the lower West Canada Valley (Figs. 2 and 3).


Lower Newport Beds - Basal Unit
West Canada Creek
Dairy Hill
Deerfield Hills
Minimum level of Lake Newport
Minimum level of Lake Newport
283
511
184
829
307
309
161—163
205
168
159-160
314-316
226
209
158
41
225
155-156
152
327
909
147
146
145
542
541
793
611
0 1 2 miles
0 1 2 kilometers
Newport Q.
Middleville Q.
43° 15'
43° 07' 30"
75°07'30"
75°00'
74°52'30"

EXPLANATION

● - site of detailed field description.

793 - measured section number (Fig. 2).

 - paleocurrent trend or azimuth inferred from parting lineation.

 - range of paleocurrent directions inferred from crossbedding.

Figure A2. Distribution of exposures and directional data of the basal unit of the lower Newport Beds in the West Canada Valley. Numbered sections are shown in Figure 2.

LOWER NEWPORT BEDS AND WEST CANADA "A" DIAMICTON

The lower Newport Beds (Figs. 2 and 3) are exposed along West Canada Creek and its tributaries from Poland to White Creek (Fig. A2). The West Canada "A" Diamicton (Figs. 2, 3, and A3) separates the basal and top units of the lower Newport Beds along the lower reaches of White Creek (sections 144-149 in Fig. 2) and in exposures along West Canada Creek (sections 610-611 and 793 in Fig. 2).

Basal Unit of the Lower Newport Beds

The lower half of the basal unit of the lower Newport Beds is composed mostly of upward thinning, rhythmic couplets of medium to dark gray, laminated, micrograded, muddy fine sand and bluish to greenish gray clay of Adirondack provenance. The unit also contains poorly sorted gravel, megarippled sand, rippled fine to medium sand, and massive muddy sand beds where it is interbedded with the White Creek Diamicton (sections 144-149 and 152 in Fig. 2). Current directions inferred from ripples, parting lineations and flutes range from east to southwest reflecting generally south to southeast current flow (Fig. A2). Variability in paleocurrent directions is due to deposition across irregular topography on the White Creek diamicton and changing current directions as a result of changing ice front sediment sources and ice recession. The bottom couplets give way to upward thickening, rhythmic couplets composed of dark gray clay and silt of Mohawk provenance which contain parting lineations that indicate current flow to the northwest (Fig. A3). The upper 5-7 m of the basal unit in the northern White Creek valley contain mostly dark gray rhythmic, graded silty clay with light to medium gray silt clasts, dark gray, sparsely stony diamicton beds, and contorted beds of sandy and clayey silt (sections 225, 226, and 314-317 in Fig. 2). The diamicton beds and associated graded silt and clay are lateral equivalents of the West Canada "A" Diamicton (Figs. 3 and A3). More than 100 varve years are represented by the basal unit of the lower Newport Beds (Fig. 3).

The basal unit of the lower Newport Beds is subaqueous outwash and varves deposited by south to southeast flowing bottom currents derived from ice receding to the north-northwest (Fig. A2). The upper part of the unit shows a change in bottom current directions and provenance that represent a shift to a southeastern Mohawk Lobe source (Fig. A3). Graded clayey silt and diamicton beds at the top of the unit are turbidites and proglacial diamicton beds of an ice-proximal environment of the Mohawk Lobe.

West Canada "A" Diamicton

The West Canada "A" Diamicton (Fig. 3) is exposed along the lower reaches of White Creek (sections 144-149 in Figs. 2 and A3) and in bluffs on West Canada Creek (sections 611 and 793 in Figs. 2 and A3). It does not extend north to the most complete exposures of the lower Newport Beds in the Factory Brook and northern White Creek valleys (sections 225, 226, and 314-317 in Figs. 2 and A2). The West Canada "A" Diamicton is a non-stony massive mud to very sparsely stony diamicton with a clayey to sandy silt matrix. The unit is apparently massive subglacial till in its lower portions and is faintly bedded to massive diamicton and sandy mud of rain-out and sediment-flow origins in its upper portion where it grades into the top unit of the lower Newport Beds. Sheared clay and silt beds are observable upon close examination of the massive portions of the unit. Only one exposure of the unit yielded enough pebbles for a pebble count and fabric (region III in Fig. 5; Fig. A3). The fabric, in a massive part of the unit, is parallel to the dip directions of glaciotectonic structures that indicate transport to the north by a Mohawk Lobe readvance.

Top Unit of the Lower Newport Beds

Along White and West Canada creeks the top unit of the lower Newport Beds (Fig. A4) is interbedded with the top of the West Canada "A" Diamicton or equivalent beds of the basal unit of the lower Newport Beds (sections 144-149, 225, 226, 313, 314-317, 610 and 611 in Fig. 2). In most exposures, the unit is truncated and glaciotectonically deformed beneath the West Canada Diamicton (Fig. 3). In the northern exposures of the unit it is interbedded with diamicton beds in the base of the West Canada Diamicton (section 262 in Fig. 2). The lower Newport Beds are continuous with the upper Newport Beds in bluff exposures at the Hinckley Reservoir which lie beyond the limits of the West Canada Diamicton.

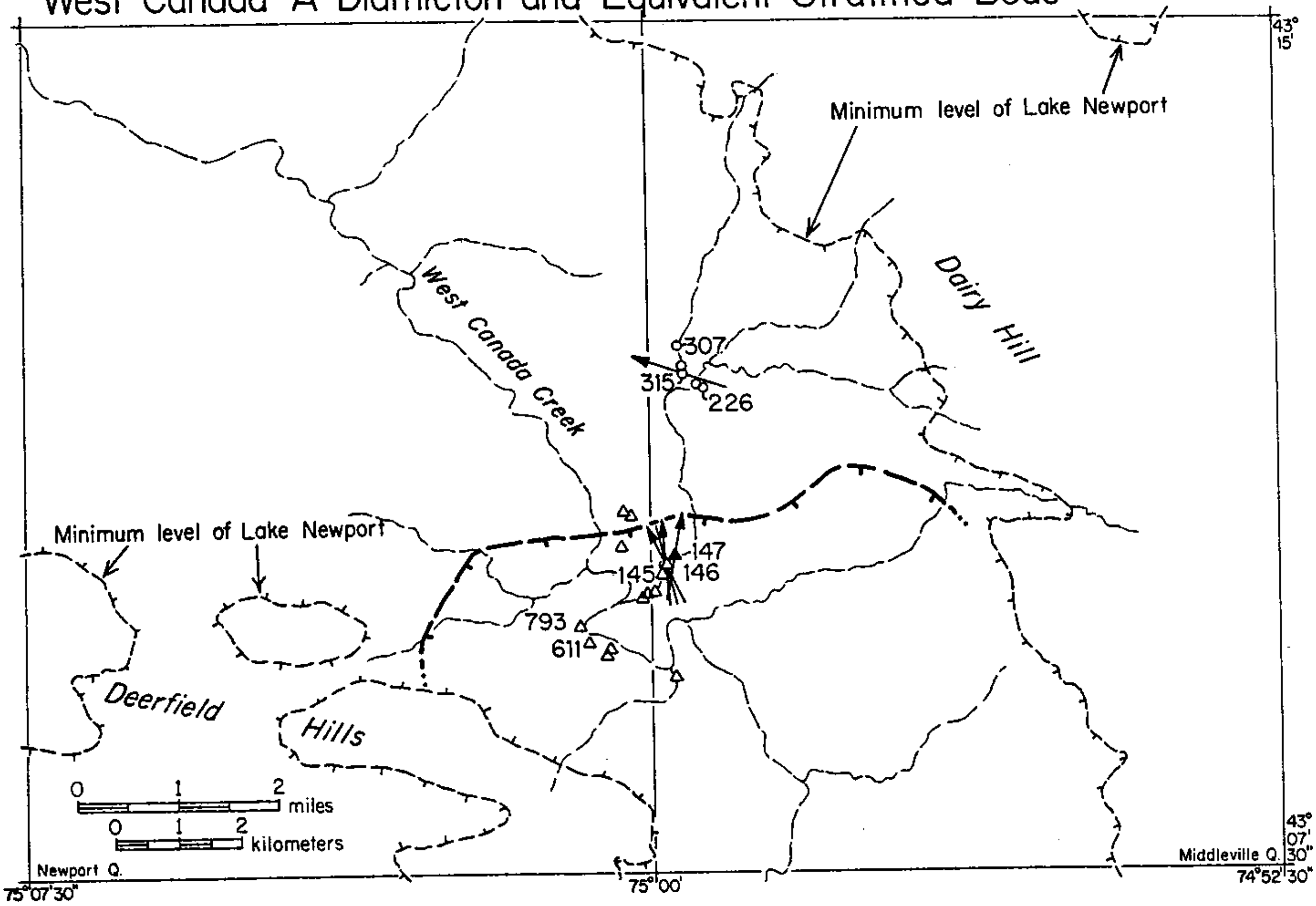
The top unit of the lower Newport Beds is composed primarily of rhythmically bedded dark gray clay and dark to medium gray clayey silt beds of Mohawk provenance, but the bottom of this unit also includes crossbedded and rippled, medium to fine sand and sparsely stony dark gray diamicton beds that contain abundant silt and diamicton clasts (sections 314-317 and 610-611 in Fig. 2). Paleocurrent directions inferred from crossbeds and flutes in the lowest part of the unit range from north to south-southwest with a mean of west-northwest (Fig. A4). Bed thickness, grain size, and the abundance of sediment clasts increase slightly upwards to the base of the West Canada Diamicton. The unit is mostly varves deposited initially during recession and later during a readvance of the Mohawk Lobe.

WEST CANADA DIAMICTON

The West Canada Diamicton is exposed in the West Canada Valley from Poland to south of Kast Bridge and it is interbedded above and below with the Newport Beds (Figs. 2, 3, and A5). From Middleville to the south, where the unit rests on striated bedrock (sections 116, 810-811, 828, and 942 in Fig. 2), it is very stony and has a matrix of clayey to sandy silt. Most of the exposures in the southern part of the valley are dominated by a compact, massive, stony diamicton of up to 30 m thickness that is subglacial till. As much as 10 m of thick beds of stony to sparsely stony diamicton beds may overlie the massive unit where it interbeds with the upper Newport Beds (section 116 in Fig. 2).

Northwest of Middleville, and immediately west of a northwest-facing dolostone escarpment on the valley floor, the West Canada Diamicton is sparsely stony silty clay (Fig. A5). Northern exposures of the diamicton are so sparsely stony that it was not possible to collect a sufficient number of pebbles for provenance analysis. The West Canada Diamicton in the center of the valley, overlies deformed silt and clay of the lower Newport Beds and is subglacial till composed of reworked silt and clay and massive subaqueous mud. The West Canada Diamicton becomes progressively

West Canada "A" Diamicton and Equivalent Stratified Beds



EXPLANATION

SITES OF DETAILED FIELD DESCRIPTIONS

△ ▲ - diamicton (dark triangle = pebble count site).

o - stratified unit.

793 - measured section number (Fig. 2).

DIRECTIONAL DATA

 - ice flow direction inferred from glaciotectonic feature.

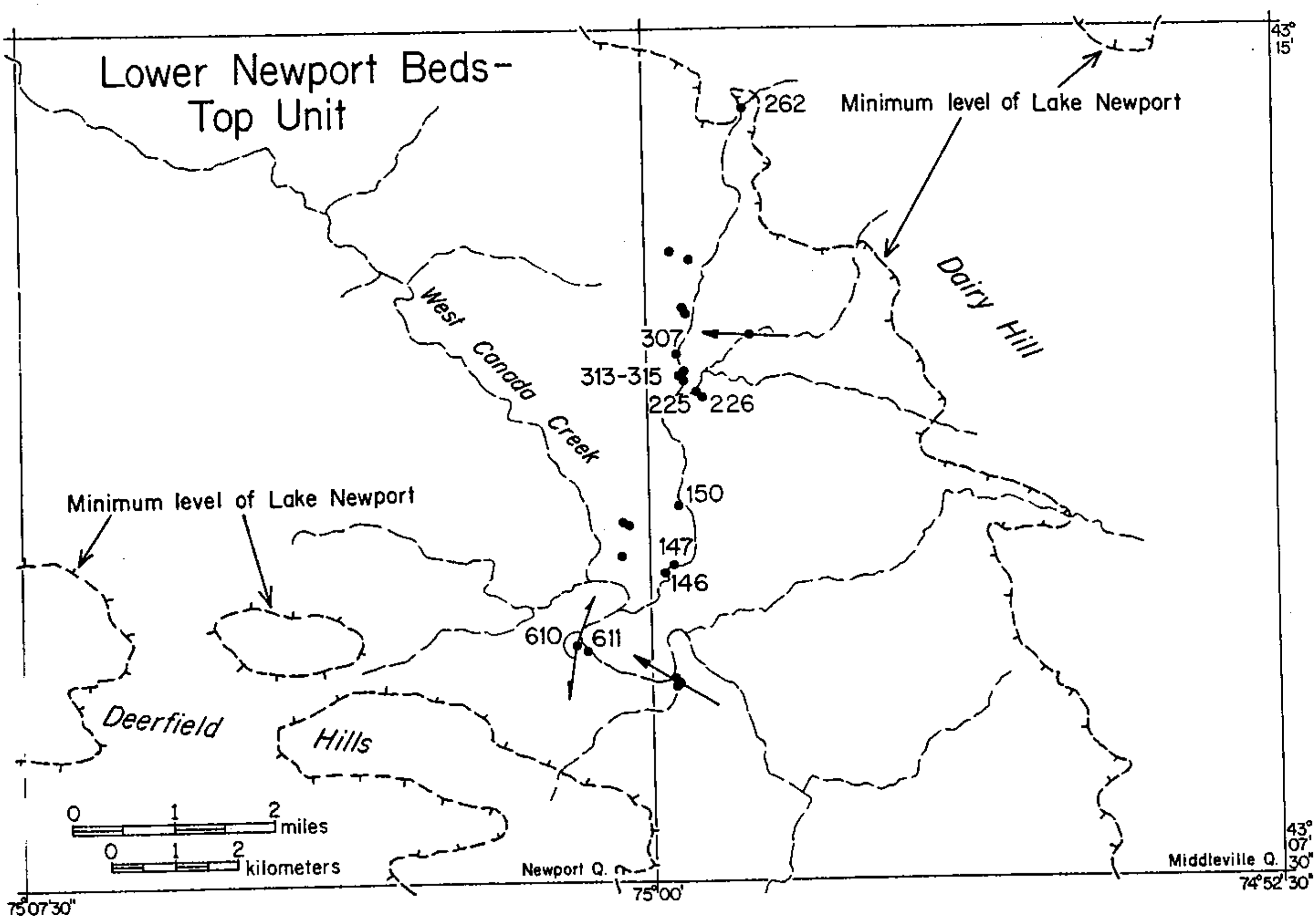
 - trend of pebble fabric.

 - current direction inferred from parting lineation.

OTHER FEATURES

 - northward limit of till and glaciotectonic features.

Figure A3. Distribution of exposures and directional data of the West Canada "A" Diamicton and equivalent parts of the lower Newport Beds in the West Canada Valley. Numbered sections are shown in Figure 2.


Lower Newport Beds-
Top Unit
262
Minimum level of Lake Newport
Dairy Hill
West Canada Creek
307
313-315
225
226
150
147
146
Minimum level of Lake Newport
610
611
Deerfield
Hills
0 1 2 miles
0 1 2 kilometers
Newport Q.
Middleville Q.
75°07'30"
75°00'
74°52'30"
43° 15'
43° 07' 30"

EXPLANATION

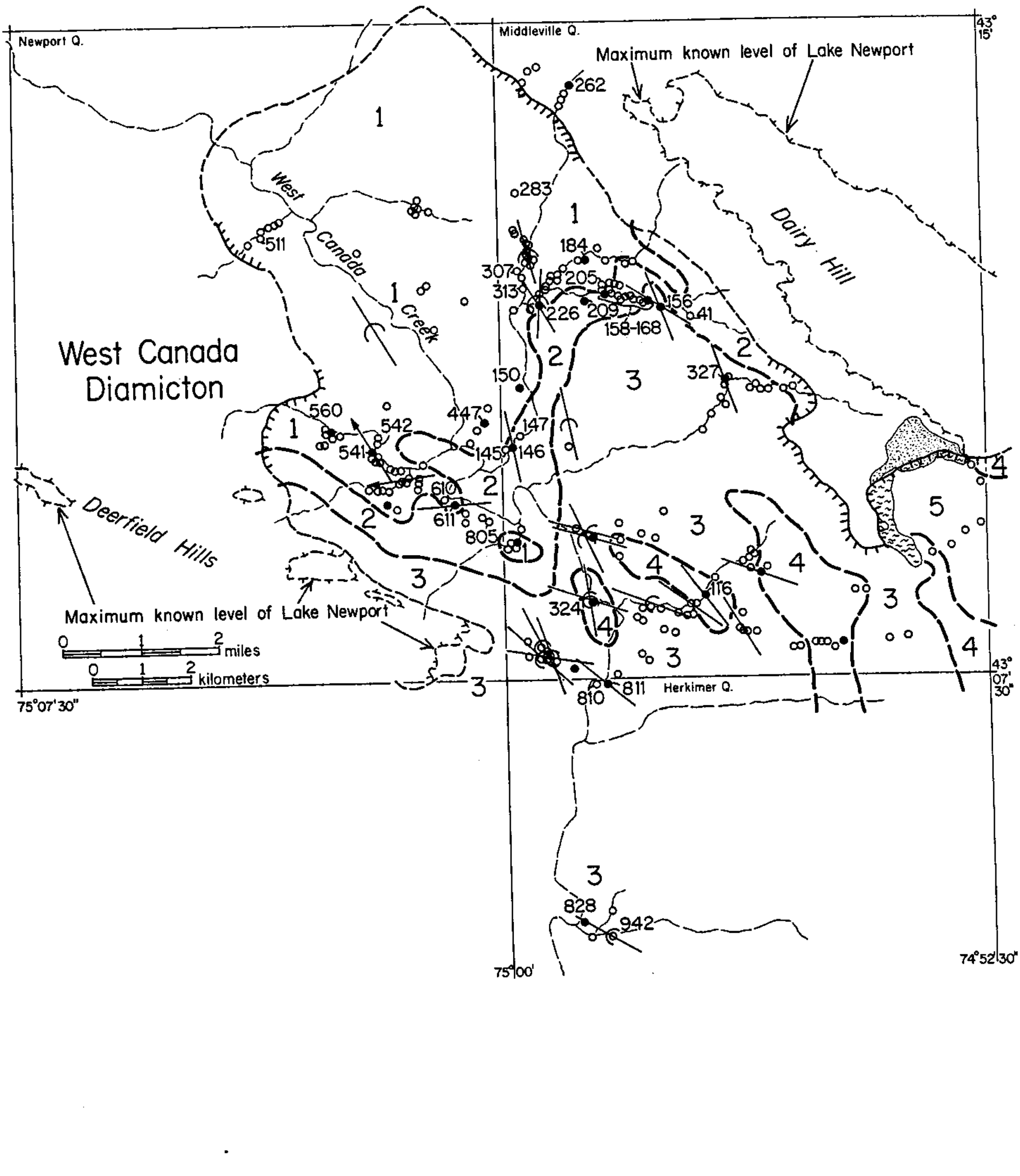
• - site of detailed field description.

226 - measured section number (Fig. 2)

 - paleocurrent direction inferred from parting lineation.

 - range of paleocurrent direction inferred from crossbedding.

Figure A4. Distribution of exposures and directional data of the top unit of the lower Newport Beds in the West Canada Valley. Numbered sections are shown in Figure 2.


Newport Q.
Middleville Q.
Herkimer Q.
Maximum known level of Lake Newport
West Canada Creek
Dairy Hill
Deerfield Hills
West Canada Diamicton
0 1 2 miles
0 1 2 kilometers
43° 15'
43° 07' 30"
75°07'30"
75°00'
74°52'30"

EXPLANATION

EXPOSURES AND DIRECTIONAL DATA

● ○ - sites of detailed field descriptions (dark circles = pebble count site).

447 - measured section number (Fig. 2).

- trend of pebble fabric.

- azimuth of bedrock striations or grooves on diamicton surface.

- ice flow direction inferred from glaciotectonic feature.

DIAMICTON TEXTURE

- approximate boundaries of textures.

1 - very sparsely to non-stony with clayey silt matrix.

2 - sparsely stony with clayey silt matrix.

3 - moderately stony with sandy, clayey silt matrix.

4 - moderately to very stony with sandy silt matrix.

5 - very stony with sand matrix.

OTHER FEATURES

- limit of till and glaciotectonic features, dashed where inferred.

- sand and gravel.

- morainic topography.

Figure A5. Distribution of exposures, and textural and directional data of the West Canada Diamicton in the West Canada Valley. Numbered sections are shown in Figure 2.

coarser and more stony toward either side of the valley. This textural change probably resulted from erosion of thinner lacustrine sediments and a greater reworking of the White Creek Diamicton or bedrock sources at higher elevations.

The West Canada Diamicton has low percentages of metamorphic and non-calcareous shale pebbles and high percentages of limestone and calcareous shale pebbles. Rat-tailed striations on limestone beneath the unit between Kast Bridge and Middleville (Fullerton, 1971; Ridge, 1985) indicate ice flow toward the west-northwest (Fig. A5). Pebble fabrics in lower, massive parts of the diamicton are parallel to striation directions, and combined with provenance of the diamicton indicate a readvance of the Mohawk Lobe.

UPPER NEWPORT BEDS - Lower West Canada Valley

The upper Newport Beds are exposed throughout the lower West Canada Valley from south of Kast Bridge to the northwest end of Dairy Hill (Figs. 2, 3, and A6). The unit is dominated by rhythmically laminated dark gray clay and dark gray clayey silt beds that are varves deposited during Mohawk Lobe recession. Fine sand partings and clasts of dark gray diamicton, light to medium gray silt, and gray clay are common, especially in lower parts of the unit. Rippled, fine to medium sand beds occur sporadically throughout the sequence. The base of the unit contains numerous dropstones, sparsely to moderately stony dark gray diamicton beds, and faintly laminated and graded mud with abundant clasts of dark gray diamicton. These basal units are turbidites, sediment flows, and rain-out deposits. Lamination thickness, grain size, and sediment clast abundance decrease upward through the unit. Paleocurrent directions inferred from flutes, ripple cross-laminations, and crossbeds range from northeast to southwest with a mean to the northwest (Fig. A6).

The base of the upper Newport Beds near Middleville (sections 116, 324, and 810-811 in Fig. 2) consists of a three unit sequence from bottom to top of: 1) crudely to moderately well stratified, muddy to openwork, pebble to boulder gravel and course crossbedded sand; 2) a unit composed of thick (0-2 m), dark gray, sparsely to moderately stony diamicton beds and lenses with load-deformed tops; and 3) laminated and rippled, fine to medium sand with thin (5-30 cm) diamicton beds. This sequence (especially at section 324 in Fig. 2) resembles sequences in ice-contact submarine fans deposited in the Champlain Sea (Sharpe, 1988). The beds near Middleville comprise a large esker and subaqueous fan complex that contains muddy debris flows (Fig. A6). Varves overlying the sand and gravel at Middleville (section 460 in Fig. 2) were deposited in a more distal glaciolacustrine environment during Mohawk Lobe recession.

NEWPORT BEDS - Upper West Canada Valley

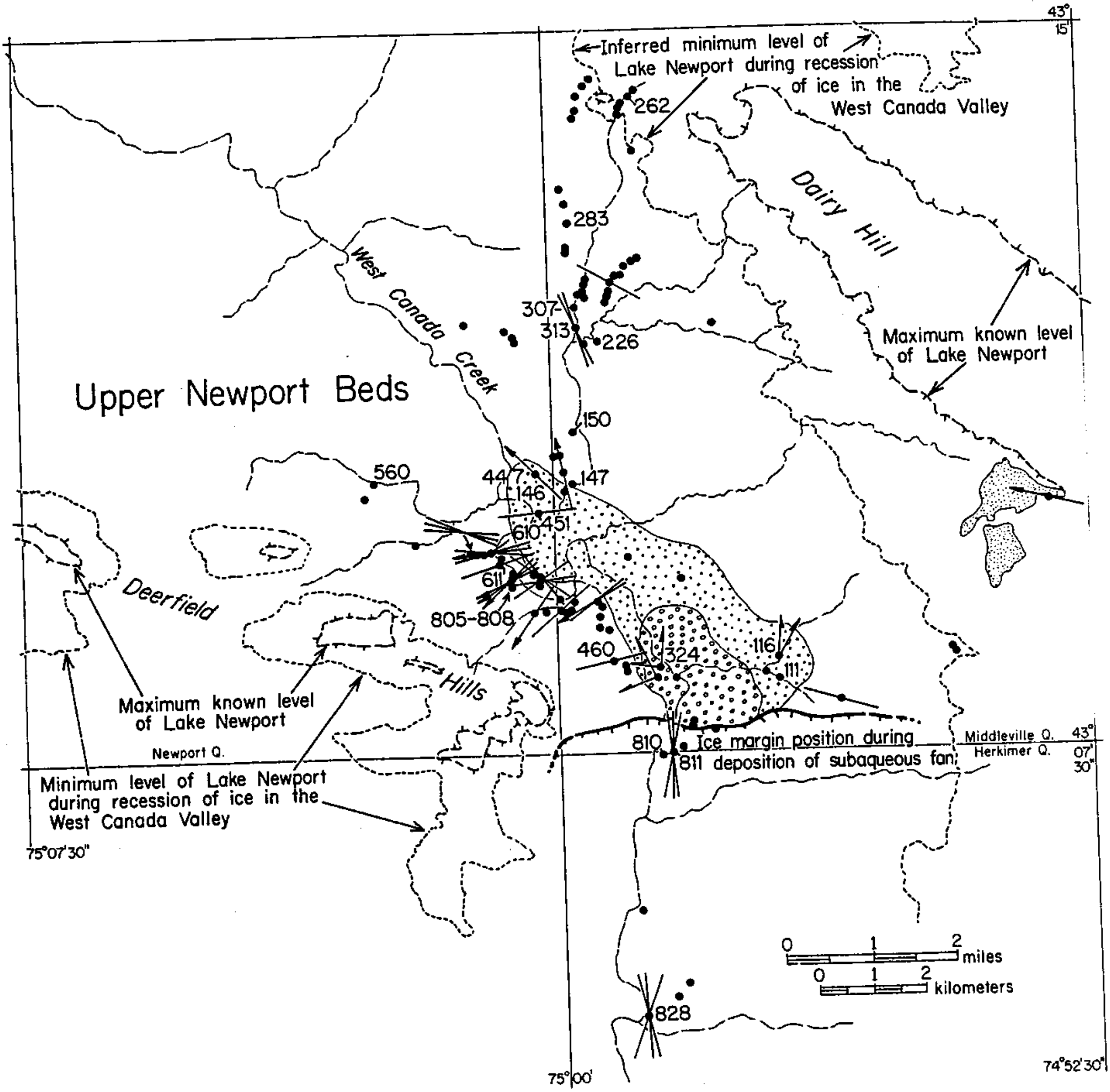
In the upper West Canada Valley at the Hinckley Reservoir (Fig. 1), which is beyond the limit of the West Canada Diamicton, the lower and upper Newport Beds are a continuous sequence (Fig. 6). Three units (A, B, and C) of laminated fine sand, silt, and clay in the Newport Beds have been delineated based on grain size, carbonate content, and color differences (Franzi, 1984; Ridge, 1985). Contacts between the units are gradational over several centimeters, and mark abrupt provenance changes. Combined, units A thru C represent almost 300 varve years.

The lowest unit in the sequence, Unit A, is composed of rhythmically laminated light to medium gray, fine sandy silt to fine micaceous sand and medium to dark greenish gray clay with low carbonate content. Unit A contains about 90 varves and the basal part of the unit, which was briefly exposed in 1984 when the Hinckley Reservoir was drained for dam repairs, contains sandy diamicton beds and metamorphic dropstones. The base of Unit A is interbedded with a diamicton of Adirondack provenance which is interpreted to be the Adirondack facies of the White Creek Diamicton. The rhythmically laminated couplets in Unit A thin upward from the base of the exposure but thicken again before grading into Unit B. Paleocurrent directions in Unit A, inferred from rib and furrow structures, are predominantly west to southwest. The paleocurrent directions, texture, and composition of Unit A indicate an Adirondack source (Franzi, 1984; Ridge, 1985).

Unit B at the Hinckley Reservoir, which comprises the middle of the section, is a sequence of highly calcareous and non-micaceous, rhythmically laminated to bedded, medium to dark gray clayey silt to fine sandy silt and dark gray clay that represent about 80 varve years. The unit contains dark gray limestone and black calcareous shale dropstones, and dark gray diamicton clasts. Couplets in Unit B are thicker and more clayey than in either Units A or C. Paleocurrent directions inferred from rib and furrow structures are N18E. The texture, composition, and paleocurrent directions (Franzi, 1984; Ridge, 1985) indicate a source to the south and either a Mohawk or Ontario provenance. An absence of red or pink sediment clasts and remanent magnetic declinations of 25-30 degrees East (site 937UN in Ridge and others, 1990), are consistent with Unit B being predominantly a deposit of Mohawk Lobe provenance in the Newport Beds.

Unit C comprises the top of the upper Newport Beds at the Hinckley Reservoir and is texturally and compositionally similar to Unit A and thus it is also considered to be of Adirondack provenance. The lower 75 couplets of Unit C thin upward. In its westernmost exposures, Unit C is not truncated by younger stream terraces as shown in Figure 6, and it contains at least 50 more couplets that become sandier upward. The upper contact of Unit C in its thickest exposure at the Hinckley Reservoir (west of the bluff shown on Fig. 6) is truncated along an erosion surface that is overlain by a lacustrine unit of Valley Heads age (Franzi, 1984). Rib and furrow structures in Unit C record a paleocurrent of S82W (Ridge, 1985). The unit contains slump scarps and deposits, and thick packages of contorted beds that Franzi (1984) related to hydrostatic pressure changes produced by rapid drops in lake level.

The Newport Beds at the Hinckley Reservoir are varves that record an advance of the Mohawk Lobe from the south. Changes from an Adirondack source to a Mohawk source and back to an Adirondack source are the combined result of oscillation of the Mohawk Lobe and changing lake levels. When the Mohawk Lobe to the south was closest



Inferred minimum level of Lake Newport during recession of ice in the West Canada Valley
262
283
307
313
226
Dairy Hill
Maximum known level of Lake Newport
West Canada Creek
Upper Newport Beds
150
560
447
146
147
451
610
611
805-808
460
324
116
111
Deerfield
Hills
Maximum known level of Lake Newport
Newport Q.
Minimum level of Lake Newport during recession of ice in the West Canada Valley
810
811
Ice margin position during deposition of subaqueous fan
Middleville Q.
Herkimer Q.
43°
15'
43°
07'
30"
75°07'30"
75°00'
74°52'30"
0
1
2
miles
0
1
2
kilometers
828

EXPOSURES AND DIRECTIONAL DATA

● - site of detailed field description.

447 - measured section number (Fig. 2).

 - paleocurrent trend or azimuth inferred from parting lineation.

 - range of paleocurrent directions inferred from crossbedding.

OTHER FEATURES

 - lacustrine sand and gravel other than in subaqueous fan at Middleville.

 - gravel in subaqueous fan and esker deposits at Middleville (Fig. 12).

 - extent of sand beyond limits of gravel in subaqueous fan at Middleville (Fig. 12).

Figure A6. Distribution of exposures, directional data, and sand and gravel of the upper Newport Beds in the West Canada Valley. Numbered sections are shown in Figure 2.

to the bluff sections, lake level was probably highest and sediment of Mohawk Lobe provenance dominated lacustrine deposition. As the Mohawk Lobe receded, lake levels fell, and lacustrine sedimentation was again dominated by Adirondack sources.

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ARTICLE D

THE SHED BROOK DISCONTINUITY AND LITTLE FALLS GRAVEL, POSSIBLE ERIE INTERSTADE EQUIVALENTS IN CENTRAL NEW YORK

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ABSTRACT

The Shed Brook Discontinuity in the West Canada Valley of central New York is an unconformity separating late Wisconsinan glaciolacustrine beds of the Valley Heads drift from underlying pre-Valley Heads deposits. The Little Falls Gravel is a fluvial unit that underlies the lowest Valley Heads deposits along the axis of the western Mohawk Valley. The Shed Brook Discontinuity represents a period of subaerial erosion and tributary valley formation in response to lake drainage and river development in the Mohawk Valley recorded by the Little Falls Gravel. The Shed Brook Discontinuity and Little Falls Gravel have a numerical (radiocarbon) age which can be constrained to 14-17 ka based on regional morpho- and litho- stratigraphic relationships. In addition, a minimum age of 14.8 ka for the base of lacustrine deposits immediately overlying the Shed Brook Discontinuity is inferred by correlation of paleomagnetic declination records from Valley Heads deposits in central New York and a radiocarbon dated varve sequence in New England. The Shed Brook Discontinuity and Little Falls Gravel appear to be features equivalent in age to the Erie Interstade, a period of low lake levels in the Erie Basin. River development in the Mohawk Valley at this time indicates that it may have served as the eastern outlet for lakes in the Erie and Ontario Basins.

INTRODUCTION

Widespread evidence of subaerial erosion, shoreline development, and shallow lacustrine deposition in the Erie Basin of Michigan, Ohio, and Ontario indicates that late Wisconsinan ice recession led to low lake levels during the Erie Interstade (15.5-14.6 ka; Dreimanis, 1958, 1969; Morner and Dreimanis, 1973). In Ontario, deposits and features of the Erie Interstade are underlain by the Catfish Creek till, a Nissouri Stadial deposit, and are overlain by the clayey Port Stanley till, a Port Bruce Stadial deposit (Dreimanis and Karrow, 1972; Dreimanis and Goldthwait, 1973; Dreimanis, 1977; Fullerton, 1980). The lowest lake level developed in the Erie Basin during the Erie Interstade is defined as Lake Leverett (Fig. 1; Morner and Dreimanis, 1973). Lack of a western outlet, low enough to serve as a spillway for Lake Leverett, has led to an hypothesis of eastern drainage for both the Erie and Ontario Basins via a river in the Mohawk Valley. An important implication of this hypothesis is that glacial lobes in central and eastern New York (Ontario and Hudson-Champlain Lobes) did not block eastward river drainage through the Mohawk Valley. To test this hypothesis, a detailed investigation of the glacial deposits in the western Mohawk Valley has focused on whether ice cover, glacial lake impoundment, or river drainage occurred in east-central New York during the Erie Interstade. In this paper, I document an

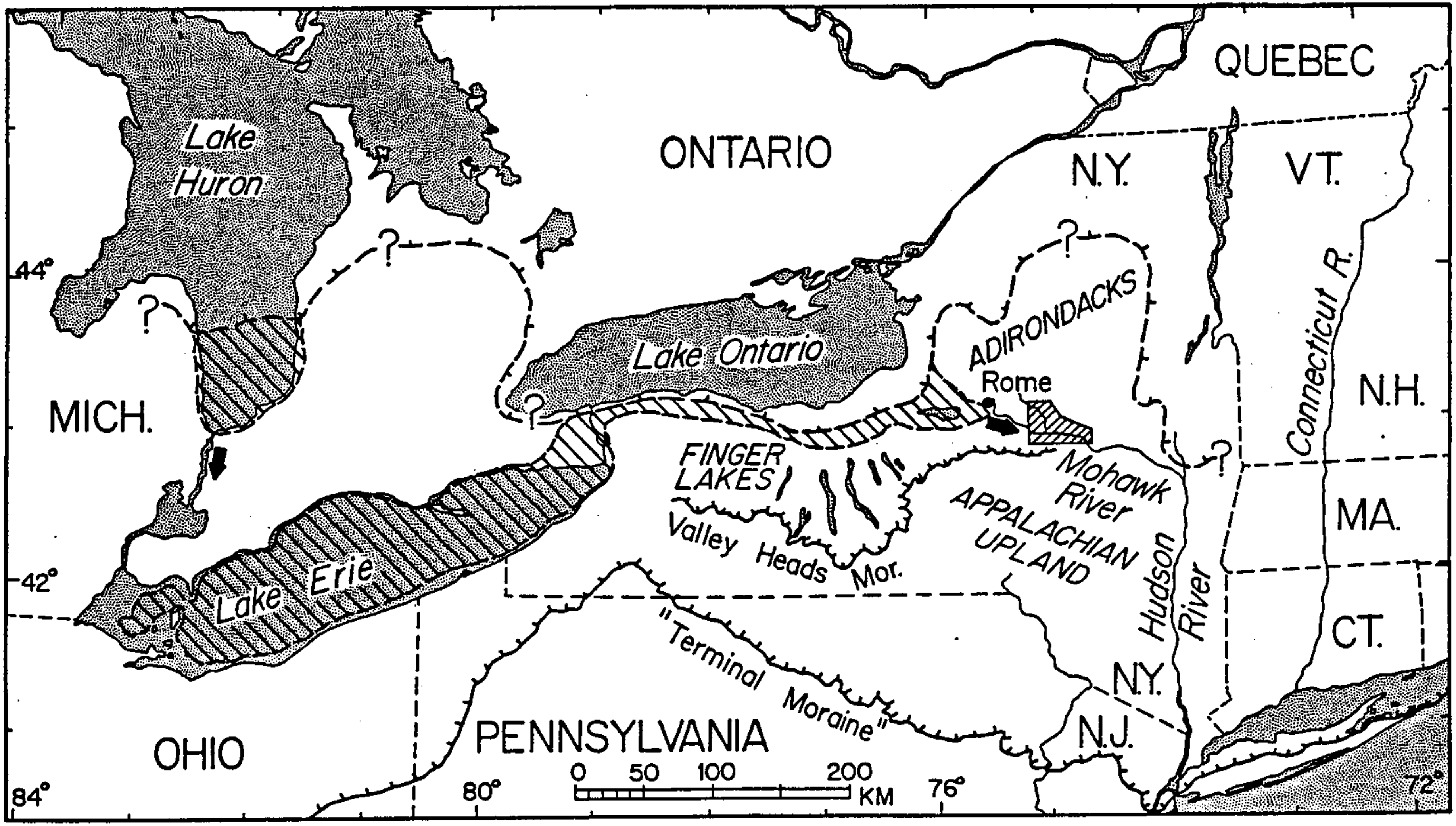

Figure 1. Hypothetical configuration of the Laurentide ice sheet (dashed hachured line with "?") and low level lakes (scribed areas) during the Erie Interstade in the Erie (modified from Morner and Dreimanis, 1973) and Ontario Basins. The "Terminal Moraine" (modified from Flint, 1959) is the maximum extent of late Wisconsinan ice margin. The Valley Heads moraine system in the Finger Lakes area of central New York (modified from Muller, 1977, and Muller and Cadwell, 1986) is the approximate limit of ice readvance after the Erie Interstade. Scribed box in the Mohawk Valley is the area discussed in this paper.

unconformity and period of river development in the Mohawk Valley that occurred at about the time of the Erie Interstade and between two separate periods of late Wisconsinan glaciation and lake impoundment.

LATE WISCONSINAN DEGLACIATION - CENTRAL NEW YORK

The most complete record of late Wisconsinan ice recession in the western Mohawk Valley region is the complex glacial stratigraphy of the West Canada Valley (Franzi, 1984; Ridge et al. 1984, 1990, 1991; Ridge, 1985; Muller et al. 1986), the upper part of which is traceable into the western Mohawk Valley. Detailed logging of abundant bluff exposures and surficial mapping have revealed the relative ages, geometry, and facies variations of stratigraphic units in the West Canada Valley (Fig. 2; Ridge, 1985; Ridge et al. 1990, 1991). Analysis of pebble provenance and facies variations of diamicton units, and their associated striated bedrock surfaces, is the basis for determination of directions, sources, and limits of glacial readvances. An analysis of elevations, sedimentary structures, and provenance of lacustrine stratified deposits, especially varved and non-varved clay and silt, has also allowed a reconstruction of glacial lake levels and environments in the region.

Paleomagnetic declination records have been formulated for sequences of laminated silt and clay representing two periods of glacial readvances and lake impoundments (Ridge et al. 1990). Declination records provide a means of chronostratigraphically testing correlations in the western Mohawk Valley region and of formulating correlations with other areas in New York (Brennan et al. 1984; Braun et al. 1984, 1985) and New England (Johnson et al. 1948; Verosub, 1979). A complete description of field and laboratory procedures used in formulating the paleomagnetic records are given elsewhere (Ridge, 1985; Ridge et al. 1990).

Late Wisconsinan deglaciation in the western Mohawk Valley generally involved the development of active ice lobes that flowed into deep lacustrine troughs. Ice that flowed into the Mohawk Valley from the west and northwest was part of the eastern Ontario Lobe. Ice that flowed into the Mohawk Valley from the east (Krall, 1977), having its source in the Hudson-Champlain Lobe and possibly the eastern Adirondacks, is here referred to as the Mohawk Lobe. Deep lakes impounded between the Mohawk and Ontario Lobes, were forced to drain southward across the Appalachian Upland at various times (Ridge, 1985; Muller et al. 1986; Ridge et al. 1991).

Late Wisconsinan deglaciation of the western Mohawk Valley occurred as two distinct periods of oscillatory readvances and lake impoundment, here referred to as pre-Valley Heads glaciation and Valley Heads glaciation. Moraines that were formed across central New York during Valley Heads glaciation (Fairchild, 1932) mark the drainage divide between the Ontario Basin and river systems draining to the south (Fig. 1). Pre-Valley Heads glaciation in the western Mohawk Valley culminated with widespread deposition of varved silt and clay in the uppermost unit of the Middleville Formation (upper Newport Beds) in the West Canada Valley (Fig. 2). This unit records

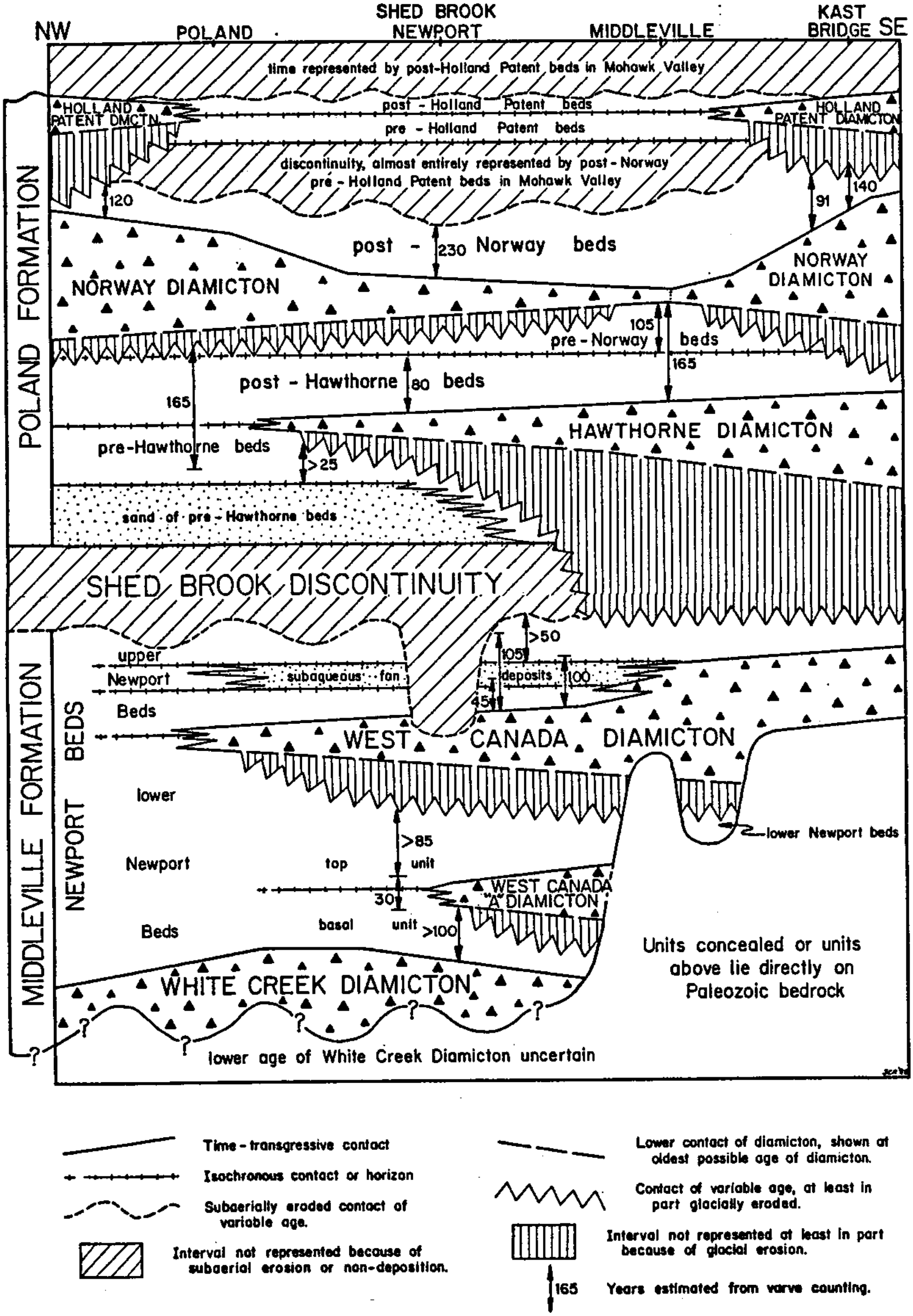

Figure 2. Relative ages of late Wisconsinan lithostratigraphic units along the axis of the West Canada Creek valley (see location map in Fig. 3; Ridge *et al*. 1990).

the impoundment of Lake Newport between the receding Mohawk and Ontario Lobes (Ridge et al. 1990, 1991). Pre-Valley Heads deposits in the Middleville Formation are (1) unconformably overlain by the lowermost lacustrine unit of the Poland Formation (pre-Hawthorne beds) along what is here defined as the "Shed Brook Discontinuity", or (2) they are truncated along a glaciotectonic contact at the base of till in a Valley Heads diamicton unit of the Poland Formation (Fig. 2; Ridge et al. 1990, 1991).

Valley Heads glaciation in central New York is much more complex than previously summarized (Fairchild, 1912; Fullerton, 1971, 1980; Krall, 1977; Mayewski et al. 1981; Mickelson et al. 1983; Dyke and Prest, 1987a, 1987b). The Poland Formation represents Valley Heads glaciation in the West Canada Valley (Ridge, 1985; Muller et al. 1986; Ridge et al. 1990), and can be traced into the Mohawk Valley where it overlies a fluvial gravel unit (Lykens, 1983; Ridge, 1985), here defined as the "Little Falls Gravel". The Poland Formation records several deep Mohawk Valley lakes, at least one major readvance of the Mohawk Lobe, and two major readvances of the Ontario Lobe in the Mohawk Valley (Ridge, 1985; Muller et al. 1986). A third major Ontario Lobe readvance near Rome, New York, occurred prior to final ice recession (Fullerton, 1971; 1980; Muller et al. 1986) and the development of Lake Iroquois in the Ontario Basin. Lake Iroquois drained across a spillway at Rome, New York, into a river in the Mohawk Valley (Fullerton, 1980; Muller and Prest, 1985). This, in turn, flowed eastward to Lake Albany in the Hudson Valley of eastern New York.

The distribution of deposits of the Middleville and Poland Formations indicates that eastward drainage of the Ontario Basin by way of a river in the Mohawk Valley could not occur during pre-Valley Heads glaciation (Ridge and others, 1991) and not until very late in the Valley Heads glaciation (Valley Heads Moraine on Fig. 1). During both periods, the eastern Mohawk Valley was blocked by the Mohawk Lobe, or the western end of the valley was filled by ice of the Ontario Lobe. However, unrestricted eastward drainage from as far west as the Erie Basin may have occurred during the time represented by the Shed Brook Discontinuity and Little Falls Gravel. This paper documents the character of the Shed Brook Discontinuity and Little Falls Gravel, and evaluates the age of these features relative to the Erie Interstade.

THE SHED BROOK DISCONTINUITY

In the West Canada Valley, the pre-Hawthorne beds overlie what is here defined as the "Shed Brook Discontinuity", which appears to represent a paleo-valley system and subaerial erosion surface. The Shed Brook Discontinuity crosscuts deposits of different ages in the Middleville Formation indicating varying amounts of erosion prior to deposition of the pre-Hawthorne beds (Fig. 2). Unfortunately, seepage of groundwater in sand and gravel in the basal pre-Hawthorne beds promotes slumping of overlying clayey units which makes the Shed Brook Discontinuity difficult to study. In other areas, erosion beneath till in diamicton units of the Poland Formation, which overlie the Middleville Formation along a subglacially deformed surface, makes it impossible to study the interval between

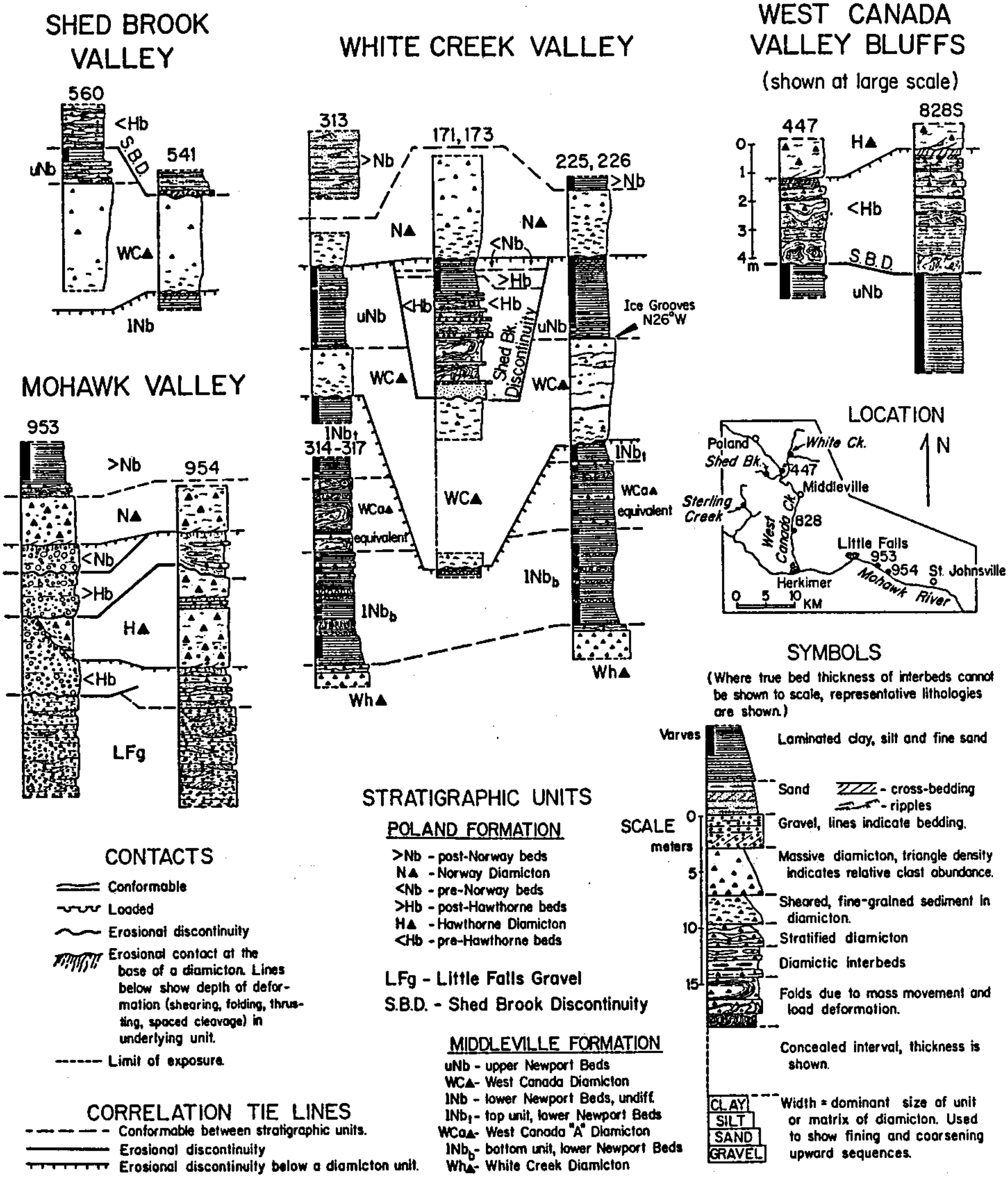

Figure 3. Stratigraphic sections in the West Canada and western Mohawk Valleys which show the stratigraphic relationships of the Shed Brook Discontinuity and Little Falls Gravel. The West Canada Valley bluffs are 2.5 times the vertical scale of the other sections.

pre-Valley Heads and Valley Heads glaciations. However, several critical exposures of the Shed Brook Discontinuity and Little Falls Gravel (Fig. 3), as well as paleomagnetic data, provide the basis for reconstructing paleogeography and time constraints.

Type section: Shed Brook valley

The type section of the Shed Brook Discontinuity occurs along Shed Brook, a small tributary of West Canada Creek south of Newport, New York (sections 541 and 560 in Fig. 3). In the Shed Brook valley at section 541, the discontinuity is represented by a surface cut through the upper Newport Beds into the West Canada Diamicton. Immediately overlying the discontinuity is a rounded boulder and cobble lag and coarse sand that contains rounded clasts of compacted clayey till from the underlying West Canada Diamicton. The irregular discontinuity on which the gravel sits has depressions resembling irregular potholes. A large (0.7-m), angular black shale boulder in the West Canada Diamicton is partly excavated, surrounded by gravel, and its upper surface is rounded. The discontinuity is interpreted to be a stream bed with an overlying channel and lag deposit. The gravel unit is sharply overlain by laminated sand and silty clay in the pre-Hawthorne beds.

In another exposure in the Shed Brook valley, interbedded muddy diamicton and laminated sand and silt in the pre-Hawthorne beds overlie the Shed Brook Discontinuity (section 560 in Fig. 3). Diamicton beds within the sand are probably subaqueous slump and muddy flow deposits resulting from mass movement shortly after drowning of a valley side represented by the Shed Brook Discontinuity. The discontinuity is at a higher elevation than at section 541 (+30 m) and it crosscuts about 3.5 m of the upper Newport Beds that overlie the West Canada Diamicton. In many exposures in the Shed Brook area, the upper Newport Beds are much thicker than 3.5 m (up to 25 m), they reach a higher elevation, and they are truncated above by a diamicton unit of the Poland Formation (Ridge, 1985; Ridge et al. 1990).

The contact relationships in the Shed Brook area depict a valley cut into the Middleville Formation that was later infilled by lacustrine sediment of the pre-Hawthorne beds (Fig. 2). Valley formation occurred after deposition of the upper Newport Beds, and thus did not occur subglacially beneath ice that deposited the West Canada Diamicton. The Shed Brook Discontinuity is interpreted to represent a period of fluvial erosion and valley widening resulting from drainage of lakes in the West Canada Valley below an elevation of 235 m. The pre-Hawthorne beds represent re-impoundment of a lake in the West Canada Valley at the start of Valley Heads glaciation.

White Creek valley

Along the upper reaches of White Creek, which enters West Canada Creek from the north, the Shed Brook Discontinuity (sections 171 and 173 on Fig. 3) has characteristics and a stratigraphic position similar to those in the Shed Brook valley. The discontinuity has a steeply dipping surface where it appears to represent a valley side. The upper White Creek valley is beyond the limits of the Hawthorne Diamicton, and the discontinuity is overlain by a continuous sequence of the pre- and post-Hawthorne beds. The basal part of the overlying pre-Hawthorne beds consists of interbedded massive and contorted muds with few stones, interpreted as mudflow and slump deposits, and coarse sand and pebble gravel. Above the basal part of the unit are clay and medium sand varve couplets that rapidly thin and fine upward into varved couplets of silt and clay. Varve couplets in the continuous pre- and post-Hawthorne beds are distinct from varves in the upper Newport Beds. Varves in the Hawthorne units have darker (almost black) and thinner clay beds, thinner couplets, and grade into distinct medium sand and clay couplets in their base. Also, the Hawthorne bed sequence has a remanent declination of $7.7^{\circ} \pm 3.1^{\circ}$ (vector mean of 10 specimens at section 173 in Fig. 3, ±95% confidence interval), while declination in the upper Newport Beds (sections 226 and 313 in Fig. 3, 4 sites, 8-10 specimens/site) ranges from $21.3\text{-}24.8^{\circ} \pm 2.3\text{-}3.9^{\circ}$ (Ridge, 1985; Ridge et al. 1990). Significantly different paleomagnetic declinations, along with the sedimentologic distinctions, indicate that the lacustrine sediments are not the same lithostratigraphic units and that they are distinctly different in age.

Throughout the surrounding region (sections 225-226 and 313 in Fig. 3), and at elevations 10-15 m higher than the lowest exposure of the discontinuity (section 173), the Norway Diamicton forms the base of the Poland Formation and overlies more than 7 m of the upper Newport Beds along a subglacially deformed surface. The top of the Newport Beds, as well as the pre-Hawthorne through pre-Norway beds have been removed by subglacial erosion at the base of the Norway Diamicton. The pre- and post-Hawthorne beds in the White Creek valley are preserved only where they infill low spots on the Shed Brook Discontinuity representing incised stream valleys. Massive and contorted mud and pebble gravel beds in the base of the pre-Hawthorne beds are interpreted to represent muddy flow or slump deposits and stream beds formed under subaerial conditions.

West Canada Valley bluff exposures

Two large bluff exposures in the West Canada Valley (sections 447 and 828S on Fig. 3) display the Shed Brook Discontinuity at the base of the pre-Hawthorne beds. The pre-Hawthorne beds are sandwiched between overlying till in the Hawthorne Diamicton and an eroded surface on the upper Newport Beds. In both exposures, the pre-Hawthorne unit is composed of interbedded dark gray diamicton, contorted and faintly laminated, clayey silt and fine sand, massive and rippled, yellow fine to medium sand, and sparse dark gray laminated clay and silt beds. These units have been deformed by syndepositional loading and were discretely deformed by ice which deposited the overlying till. Till in the base of the overlying Hawthorne Diamicton contains deformed sediment incorporated from the pre-Hawthorne beds.

The pre-Hawthorne beds are distinguished from the underlying upper Newport Beds by less distinct bedding, coarser grain size, darker gray clay beds, and stony diamicton beds that are in sharp contrast to the distinctly laminated silt and clay varves of the upper Newport Beds. The base of the pre-Hawthorne beds is often a discontinuous unit composed of separate contorted masses of laminated silt and clay derived from the upper Newport Beds in a massive to faintly laminated muddy matrix (Fig. 4). The contorted masses in the base of the pre-Hawthorne beds are interpreted to be either slump debris on a subaerially eroding slope, or subaqueous slump deposits formed during the first phases of Valley Heads lake impoundment.

Hawthorne Gulf - Sterling Creek valley

Hawthorne Gulf in the Sterling Creek valley, which is a tributary to the Mohawk River, displays an erosion surface equated with the Shed Brook Discontinuity. Along most of Sterling Creek, black stony Hawthorne Diamicton of Mohawk Lobe provenance rests on striated black, calcareous Utica Shale indicating Mohawk Lobe flow of N55-60^{o}W (Fig. 5). At one locality, however, a 2 m-deep channel in the shale surface preserves a pocket of the pre-Hawthorne beds which is composed of black, faintly laminated clay that encases a rounded boulder lag. Till immediately above the clay contains clusters of shale fragments, and smudges of black clay. The boulder lag sits on a smooth, non-striated shale surface which, like the lag boulders, appears to be water worn. The steep side of the bedrock channel is ragged black shale that was weathered prior to burial by lacustrine clay of the pre-Hawthorne beds (Fig. 5). The ragged appearance of the shale is typical of modern stream banks in the shale where dissolution and frost action have weathered the rock. The bedrock channel and boulder lag are interpreted to represent subaerial fluvial erosion which was active just prior to initial Valley Heads lake impoundment.

PALEOMAGNETIC DISCONTINUITY

North and west of the limit of the Hawthorne Diamicton in the West Canada Valley (Fig. 2; sections 171 and 173 in Fig. 3), the pre- and post-Hawthorne beds form an uninterrupted lacustrine sequence that records the initial impoundment of lakes during Valley Heads glaciation. The upper Newport Beds (Figs. 2 and 3), which are overlain by the Shed Brook Discontinuity, represent the last impoundment of Lake Newport in the West Canada Valley during pre-Valley Heads glaciation (Ridge et al. 1991). A continuous paleomagnetic declination record has been obtained from the pre- and post-Hawthorne beds which can be compared with paleomagnetic declinations from the upper Newport Beds. Throughout the West Canada Valley, the pre- and basal post-Hawthorne beds (9 sites, 8-10 specimens/site) consistently have a declination of 3-8^{o} (Fig. 6) and the upper Newport Beds (14 sites, 8-10 specimens/site) consistently have a declination of 20-25^{o} (Ridge, 1985; Ridge et al. 1990). This

Figure 4. The pre-Hawthorne beds overlying the eroded top of the upper Newport Beds along the Shed Brook Discontinuity (dashed line) in the West Canada Valley (section 447 on Fig. 3). The base of the pre-Hawthorne beds is a discontinuous bed composed of contorted masses of laminated silt and clay derived from erosion of the upper Newport Beds.

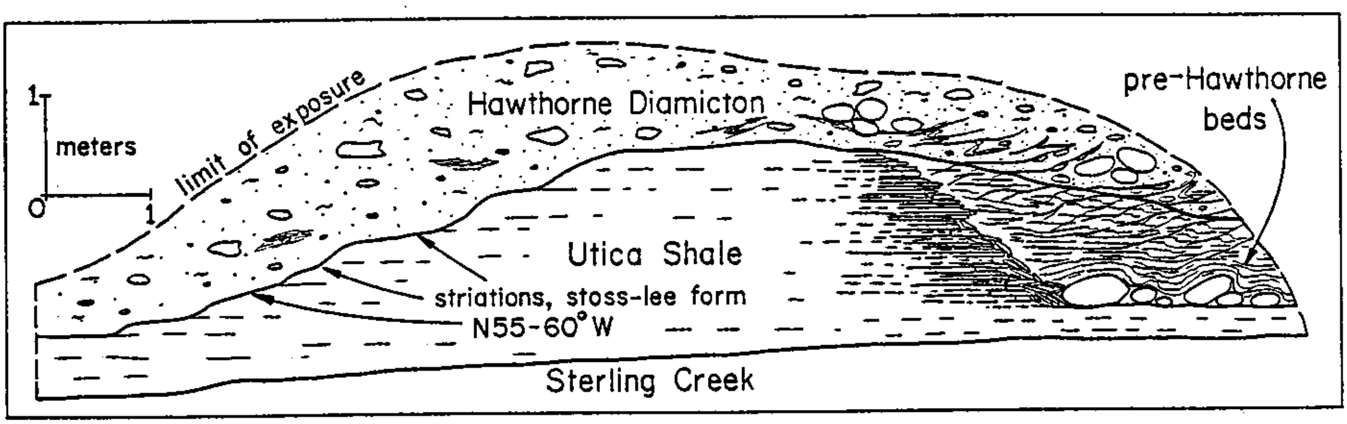

Figure 5. The basal part of the Poland Formation (pre-Hawthorne beds and Hawthorne Diamicton) overlying calcareous black Utica Shale in Hawthorne Gulf (Sterling Creek in location map of Fig. 3).

basin-wide contrast between declination in the two units indicates that the Shed Brook Discontinuity is not only a lithologic discontinuity, but an unconformity.

It has not been possible to test the existence of an unconformity at the Shed Brook Discontinuity by comparing remanent declination of the pre-Hawthorne beds and upper Newport Beds at single exposures. In many exposures in the West Canada Valley, the upper Newport Beds have been completely eroded beneath the Shed Brook Discontinuity. Load deformation, subglacial deformation beneath the Hawthorne Diamicton, sandy textures, and oxidation usually make the pre-Hawthorne beds inappropriate for recording a paleomagnetic declination which is useful for testing chronostratigraphic relationships.

LITTLE FALLS GRAVEL IN THE MOHAWK VALLEY

A continuous, well sorted gravel unit, 2.5-8.0 km east of Little Falls and at the base of exposures along the north side of the Mohawk River flood plain (sections 953 and 954 in Fig. 3), is here defined as the "Little Falls Gravel". The Little Falls Gravel is well sorted and highly rounded, cobble to pebble gravel with flat horizontal beds or lenticular crossbedded units. The gravel contains lenses of coarse crossbedded sand which, along with gravel crossbeds, indicate a down valley (East) paleocurrent direction. The Little Falls Gravel is traceable over a distance of more than 5 km with its top defining a flat surface that dips gently down valley and reaches an elevation of about 122 m. This unit is interpreted, based on its paleocurrent directions, sedimentary structures, geometry, and high sorting, to be a subaerial fluvial gravel.

The Little Falls Gravel occurs just beneath the Poland Formation which has been traced eastward from the West Canada Valley into the Mohawk Valley (Lykens, 1983; Ridge, 1985; Muller, et al. 1986). The base of the Poland Formation consists of either (1) lacustrine sediment of the pre-Hawthorne beds which drapes across the Little Falls Gravel (section 954 in Figs. 3 and 7), (2) black till in the Hawthorne Diamicton which overlies a subglacially deformed surface at the top of the gravel, or (3) gravels which infill channels cut through older units of the Poland Formation (Fig. 3). In contrast to the Little Falls Gravel, gravel units in the Poland Formation are of subglacial fluvial and ice-marginal subaqueous fan origins. Poland Formation gravels are more poorly sorted, more bouldery, less well rounded, and contain long east- and west-dipping beds. Poland gravels are composed of matrix-supported and inversely graded cobble and boulder units, as well as thick, clast-supported and normally graded units. Furthermore, the Poland gravels are interlayered with diamicton beds, laminated, rippled and massive sand, and laminated silt and clay, all of proglacial lacustrine origin.

The Little Falls Gravel appears to represent an eastward-flowing river in the Mohawk Valley which was active after pre-Valley Heads ice recession and prior to initial Valley Heads lake impoundment. A river in the western Mohawk Valley at an elevation of 122 m, only 14 m above the modern Mohawk Valley flood

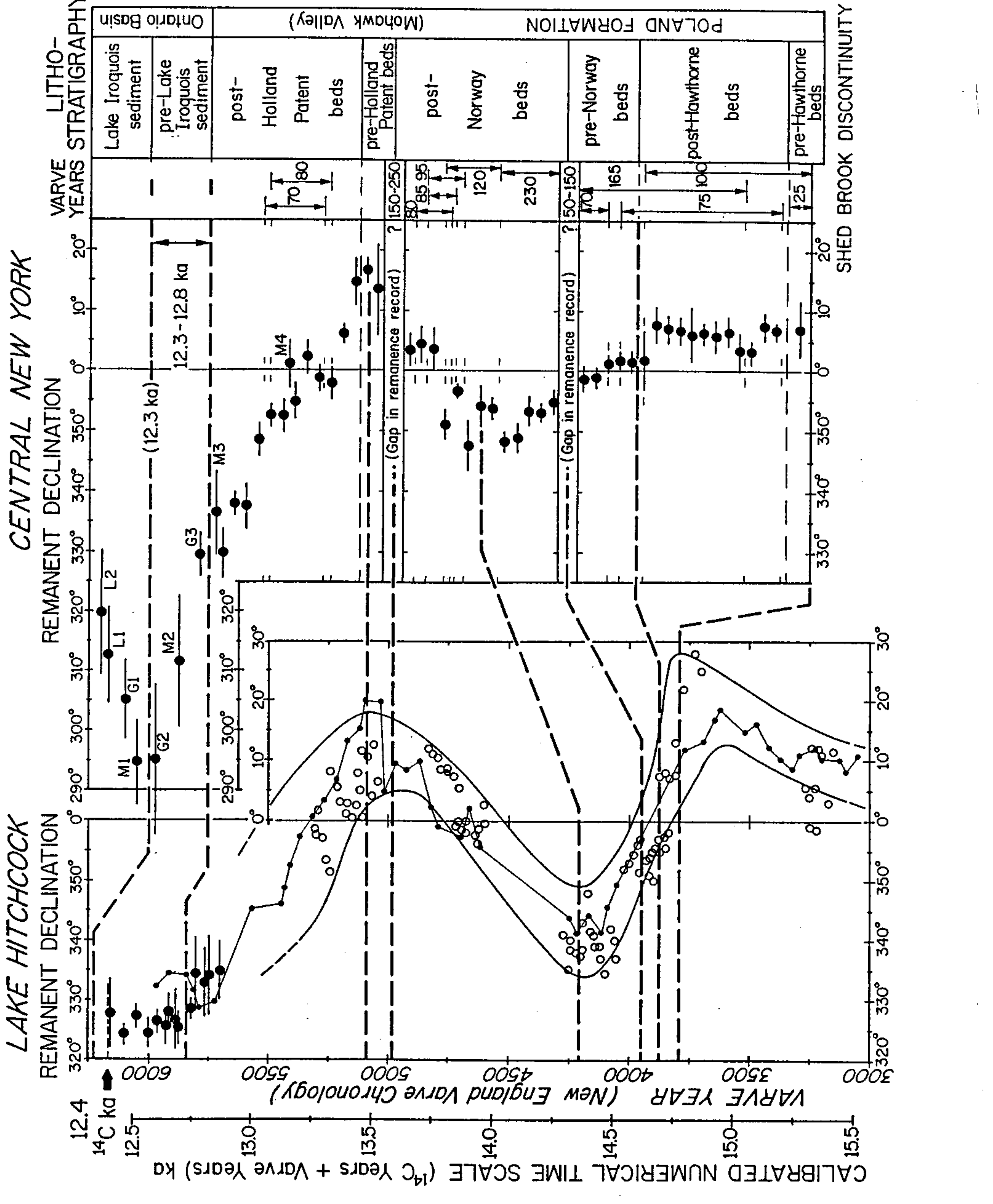
LAKE HITCHCOCK
REMANENT DECLINATION
CENTRAL NEW YORK
REMANENT DECLINATION
VARVE YEARS
LITHO-STRATIGRAPHY
Ontario Basin
(Mohawk Valley)
POLAND FORMATION
Lake Iroquois sediment
pre-Lake Iroquois sediment
post-Holland Patent beds
pre-Holland Patent beds
post-Norway beds
pre-Norway beds
post-Hawthorne beds
pre-Hawthorne beds
SHED BROOK DISCONTINUITY
(12.3 ka)
12.3-12.8 ka
(Gap in remanence record)
(Gap in remanence record)
VARVE YEAR (New England Varve Chronology)
CALIBRATED NUMERICAL TIME SCALE (^{14}C Years + Varve Years) ka
^{14}C ka

Figure 6. Correlation of remanent declination records from lacustrine silt and clay deposited during late Wisconsinan ice recession in Lake Hitchcock (Connecticut River valley in Fig. 1) and in central New York (West Canada and western Mohawk Valleys). Correlations of the two declination records are shown by heavy dashed tie lines. Lake Hitchcock records are from varve sections which have been matched with the New England varve chronology shown on the vertical axis in arbitrary varve years (3,000 to 6,250; Antevs, 1922). Calibration of the varve chronology is based on radiocarbon ages of 12.4 ka from Canoe Brook, Vermont (42°56'44", 72°32'06"; Ridge and Larsen, 1990). The area between the two smoothed curves on the Lake Hitchcock record represents the region within which geomagnetic declination lies as interpreted by Verosub (1979) from natural remanences (Johnson et al. 1948; solid circles with tie line) and remanences after AF demagnetization at 17.5-20 mT (Verosub, 1979; open circles). Remanent declination means after AF demagnetization at 30 mT from sites in couplets 5,700-6,200 (new data, 9-18 specimens/site spanning 8-20 yr intervals) are shown as large solid circles with error bars (alpha-95 confidence intervals). New data is from varve sections at Canoe Brook, Vermont and from Mill Brook, Vermont (42°57'37", 72°31'58"). Remanent declination means and confidence intervals (alpha-95) from central New York (unlabeled sites, 9-16 specimens/site, AF demagnetized at 30 mT are from Ridge et al. 1990; sites L1-2, G1-3, and M1-4, 6-16 specimens/site, AF demagnetized at 10-40 mT are from Brennan et al. 1984) are plotted by relative age as indicated by position in superposed lithostratigraphic units or morphologic successions in the western Mohawk and West Canada Valleys (Fig. 3; Ridge et al. 1990) and the eastern Ontario Basin (Fullerton, 1980). Numerical ages of pre-Iroquois and Lake Iroquois sediments are based on Fullerton (1980) and Muller and Prest (1985).

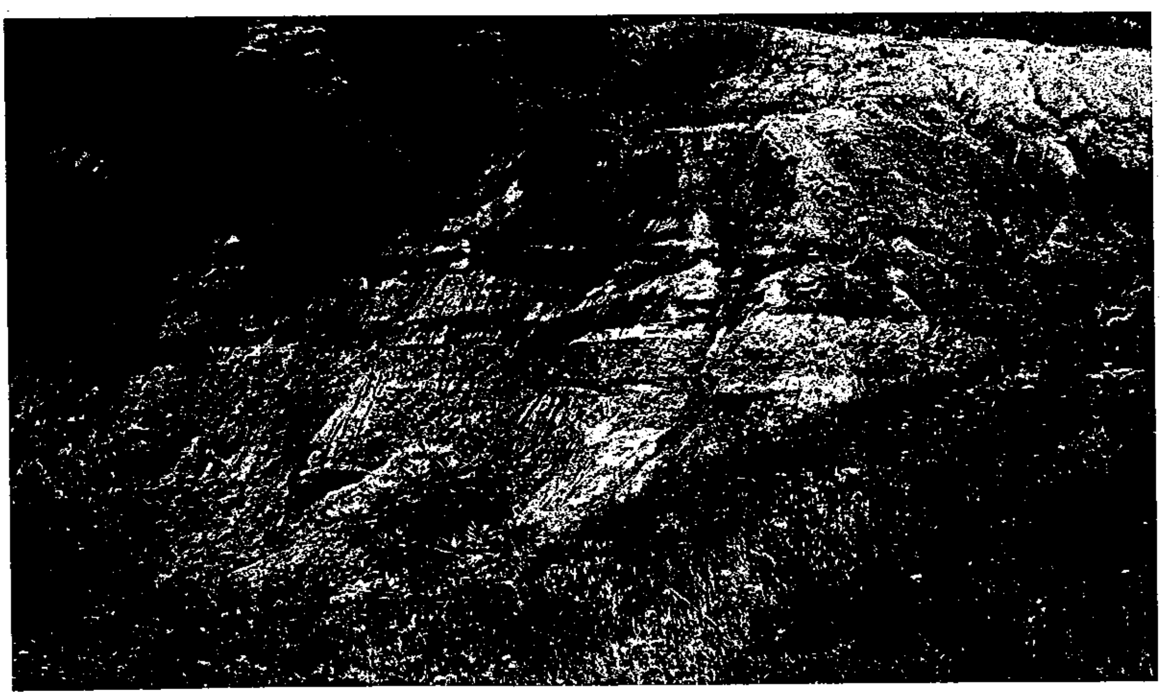

Figure 7. Exposure of the fluvial Little Falls Gravel (lower dashed line marks top) beneath the pre-Hawthorne beds and Hawthorne Diamicton (upper dashed line marks base) in the axis of the Mohawk Valley east of Little Falls, New York (section 954 on Fig. 3).

plain, indicates that the Mohawk Lobe receded from the eastern end of the valley and allowed unrestricted fluvial drainage to the Hudson Valley.

AGE OF THE SHED BROOK DISCONTINUITY AND LITTLE FALLS GRAVEL

No radiocarbon or other ages are known for any late Wisconsinan sediments in the western Mohawk Valley or correlative units in central New York. This may reflect long periods of ice cover and lake impoundment that restricted colonization by terrestrial vegetation to high elevations. Interstadial periods, such as the one which may be represented by the Shed Brook Discontinuity and/or Little Falls Gravel, may have been short episodes during which rapid periglacial slope erosion of clayey glacial sediment prevented widespread plant colonization. In addition, the region may have had a harsh climate during interstades because it was surrounded by ice covered areas from the Ontario Basin in the west to the Adirondacks in the northeast (Fig. 1).

Morpho- and lithostratigraphic relationships in central New York

The limit of Valley Heads drift (Mickelson et al. 1983) and the Valley Heads moraine system in central New York define the southern drainage divides of the Finger Lakes basins and divides in through valleys of central New York (Fairchild, 1932; Muller and Cadwell, 1986). The Valley Heads moraine system is correlative to several episodes of moraine building and readvances in western New York which succeeded the Erie Interstade (Port Bruce through Port Huron Stades; Muller, 1977; LaFleur, 1979, 1980; Fullerton, 1980; Calkin and Feenstra, 1985; Muller and Prest, 1985; Calkin and Barnett, 1990). The Valley Heads moraine system can be traced from western New York to the south side of the western Mohawk Valley (Muller, 1977; Fullerton, 1980; Muller and Cadwell, 1986) where two separate Ontario Lobe readvances of Valley Heads age are represented by the Norway and Holland Patent Diamictons of the Poland Formation. Therefore, the Poland Formation would appear to represent post-Erie Interstadial events.

Based on regional morphologic and lithostratigraphic relationships, numerical time constraints can be placed on the deposition of the Poland Formation. Its upper deposits in the Mohawk Valley are older than not only the development of Lake Iroquois in the Ontario Basin at about 12.3 ka (Fullerton, 1980; Muller and Prest, 1985), but also deposits in the eastern Ontario Basin near Rome (Fig. 1) that record oscillatory ice recession prior to the development of Lake Iroquois (12.8-12.3 ka; Fullerton, 1971, 1980; Muller et al. 1986). The upper unit of the Poland Formation (Figs. 2 and 6), therefore, cannot be much younger than 13 ka.

The minimum length of time during which the Poland Formation was deposited is estimated from varve counting to be more than 1,000 yr (Ridge, 1985; Ridge et al. 1990). This estimate along with the overall complexity of the unit suggest that the Poland Formation represents deposition spanning the Port Bruce, Mackinaw, and Port

Huron Stades. Given the age constraints on the top of the Poland Formation (13 ka), it, as well as the Shed Brook Discontinuity and Little Falls Gravel, are at least as old as 14 ka.

There is a long record of late Wisconsinan, pre-Valley Heads deglaciation across about 200 km of northeastern Pennsylvania and south-central New York (Fig. 1; Denny, 1956; Crowl and Sevon, 1980; Cadwell, 1986; Cotter et al., 1986; Fleisher, 1986; Ozsvath and Coates, 1986) which pre-dates the Middleville Formation. The Middleville Formation (Fig. 2) records a minimum of an additional 500 yr of lacustrine sedimentation and ice recession (Ridge et al. 1990, 1991). All of these events, preceding the formation of the Shed Brook Discontinuity and Little Falls Gravel, took a substantial amount of time. Therefore, it does not seem likely that the Little Falls Gravel and Shed Brook Discontinuity are older than 17 ka. Although more conclusive evidence will be needed to firmly establish the age of the Shed Brook Discontinuity and Little Falls Gravel, all existing morpho- and lithostratigraphic constraints (17-14 ka) are consistent with an age similar to the Erie Interstade.

Paleomagnetic correlation

A paleomagnetic correlation presently provides the best estimate for the age of the Shed Brook Discontinuity and Little Falls Gravel. Paleomagnetic declination records from Valley Heads sediments in the western Mohawk Valley and eastern Ontario Basin (Brennan et al. 1984; Ridge et al. 1990) have been correlated with a late Wisconsinan declination record from sediments of Lake Hitchcock in the Connecticut Valley of New England (Fig. 6; Johnson et al. 1948; Verosub, 1979; and new data).

The Lake Hitchcock paleomagnetic record (Fig. 6) is tied to the 4,400-yr long New England varve chronology (Antevs, 1922), which has recently been calibrated with radiocarbon ages (Ridge and Larsen, 1990). Extreme western declinations that shift from 335° to 324° at 12.9-12.4 ka are recorded from sediments of Lake Hitchcock (couplets 5700-6200). This shift in New England corresponds to a similar westward shift in declination recorded from pre-Lake Iroquois sediments in the Ontario Basin at 12.3-12.8 ka (Fig. 6). This is the only existing independent radiocarbon test of the contemporaneity of the paleomagnetic records from New England and central New York and it supports the proposed correlation.

Calibration of the New England varve chronology with radiocarbon ages allows the application of a numerical time scale (radiocarbon yr plus varve yr) to the sediments of Lake Hitchcock, and by correlation, to deposits of central New York. Correlation of the paleomagnetic records gives an estimated age of 14.8 ka for the base of the Poland Formation. This age of 14.8 ka also marks the end of erosion and fluvial activity associated with the Shed Brook Discontinuity and Little Falls Gravel, and probably corresponds to the end of the Erie Interstade. However, more radiocarbon control in both New York and New England will be needed to test the applied numerical time scale of the paleomagnetic records, and also to calibrate the time scale to calendar years in order to account for the secular variation in radiocarbon (Fairbanks, 1989, 1990).

CONCLUSIONS

All existing morpho- and litho-stratigraphic constraints, and correlation of paleomagnetic declination records from central New York and New England, are consistent with an Erie Interstadial age for the Shed Brook Discontinuity and Little Falls Gravel. Events recorded by these units in the western Mohawk Valley do not prove or disprove the existence of low water levels in the Erie Basin during the Erie Interstade. However, at approximately the same time as the Erie Interstade, conditions in the Mohawk Valley appear to have met all requirements for eastern drainage of low level lakes in the Erie and Ontario Basins. These conditions included complete recession of the Mohawk Lobe, drainage of all glacial lakes from the western Mohawk Valley, a river flowing east in the valley, and widespread upland erosion and stream valley development in tributary systems to the Mohawk Valley. What still needs to be demonstrated from central to western New York in the Ontario Basin is an adequate amount of Ontario Lobe recession during the Erie Interstade (Fig. 1) which would have permitted eastward drainage of the Erie Basin at a low elevation.

ACKNOWLEDGMENTS

This study was supported by grants from the Geological Society of America, Sigma Xi, the Senate Research Committee of Syracuse University and National Science Foundation Grant No. EAR-8116097, and support for field work from the New York State Geological Survey and the Geology Department of Syracuse University. Paleomagnetic laboratory facilities were provided by the Department of Geological Sciences of the State University of New York College at Geneseo and Tufts University. William J. Brennan, David A. Franzi, Cheryl L. Marvinney, and Ernest H. Muller deserve thanks for provocative discussions regarding many aspects of the paper. Review by Parker E. Calkin of an early draft of the manuscript resulted in significant improvements and simplification. Matthew R. Bertrand, Mark R. Besonen, Brian D. DesMarais, and Todd M. Hurley deserve credit for help in the field, while Patrice E. Connelly, James R. King, and Sharon L. Zaboly, all of Tufts University, deserve thanks for there diligence in processing paleomagnetic samples.

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ARTICLE E

A SUMMARY OF VALLEY HEADS GLACIATION IN THE WESTERN MOHAWK VALLEY

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INTRODUCTION

The Valley Heads Drift (Mickelson and others, 1983) in the western Mohawk Valley region of central New York (Poland Formation, Fig. 1; Ridge, 1985; Ridge and others, 1990, Article A) records a complex history of ice advances and glacial lake impoundment (Fig. 2; see also Muller and others, 1986). Valley Heads deposits between Little Falls and St. Johnsville overlie the Little Falls Gravel, a fluvial unit which represents an eastward draining river in the Mohawk Valley at the end of pre-Valley Heads time. Valley Heads diamicton units in the western Mohawk Valley record three readvances of the Ontario Lobe and one readvance of the Mohawk Lobe, while a second Mohawk Lobe readvance is inferred from the lake level history of the valley. Lacustrine deposits in the western Mohawk Valley record glacial lakes impounded at various levels between the Ontario and Mohawk Lobes.

LITHOSTRATIGRAPHIC ANALYSIS

In the West Canada Valley, and along a few stretches of the Mohawk Valley axis, stratified deposits of the Poland Formation are dominated by silt and clay varves which are laterally traceable over much of the region (Fig. 1; see also Figs. 2 and 3 Ridge and others, 1990, Article A). In several areas along the axis of the western Mohawk Valley, however, stratified deposits are coarse gravel to sand sequences representing esker and ice-marginal subaqueous fan environments (Fig. 1). Associated with highly energetic subglacial deposition of gravel was the meltwater erosion of older units and the development of unconformities (especially sections 951-954 in Fig. 1). Tracing and identification of lithostratigraphic units in the axis of the valley is very much dependent on more complete sections on the sides of the Mohawk Valley at higher elevations, and knowledge of the much more complete and continuous stratigraphic section in the West Canada Valley (Figs. 2 and 3, Ridge and others, 1990, Article A).

Although all the stratigraphic units in the western Mohawk Valley have provenances which are partly diluted by the reworking of older units, several overriding differences allow a distinction between Ontario and Mohawk Lobe deposits.

<u>Near St. Johnsville</u>: Mohawk Lobe diamicton is very sandy and stony with a high percentage of dolostone and metamorphic pebbles, reflecting sources to the east in the Adirondacks and the central Mohawk Valley; Ontario Lobe diamicton is very clayey, very sparsely stony and may have a reddish or pinkish tint, reflecting the reworking of lacustrine sediment (sections 934, 820, and 821 in Fig. 1).

Near Little Falls and Herkimer: Mohawk Lobe diamicton is very dark gray to black in color as a result of ice overriding several kilometers of black Utica Shale; Ontario Lobe diamicton is dark to medium gray and has more limestone pebbles (sections 949-954, and 959 in Fig. 1).

In the Sterling Creek area: Mohawk Lobe diamicton has a high percentage of non-calcareous shale pebbles as a result of ice crossing the Lorraine Group between Sterling and West Canada Creeks; Ontario Lobe diamicton has more black shale, limestone and red sandstone pebbles derived from western sources (sections 693-893 in Fig. 1).

Mohawk Valley floor, Utica and Rome areas: Ontario Lobe diamicton is either gray or red in color depending on the Ontario Lobe flow trajectory at various times; Mohawk Lobe diamicton has not been found this far west (sections 814, 946, 947, and 961-963 in Fig. 1).

Throughout the region, lacustrine silt and clay associated with Mohawk Lobe deposition are black to medium gray in color and have gray and black pellets (pre- and post-Hawthorne beds in Fig. 1); Ontario Lobe silt and clay have reddish to pinkish gray, red and pink beds, and red and pink pellets are usually abundant (pre- and post-Norway, Holland Patent, and Rome beds in Fig. 1).

(Note: see Article F, this guidebook for an explanation of pellets.)

DIFFERENCES WITH PREVIOUS MODELS

Detailed mapping in the western Mohawk and West Canada Valleys has revealed that the chronology and events of Valley Heads glaciation (Muller and others, 1986, and the following discussion) are much more complex than previous regional models seem to indicate (Fullerton 1971, 1980; Mayewski and others, 1981; Mickelson and others, 1983). Differences between previous models are listed below.

1. Ontario Lobe diamicton units east of Herkimer represent two separate readvances which replace the Indian Castle Readvance (Fullerton, 1971).

2. The Indian Castle Readvance limit as mapped by Fullerton (1971) does not coincide with the edge of a till sheet or ice-marginal deposits.

3. The Mohawk Lobe is now known to have readvanced into the western Mohawk and West Canada Valleys during Valley Heads time.

4. All of the Ontario Lobe readvances were fronted by lakes (Lakes Cedarville, Gravesville, and Amsterdam in Fig. 2), and not by fluvial outwash plains (see laminated silt and clay units in sections 820, 821, 934, 946, 947, 951-953, and 963 in Fig. 1). Lakes at the margin of the Ontario Lobe imply that the eastern end of the Mohawk Valley was blocked by the Mohawk Lobe during almost the entire period of Valley Heads glaciation.

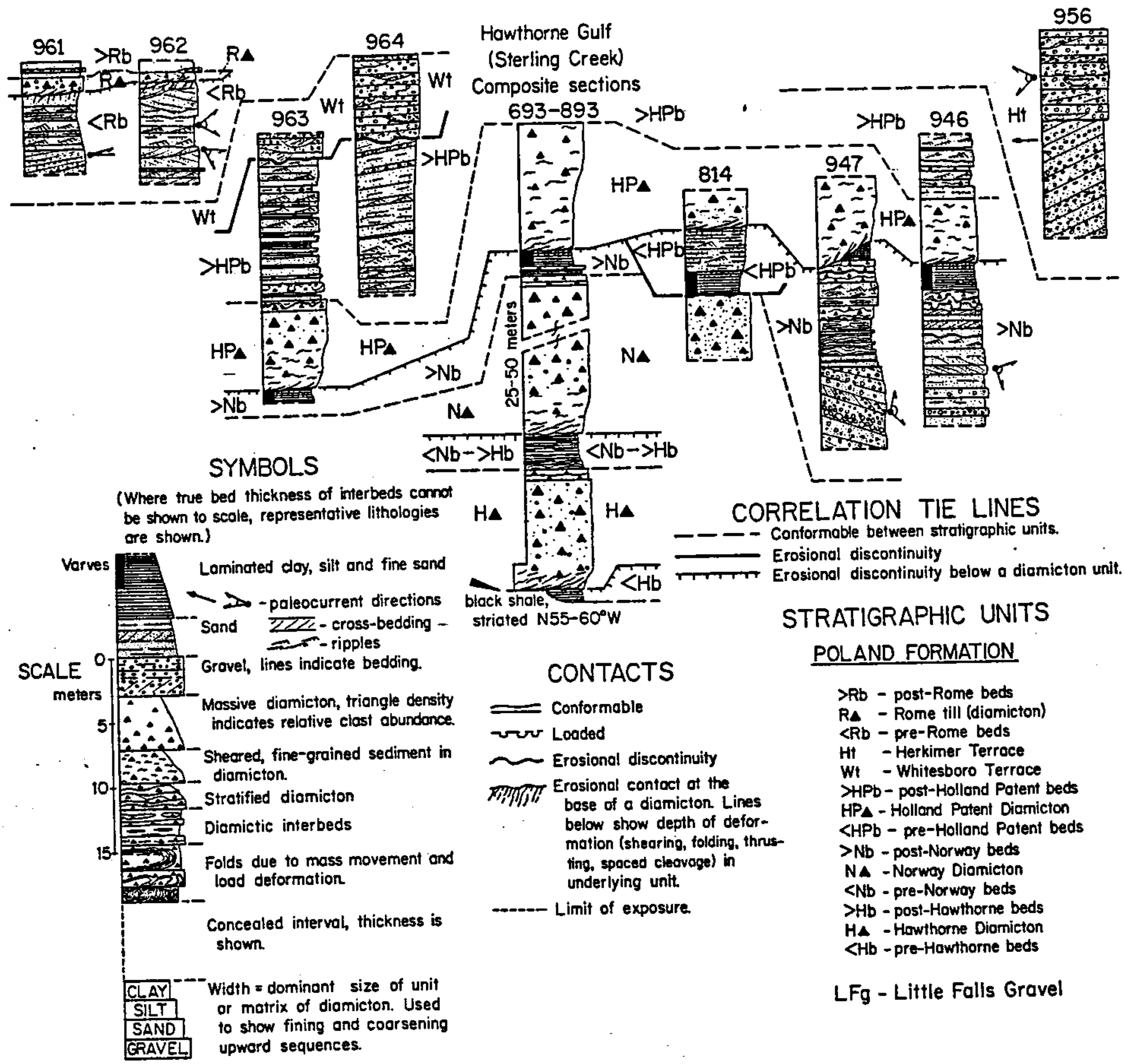
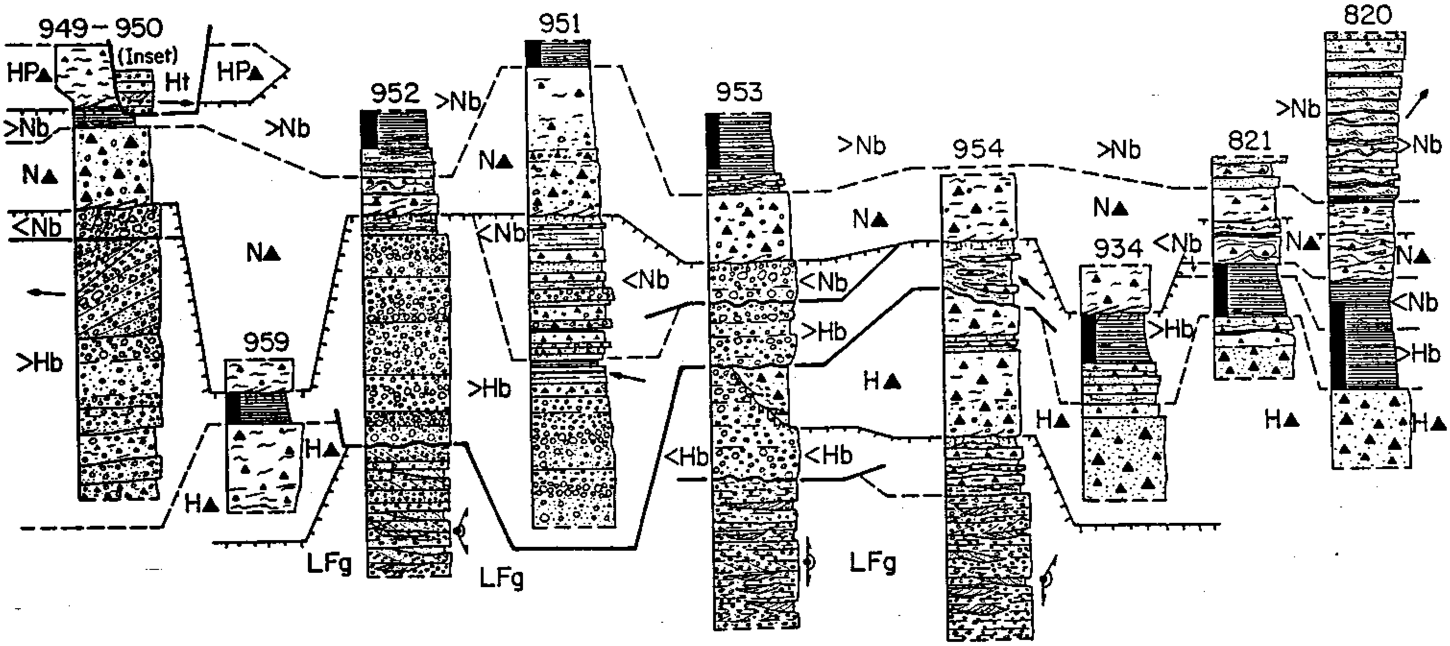


Figure 1. Representative lithostratigraphic sections in the western Mohawk Valley. Sections are not plotted to show relative elevations which vary by as much as 200 m from place to place.


949–950
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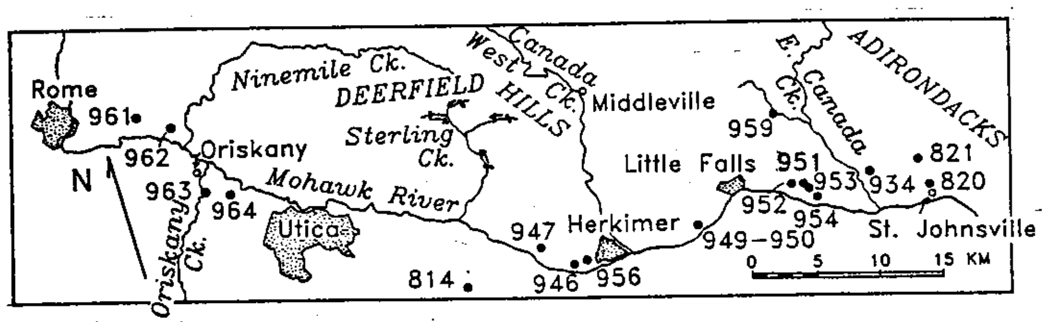
LOCATION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962
Oriskany
963
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Oriskany Ck.
Ninemile Ck.
DEERFIELD
HILLS
Sterling Ck.
Mohawk River
Utica
West Canada Ck.
Middleville
814
947
946
956
Herkimer
959
Little Falls
951
953
952
954
949–950
E. Canada Ck.
ADIRONDACKS
934
821
820
St. Johnsville
0 5 10 15 KM

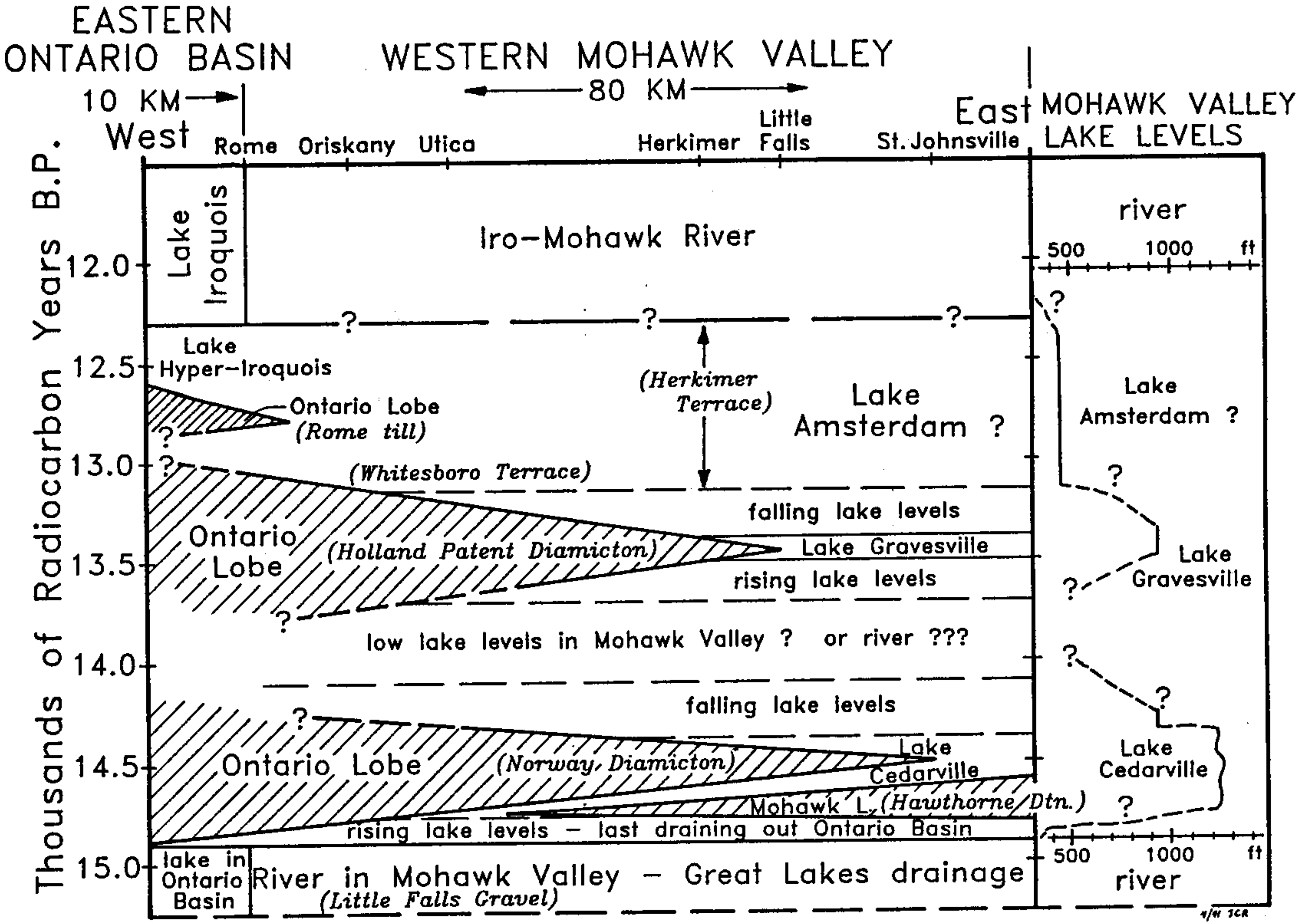


Figure 2. Time-distance plot of Valley Heads glacial events in the western Mohawk Valley. Litho- and morpho-stratigraphic units are shown in italics.

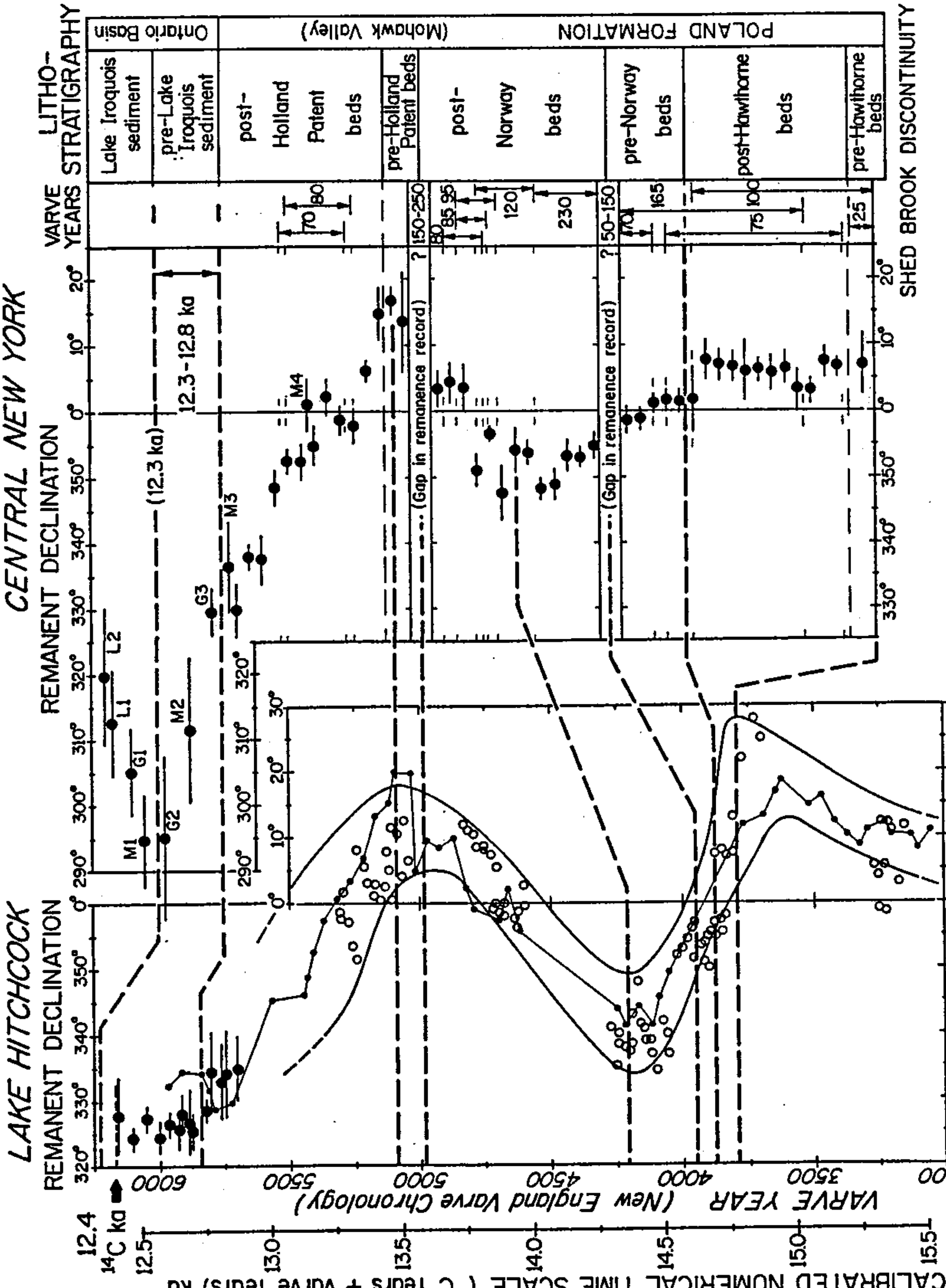
5. Readvances of the Ontario Lobe to positions east of Herkimer were by glaciers with deep water (>150 m), calving margins.

6. Neither the prominent basement rock high at Little Falls, or a drift dam in this area, appear to have been dams or controlling outlets for Mohawk Valley lakes which are represented by low level terraces west and east of Little Falls.

NUMERICAL AGES FOR VALLEY HEADS DEPOSITS AND EVENTS

Numerical ages for Valley Heads deposits and events in the western Mohawk Valley have been inferred from the radiocarbon age of Lake Iroquois sediments in the Ontario Basin, and by paleomagnetic correlation with sediments in New England (Fig. 3). Paleomagnetic declination records from lacustrine sediments of the Poland Formation and early sediments of Lake Iroquois (Ridge and others, 1990, Article A; Brennan and others, 1984) have been matched with a paleomagnetic declination curve from sediments of glacial Lake Hitchcock in the Connecticut River valley of western New England (Johnson and others, 1948; Verosub, 1979). Highlights of the paleomagnetic correlation (Fig. 3) are the matching of two declination maxima of equal amplitude and the coincidence of relatively rare, extremely western declinations (320-330^{o}).

A 4,400-yr floating time scale has been applied to Lake Hitchcock sediments in the form of the New England Varve Chronology (Antevs, 1922). The varve chronology has recently been calibrated with radiocarbon dates (Ridge and Larsen, 1990), which allows the application of a numerical time scale (radiocarbon yr + varve yr) to the Lake Hitchcock sediments. The paleomagnetic correlation of the western Mohawk Valley and Lake Hitchcock sediments allows the application of the New England numerical time scale to Mohawk Valley sediments and events. In addition, the closing phases of Valley Heads glaciation can be tied to the formation of Lake Iroquois at 12.2-12.4 ka, a relatively well dated event in central New York (Fullerton, 1980; Muller and Prest, 1985). The age of about 12.3 ka for Lake Iroquois deposits is the same as for paleomagnetically correlative Lake Hitchcock sediments in New England (Fig. 3; Ridge and Larsen, 1990). The radiocarbon age of Lake Iroquois is the only independent radiocarbon test in central New York of the proposed numerical time scale. The paleomagnetic correlation and numerical time scale also provide the basis for identifying the Little Falls Gravel and the Shed Brook Discontinuity as Erie Interstadial equivalents (Ridge, in prep., Article D). The proposed time scale and chronology are bound to undergo revision, and will be more adequately tested, as new radiocarbon dates become available and as numerical ages are recalibrated to account for the secular variation of radiocarbon (Fairbanks, 1989, 1990).



LAKE HITCHCOCK
REMANENT DECLINATION
CENTRAL NEW YORK
REMANENT DECLINATION
VARVE YEARS
LITHO-STRATIGRAPHY
Ontario Basin
Lake Iroquois sediment
pre-Lake Iroquois sediment
(Mohawk Valley)
post-Holland Patent beds
pre-Holland Patent beds
POLAND FORMATION
post-Norway beds
pre-Norway beds
post-Hawthorne beds
pre-Hawthorne beds
SHED BROOK DISCONTINUITY
(12.3 ka)
12.3-12.8 ka
(Gap in remanence record)
(Gap in remanence record)
L1
L2
G1
G2
G3
M1
M2
M3
M4
150-250
50-150
VARVE YEAR (New England Varve Chronology)
^{14}C ka
CALIBRATED NUMERICAL TIME SCALE (^{14}C Years + Varve Years) ka

Figure 3. Correlation of remanent declination records from lacustrine clay and silt deposited during late Wisconsinan ice recession in Lake Hitchcock in western New England and in central New York. Correlations of the two declination records are shown by heavy dashed tie lines. Lake Hitchcock records are from varve sections which have been matched with the New England Varve Chronology shown on the vertical axis in arbitrary varve years (3,000 to 6,250, Antevs, 1922). Calibration of the varve chronology is based on radiocarbon dates of 12.4 ka at Canoe Brook in Vermont ($42^{o}56'44"$, $72^{o}32'06"$; Ridge and Larsen, 1990). The area between the two smoothed curves on the Lake Hitchcock record represents the region within which geomagnetic declination lies as interpreted by Verosub (1979) from natural remanences (Johnson and others, 1948; solid circles with tie line) and remanences after AF demagnetization at 17.5-20 mT (Verosub, 1979; open circles). Remanent declination means after AF demagnetization at 30 mT from sites in couplets 5700-6200 (new data, 9-18 specimens/site spanning 8-20 year intervals) are shown as large solid circles with error bars (alpha-95 confidence intervals). New data is from varve sections at Canoe Brook, Vermont and from Mill Brook, Vermont ($42^{o}57'37"$, $72^{o}31'58"$). Remanent declination means and confidence intervals (alpha-95) from central New York (unlabeled sites, 9-16 specimens/site, AF demagnetized at 30 mT are from Ridge and others, 1990; sites L1-2, G1-3, and M1-4, 6-16 specimens/site, AF demagnetized at 10-40mT are from Brennan and others, 1984) are plotted by relative age as indicated by position in superposed lithostratigraphic units or morphologic successions in the western Mohawk Valley (Ridge and others, 1990, Article A this guidebook) and the Ontario Basin (Fullerton, 1980). Numerical ages of pre-Lake Iroquois and Lake Iroquois sediments are based on Fullerton (1980) and Muller and Prest (1985).

A SEQUENCE OF EVENTS - VALLEY HEADS GLACIATION

The following sequence of events can be followed on Figure 2 which shows the glacial readvances and lake level history of the western Mohawk Valley and eastern Ontario Basin between 15 and 12 ka.

During latest pre-Valley Heads time (15.5-15.0 ka) the Ontario Lobe margin was well back in the Ontario Basin, thus allowing eastward drainage of the Great Lakes through the Mohawk Valley (Fig. 2). Eastward drainage in the Mohawk Valley was not blocked by the Mohawk Lobe at the eastern end of the Mohawk Valley. These events are represented by the fluvial Little Falls Gravel in the Mohawk Valley (sections 951-954 in Fig. 1), and subaerial erosion associated with the Shed Brook Discontinuity in the West Canada Valley (Ridge, in prep., Article D; see also Figs. 2 and 3, Ridge and others, 1990, Article A).

1. (About 15.0 ka) - At the start of Valley Heads glaciation both the Mohawk and Ontario Lobes began to readvance.

2. (About 14.9 ka) - The eastward drainage of water via a river in the Mohawk Valley was blocked by the advance of the Mohawk Lobe in the eastern Mohawk Valley so that proglacial lakes were formed in the Mohawk Valley. The Little Falls Gravel (section 954 in Fig. 1) and bedrock (Hawthorne Gulf in Fig. 1) in the Mohawk Valley, and the Shed Brook Discontinuity in the West Canada Valley (Ridge, in prep., Article D), were overlain by lacustrine sediment in the base of the pre-Hawthorne beds.

3. (14.9-14.8 ka) - As the Mohawk Lobe advanced, lake levels in the Mohawk Valley rose to an elevation of at least 700 feet. In the West Canada Valley from Newport to Poland, lake bottom sand in the pre-Hawthorne beds was deposited by southward flowing currents coming from the upper West Canada Valley (sections 338 and 387 in Fig. 2, Ridge and others, 1990, Article A).

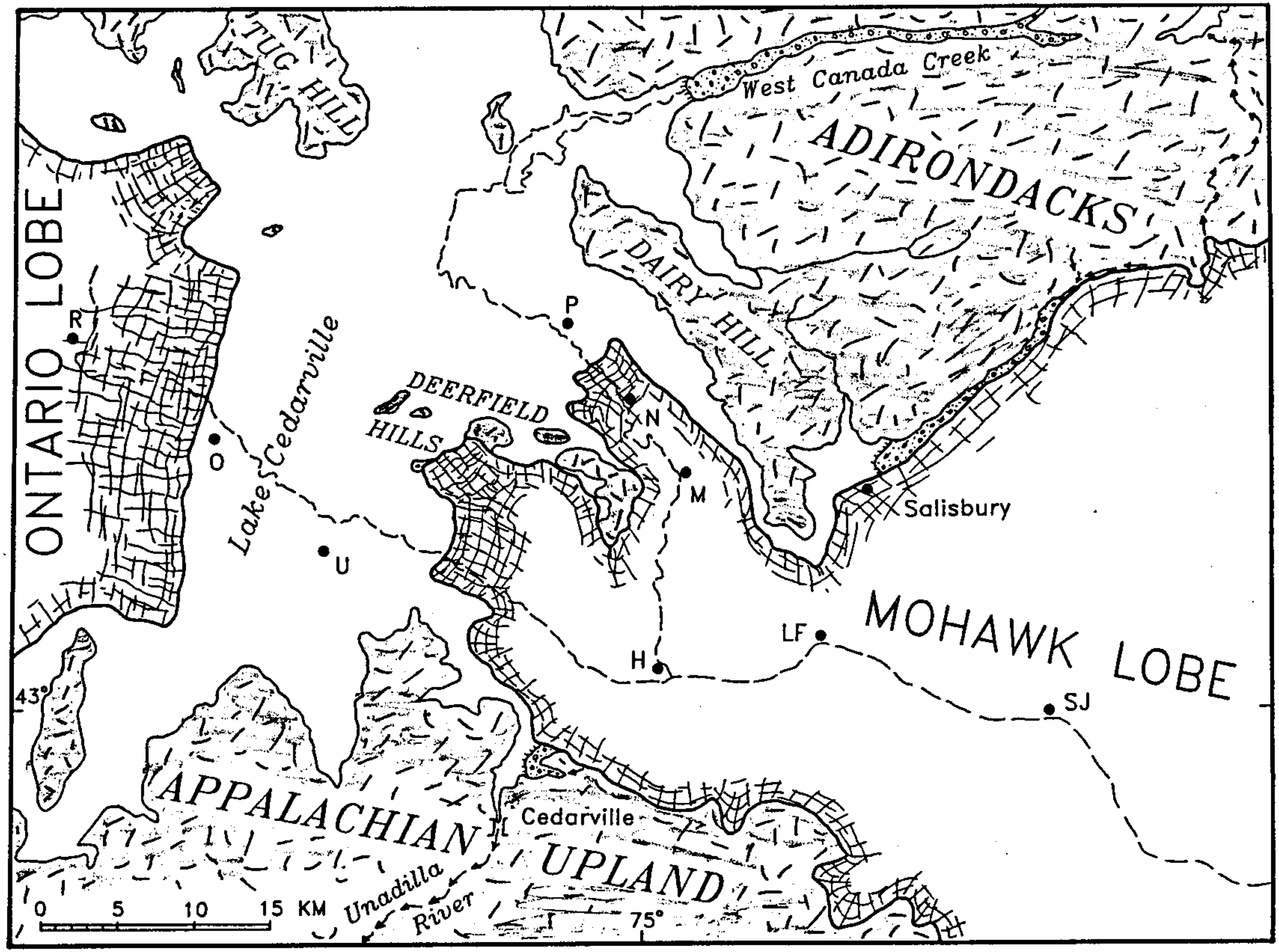


Figure 4. The Salisbury readvance of the Mohawk Lobe. Abbreviated place names are H = Herkimer, LF = Little Falls, M = Middleville, N = Newport, O = Oriskany, P = Poland, R = Rome, SJ = St. Johnsville, U = Utica.

4. (14.8 ka) - Within 25 years of the Mohawk Lobe reaching its maximum extent, there was a rapid rise in lake level in the Mohawk and West Canada Valleys representing impoundment to the level of an outlet at Cedarville (Lake Cedarville, Figs. 2 and 4). Deposition of the pre-Hawthorne beds in the West Canada Valley changed abruptly from sand to silt and clay varves with northward paleocurrent indicators (sections 338 and 387 in Fig. 2, Ridge and others, 1990, Article A). By the time lake water rose to the level of Lake Cedarville, the Mohawk Lobe was effectively to far west to close off any additional drainage outlets that could account for impoundment of water to the level of Lake Cedarville. Therefore, the impoundment of Lake Cedarville was probably the result of the closure of an outlet in the Ontario Basin by the advance of the Ontario Lobe.

5. (14.8 ka) - The Salisbury Readvance of the Mohawk Lobe reached its maximum westward position in the Mohawk and West Canada Valleys (Fig. 4). The Salisbury Readvance is responsible for the deposition of the Hawthorne Diamicton. Ice-contact deltas and ice-marginal subaqueous fans were deposited along the northern Mohawk Lobe margin at Salisbury. The advance of the Mohawk Lobe may have been retarded by rapid calving resulting from the sudden rise in water to the level of Lake Cedarville.

6. (14.8-14.6 ka) - Recession of the Mohawk Lobe was marked by deposition of the post-Hawthorne beds in both the West Canada and Mohawk Valleys (Fig. 1; Figs. 2 and 3, Ridge and others, 1990, Article A). Advance of the Ontario Lobe into the western Mohawk Valley region caused a change in the provenance of lacustrine sediments marked by deposition of the pre-Norway beds. Lake water remained at the level of Lake Cedarville. At no time did grounded Ontario and Mohawk Lobes collide because Mohawk and Ontario Lobe till units are separated by laminated lacustrine sequences (Hawthorne Gulf sections and sections 820, 821, 934, 949-954, and 959 in Fig. 1; see also Figs. 2 and 3 of Ridge and others, 1990, Article A).

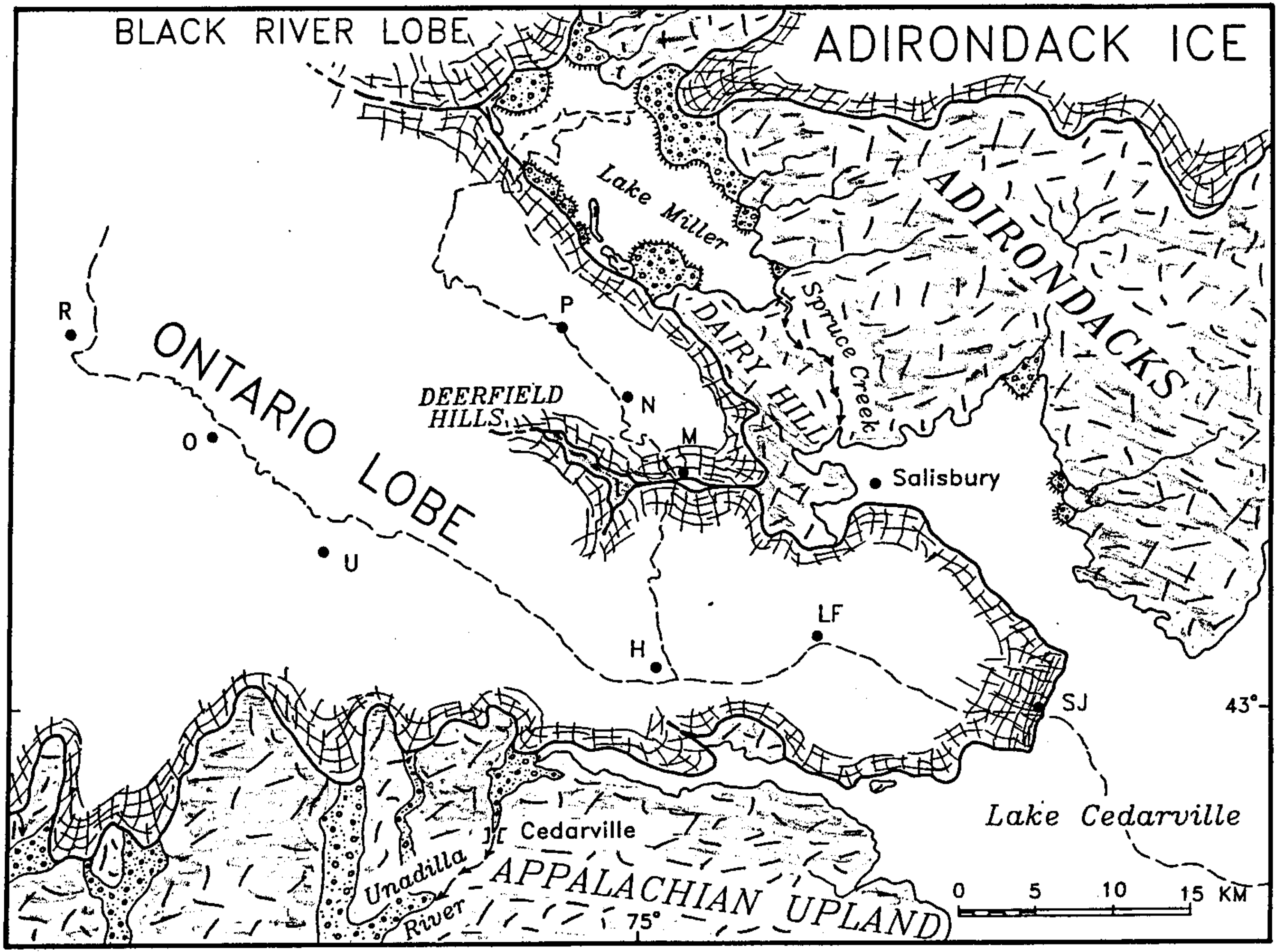


Figure 5. The St. Johnsville Readvance of the Ontario Lobe. Abbreviated place names are the same as in Figure 4.

7. (14.6-14.5 ka) - The St. Johnsville Readvance of the Ontario Lobe reached its maximum extent (Fig. 5), while the Mohawk Lobe receded further east. The St. Johnsville Readvance is recorded by deposition of the Norway Diamicton and a morainal bank composed of mud and sand at St. Johnsville (sections 820 and 821 in Fig. 1). The Deerfield Hills were not completely overtopped by the Ontario Lobe and became a nunatak surrounded by separate projections of the Ontario Lobe that advanced up the valley from Herkimer, down the valley from the west, and collided near Middleville. Lake Miller was impounded in the upper West Canada Valley at the margin of the Ontario Lobe where a large ice-contact delta (Ohio Delta) prograded into the lake. The Black River Lobe coalesced with the Ontario Lobe at the western end of Lake Miller and the readvance of Adirondack ice reached its maximum extent along the northeast shore of Lake Miller (Franzi, 1984). The outlet at Cedarville remained as the controlling elevation for water in the Mohawk Valley (Lake Cedarville), provided that the southern margin of the Ontario Lobe did not advance any further than is shown on Figure 5. Further advance of the Ontario Lobe would have caused closure of the Cedarville outlet, but no evidence has been found for lake levels higher than Lake Cedarville in the Mohawk Valley during Valley Heads time. About 175-200 years separate the maxima of the Salisbury and St. Johnsville Readvances. The maxima do not appear to be non-synchronous enough to conclude that the readvances were caused by different stimuli.

8. (14.5-13.8 ka) - Ontario Lobe recession was marked by deposition of the post-Norway beds (Fig. 1; Figs. 2 and 3, Ridge and others, 1990, Article A). Lake Miller catastrophically broke out of the upper West Canada Valley and cut a southward draining channel through the Ohio Delta. Lake water escaped eastward to Lake Cedarville along the northern margin of the Ontario Lobe at Dairy Hill (Fig. 5). The Ontario Lobe receded to at least as far west as Oriskany where lacustrine deposits occur beneath the Holland Patent Diamicton (section 963 in Fig. 1). Lake levels dropped to below a level attained during the next Ontario Lobe readvance (Lake Gravesville). In the West Canada Valley an erosion surface was cut into the post-Norway beds that were later buried by younger deltaic deposits of Lake Gravesville (section 342 in Fig. 2, Ridge and others, 1990, Article A). It is not known to what low level lakes fell in the Mohawk Valley. Thus far, evidence in the West Canada Valley indicates that water levels fell in the Mohawk Valley to below 850 feet. If the Mohawk Valley was used as an eastern outlet for water in the Great Lakes region (Mackinaw Interstadial events ?), lake levels may have been as low as 500 feet, or a river could have formed in the valley.

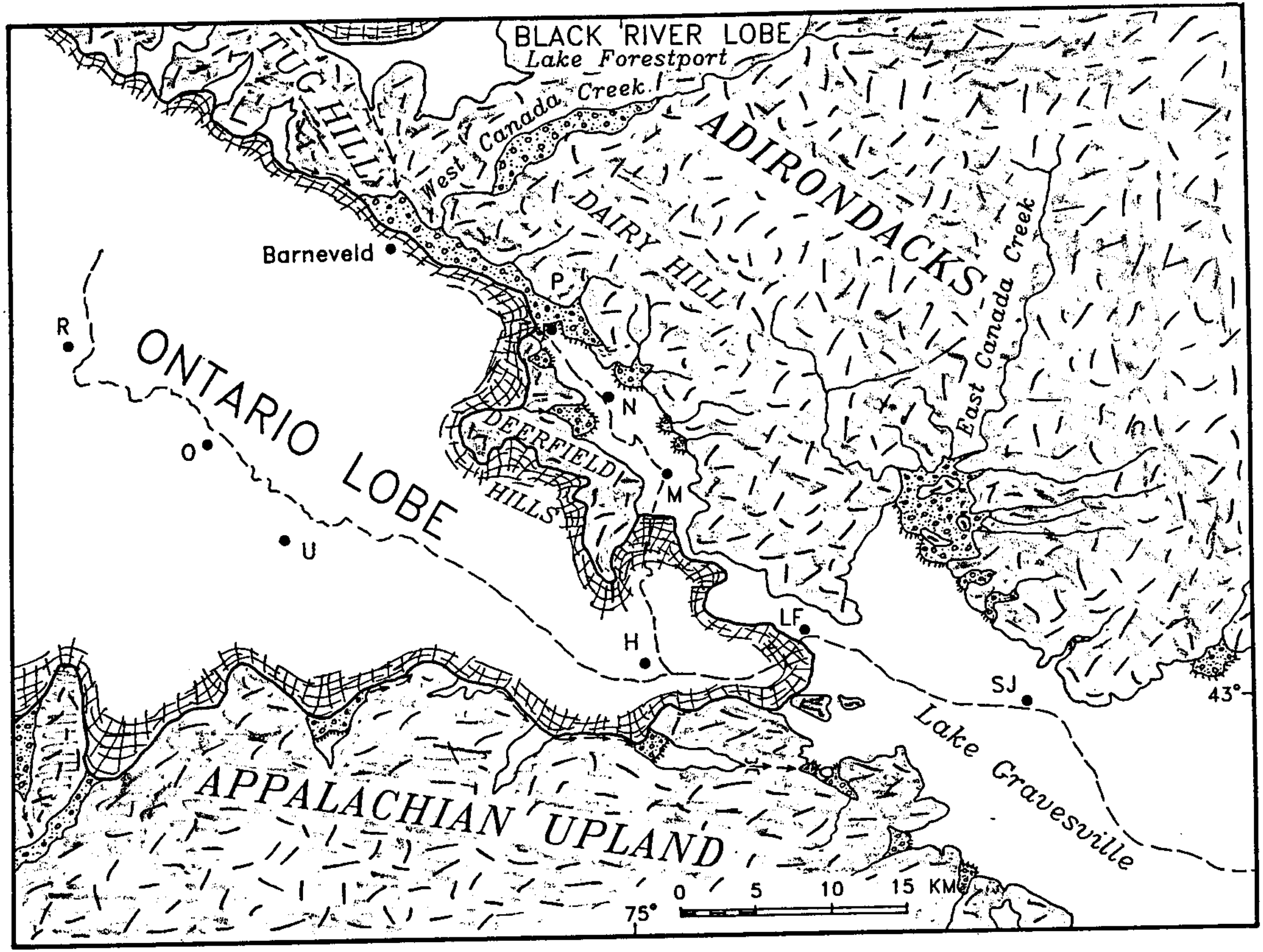


Figure 6. The Little Falls Readvance of the Ontario Lobe. Abbreviated place names are the same as in Figure 4.

9. (13.8-13.5 ka) - The Ontario Lobe began to advance for the second time during Valley Heads glaciation. Rising lake levels in the Mohawk Valley, and local ice-marginal lakes, are recorded by rare exposures of the pre-Holland Patent beds (section 814 in Fig. 1).

10. (13.5-13.4 ka) - The Little Falls Readvance of the Ontario Lobe reached its maximum extent (Fig. 6), and deposited a morainal bank at Little Falls and the Holland Patent Diamicton. Lake levels in the Mohawk Valley rose to form Lake Gravesville which had its outlet at Delanson which is on the perimeter of the Schoharie Basin (southeast side of the Mohawk Valley). Deltas were deposited along the Ontario Lobe ice margin in the West Canada Valley from Poland to northwest of Barneveld and a fluvial surface graded to Lake Gravesville was cut into varves of the post-Hawthorne and pre-Norway beds along East Canada Creek. A delta prograded into Lake Gravesville at the mouth of East Canada Creek and other tributaries in the Mohawk Valley. Because the Holland Patent Diamicton has only been found to overlie the post-Norway beds, and not the pre-Holland Patent beds in the West Canada Valley, the impoundment of Lake Gravesville appears to have occurred at about the time the Ontario Lobe reached its maximum position. This implies that an advance of the Mohawk Lobe in the eastern Mohawk Valley was responsible for a rise in water to the level of Lake Gravesville. The final few kilometers of Ontario Lobe readvance could not close off any additional outlets which would have triggered the formation of Lake Gravesville. More information will be necessary to determine the exact timing of the formation of Lake Gravesville. The Ontario and Mohawk Lobes appear to have readvanced synchronously at the time of the Little Falls Readvance.

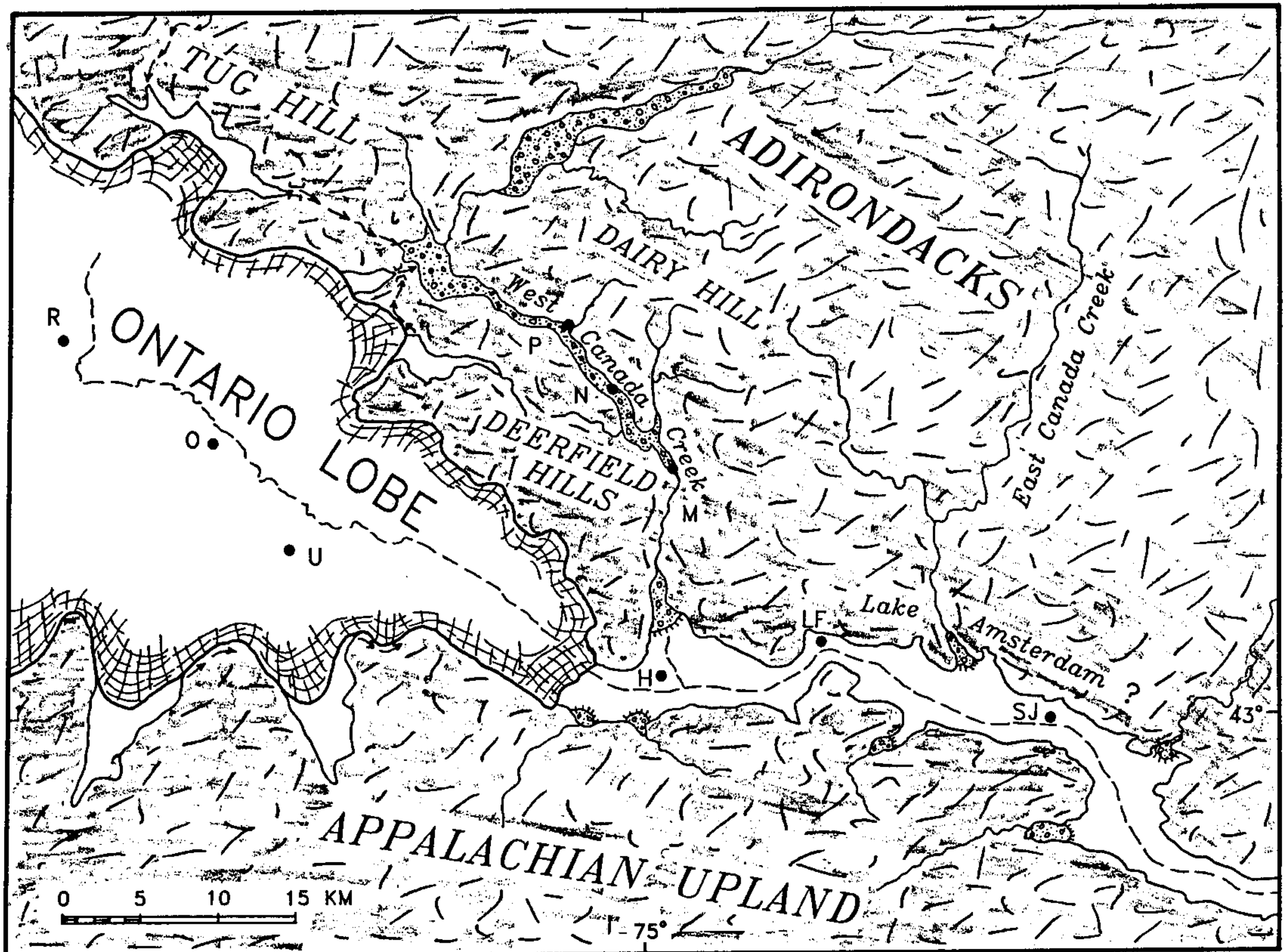


Figure 7. The final recession of the Ontario Lobe to west of Herkimer, New York. Abbreviated place names are the same as in Figure 4.

11. (13.4 ka) - Lake Gravesville (Fig. 6) persisted for a short period of time after the onset of Ontario Lobe recession because deltas of Lake Gravesville overlie till in the Holland Patent Diamicton in a small area of the West Canada Valley (Figs. 2 and 3, Ridge and others, 1990, Article A). Lake Gravesville deposits, however, do not occur along the west side of the West Canada Valley. The discharge of the West Canada Valley at the time of Lake Gravesville was large as is indicated by extensive Lake Gravesville deltas and younger terrace deposits. Lake Gravesville deltas would likely have filled the west side of the valley if the lake had been in existence when ice receded from the west side of the valley. Drainage of Lake Gravesville appears to be the result of Mohawk Lobe recession in the eastern Mohawk Valley because Ontario Lobe recession alone, by the time of lake drainage, does not appear to have been enough to open a lower drainage outlet.

12. (13.4-13.3 ka) - The exact pattern of lake drainage following the Little Falls readvance is not known. By the time the Ontario Lobe receded to just west of Herkimer (Fig. 7) water levels in the Mohawk Valley remained temporarily at an elevation of <u>at least</u> 560 feet (section 946 in Fig. 1). This lake may be an early version of Lake Amsterdam. Erosion of thick glacial sediments in the West Canada Valley was triggered by dropping base level. Fluvial terraces began to form in the West Canada Valley graded to Mohawk Valley lakes.

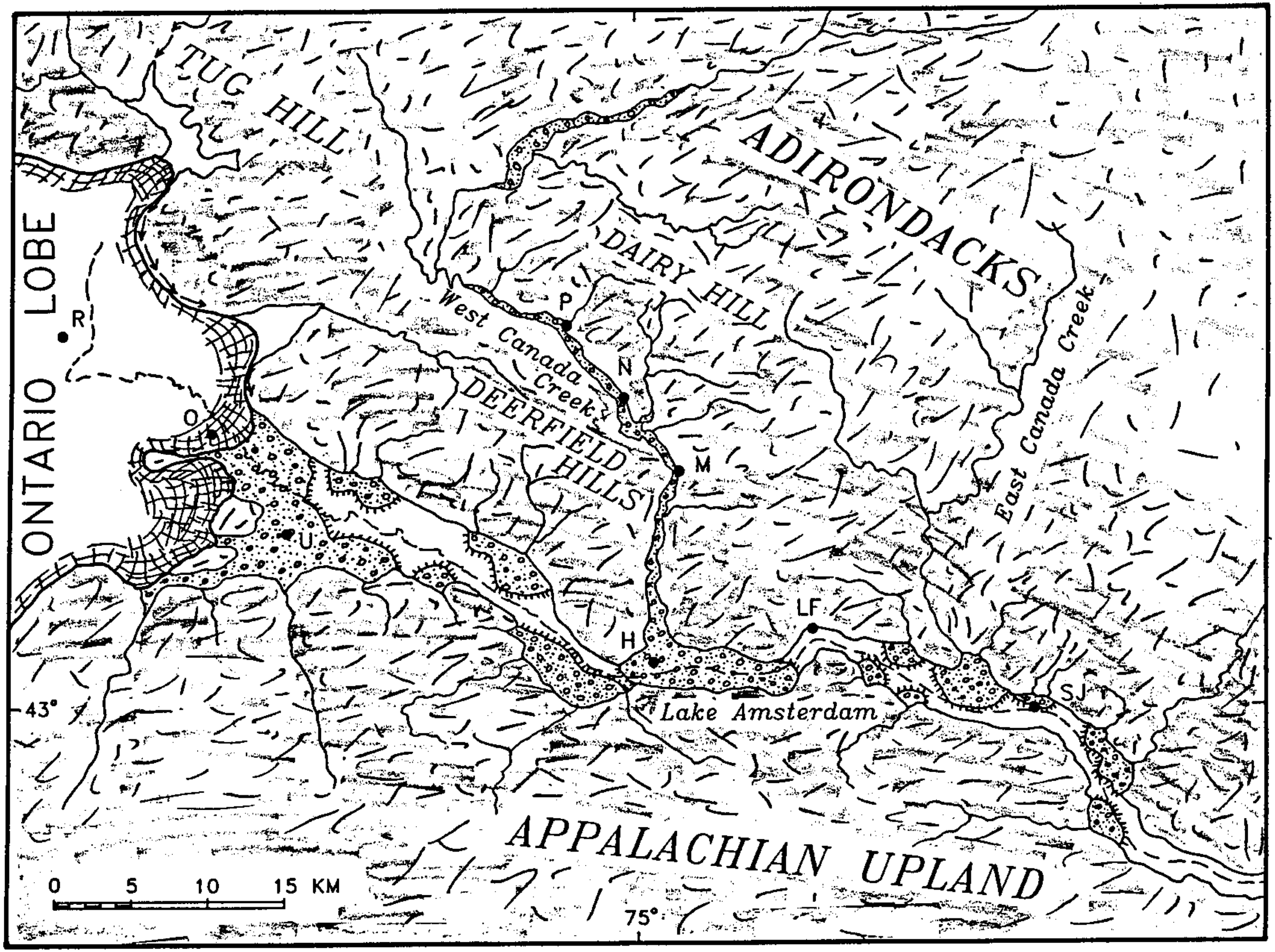


Figure 8. The final recession of the Ontario Lobe to Oriskany and development of the Whitesboro Terrace and Lake Amsterdam. Abbreviated place names are the same as in Figure 4.

13. (13.3-13.1 ka) - Recession of the Ontario Lobe continued to Oriskany where the Whitesboro Terrace was formed (sections 963-964 in Fig. 1; Fig. 8). The Whitesboro Terrace represents the earliest evidence for ice-marginal deposition graded to a Mohawk Valley lake level of 500 feet or lower. The Whitesboro Terrace may represent the initial drop in lake water to the level of Lake Amsterdam. Inwash deltas began to form at the mouth of almost every tributary in the Mohawk Valley, especially West and East Canada Creeks and small streams draining the steep slopes of the Deerfield Hills and Appalachian Upland. The Herkimer Terrace began to form at the mouth of West Canada Creek (sections 949 and 956 in Fig. 1).

14. (13.2-13.0 ka) - Recession of the Ontario Lobe occurred to at least Rome while Lake Amsterdam remained impounded in the Mohawk Valley (sections 961 and 962 in Fig. 1).

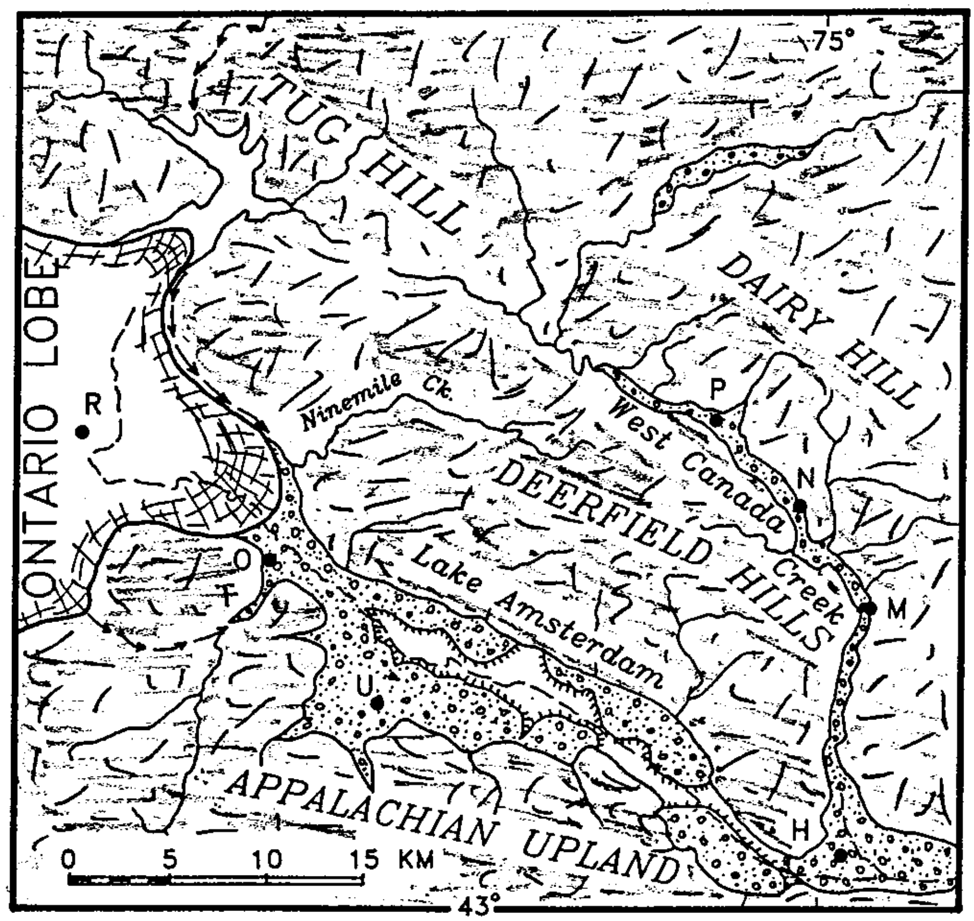


Figure 9. The Ninemile Readvance of the Ontario Lobe. Abbreviated place names are the same as in Figure 4.

15. (13.0-12.8 ka) - The Ninemile Readvance of the Ontario Lobe into the Mohawk Valley deposited red till (Rome till of Muller and others, 1986) as far east as Ninemile Creek (sections 961 and 962 in Fig. 1; Fig. 9). Deposits and features near Rome, that were used to recognize the Stanwix Readvance (Fullerton, 1971, 1980), may be in part the result of the more extensive ice cover of the Ninemile Readvance. A fluvial terrace deposited at the margin of the Ninemile Readvance, and inset in the Whitesboro Terrace, appears to be graded to the same level of Lake Amsterdam as the Herkimer Terrace (sections 949 and 956 in Fig. 1) which is the top of an inwash delta system. Other inwash deltas continued to prograde at the mouths of tributaries and some sections of the Mohawk Valley may have been closed off by the infilling of Lake Amsterdam (Fig. 9).

16. (12.8-12.3 ka) - The Ontario Lobe finally receded from the Mohawk Valley and into the Ontario Basin while water levels remained at the level of Lake Amsterdam. This lake level in the Ontario Basin is called Lake Hyper-Iroquois (Fullerton, 1980). Lake Hyper-Iroquois does not appear to be controlled by outlets at either Rome or Little Falls, but instead is continuous with a lake in the Mohawk Valley (Lake Amsterdam).

17. (12.3 ka - ?) - Eventually Lake Amsterdam in the Mohawk Valley drained, and Lake Iroquois was impounded behind the Ontario Basin/Mohawk Valley divide at Rome. Drainage of Lake Iroquois was via the Iro-Mohawk River in the Mohawk Valley which is represented by an extremely wide fluvial terrace between Rome and Herkimer. It is not known from evidence in the western Mohawk Valley whether the drainage of Lake Amsterdam was by catastrophic dam breaching or the slow decanting of water by isostatic adjustments. The numerous terrace levels between 400-480 feet, which truncate older glacial deposits in the Mohawk Valley, suggest that drainage was slow. Drainage may have been by isostatic decanting and the complex evolution of bedrock nick points at the eastern end of the Mohawk Valley.

18. (post-Iroquois events) - Drainage of the Ontario Basin into the St. Lawrence Lowland allowed the modern Mohawk River to develop and resulted in a drastic drop in discharge down the Mohawk Valley. In many places small streams built alluvial fans on terraces of the Iro-Mohawk River.

SOME UNANSWERED QUESTIONS

1. What is the significance of the general synchroneity of the Valley Heads readvances of the Ontario and Mohawk Lobes?

2. Can the Valley Heads readvances be postulated as climatic events, or are they the result of glaciological changes experienced over a wide area of the Laurentide ice sheet?

3. What is the significance of the advance of ice out of the Adirondacks in early Valley Heads time? Were the Adirondacks overtopped by continental ice flow, or were the Adirondacks an area of ice accumulation and nourishment?

4. What role did deep (>100 m) lakes play in controlling glacial readvances? rates of ice advance? rates of ice recession? Did rising water levels in a deep lake cut short the early advance of the Mohawk Lobe (Salisbury Readvance)?

5. What role did different lake levels and valley topography play in controlling the shapes of advancing versus receding glaciers? lobate or embayed?

6. Why did the Mohawk Lobe cover almost the entire western Mohawk Valley during pre-Valley Heads time (Ridge and others, 1991, Article B), while the Ontario Lobe dominated the scene during Valley Heads time? Is it because the pre-Valley Heads Mohawk Lobe did not have to readvance more than 100 km from as far east as the Hudson-Champlain Valley? Was the advance of the Mohawk Lobe during Valley Heads time impeded by rising proglacial lake water?

7. Why do esker and subaqueous fan deposits of Valley Heads drift appear to be limited to the deepest part of the Mohawk Valley axis? (These deposits have not been found at higher elevation <u>or</u> in the West Canada Valley.) Does the apparent absence of sand and gravel esker and fan deposits in Valley Heads sediment of the West Canada Valley reflect the grain size of subglacial materials? lower meltwater discharges than in the Mohawk Valley? a different form of meltwater discharge? the rapid destruction of sub-ice channels by a poorly drained and easily deformed substrate? or, very rapid ice recession?

8. Along the axis of the Mohawk Valley, what controls the occurrence of sand and gravel fan deposits? Do they reflect standstills of receding or advancing ice margins? Do they represent deposition controlled by valley topography? Do they represent large meltwater discharge events, possibly related to stages in the drainage of proglacial lakes?

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ARTICLE F

TILL AND DIAMICTON TERMINOLOGY AND DEPOSITION IN THE WESTERN MOHAWK VALLEY REGION

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INTRODUCTION

The following discussion is an attempt to evaluate the different processes of diamicton formation (Fig. 1), and subglacial conditions (especially for the Ontario Lobe) as they relate to modes and rates of till deposition by late Wisconsinan glacial readvances in the Mohawk Valley. Subglacial thermal limitations, widespread evidence of subglacial deformation, and high rates of deposition favor a deformation till origin for subglacial Ontario Lobe till in the Norway Diamicton. Subglacial till appears to represent a deforming bed load derived from the erosion of an overridden substrate possibly without any significant entrainment in basal ice. For clarity, definitions as they have been used in the western Mohawk Valley are given below.

A DEFINITION OF DIAMICTON

Diamicton: A non-lithified, very poorly sorted (i.e. muddy) gravel. A non-lithified diamictite (Frakes, 1978).

Diamicton by this definition can be either matrix or clast-supported, and may be either sandy and very stony or clayey and very sparsely stony. The definition does not imply a process or environment of origin. In the western Mohawk Valley the term diamicton has been used for the naming of lithostratigraphic units which in the past were given names that included the term "till". Although exposures of diamicton units in the Mohawk Valley are usually dominated by till, they are also partly composed of proglacial lacustrine diamicton. Therefore, the descriptive term "diamicton" seems more appropriate for describing both till and other diamictons in the lithostratigraphic units.

A DEFINITION OF TILL

A strict definition of till has been given by Lawson (1979, p.28) as: "sediment deposited directly <u>from</u> glacier ice, which has not undergone subsequent disaggregation and resedimentation." A modified definition is given below which allows till to be composed of debris which was not necessarily transported <u>in ice</u> as is implied by the wording "from glacier ice."

Till: Sediment that owes its final position to the release of debris from ice, or the processes of translocation, shear, drag, and squeeze flow (fluidized flow under subglacial pressure gradients) of debris by ice, without subsequent disaggregation or resedimentation.

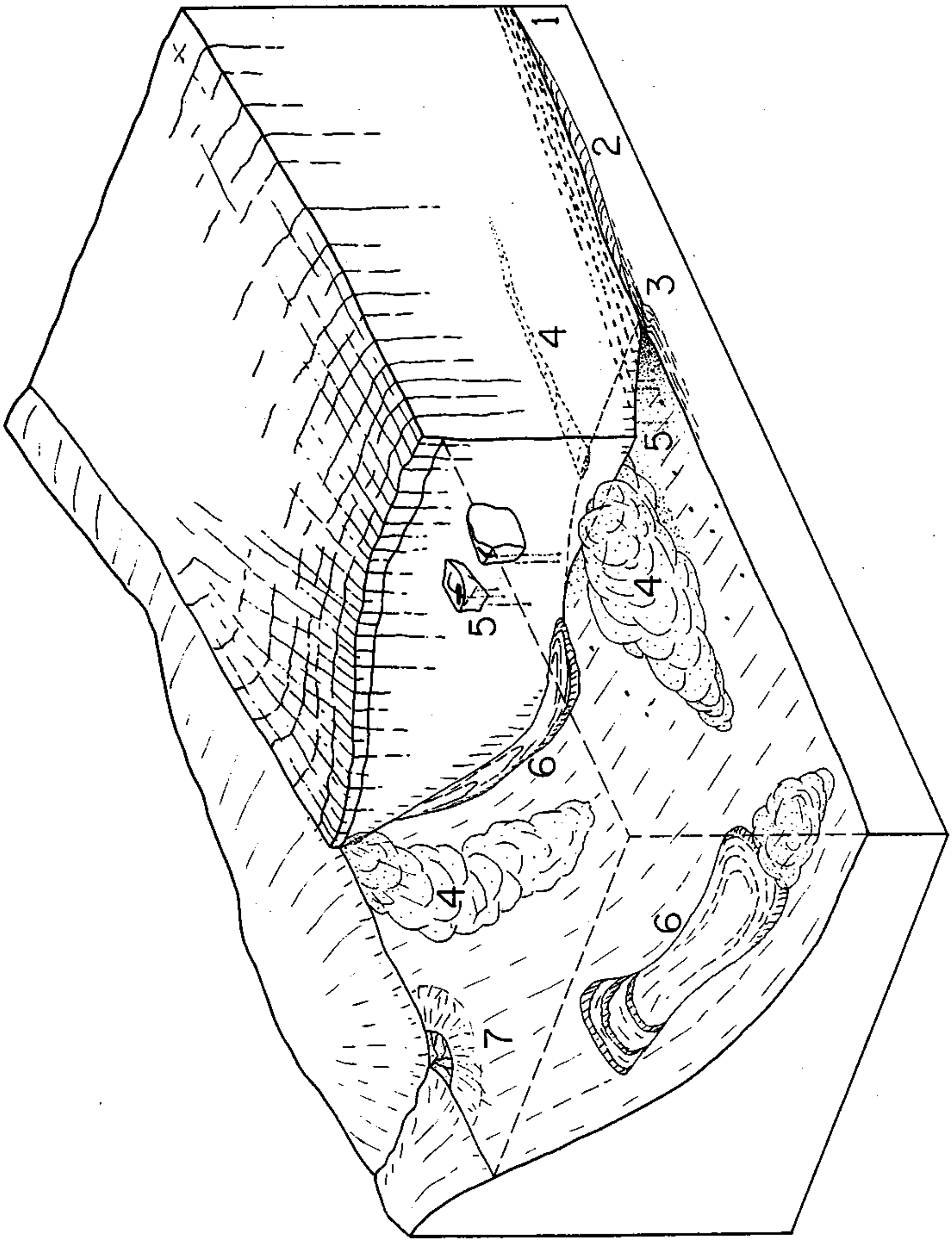
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Figure 1. Processes responsible for deposition in a deep water (100-350 m) glaciolacustrine trough such as in the West Canada and western Mohawk Valleys.

1. Freezing on of subglacial debris and materials. This process produces bed-parallel debris bands in basal ice.

2. Deformation of subglacial debris and substrata by overriding ice.

3. Squeeze flow or extrusion of sediment in response to pressure gradients, and plowing by an advancing grounding line.

4. Subglacial and ice-marginal meltwater channel systems delivering sediment to an ice margin. Sediment falls out of suspension from a meltwater plume or is carried further out into the lake basin by density driven bottom currents (underflow).

5. The dropping of material (stones and pellets) from floating icebergs (iceberg pellets) and the underside of a glacier ramp (undermelt diamicton and undermelt pellets).

6. The slumping and flow of lacustrine sediment to lower areas of the lake floor. These processes occur on slopes and can be triggered by the advancing front of a glacier. Larger slumps and flows can generate turbidity currents.

7. The introduction of sediment by inwash systems. Deltas and subaqueous fans are built at the mouths of inwash streams.

A

B

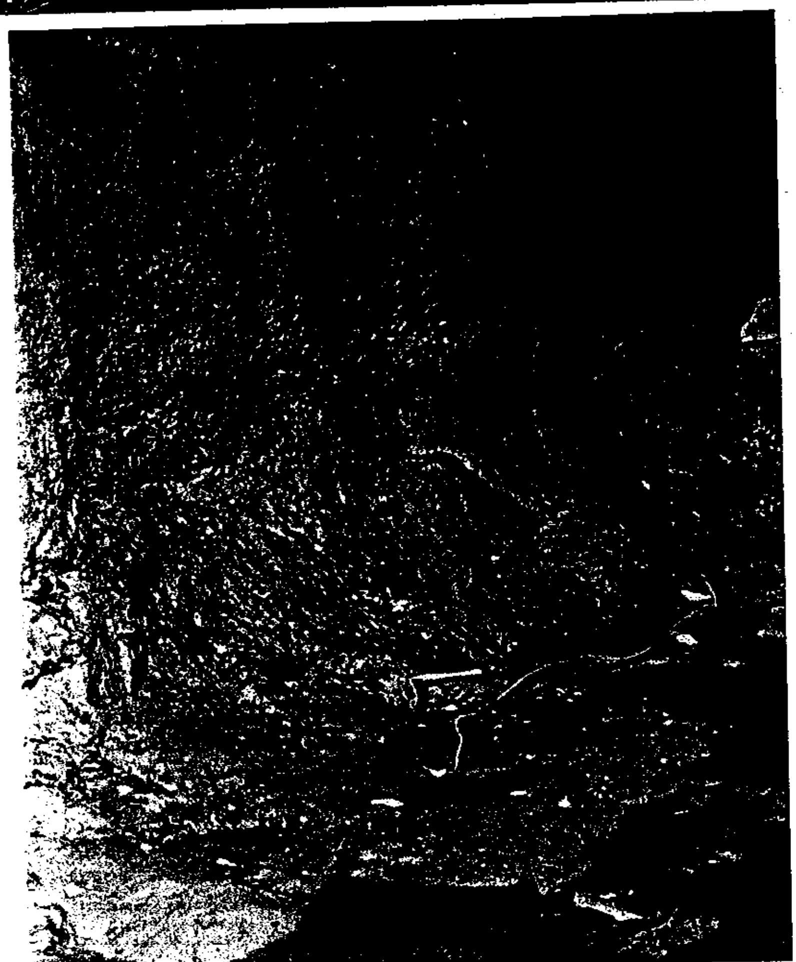


Figure 2. Subglacial till exposures in the West Canada Valley. The extremes in grain size are the result of different source materials and can occur as abrupt lateral facies changes within a single unit.

A. Stony and gritty till in the Hawthorne Diamicton.

B. Very sparsely stony, clayey till in the West canada Diamicton derived from overridden, lacustrine silt and clay of the lower Newport Beds. The lacustrine sediment has been deformed beyond the point of recognition of any original bedding or structure.

The definitions above exclude from till genesis such processes as free fall of debris through water and mass movement. The definition above does not allow the use of terms such as flow till, subaquatic till, and waterlain till.

GENETIC TYPES OF TILL

Genetic names for till are used to imply a location of formation and/or a sequence of processes responsible for till deposition.

Subglacial Till: Any till which is deposited beneath or from basal ice.

The term subglacial till is a convenient one to use in places where different subglacial processes of till deposition (release from basal ice vs. subglacial deformation) may be hard to identify (Fig. 2). Lodgement and deformation tills are subglacial tills which can be hard to distinguish in the field. The term "basal till" is not used in order to avoid confusion with another use of the term to indicate till at the base of a stratigraphic sequence.

Lodgement Till: Till deposited "by the plastering of glacial debris <u>from</u> the sliding base of a moving glacier" (Dreimanis, 1988, p.43).

This definition of lodgement till implies that the formation of lodgement till involves debris which is initially frozen in, or carried in, the ice as a requirement of it being "from" the glacier. Release and accretion of debris occurs by melting of moving basal ice, and as frictional resistance of entrained debris against the substrate becomes too great for moving basal ice to keep the debris in motion. Melting of basal ice is required for significant deposition of lodgement till. Lodgement till can be composed of debris that was deformed, sheared, translocated, dragged, or squeeze-flowed after being released from a glacier.

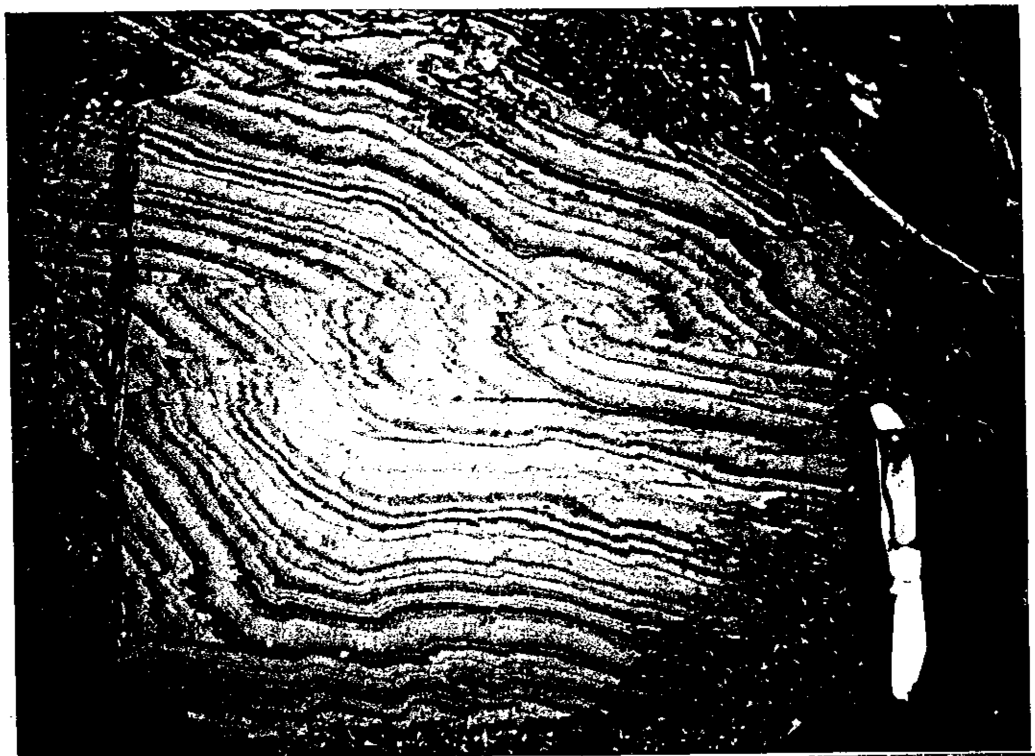
Melt-out Till: Till deposited "by a slow release of glacial debris from ice that is not sliding or deforming internally" (Dreimanis, 1988, p.45).

Melt-out till by this definition cannot be composed of debris that was dragged, sheared, translocated, or deformed by moving ice after release from glacier ice. It is strictly a phenomenon of non-moving or stagnant ice, and it should not show any evidence of deformation after its release from ice.

Deformation Till: Till that is deposited by the subglacial drag, translocation, shear, or squeeze flow of <u>subglacial</u> debris, and that does <u>not</u> owe any (or very little) of its final position to entrainment in basal ice (see also Elson, 1988).

This definition does not require that the original structure (or bedding) of the deformed debris still be identifiable. Deformation may be pervasive (penetrative) or discrete (brittle; Fig. 3). In many situations a weak, overridden substrate can be deformed to produce till (Fig. 2B). Debris can also be created by the abrasion of bedrock by debris in basal ice or the debris in a subglacially deforming load. By the definition above, debris created by abrasion would end up becoming deformation till if it was deposited without

A.



B.

Figure 3. Discrete deformation of overridden lacustrine sediments in the lower Newport Beds (see also Figs. 8 and 9, Ridge and others, 1990, Article A).

A. An overthrust with a nappe-like detachment structure in the lower Newport Beds beneath till in the West Canada Diamicton in the West Canada Valley (sections 158-168 in Fig. 2, Ridge and others, 1991, Article B).

B. High-angle thrust faults and wedging caused by horizontal compression of the basal unit of the lower Newport Beds beneath the West Canada "A" Diamicton in the West Canada Valley (sections 144-149 in Fig. 2, Ridge and others, 1991, Article B).

ever being frozen into or entrained in basal ice. It seems difficult, based on field criteria, to determine whether completely homogenized, deformed debris (Fig. 2) was at one time frozen into basal ice.

Deformable Bed or Deforming Debris: An overridden substrate or subglacial sediment that is deforming as a result of ice movement above (Boulton, 1979; Boulton and Jones, 1979; Alley and others, 1986, 1987; Boulton and Hindmarsh, 1987). The debris can be derived from the deformation or abrasion of overridden materials, or the release of debris from melting basal ice.

NON-TILL DIAMICTON

Proglacial Diamicton: Diamicton that was deposited in a glacial environment, beyond the terminus of a glacier.

Proglacial diamicton processes include mass movement (Hartshorn, 1958; Evenson and others, 1977; Lawson, 1979), or combined deposition through a water column as suspension settling and dropping of debris from floating ice (Eyles and Eyles, 1983; Eyles and others, 1983). Proglacial diamictons include mudflows, material disaggregated by slumping, and faintly or non-bedded lacustrine muds with dropstones and pellets (Fig. 4).

Undermelt Diamicton: Diamicton deposited entirely or mostly by dropping of adhered debris, and release of debris by melting of basal ice, at the underside (sole) of a water-borne glacier (see also Dreimanis, 1988, p.52).

In the definition above, a water-borne glacier front may be an ice shelf or ice ramp. An ice shelf is an expansive, relatively stable, floating part of a polar glacier that is likely to be buttressed on its seaward side by a pinning point. An ice ramp is a narrow, temporarily water-borne zone at a glacier margin that results from: (1) recession of a calving ice front from shallow to deep water, (2) ice thinning by ablation, (3) surging into deep water, or (4) fluctuating (rising) water levels. Ice ramps may be common along deep water lacustrine ice margins where fluctuations in lake level buoyantly lift an ice margin (see Holdsworth, 1973 on Generator Lake, Baffin Island). Ice ramps are likely to be temporary features when caused by rising water in a deep lake because rising water also promotes calving which will destroy the ramp. Successive lifting and grounding of an ice ramp, in response to flow rate variations or lake level changes, can cause the deposition of alternating beds of subglacial till, lacustrine sediment, and undermelt deposits (Fig. 5). Ice ramps are likely to be more prevalent away from parts of a glacier floored by subglacial channels because the melting of channel roofs promotes drawdown of surface ice and ice thinning that leads to calving.

A.

B.

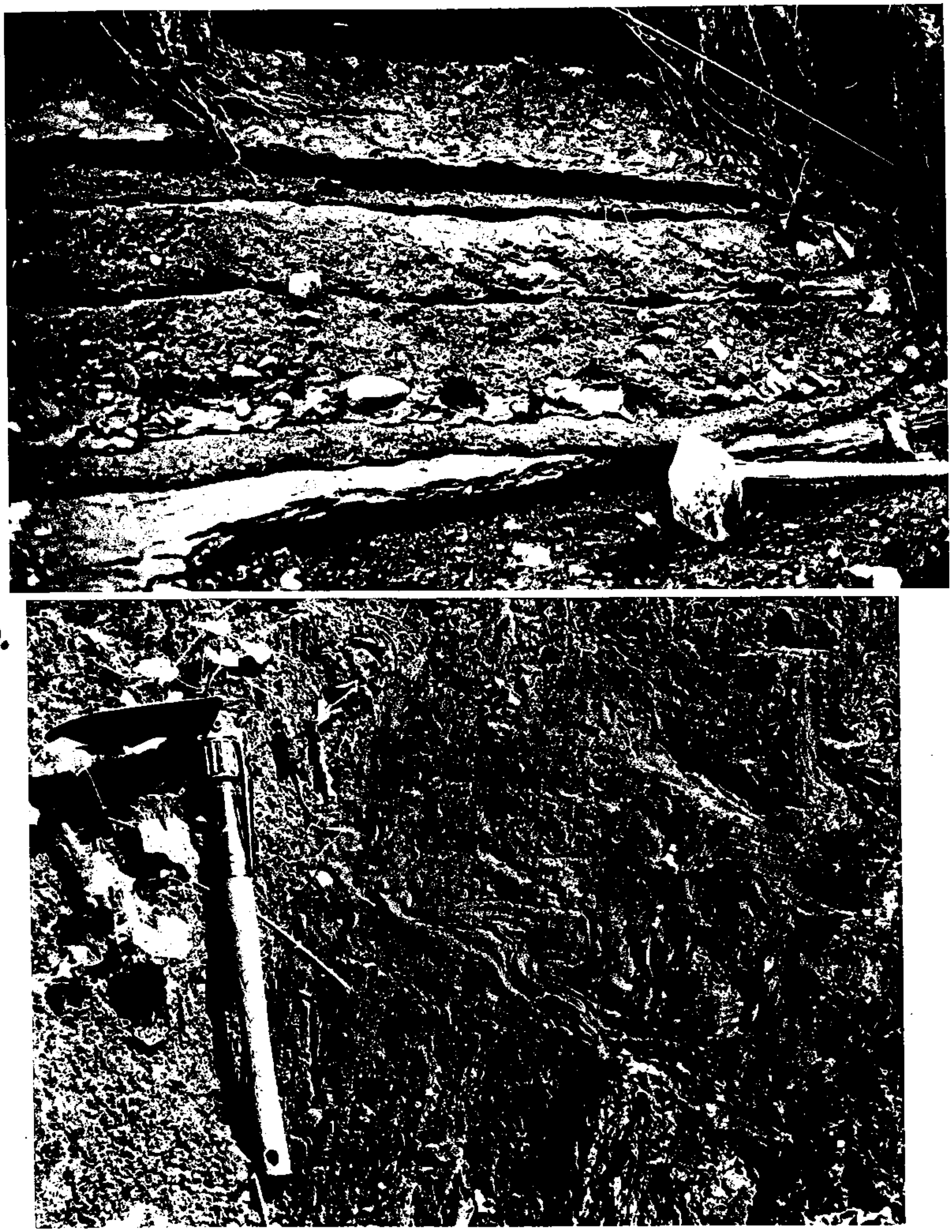
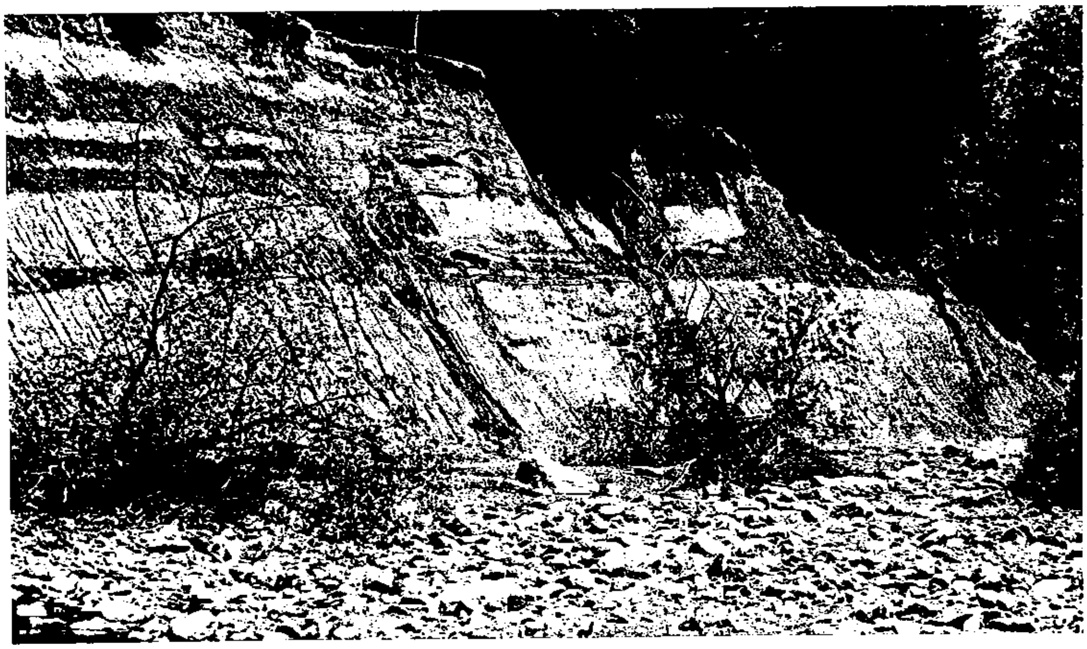


Figure 4. Proglacial diamicton exposures in the West Canada Valley.

A. Stacked mudflows (note clast concentration in base of central unit) interbedded with lacustrine muds (recessed areas) in the top of the Norway Diamicton (sections 812-813 in Fig. 2, Ridge and others, 1990, Article A).

B. Load deformation in very faintly bedded diamicton in the top of the Hawthorne Diamicton (section 447 in Fig. 2, Ridge and others, 1990, Article A).

A.



B.

Figure 5. Exposures of the top of the White Creek Diamicton along White Creek in the West Canada Valley (section 147 in Fig. 2, Ridge and others, 1991, Article B).

A. A stack of subglacial till beds and lacustrine sediments resulting from the alternate buoyant lifting and grounding of an ice ramp.

B. The top surface of a subglacial till bed which preserves grooves from a sliding glacier sole.

ICE RAFTING AND PELLET FORMATION

Pellets: Fragments of clastic sediment (non-lithified clasts) which occur within water deposited sediments.

Pellets can be found in glaciomarine, glaciolacustrine, proglacial, undermelt, and subglacial environments (Fig. 6). The pellet shape can be partly the result of processes of entrainment, deformation, and differential melting in basal ice, or settling and transport of debris in subaqueous environments. Most pellets that were dropped from water-borne ice or icebergs have been eroded somewhat during their fall to the substrate. Pellets may be flattened to disks by compaction.

Iceberg Pellets: Pellets that fall to the floor of a water body from icebergs as a result of melting of debris bands or dropping of adhered sediment (Figs. 6A-6C). Ovenshine (1970) referred to iceberg pellets as "till pellets".

Identification: Pellets interspaced with lacustrine silt and clay (matrix-supported), but are often concentrated on specific partings. The pellets have the full range of provenance and sediment types found in basal-ice debris bands and adhered sediment (diamicton, overridden lacustrine clay and silt, stones, etc.). The variety of sediment types and provenances reflects mostly the melting of debris from different icebergs and separate basal debris bands. They can be found in beds that have abundant fossil tracks and trails.

Undermelt Pellets: Pellets that fall from the sole of a water-borne glacier (ice shelf or ice ramp) in a subaqueous environment (Fig. 6D).

Identification: High concentrations of pellets in thin beds (pellet-supported) with poorly sorted inter-pellet sediment. The pellets are one sediment type and provenance (or nearly so) reflecting a dominance by debris adhered to and exposed in basal-ice of a temporarily floating glacier front. These beds occur almost immediately above subglacial till and the pellets are limited to the same sediment type and provenance as the underlying till.

Cavitation or Intra-till Pellet Beds: Pellets released by basal-ice melting or dropping of adhered sediment from a glacier sole in a subglacial cavity. These deposits occur within subglacial till (intra-till lens), or beneath till in the lee of bedrock ledges, where subglacial cavitation occurred.

Identification: Occur within till or at the base of till as isolated lenses. Pellets are the same sediment type and provenance as the associated subglacial till. Associated laminated silt and clay beds should not contain fossil tracks and trails.

Rip-up Pellets: Pellets that are the result of mass flow and turbidity current transport of material from a ripped up bed (Fig. 6E).

Identification: Usually occur dispersed through the bottoms of massive silt and clay beds where they were suspended or bed load fragments in a mudflow or turbidity current. The pellets tend to be dominated by, or are entirely, one sediment (usually silty clay) and provenance type reflecting a single source bed somewhere up slope. They may show crude grading and evidence of transport in the form of rounding or wisp-like extensions).

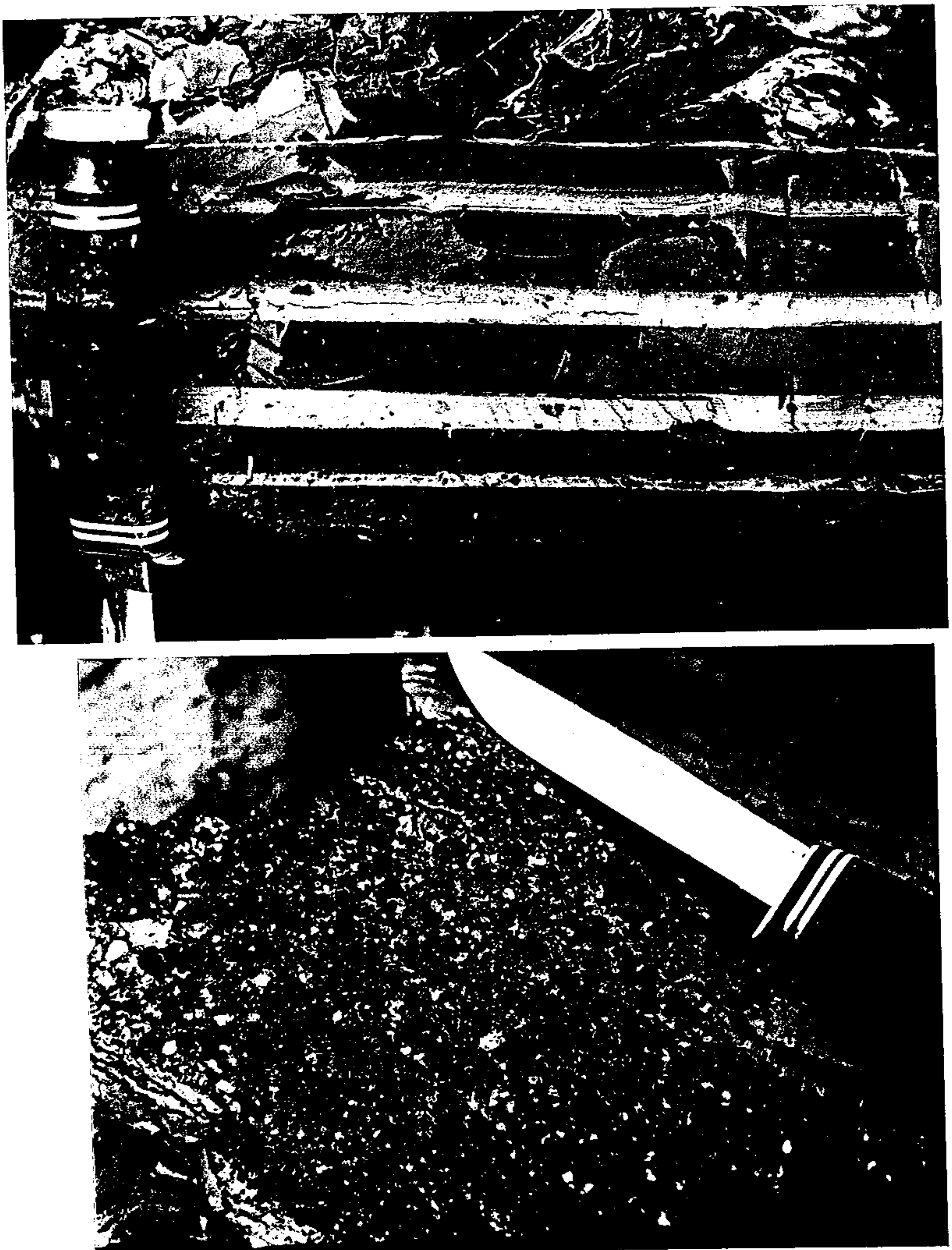


Figure 6. Pellets in glaciolacustrine sediments of the Western Mohawk and West Canada Valleys.

A. Iceberg pellets in the post-Norway beds (section 946 in Fig. 1, Ridge, in prep., Article E).

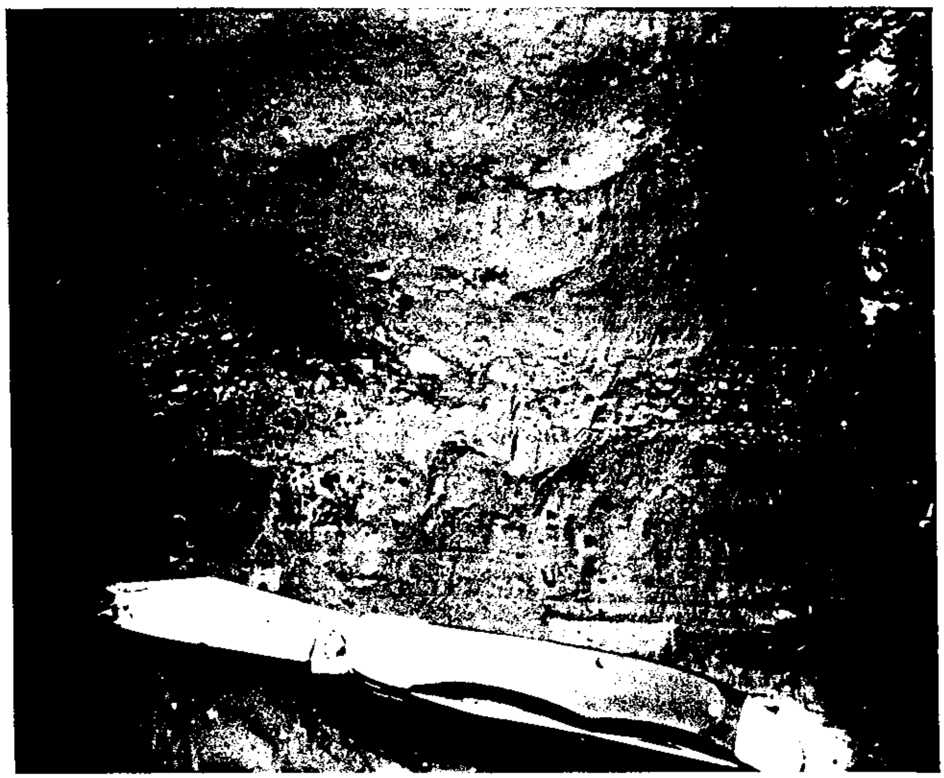
B. Iceberg pellets concentrated on a bedding plane in the post-Norway beds. Pellets are composed of diamicton, silt and clay of different colors (section 946 in Fig. 1, Ridge, in prep., Article E).

C.

D.

6 C. Dark gray iceberg pellets and small dropstones in the basal part of the upper Newport Beds in the West Canada Valley (section 447 in Fig. 2, Ridge and others, 1991, Article B). The dispersed concentration of pellets in this bed may be the result of deposition by mass flow processes.

6 D. An undermelt pellet bed overlain by thin, graded silt beds in the base of the post-Hawthorne beds (section 611 in Fig. 2, Ridge and others, 1990, Article A). The sediment block is about 18 cm long.



6 E. Light gray, rip-up pellets in the basal part of the upper Newport Beds in the West Canada Valley (section 447 in Fig. 2, Ridge and others, 1991, Article B). The bed below has pea-sized dropstones of black shale and limestone.

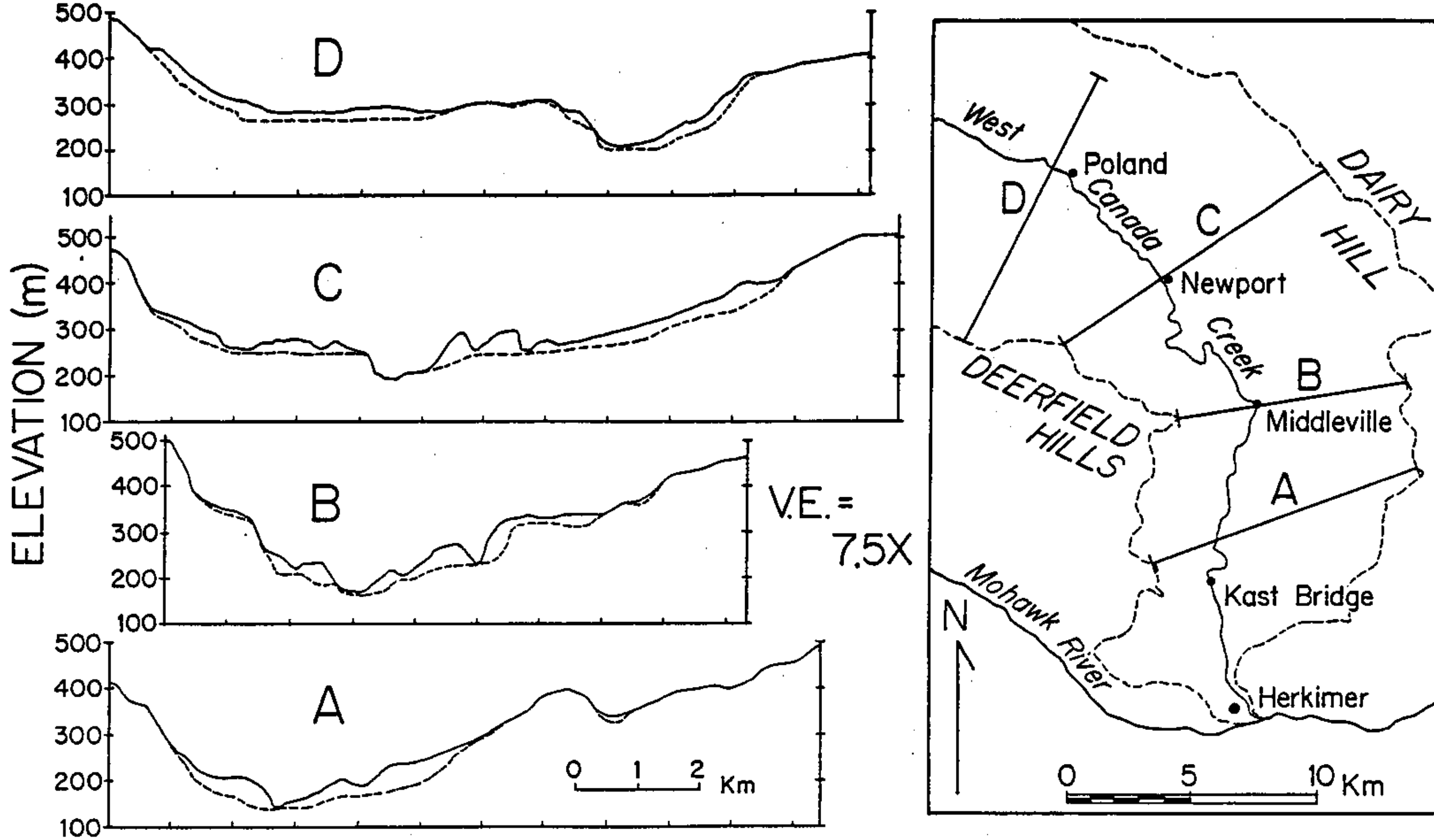


Figure 7. Topographic profiles of the West Canada Valley between the Deerfield Hills and Dairy Hill showing the thickness of glacial sediment (bottom is dashed line) over bedrock. Vertical Exaggeration is 7.5X. Unit conversions are 100 m = 328 ft, 200 m = 656 ft, 300 m = 984 ft, 400 m = 1312 ft, 500 m = 1640 ft.

Glacier Dynamics and Calving

Late Wisconsinan glaciers in the western Mohawk Valley region advanced and receded in lacustrine troughs (Fig. 7) with water depths of 100-350 meters (Fig. 1; see glacier reconstructions in Ridge and others, 1991, and Ridge, in prep., Articles B and E). As a result, buoyant ice margins with straight or embayed (not lobate) outlines were developed, and calving was an important, if not dominant, ablation process. Abundant iceberg pellets and dropstones provide ample evidence of the importance of calving. Deep water calving excludes the possibility of stagnation zone formation because calving rapidly removes fractured buoyant ice at a glacier margin. Stability of deep water glacier margins with a high calving flux was probably dependent to a large extent on the positions of bedrock highs and constrictions in a valley where ice fronts could be buttressed in shallow water. Glacial readvances into deep water required high flow velocities to keep pace with calving rates. Rises in water level during an advance, a reduction in flow rate, or increased surface melting, would certainly have impeded a readvance or caused ice recession.

Thermal Conditions

Several observations together provide evidence of widespread subglacial freezing conditions beneath glaciers in the Mohawk Valley.

(1) Muddy lacustrine deposits from both periods of readvance and recession are full of pellets derived from the melting of debris-laden icebergs (iceberg pellets). Debris in the icebergs was derived from the freezing on of subglacial sediment and not by shear plane formation, or infolding, of subglacial debris. Incorporation of debris by these later processes would require a highly compressional environment. Compression was significantly reduced in western Mohawk Valley glaciers because ice-marginal areas had a high buoyancy and glaciers were advancing into lake covered areas where wet sediment provided a low shear resistance to ice flow (Fig. 1). Advance of ice over dry sediment or frozen ground would have been restricted to a very small percentage of the landscape at high elevations that were not generally overtopped by glacial readvances.

(2) Subglacial freezing occurred across the overridden floors of lakes and along valley walls because iceberg pellets are composed of sediment frozen into basal ice in both these areas. Gritty diamicton pellets are derived from subglacial freezing on upper slope areas and across low divides, where subglacial debris was course and lake sediment cover was thin. Clay and silt pellets are derived from lowland areas where ice advanced over thick sequences of clayey lacustrine deposits.

(3) Subglacial freezing occurred near ice margins and tens of kilometers up glacier at the bottom of basal ice. In the case of Ontario Lobe deposits, iceberg pellets are composed of both gray and red sediments. Freezing on of subglacial sediment,

during the whole period of glacial readvance and recession, was simultaneously occurring in areas with red and gray subglacial debris (see area marked RED in Fig. 8). Areas where subglacial sediment beneath the Ontario Lobe was partly red occur in an area from west of Rome to just east of Utica. East of this red subglacial sediment zone, and on adjacent upper slope areas, glacial sediment is gray.

(4) Both items 2 and 3 above provide evidence of <u>widespread</u> subglacial freezing beneath the Ontario Lobe. Subglacial freezing of debris into basal ice was occurring at high elevations and on the valley floor. Subglacial freezing was also occurring near the glacier margin, and in areas at least 40 km up glacier from the ice margin. It is expected that similar conditions probably prevailed beneath an advancing Mohawk Lobe because of the abundant iceberg pellets in lake sediments associated with Mohawk Lobe diamictons. Mohawk Lobe iceberg pellets are only gray or black in color, but like their Ontario Lobe counterparts, can be either diamicton or clayey sediment types.

(5) The abundant iceberg pellets, which survived basal-ice transport to a glacier margin prior to calving, indicate that subglacial freezing was dominant over subglacial melting (net freezing zone). If this were not the case, basal debris-rich ice would not be thick, or would not have survived transport to an ice margin before being melted off. The result would be relatively clean icebergs and few iceberg pellets.

<u>Water and Heat Fluxes Associated with Subglacial Freezing</u>

Widespread subglacial freezing requires a water source and a means of removing latent heat. Water sources include surface melting, which produces water that percolates or drains to the bottom of the glacier, and subglacial melting. Subglacial melting was not a dominant process within 40 km of the Ontario Lobe margin because this region was dominated by net freezing conditions and basal ice formation. However, subglacial melting very far up glacier, in the ice-covered Ontario Basin, may have created water that escaped to marginal areas.

Subglacial freezing of meltwater, regardless of its source, is likely to be stimulated by hydrostatic pressure changes (drops) that elevate the freezing point in subglacial environments. Surface derived meltwater is subject to pressure changes which are seasonal and diurnal in response to surface meltwater production. Meltwater from subglacial areas far up glacier moves towards glacier margins in the direction of decreasing hydraulic head that varies mostly as a function of decreasing water pressure. The periodic drainage of subglacial meltwater will also cause pressure drops that stimulate subglacial freezing. Periodic drainage of subglacial meltwater can be caused by either drops in proglacial lake levels, that suddenly increase hydraulic gradients in subglacial meltwater systems, or the release of water as the ice buoyancy (flotation) threshold is reached in a poorly draining subglacial meltwater system. In any case, drops in water pressure will elevate the pressure melting temperature of ice, and thus stimulate the freezing of super-cooled water.

Mohawk Valley glaciers could not have had thermal gradients that were sufficiently steep to completely dissipate the latent heat (310-334 J/g at 0-5^{o}C) generated by widespread subglacial freezing. In addition to latent heat, geothermal heat flux and frictional and strain heating would also have been dissipated before freezing occurred (Weertman, 1961; Boulton, 1972).

If glacier ice absorbed geothermal heat flux, thermal gradients necessary to dissipate this heat alone can be estimated from the expression:

i_t, thermal gradient of ice = H_{geo}/K_{ice}, where

H_{geo} = geothermal heat flux, and

K_{ice} = thermal conductivity of ice (2.1×10^{-2} J $cm^{-1}C^{o-1}s^{-1}$ or 6.62×10^{5} J $cm^{-1}C^{o-1}yr^{-1}$).

A thermal gradient (i_t) of about 0.022 C^o/m would have been required to remove the geothermal heat flux in the Mohawk Valley,

H_{geo} = 150 J $cm^{-2}yr^{-1}$ (Lee, 1970).

The production of latent heat by subglacial freezing can also be estimated from the following expression (Weertman, 1961, Boulton, 1972):

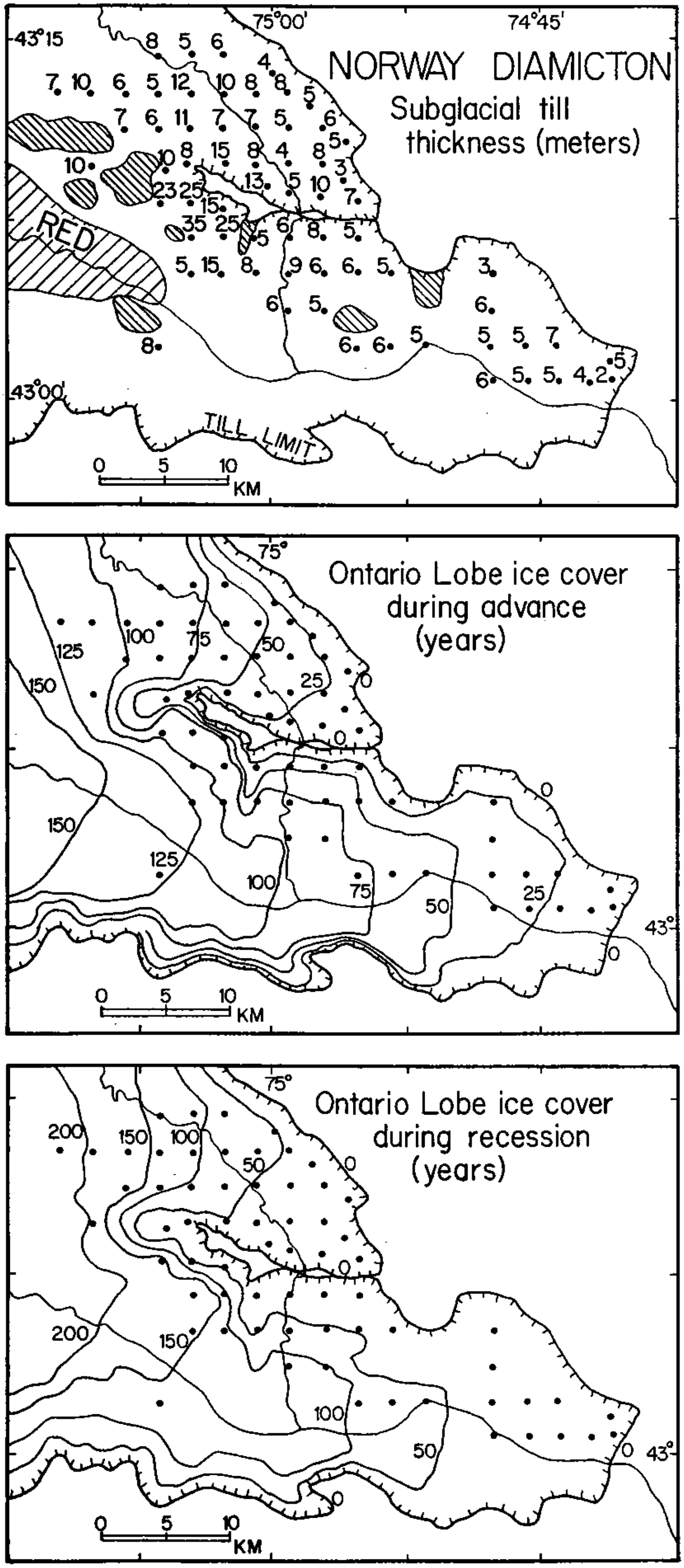
H_f, latent heat flux = $h_i L_f p_i$, where

h_i = rate of basal ice formation (cm/yr),
L_f = latent heat of ice at 0^{o}C (334 J/g), and
p_i = density of ice (0.91 g/cc).

If 1.0 cm/yr of basal ice was produced, and latent heat was dissipated through overlying ice, a thermal gradient of

$i_t = H_f/K_{ice}$ = 0.046 C^o/m

would have been required to remove latent heat. The removal of geothermal and latent heat fluxes by vertical dissipation in glacier ice would require a total thermal gradient of about 0.068 C^o/m. A glacier that was 300 m thick with a thermal gradient of 0.068 C^o/m (linear temperature profile) would have had a surface ice temperature that was about 20^{o}C colder than basal ice at the freezing point. A thermal gradient of this magnitude is probably too high for late Wisconsinan glaciers in the Mohawk Valley region and is not likely if the glaciers were temperate. An additional mechanism, besides upward absorption into glacier ice, was necessary for dissipating heat if basal freezing was prevalent (see NOTE below). The only apparent mechanism for removing additional heat from subglacial areas would have been meltwater export (advection) to proglacial environments.



NORWAY DIAMICTON
Subglacial till thickness (meters)
75°00'
74°45'
43°15
43°00'
RED
TILL LIMIT
0 5 10 KM
Ontario Lobe ice cover during advance (years)
75°
43°
0 5 10 KM
Ontario Lobe ice cover during recession (years)
75°
43°
0 5 10 KM

Figure 8. An analysis of the deposition of subglacial till in the Norway Diamicton (Ontario Lobe). Data points are the center points of rectangular subdivisions of 7.5-minute quadrangles (4 across x 5 vertically) for which an average subglacial till thickness could be estimated. Time spans for ice cover are estimated from varve counting and a correlation of paleomagnetic declination records in the Mohawk Valley with a declination record in New England tied to the New England varve chronology (see Fig. 3, Article E).

TOP. Average subglacial till thickness in rectangular subdivisions. Closely scribed areas are hilltops with very thin till cover (<1.5 m). These areas were eliminated from analysis because they were not considered depositional environments, or because postglacial erosion has made an estimate of original till deposition impossible. The widely scribed area marked "RED" is where subglacial till or overridden units are partly red in color. Areas of abnormally thick till cover (>15 m), adjacent to the nunatak in the central part of the area, are in regions where ice flow was up a steep topographic gradient.

MIDDLE. Years of ice cover during advance of the Ontario Lobe estimated from the age of lacustrine sediments beneath the Norway Diamicton. Ice cover is a maximum because the preserved tops of underlying units are eroded.

BOTTOM. Years of ice cover during recession of the Ontario Lobe estimated from the age of lacustrine sediments overlying the Norway Diamicton. Ice cover is a maximum because lacustrine deposits used to determine paleomagnetic directions, and thus infer ages, are not usually found directly over till.

If meltwater advection did not remove heat, late Wisconsinan glaciers in New York probably were much colder than their generally assumed temperate conditions.

(**NOTE:** The formation of only 2 m of basal ice within the outer 50 km of a glacier with a flow rate of 500 m/yr would require 2cm/yr of basal ice formation and a thermal gradient of 0.114 C^{o}/m (linear temperature profile). If the glacier was 300 m thick and heat was vertically dissipated through the glacier, surface ice would be 34 ^{o}C colder than basal ice. This represents an unrealistic situation for the marginal areas of the Laurentide ice sheet in New York.)

The thermal calculations presented here are very simple, and do not account for the advection of heat by moving ice. They do, however, give a limiting case for subglacial freezing conditions, and crudely indicate the limited ability of non-polar glaciers to absorb basal heat fluxes.

Meltwater Systems

In the axis of the Mohawk Valley there are thick subglacial and ice-marginal gravel deposits between diamicton units of successive glacial readvances (Fig. 1 of Ridge, in prep., Article E). These deposits often rest on unconformities cut into older units by meltwater erosion. The subglacial deposits and erosion provide evidence of a highly active meltwater system that delivered sediment to the deepest parts of ice-marginal lakes. It has not yet been determined from the geometry of sand and gravel units in pit exposures whether subaqueous and subglacial stratified deposits represent channelized or sheet flow delivery of meltwater to ice margins. If meltwater was carried in subglacial channel systems, the channels must have prevented their ceilings from closing in on them which requires melting and/or erosion of ice. Is it possible that heated meltwater, warmed by absorbing latent heat from subglacial freezing, could effectively perform the task of melting channel roofs?

Till Deposition

All (or essentially all) till in the western Mohawk Valley is subglacial till. The general paucity of medial moraines on continental ice sheets, and the termination of basal ice at steep calving cliff faces in deep water, virtually eliminate the possibility of supraglacial debris accumulation and supraglacial melt-out till formation (Fig. 1). Also, melt-out till does not make up a significant (if present at all) percentage of subglacial till in the western Mohawk Valley, especially at lower elevations. Till in the western Mohawk Valley region displays abundant evidence of internal shearing, and shearing along contacts with underlying units, which are incompatible with the stagnant ice processes of melt-out till deposition. Where glaciers in the Mohawk Valley terminated in deep water (100-350 m), rapid ice flow was necessary to keep pace with high calving rates. These conditions make stagnation zone development, and thus melt-out till deposition, nearly impossible, except at higher elevations where lake water was shallow.

Several aspects of subglacial processes in the western Mohawk Valley seem to be more compatible with the formation of deformation till, rather than deposition of lodgement till.

(1) As lodgement till was defined previously, it requires the release of debris from basal ice. Subglacial environments in the Mohawk Valley, however, appear to have been dominated by conditions which resulted in the net freezing on of subglacial debris, rather than the net release of basal-ice debris by melting.

(2) A large volume of basal-ice debris reached calving margins where it was later released in proglacial environments by melting icebergs to form iceberg pellets. Some unknown, but possibly large, volume of iceberg debris was also released to suspension, not as pellets, or was released as pellets that disaggregated as they fell to the lake floor. Therefore, pellets found in Mohawk Valley lacustrine sediment provide a minimum estimate of the amount of debris released from icebergs. The large volume of basal-ice debris which today appears as iceberg pellets, required a subglacial system that experienced net basal freezing, not the net melting of basal ice.

(3) Till in the western Mohawk Valley was generally deposited by rapidly advancing and receding glaciers that left thick subglacial till. As an example, till in the Norway Diamicton (Ontario Lobe) is on average 5-10 m thick (Fig. 8). The relatively short time of advance and recession of the Ontario Lobe (Fig. 8; St. Johnsville Readvance, Fig. 5 in Article E) requires rapid sedimentation rates (5-10 cm/yr on average in Fig. 9) to facilitate thick subglacial till deposition. Subglacial melting and release of debris from basal ice was too slow, by more than an order of magnitude, to be the only mechanism which accounts for rapid sedimentation of subglacial till. Assuming ideal conditions for melting of basal ice (i.e. a glacier with a thermal gradient of 0 and the application of all heat fluxes to melting), a geothermal heat flux of

$$\dot{H}_{geo} = 150 \text{ J cm}^{-2}\text{yr}^{-1}$$

could have melted only 0.5 cm of ice/yr. Frictional and strain heating of basal ice was less than geothermal heating. Where overridden lacustrine muds provided a low shear resistance to ice flow, frictional and strain heating would provide little or no additional heat that could have been applied to melting basal ice. If basal ice in Mohawk Valley glaciers contained 20% debris by volume, 1 cm of ice melting/yr would produce only 2-3 mm of subglacial debris/yr. A debris concentration of 20% is high as compared to the concentration of debris in the basal ice of most modern glaciers (Pessl and Frederick, 1981), and therefore probably indicates the minimum amount of melting required to release 2-3 mm of debris/yr.

4) If subglacial till of the Ontario Lobe is lodgement till, that was deposited only by release of debris from the melting of basal ice without any subsequent deformation, unrealistically high melting rates (by 10X) would have been required for the lowest

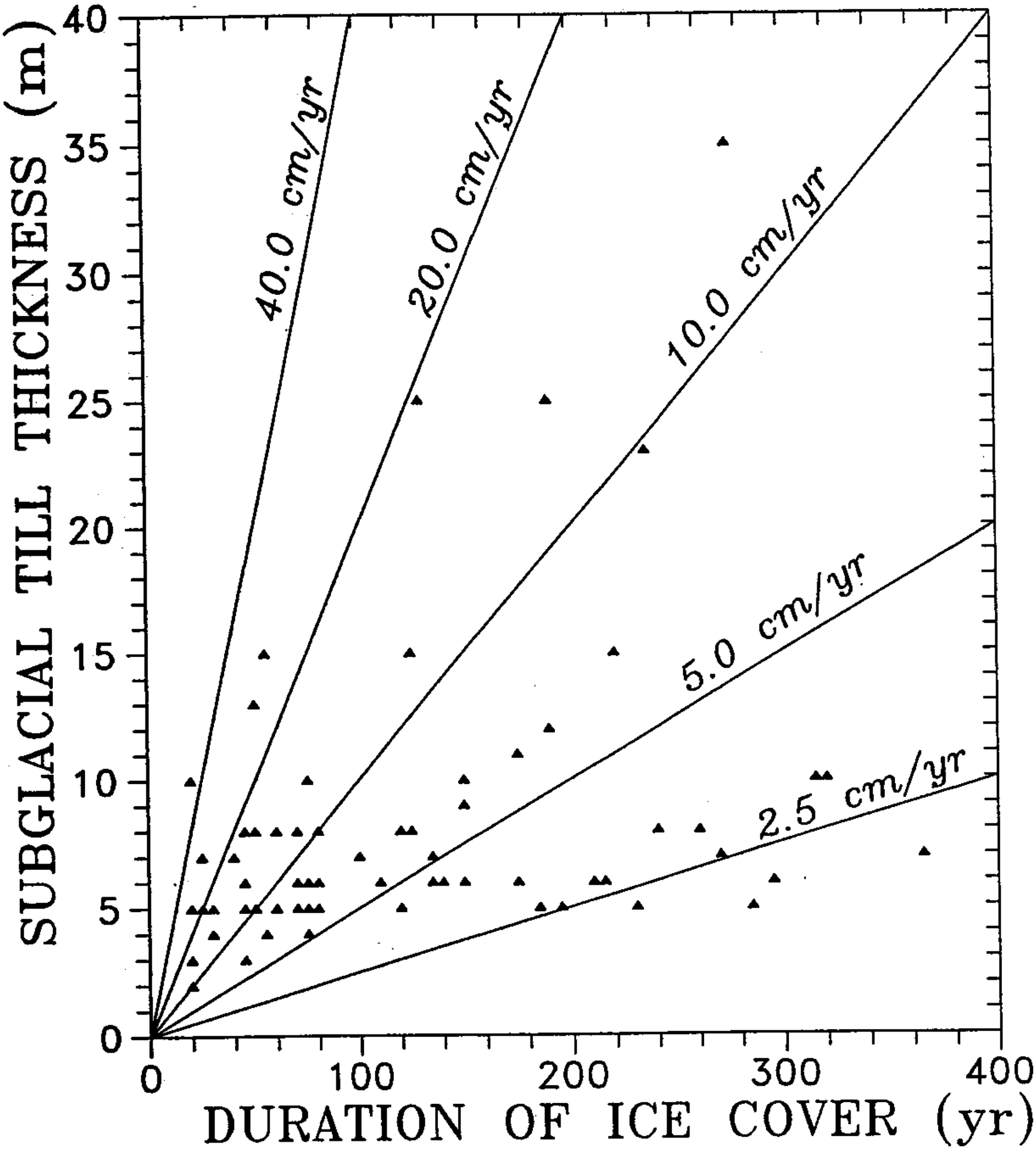


Figure 9. Subglacial till thickness in the Norway Diamicton versus the maximum duration of Ontario Lobe ice cover (during advance plus during recession, Fig. 8). Lines extending from the origin indicate average rates of till deposition in cm/yr. Rates of deposition are the lowest possible because the duration of ice cover is a maximum estimate and the deposition rates assume that till was deposited during the entire period of ice cover without periods of erosion or non-deposition.

rates of till sedimentation by the Ontario Lobe. Melting of 10 cm of ice/yr would be required for the release and accumulation of debris from basal ice with 20% debris if 2-3 cm of till/yr is deposited (Fig. 9). Clearly, transport and stacking of subglacial debris by subglacial deformation was necessary to accommodate the lowest rates of subglacial till sedimentation by the Ontario Lobe. If lodgement till (once entrained and melted from basal ice) was deposited at a rate of 2-3 cm/yr (lowest rates on Fig. 9), less than 10% of the till could have been released from basal ice without any subsequent deformation. Another way of stating the limitations above is that subglacial deformation had to be more than 9X as effective as basal ice entrainment in transporting debris to its <u>final</u> resting place during till deposition.

(5) The sedimentation rates discussed above (Fig. 9) underestimate actual sedimentation rates because durations of ice cover used in the calculations are maximum values, and the rates depict constant sedimentation over the entire period of ice cover. The tops of lacustrine units beneath subglacial till are deformed and eroded as a result of overriding ice flow. Permanent accretion of debris at the glacier bed, without any further deformation, cannot occur by either release of debris from basal ice or deformation processes, until the erosion and removal of overridden sediment is completed. The period of net erosion of sub-till units must be subtracted from the period of ice cover when considering till sedimentation rates. This subtraction makes till sedimentation rates higher than shown on Figure 9, and even more incompatible with lodgement till deposition solely by the release of debris from melting basal ice. If the period of erosion or net removal were essentially the period of glacier advance, and till deposition was limited to periods of ice recession, sedimentation rates for till would be approximately double those shown on Figure 9.

(6) Subglacial freezing conditions would have caused ice formation at the glacier sole/sediment interface. As ice growth occurred, it would have invaded the underlying sediment, thus coupling the glacier to the subglacial debris. This coupled condition, combined with the increased roughness of debris-laden basal ice, would be conducive to the deformation of sediment beneath the glacier and the formation of deformation till.

(7) Till in the Mohawk Valley is derived from local sources that were overrun by advancing glaciers. Very sparsely stony, clayey till is derived from underlying lacustrine units. Stony and sandy till is derived from higher elevations where ice overrode bedrock or older diamicton units. There is no good reason to assume that either stony or very sparsely stony tills are composed of debris that was ever entrained in basal ice. In both cases, matrix grain size and stoniness may simply reflect different sources, not separate processes.

CONCLUSIONS

The apparent dominance of subglacial freezing, over melting of basal ice of the Ontario Lobe, strongly suggests that the release of debris from basal ice by melting would have been an inefficient process. The high rates of subglacial till deposition by the Ontario Lobe would necessitate the transport of more than 90% of all debris to its final resting place by subglacial deformation. Any debris that was originally entrained in basal ice, and was later released by melting, was likely to have been further transported by the dominant till forming process, subglacial deformation.

The widespread decapitation and shearing of glacially overridden lacustrine beds certainly provides evidence of the ability of glacial readvances in the Mohawk Valley to transport subglacial materials by deformation, without the necessity of entrainment in basal ice. Areas of extremely thick subglacial till in the Norway Diamicton, around the nunatak created by advance of the Ontario Lobe (Fig. 9), are where ice was forced to flow up the steepest topographic gradients. Shear stresses may not have been as effective in subglacially deforming debris uphill in these areas, and the stacking of subglacial debris may account for the thick till.

There is no evidence to indicate that subglacial till was formed from debris that was originally entrained in glacier ice. Given the evidence of widespread subglacial freezing conditions, the widespread deformation of overridden lacustrine units, and the rapid rates of subglacial till sedimentation, it seems reasonable that subglacial till in the Mohawk Valley may be primarily deformation till (debris never entrained in ice) with very little lodgement till (debris once entrained in, but later melted from moving ice).

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ROAD LOG

The use of private vehicles will not allow a running commentary to be given while traveling through the field area. Please follow the road log while enroute because it gives an explanation of the geology between stops. **The road log also gives you information about conditions to expect at each outcrop (i.e. stream crossings, steep slopes, or muddy conditions).** Numbered sections and stratigraphic units in the road log can be found in Figures L2, L3, L8, and L9, which will also be given to you separately to carry in the field. References to figures in other articles in the guidebook are give by article (letter) and number (for example, Fig. B10 is Figure 10 of Article B).

DAY 1: SATURDAY, MAY 18

The purpose of Day 1's trip (Fig. L1) is to examine the late Wisconsinan stratigraphy of the West Canada Creek valley (Fig. L2 and L3). This nearly complete lithostratigraphic assemblage has been the key to establishing a late Wisconsinan glacial stratigraphy in the western Mohawk Valley region. Because of its completeness, it has also been the primary basis for interpreting the history of glacial readvances and glacial lake levels throughout the region during both pre-Valley Heads and Valley Heads glaciations.

The West Canada Valley also represents a rare opportunity to undertake a detailed examination of the sediments of a broad, but deep, glaciolacustrine trough (Figs. F1 and F7). Most deep glacial troughs are now filled with modern lakes or postglacial valley fill, which necessitates the study of cores or seismic data. Observations and sediments from modern glacial troughs might be more informative for recognizing processes, but active troughs are logistically difficult to study as compared to the West Canada Valley.

Assembly Point: The field trip leaves at 8:00 AM sharp from a rest area just beyond Kast Bridge on the west side of Rt. 28, about 3.4 miles north of State St. (Rt. 5) in Herkimer (Herkimer Quadrangle). We will consolidate vehicles at this point where cars can be parked for the day, and picked up on our return trip.

Mileage (pt. to pt.)		Route description
0.0	(0.0)	From the parking area head north on Rt. 28 toward Middleville.
0.3	(0.3)	To the west (left) in bluff sections along a cutoff loop of West Canada Ck. is almost the entire Valley Heads section (Poland Fm. from Hawthorne to Holland Patent Diamicton). To the east is the mouth of North Ck. and a steep bluff section (section 828) that exposes the entire Valley Heads section overlying the top of the pre-Valley Heads section (upper Newport Beds and West Canada Diamicton in the Middleville Fm.). The West Canada Diamicton is the dark gray stony unit which you may spot in banks of W. Canada Ck. at stream level.

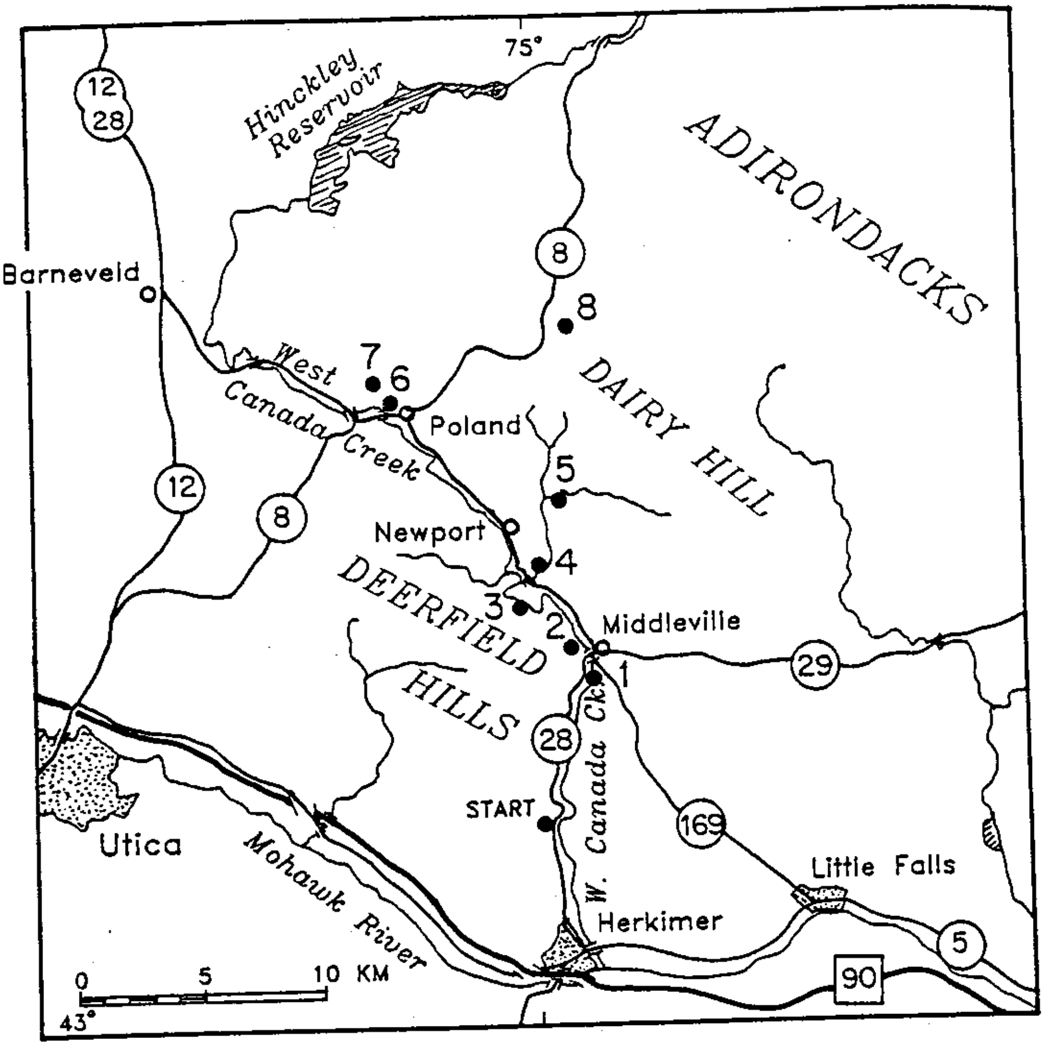


Figure L1. Location map of the West Canada Valley showing field trip stops for Day 1.

1.6	(1.3)	View to east is of steep bluff section (section 911).
3.55	(1.95)	Border of Herkimer/Middleville quadrangles.
3.7	(0.15)	View east is of large bluff section (section 811, STOP 1-1). Ahead are the famous "Herkimer Diamond" mines. Herkimer Diamonds are very clear, doubly terminated quartz crystals.
4.5	(0.8)	Sharp bend to right along Rt. 28 in Middleville. Cross over West Canada Ck. bridge.
4.7	(0.2)	Downtown Middleville. Traffic light at intersection of Rts. 28, 29, and 169. Turn right (southeast) onto Rt. 169.
5.3	(0.6)	On south (right) side of Rt. 169 across from barn is dirt farm road. If weather permits, we will take the road about 1/2 mile to the top of the hill and STOP 1-1. (Don't count mileage until we return to Rt. 169.)

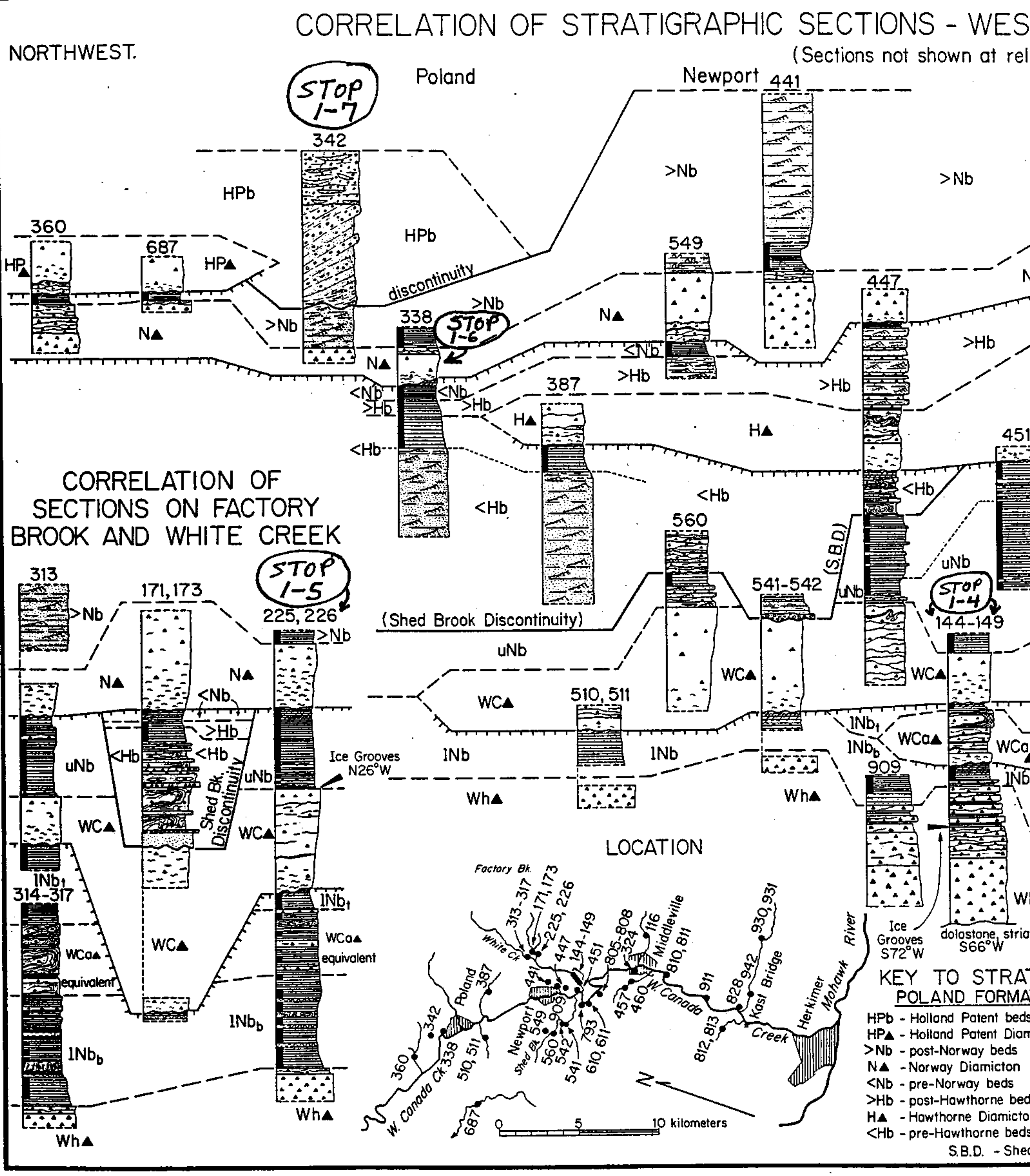
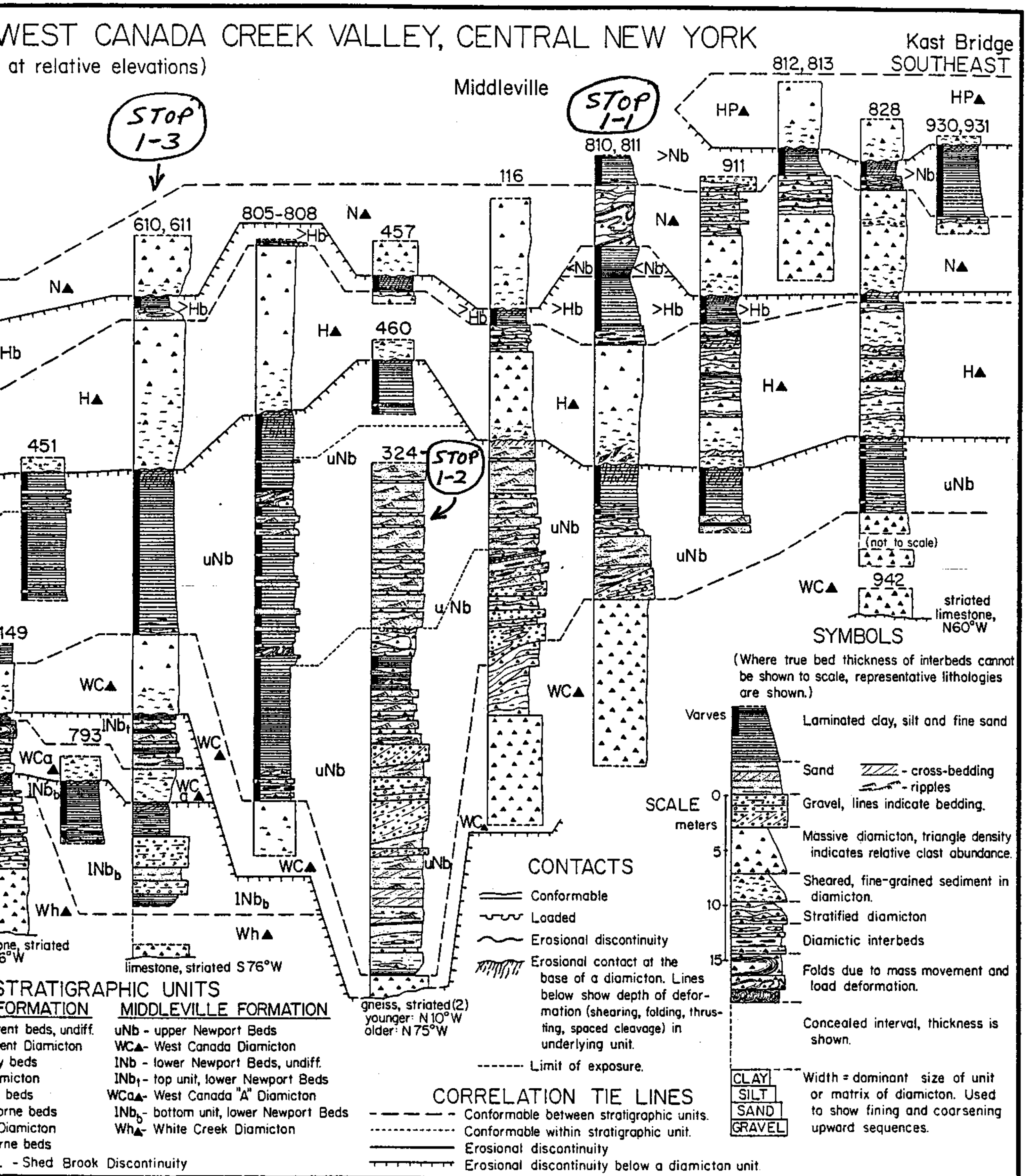


Figure L2. Late Wisconsinan stratigraphic sections in the West Creek Valley from Poland to Kast Bridge.


WEST CANADA CREEK VALLEY, CENTRAL NEW YORK
at relative elevations)
Kast Bridge
SOUTHEAST
Middleville
STOP 1-3
STOP 1-1
STOP 1-2
812, 813
828
930, 931
810, 811
911
116
610, 611
805-808
457
460
451
324
149
793
942
HP▲
N▲
H▲
Hb
>Hb
<Nb
>Nb
uNb
WC▲
WCa▲
lNb$_t$
lNb$_b$
Wh▲
(not to scale)
striated limestone, N60°W
limestone, striated S76°W
gneiss, striated (2) younger: N10°W older: N75°W
SYMBOLS
(Where true bed thickness of interbeds cannot be shown to scale, representative lithologies are shown.)
Varves
Laminated clay, silt and fine sand
Sand - cross-bedding - ripples
Gravel, lines indicate bedding.
Massive diamicton, triangle density indicates relative clast abundance.
Sheared, fine-grained sediment in diamicton.
Stratified diamicton
Diamictic interbeds
Folds due to mass movement and load deformation.
Concealed interval, thickness is shown.
Width = dominant size of unit or matrix of diamicton. Used to show fining and coarsening upward sequences.
CLAY
SILT
SAND
GRAVEL
SCALE meters
0
5
10
15
CONTACTS
Conformable
Loaded
Erosional discontinuity
Erosional contact at the base of a diamicton. Lines below show depth of deformation (shearing, folding, thrusting, spaced cleavage) in underlying unit.
Limit of exposure.
CORRELATION TIE LINES
Conformable between stratigraphic units.
Conformable within stratigraphic unit.
Erosional discontinuity
Erosional discontinuity below a diamicton unit
STRATIGRAPHIC UNITS
FORMATION
ent beds, undiff.
ent Diamicton
beds
micton
beds
rne beds
Diamicton
rne beds
- Shed Brook Discontinuity
MIDDLEVILLE FORMATION
uNb - upper Newport Beds
WC▲ - West Canada Diamicton
lNb - lower Newport Beds, undiff.
lNb$_t$ - top unit, lower Newport Beds
WCa▲ - West Canada "A" Diamicton
lNb$_b$ - bottom unit, lower Newport Beds
Wh▲ - White Creek Diamicton

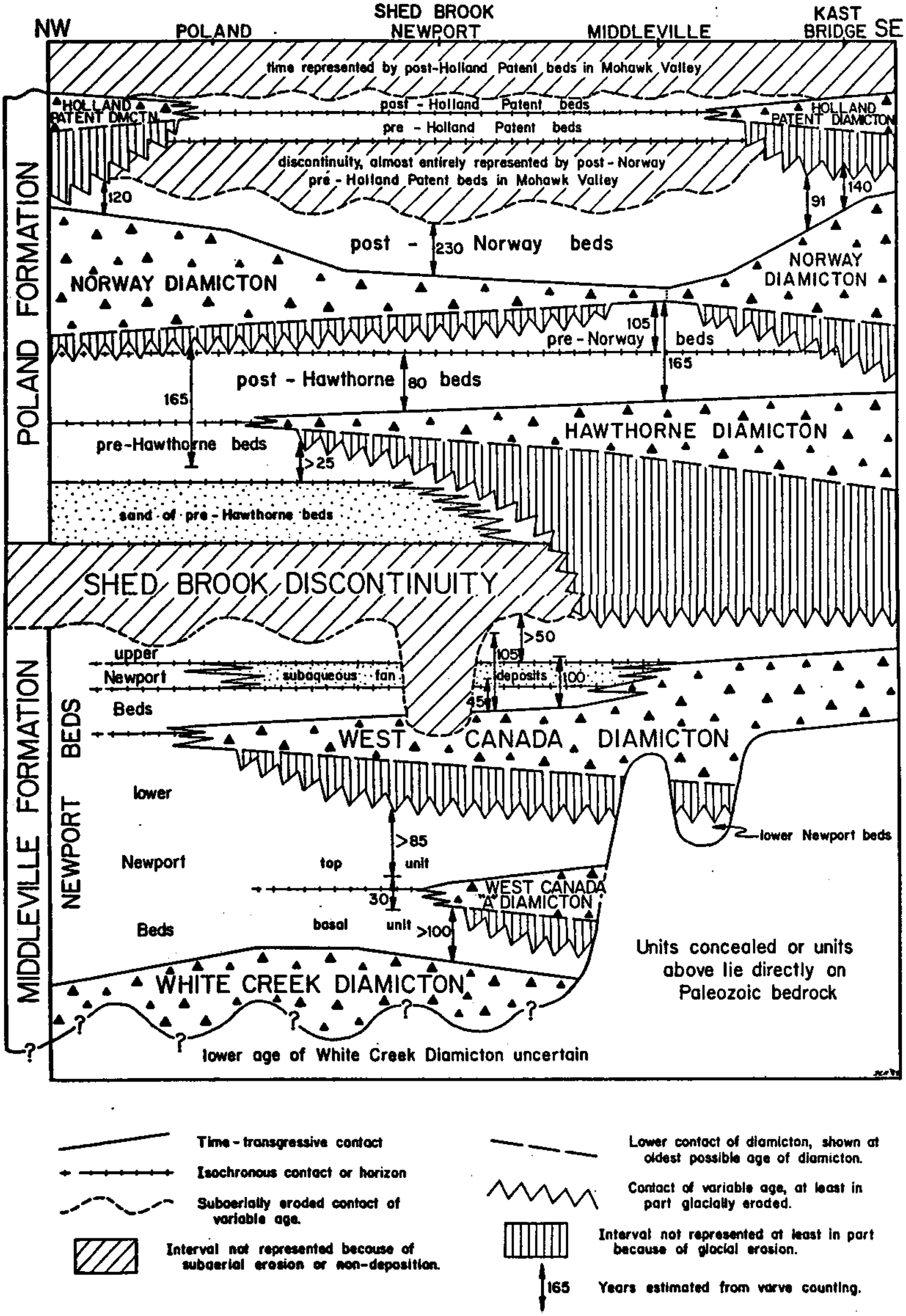
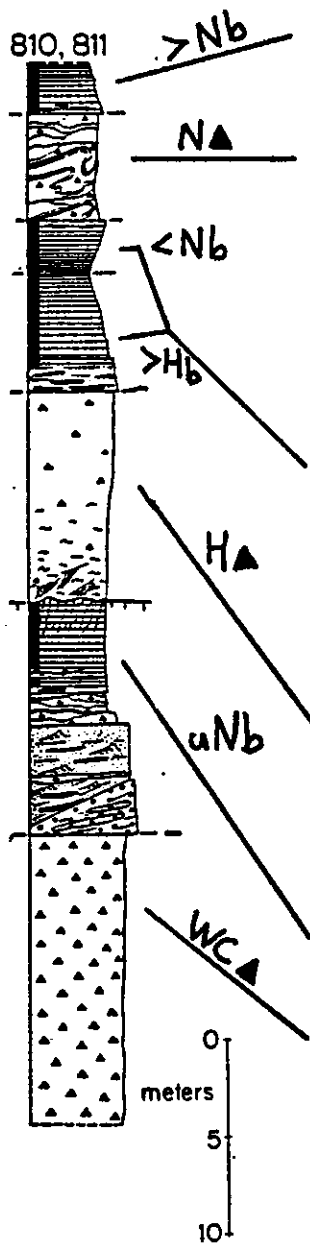


Figure L3. A summary and time-distance relationships of the late Wisconsinan stratigraphy of the West Canada Creek Valley.

STOP 1-1 Middleville Bluffs - Sections 810-811 (Good climbing shoes!)

The Middleville Bluff sections are an excellent place to introduce the physiography and late Wisconsinan stratigraphy of the Deerfield Hills and West Canada Ck. valley. The skyline in the distance across West Canada Ck. (540 ft) is Harter Hill (1650 ft) which is at the northeast corner of the Deerfield Hills. Deposits of both pre-Valley Heads (Middleville Fm.) and Valley Heads (Poland Fm.) glaciations are superposed in the bluffs. Contrasts in sediment and genetic types of stratified and diamicton units are also apparent. Diamicton units range from soft, very sparsely stony muds with faint bedding, to extremely compact massive stony diamicton. They represent proglacial lacustrine deposition near an ice margin, as well as subglacial till derived from bedrock sources and deformed lacustrine mud.

STOP 1-1



Important features: (top to bottom)

1. The bluff section is beyond the limits of the Holland Patent Diamicton and the top unit in the section is the post-Norway beds.

2. Very clayey and sparsely stony Norway Diamicton, an ice-marginal lacustrine deposit, possibly a morainal bank. Faint bedding is deformed by loading, slumping , and possibly ice shove (?). Within 1 mile of this exposure on all sides the Norway Diamicton is composed of mostly clayey till and the underlying pre-Norway and post-Hawthorne beds are truncated by subglacial erosion (section 116). Ontario Lobe provenance: >40% non calc. sh.-siltst., <35% black calc. sh.-ls., and 10% ss.-cgl.

3. Post-Hawthorne (base) thru pre-Norway beds, 165 varves with transition from Mohawk (drab, dark gray) to Ontario (tannish gray with pink and red pellets) Lobe provenance. Varves thicken upward in pre-Norway beds and thicken downward in post-Hawthorne beds. A shift in paleomagnetic declination (bottom to top): 4° East-2° West.

4. Sparsely to moderately stony till of Hawthorne Diamicton, basal parts composed of mostly deformed clayey silt from the upper Newport Beds. Mohawk Lobe provenance: <30% non calc. sh.-siltst., >60% black calc. sh.-ls. Ice-flow of a narrow lobe up the axis of the West Canada Valley (due north).

5. Deformed top of extremely compact upper Newport Beds, base undeformed. Paleomagnetic declination: 24.9° East.

6. Very stony and compact till of West Canada Diamicton which at numerous sites in the area sits on striated sh., ls., and dolost. recording N60-75°W ice-flow of a wide lobe across the upland to southeast from the East Canada valley. Mohawk Lobe provenance: 0% non calc. sh.-siltst., >85% black calc. sh.-ls.

Reboard vehicles and return to Rt. 169. Head back to Middleville.

5.9 (0.6) At traffic light in Middleville turn left onto Rt. 28 south. Cross over West Canada Ck. bridge.

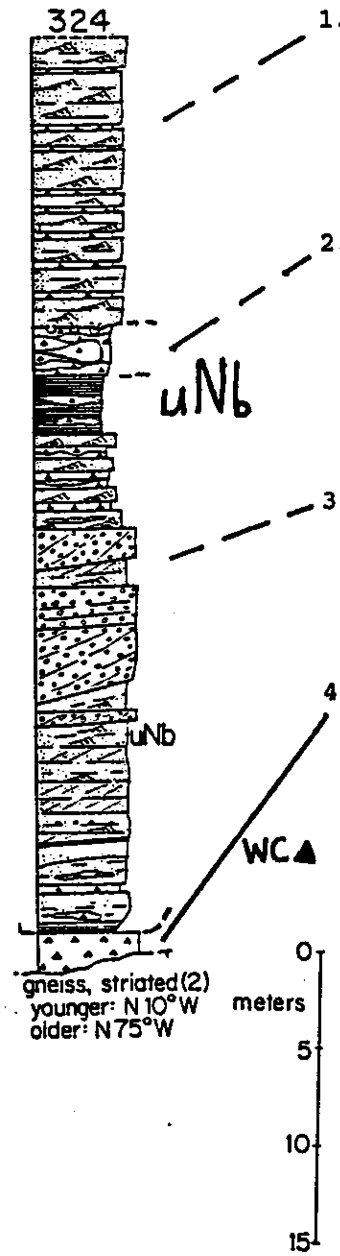
6.05 (0.15) After crossing bridge and passing a few buildings on the right, turn right onto Fishing Rock Rd.

6.4 (0.35) Pull over to right side of road at Fishing Rock on West Canada Ck.

STOP 1-2 Fishing Rock Road, Section 324 - the Middleville Fan

Exposed along Fishing Rock Road is a thick subaqueous outwash fan and esker complex in the base of the upper Newport Beds that were deposited at the front of a receding, pre-Valley Heads, Mohawk Lobe which readvanced to a position near Newport (Fig. B11). The coarse stratified deposits in the lower part of the section may sit within a subglacial channel cut into the West Canada Diamicton which is much thicker (>15 m) in surrounding areas (sections 116 and 811). Thick fan deposits are not common in lacustrine sediments of the West Canada Valley, and are not nearly as common as in the Mohawk Valley. The Middleville Fan is extensive (Fig. C6) with sand also being exposed on the east side of the valley (section 116). The fan's distal muddy facies are exposed up valley (section 805-808). Extensive fan building may have been the result of temporary ice front stability as the Mohawk Lobe became buttressed against a dolostone bench which protrudes into the valley at Middleville, thus retarding recession (Fig. B12). Alternatively, or simultaneously, falling levels of Lake Newport, triggered by Mohawk Lobe recession in the Mohawk Valley, may have caused a sudden steepening of hydraulic gradients in subglacial meltwater systems. An outpouring of large volumes of meltwater may have accelerated fan building. Sand and gravel fan deposits are not common in other areas of the valley, possibly because readvancing ice lobes sat on lacustrine clay and silt that did not allow subglacial meltwater to erode sand and gravel. In addition, ice recession may have been too rapid for extensive sand and gravel deposits to form, or expulsion of subglacial meltwater may have occurred primarily in the deepest, central part of the valley where erosion along West Canada Ck. has removed most of these deposits.

STOP 1-2



Important features: (top to bottom)

1. More than 15 m of laminated and rippled sand with muddy diamicton beds (flows), subaqueous fan deposits. The sand is abruptly overlain at sections higher on the valley wall by at least 10 m of silt and clay varves (section 460). Paleocurrents: north to west.

2. Lens-shaped diamicton units and laminated silt and clay beds, load deformed internally and by overlying sand. Lenses may be channels formed by loading of advancing flows. Mohawk Lobe provenance: >75% black calc. sh.-ls., 1% non calc. sh.-siltst. Paleomagnetic declination of laminites: 23.8° East.

3. Boulder gravel to coarse sand with crude grading and sand waves, proximal fan and/or esker sediments. Mohawk Lobe provenance: >75% black calc. sh.-ls., 2% non calc. sh.-siltst., >6% dolost. Paleocurrents: northwest.

4. Very stony (many rounded stones) West Canada Diamicton overlying striated gneiss. Two striation directions on Precambrian gneiss: N75°W (earlier) reflecting flow of a thick Mohawk Lobe; N10°W (later) reflecting readjustment during ice thinning and recession of a narrow valley lobe.

Reboard vehicles and continue north on Fishing Rock Road.

6.6 (0.2) At bend in road which crosses old railroad grade are several late Wisconsinan fluvial terraces. The highest terraces (left side of road) can be traced down valley to the surface of the Herkimer Terrace. The Herkimer Terrace is graded to a lake in the Mohawk Valley at the mouth of West Canada Ck. (STOPS 2-5 and 2-6). Lakes in the Mohawk Valley formed during the closing stages of Ontario Lobe recession (latest Valley Heads time), but prior to the development of Lake Iroquois. Along the valley wall, Holocene alluvial fans are being built on the fluvial terraces.

8.3 (1.7) Road enters small ravine at Middleville/Newport Quad. border. Drainage ditch on the left side of the road exposes rhythmites of the upper Newport Beds. At the top of the hill, the woods end at about the point where the Hawthorne Diamicton overlies the upper Newport Beds.

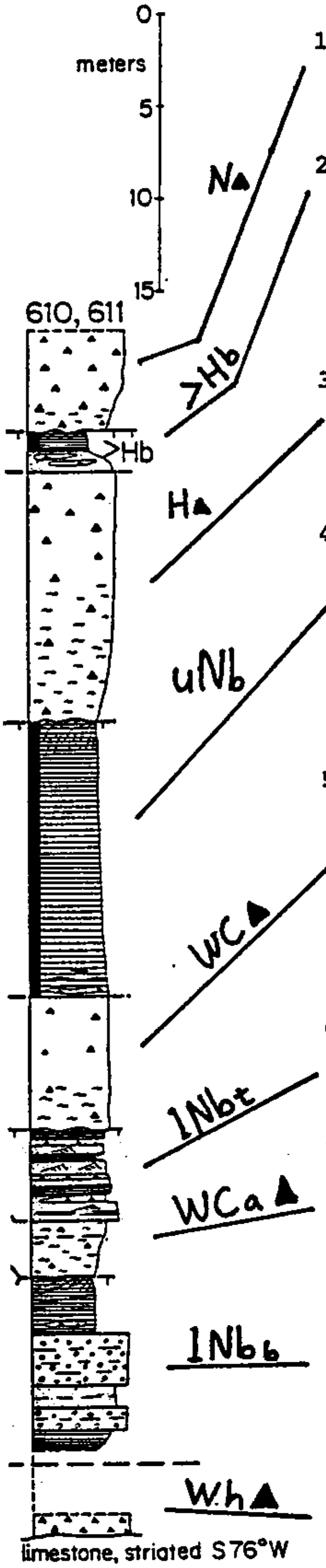
8.9 (0.6) Road intersection (stop sign). Turn right (west) onto Summit Rd. The broad gently dipping slope at this elevation is approximately the surface of the Norway Diamicton and post-Norway beds.

9.1 (0.2) Pull over to right side of road where dirt farm road heads to north across hay fields. Conditions permitting, we will drive to STOP 1-3 at the far end of the hay fields. (Don't count mileage until we return to Summit Rd.)

STOP 1-3 Newport Bluffs, Section 611 (Bank is steep!)

The Newport Bluffs expose the entire late Wisconsinan stratigraphic section in the West Canada Valley from striated bedrock at the base of the White Creek Diamicton to the Norway Diamicton. The bottom of this section (from lower Newport Beds down) is often poorly exposed because of slumping. Immediately upstream, and visible from the bottom of the section, is a better exposure (section 793) of the lower Newport Beds and West Canada "A" Diamicton.

STOP 1-3



Important features: (top to bottom)

1. Moderately stony Norway Diamicton with clayey base, subglacial till. Ontario Lobe provenance: 39.2% non calc. sh.-siltst., 50.9% black calc. sh.-ls.

2. Varves (55) of post-Hawthorne beds, top unconformably overlain by till, but not conspicuously deformed. Mohawk Lobe provenance: dark and silvery gray colors, black and gray pellets of clay and diamicton. Base has diamicton, sand, and black diamicton pellet beds. Paleomagnetic declination: 7.4-3.6^{o} East.

3. Hawthorne Diamicton, subglacial till, stony near top, base contains deformed silt and clay and rafts of silt and clay from unit below. Mohawk Lobe provenance: 17.7% non calc. sh.-siltst., 72.7% black calc. sh.-ls.

4. Upper Newport Beds, top subglacially deformed. At this section varves in top grade downward into non varved (or very thickly varved) laminites with diamicton beds. The upper Newport Beds as they are exposed here are as much as 30 m thick (sections 805-808) and are perhaps the most easily traced unit in the West Canada Valley from Poland to Kast Bridge (see strat. columns in Figure L2).

5. Very clayey, sparsely stony West Canada Diamicton, subglacial till composed of reworked lacustrine silt, clay, and gravel (10% of stones rounded and polished). Abundant low-angle, clay-skinned fractures, occasional smudges, and unit below subglacially deformed. Mohawk Lobe provenance: 0.6% non calc. sh.-siltst., 78.1% black calc. sh.-ls., 9.6% dolost.

6. Lower Newport Beds (top unit) marked by oxidized and rippled sand with laminites and diamicton beds. Paleocurrents: southwest to north.

7. Very silty and extremely compact West Canada "A" Diamicton. Subglacial till composed of deformed silty lacustrine sediment. Mohawk Lobe deposit based on geometry of unit in valley and ice-flow indicators at sections 144-149 and 793.

8. Lower Newport Beds (bottom unit). Very silty and fine sandy laminites with thin greenish gray clay beds characteristic of an Adirondack provenance, varves. Top of the unit subglacially deformed, base of unit composed of cobble gravel to coarse sand.

9. Very stony (77% angular, shard-like stones) White Creek Diamicton. Extremely compact with only local rock types: 12.6% black calc. sh., 57.7% dark gray ls., 29.7% dolost. Exposed only at stream level where it overlies limestone striated S76^{O}W.

Reboard vehicles and return to Summit Rd. Continue west on Summit Rd.

9.5 (0.4) Turn off to right onto old section of Summit Rd.

9.7 (0.2) Turn right onto Newport Rd. and head down into valley of Shed Bk.

10.5 (0.8) Bridge over Shed Brook. Near the bridge, Shed Bk. runs across a limestone bench and further up valley it cuts down through the glacial stratigraphy. Also up valley is the type section of the Shed Brook Discontinuity (sections 541 and 560), which is an unconformity separating lacustrine deposits of the Poland Formation (Valley Heads) from underlying deposits of the Middleville Formation (pre-Valley Heads). The Shed Brook Discontinuity was formed as a result of subaerial erosion and stream valley development during what appears to be the Erie Interstade (see Ridge in prep., Article D). Downstream from the Shed Bk. bridge are waterfalls that are famous for exposures of fossiliferous late Ordovician limestone in the Trenton Group.

11.95 (1.45) Continue toward Newport across terraces. In the middle distance to the west is a gravel pit exposure of a late Wisconsinan terrace graded to a lake in the Mohawk Valley at Herkimer. Terraces at road level are actually eroded limestone benches which outcrop in the adjacent fields. Enter southwest side of Newport and come to stop sign. Turn right toward center of Newport where road crosses over West Canada Ck.

12.2 (0.25) Come to T-intersection in downtown Newport (flashing traffic light). Turn right following Rt. 28 south.

12.75 (0.55) Leaving town limits of Newport. Highway follows flood plain of West Canada Ck. The valley wall to the east is a steep bluff on the side of Woodchuck Hill (sections 441, 447, and 909). Exposures on Woodchuck Hill reveal the entire stratigraphic section from the post-Norway beds down to the White Creek Diamicton. The back side of Woodchuck Hill is the location of STOP 1-4 along White Ck.

13.5 (0.75) Rt. 28 runs parallel to West Canada Ck. between a cutbank and road side parking area. The cutbank is the site of section 451.

13.9 (0.4) Bridge over White Ck. After the bridge, Rt. 28 rises onto the surface of a late Wisconsinan fluvial terrace.

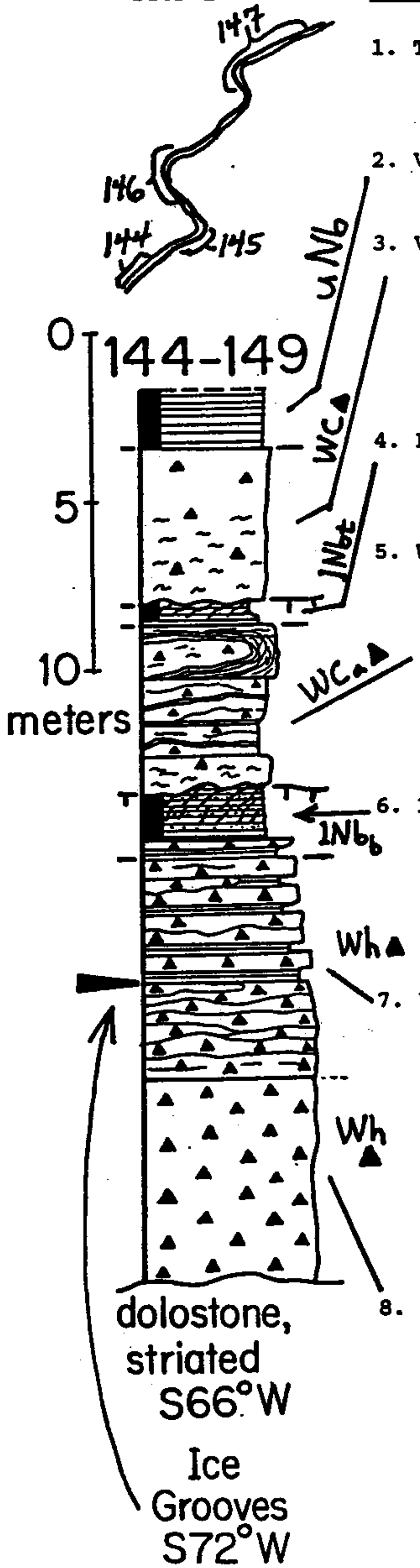
14.2 (0.3) Turn left (north) onto White Ck. Rd. which is at the intersection in front of West Canada Valley High School. View back to the southwest is across the West Canada Valley to STOP 1-3.

14.6 (0.4) Pull over to right side of White Ck. Rd. STOP 1-4 is a series of bluff sections along White Ck. to the west. The large hill to the east is an isolated remnant of glacial sediment from a time when White Ck. drained around the east side of this hill. Several strath terraces (like the one we are parked on) represent stages of late Wisconsinan headward erosion in the White Ck. valley.

STOP 1-4 Lower White Creek, Sections 144-149 (You may have to cross a stream, rubber boots helpful.)

The exposures along the lower part of White Creek display the entire pre-Valley Heads section of the late Wisconsinan stratigraphy (Middleville Fm.) in the West Canada Ck. valley. It has been a very difficult place, however, to piece together the stratigraphy because of relief on the surface of the White Creek Diamicton, and subglacial erosion at the base of the West Canada "A" and West Canada Diamictons. Sections are numbered here from 144 downstream to 149 upstream. Shown below is a crude map of the stream valley and a composite section. The deposits at this section record the recession of ice flowing from across the western and southwestern Adirondacks (Fig. B9), and two subsequent Mohawk Lobe readvances which deposited the West Canada "A" (Fig. B10) and West Canada (Fig. B11) Diamictons.

STOP 1-4



Important features: (top to bottom)

1. The high hills in the distance are composed of Valley Heads sediments overlying the upper Newport Beds which are thicker than exposed here (see sections 447 and 451).

2. Varves in upper Newport Beds exposed in soil at sections 146 and 147.

3. Very clayey and sparsely stony West Canada Diamicton is an easily traceable unit at sections 146 and 147, composed of mostly deformed lacustrine silt and clay. Traceable to outcrops east and southeast where it is very stony and shaley. High percentages of metamorphic rocks indicate reworking of the White Creek Diamicton.

4. Lower Newport Beds (top unit), 1 m or less, top subglacially deformed, laminated silt and clay varves which are highly fractured by horizontal compression.

5. West Canada "A" Diamicton which is an extremely sparsely stony and very sandy or silty unit. The top part of the unit at sections 146 and 147 is composed of load deformed proglacial mud, the basal 1-2 m is an exceedingly compact silty subglacial till composed of deformed lacustrine sediment (especially at section 147). The few pebbles found in the unit appear to be reworked from the White Creek Diamicton.

6. Lacustrine fine sand and greenish clay varves of the bottom unit of the lower Newport Beds (sections 145-147). Top is highly deformed (sheared, folded, thrusted, enechelon fracture systems). Adirondack provenance. Is the steep dip seen in the White Ck. outcrops syndepositional or post-depositional?

7. Very stony diamicton beds of the top of the White Creek Diamicton (section 147 only). Glacial sole ice-grooving indicates flow of S72°W (Fig. F5). The top of the White Creek Diamicton has more than 15 m of relief through sections 144-147 with basins being the sites of lacustrine ponding of the lower Newport Beds. Is the diamicton bedding the result of mass flow deposition or the result of intermittent till deposition by a buoyant glacier margin (ramp) that is repeatedly grounded and floated during recession?

8. Massive, very stony White Creek Diamicton, subglacial till. Adirondack provenance indicated by abundant metamorphic pebbles (12-15%) and boulders, and occasional sandstone pebbles (derived from the north or northeast side of the Adirondacks). Striations on dolostone at section 149 indicate ice-flow of S66°W. Elongate hills composed of the massive till appear to be transverse to ice-flow.

Reboard vehicles and continue around bend to east on White Ck. Rd.

14.8 (0.2) Bear right off of White Ck. Rd. onto dirt road (Old City Rd.) which cuts between farm house and barn. Old City Rd. follows late Wisconsinan course of White Ck.

15.3 (0.5) Bridge over Wolf Hollow Ck. (known on old maps and locally as City Bk.). This stream valley exposes most of the Cambrian through late Ordovician carbonate sequence in the western Mohawk Valley region and is famous as a fossil locality in limestones of the Trenton Group. The house that sits along the stream just west of the road experienced the full wrath of Wolf Hollow Ck. in the late 1800's during a flash flood triggered by a thunderstorm on Dairy Hill. The flood water rose to the middle of the 2nd floor!

15.45 (0.15) Follow Old City Rd. up hill to the intersection with Castle Rd. Bear to the right onto Castle Rd. which will take us to Rt. 28.

15.65 (0.2) Intersection of Castle Rd. and Rt. 28. Turn left onto Rt. 28 south toward Middleville.

15.8 (0.15) View to southeast along Rt. 28 reveals the top of a large dolostone quarry. Till in the West Canada Diamicton sits on a striated bench at the top of the quarry and records an up valley ice flow direction of N72°W.

16.4 (0.6) After passing vuggy dolostone outcrops, the valley floor widens into a series of terraces. Rt. 28 travels along the rim of a fluvial terrace which is presently being buried by an alluvial fan at the mouth of a stream to the east.

17.35 (0.95) Traffic light in downtown Middleville. Turn right continuing to follow Rt. 28 south.

17.5 (0.15) After crossing the bridge over West Canada Ck., follow Rt. 28 south around sharp bend in road.

18.1 (0.6) Entrance to KAO Campground which is our lunch stop.

LUNCH STOP Herkimer Diamond Party Pavillion

Reboard vehicles and head north on Rt. 28 toward Middleville.

18.85 (0.75) Retrace our earlier route back to the traffic light in Middleville and make a left following Rt. 28 north through Middleville.

21.2 (2.35) Follow Rt. 28 north and pass by Castle Rd. Across from West Canada H.S. turn right onto White Ck. Rd.

21.6 (0.4) Pass by STOP 1-4.

21.8 (0.2) Follow White Ck. Rd. around bend to left.

23.8 (2.0) Follow White Ck. Rd. up White Ck. valley until you come to a stop sign at the foot of a bridge over Hurricane Brook. Many stream bank exposures of the White Creek Diamicton will be visible while enroute. Turn right over bridge continuing to follow White Ck. on the Newport-Gray Rd.

24.0 (0.2) Pull over to right side of the road at gate in barb wire fence.

STOP 1-5 Factory Brook, Sections 225-226. (You may have to cross a small stream.)

The bank along Factory Bk. exposes much of the pre-Valley Heads section (Middleville Formation) which is truncated at the base of the Norway Diamicton of Valley Heads age. This outcrop occurs beyond the limits of the Hawthorne and Holland Patent Diamictons. Laminated silt and clay in the Poland Fm., which occur below the Norway Diamicton, are preserved in this area only in low spots marked by the Shed Brook Discontinuity (sections 171 and 173). The Shed Brook Discontinuity defines the bottom of stream valleys cut into the pre-Valley Heads deposits during a period of lake drainage in the western Mohawk Valley region.

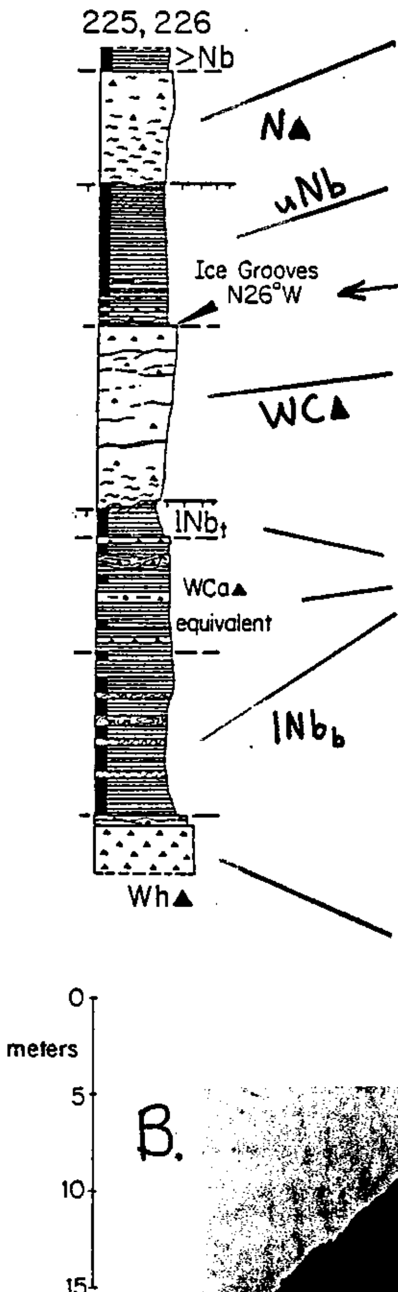
A.

Figure L4. A. Ice sole grooving on the upper surface of subglacial till in the West Canada Diamicton (section 226 in Figs. L2 and B2; Stop 1-6).

B. Sole cast of subglacial grooving at the same locality as above. →

STOP 1-5

<u>Important features</u>: (top to bottom)



1. Very clayey Norway Diamicton composed of deformed silt and clay. Ontario Lobe provenance: 5.2% ss.-cgl., 8.1% non calc. sh.-siltst., 63% black sh.-ls., 15.0% metamorphic rocks (probably derived from gravel).

2. Varves in the upper Newport Beds. Paleomagnetic declination: 23.8° East. Top is subglacially deformed.

3. Glacial sole grooving on upper surface of till in the West Canada Diamicton indicates ice-flow at N26°W (Fig. L4).

4. West Canada Diamicton composed of mostly reworked lacustrine silt and clay. Pebbles reflect reworking of White Creek Diamicton: 2.0% ss., 0% non calc. sh.-siltst., 70.5% black sh.-ls., 19.0% metamorphic rocks.

5. Laminated silt and clay of lower Newport Beds. Top of unit is subglacially deformed and eroded. Top of unit contains sparsely stony dark gray diamicton beds and massive beds of mud with rafts of contorted laminites. Diamicton beds are proglacial equivalents of till in the West Canada "A" Diamicton to the south at sections 146 and 147 (Stop 1-4). Base of unit composed of varves and turbidites with layers of contorted beds. Progressive fining of sediment upward reflecting a change from Adirondack to Mohawk provenance. Paleomagnetic declination: 7-12° East (bottom to top).

6. Very stony black till of White Creek Diamicton. Exposed downstream at sections 225 and 224. Adirondack and local provenance: 8.5% metamorphic rocks, 1.6% ss., 0.8% non calc. sh., 81.7% black calc. sh.-ls.

B.

Reboard vehicles and head back to White Ck. Rd.

24.2 (0.2) Turn right onto White Ck. Rd. after recrossing Hurricane Bk.

24.4 (0.2) Take sharp left at duck pond onto Gage Rd. which leads west to Newport.

24.7 (0.3) Gage Rd. rises up over sand bank in post-Norway beds and then descends small stream valley to Middleville and Newport Quad. border. Abundant large boulders appear on the hillslopes where the topography intersects the White Creek Diamicton. This type of field relationship has been extremely useful for mapping the top of the White Creek Diamicton.

25.9 (1.2) Gage Rd. continues down hill into Newport where it arrives at an intersection with Rt. 28. Make a right turn (north) onto Rt. 28 toward Poland. The octagonal limestone house on your right was built by Linus Yale and it was on this site that he evented the Yale Lock.

27.3 (1.4) On right (east) side of Rt. 28 a bank of lacustrine sand is exposed. This sand is the basal part of the pre-Hawthorne beds and it extends throughout the upper West Canada Valley (STOP 1-6, section 338) and beneath the hills forming the valley wall to the east. The sand is at least 15 m thick in a nearby stream valley known as Oklahoma Gulf (section 387). Water wells in this area are frequently drilled to this unit which is capped by clayey sediments of the post-Hawthorne and pre-Norway beds, and Norway Diamicton.

27.8 (0.5) Old cutbank and loop of West Canada Ck.

28.4 (0.6) Cemetary on south side of Poland which sits on a fluvial terrace (probably Holocene) that is cut into an alluvial fan composed of sediment derived from the eroding glacial section to the east.

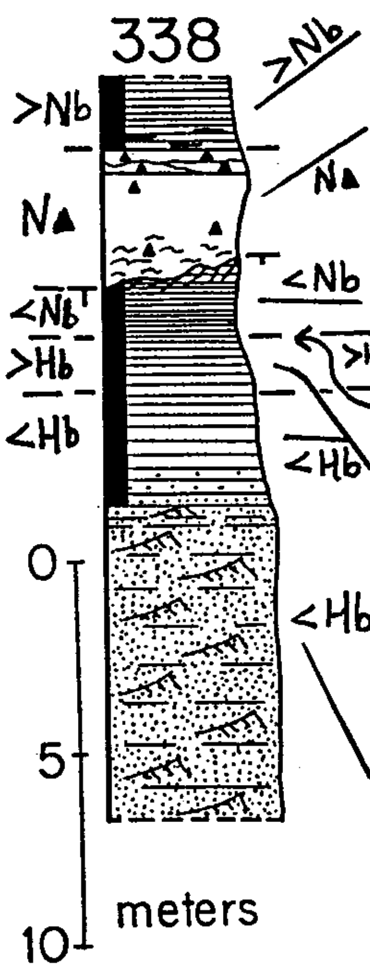
29.2 (0.8) Center of Poland and intersection of Rt. 8 south and Rt. 28 north. Continue through Poland on Rt. 28 north. The town of Poland sits on a fluvial terrace and alluvial fan at the mouth of Cold Brook.

29.7 (0.5) At the west end of Poland, pull off to right on dirt road leading to gravel and clay pits.

STOP 1-6 Poland clay and gravel pits, Sections 338 and 341.

There are two separate exposures at this stop. One section to the north (338) exposes Valley Heads deposits (Poland Fm.) from the pre-Hawthorne beds to the post-Norway beds that span the time of Mohawk (Fig. E4) and Ontario Lobe (Fig. E5) readvances. The second exposure (section 341) is in a fluvial terrace which is inset in the Valley Heads section and represents post-Holland Patent lake drainage and river formation just prior to the eastward drainage of Lake Iroquois through the Mohawk Valley (Figs. E7 through E9).

<u>Section 338. Important features</u>: (top to bottom, clay pit)



1. Post-Norway varve couplets are oxidized and sometimes visible in soil.

2. Clayey and silty sparsely stony Norway Diamicton. Subglacial till composed of deformed lake beds. Ontario Lobe provenance: 17.9% ss.-cgl., 12.4% non calc. sh.-siltst., 47.6% black calc. sh.-ls., 9.4% light gray ls.-dolost., 12.8% metamorphic pebbles.

* 3. Deformed top of pre-Norway beds, up to 40 varves. Ontario Lobe provenance: tannish and pinkish colors, pink and red clay and diamicton pellets.

* 4. Downward change from Ontario to Mohawk Lobe provenance.

* 5. Dark and silvery gray clay and silt varves (80) of post- and pre-Hawthorne beds, small hiatuses in section. This exposure is beyond the limits of the Hawthorne Diamicton and Mohawk Lobe readvance. Paleocurrents from rib and furrows: north, source from the Mohawk Lobe to the south.

* Paleomagnetic declination (units 5 through 3): $7-1^{\circ}$ East (bottom to top).

6. Abrupt contact. Rippled and cemented fine to medium micaceous sand of pre-Hawthorne beds. Paleocurrents shift from south and east in unit to north near top of unit indicating a shift from an Adirondack to Mohawk Lobe source.

<u>Section 341. Important features</u>: (gravel pit)

This exposure consists of fluvial sand and pebble gravel with cut and fill structures and crossbedding indicating a down valley current flow (south to east). Sediment in the section gets progressively coarser downward from the top of a terrace landform to the floor of the pit which exposes flat beds of cobble to pebble gravel. This fluvial sequence records aggradation after a period of valley incision (to below pit level). Aggradation during the formation of the terrace cannot be interpreted simply as a period of downcutting following post-Holland Patent lake drainage. Fluvial aggradation appears to have been in response to delta progradation in a lake where West Canada Ck. enters the Mohawk Valley at Herkimer (Herkimer Terrace).

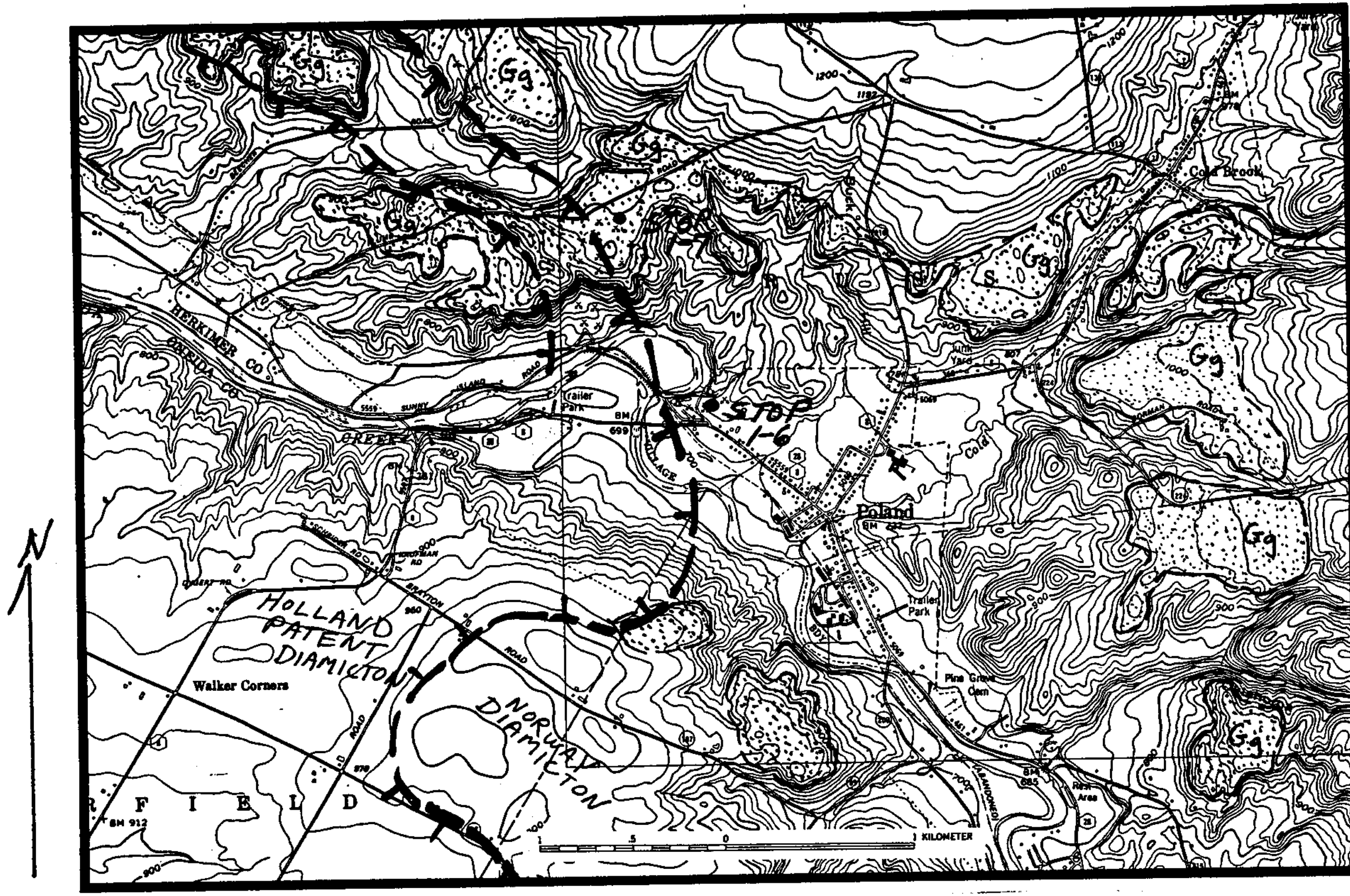


Figure L5. Topography in the area of Stops 1-6 and 1-7. Dotted areas are the tops of deltas from Lake Gravesville.

Reboard vehicles and continue north on Rt. 28.

30.7 (1.0) Continue to follow Rt. 28 over West Canada Ck. bridge. Rt. 8 splits off to the left.

31.4 (0.7) Turn right (north) onto Plumb Rd.

32.5 (1.1) Enter gravel pit at end of Plumb Rd.

STOP 1-7 Plumb Road pit, Section 342. Lake Gravesville delta.

The exposure off of Plumb Road (Eastern Rock Products, Poland Plant, Fig. L5) is one in a series of ice-contact deltas lined up from southeast to northwest along the east side of the West Canada Creek valley (from Poland to north of Barneveld). Upper topset surfaces of these deltas are at 1000-1060 ft (from south to north) and topset/foreset contacts are between 970 and 1010 ft. The deltas represent the impoundment of Lake Gravesville at the limit of the Ontario Lobe readvance which deposited the Holland Patent Diamicton (Fig. E6). Deltaic deposition continued for a short time after the beginning of Ontario Lobe recession because till in the Holland Patent Diamicton is partly buried by deltaic sediment. In the past, the pit exposure has revealed an unconformity between the medium sand bottomsets of the Gravesville Delta (Holland Patent age), and underlying rippled and laminated lacustrine fine sand and silt of the post-Norway beds. This unconformity indicates a period of erosion between Ontario Lobe readvances, possibly as a result of lake drainage, which was followed by impoundment of Lake Gravesville. Lake Gravesville appears to have extended into the Mohawk Valley where deltas and graded fluvial surfaces have a similar elevation in the East Canada Ck. valley (north of Little Falls, Fig. E6). If Lake Gravesville extended into the Mohawk Valley, a likely spillway for the lake is Delanson Col (835 ft) southeast of the Mohawk Valley along the eastern edge of the Schoharie Basin. Delanson Col could have been an outlet if isostatic tilting since the time of Lake Gravesville was about 3.5-5 ft/mile.

Reboard vehicles and head back to Rt. 28.

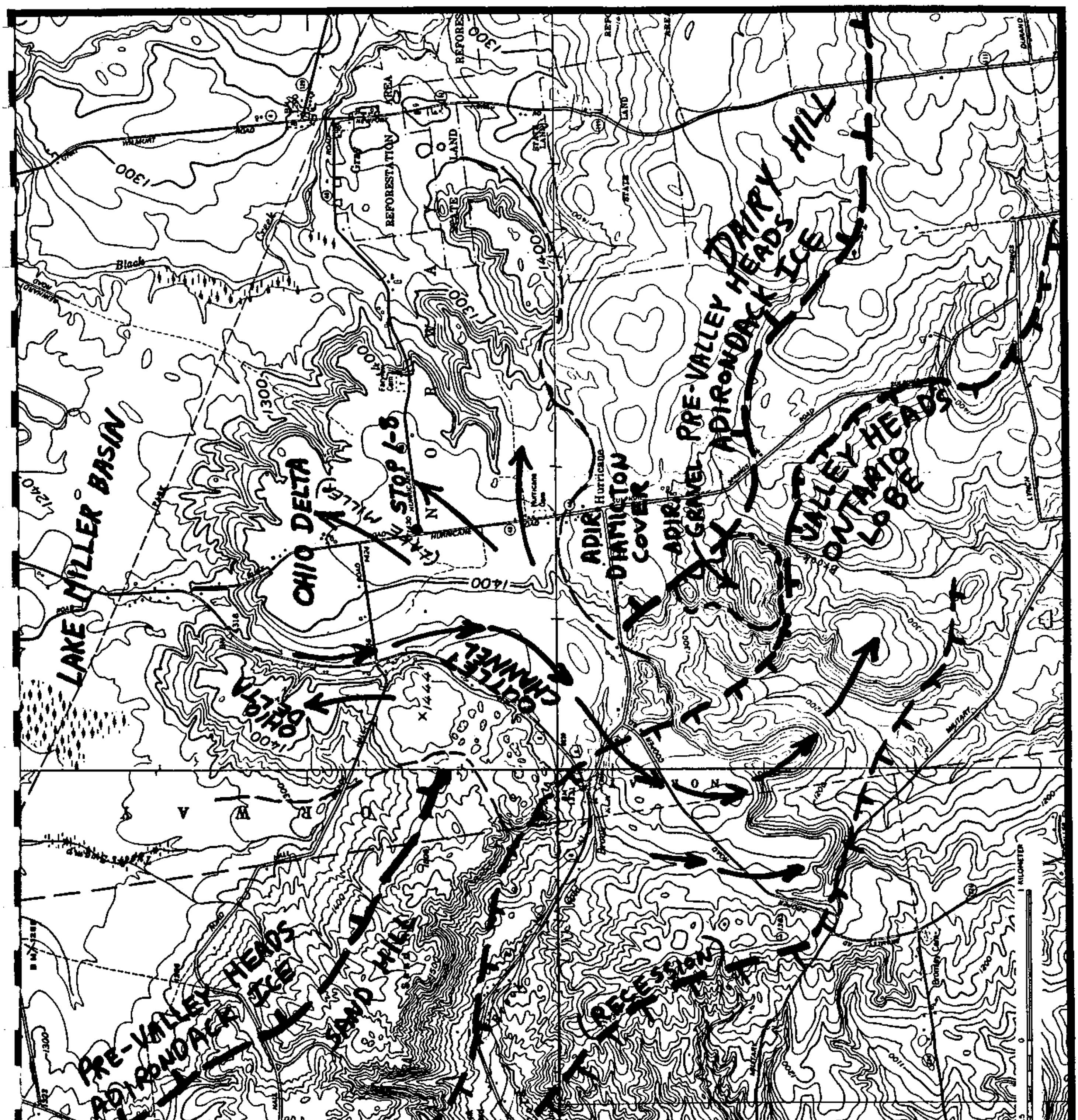
33.6 (1.1) Turn left onto Rt. 28 toward Poland. Stay on Rt. 28 to the center of Poland.

35.8 (2.2) In the center of Poland turn left onto Rt. 8 north toward Cold Brook.

36.3 (0.5) Bear right on sharp turn continuing to follow Rt. 8 north. To your right is a large alluvial fan built at the mouth of Cold Brook.

37.5 (1.2) Center of town of Cold Brook. Continue on Rt. 8 north.

38.2 (0.7) Rt. 8 crosses from the Newport into the Hinckley Quad.



LAKE MILLER BASIN
OHIO DELTA
OHIO DELTA
LAKE MILLER
STOP L-8
OUTLET CHANNEL
ADIR
DIAMICTON COVER
ADIR GRAVEL
PRE-VALLEY HEADS ADIRONDACK ICE
DAIRY HILL
VALLEY HEADS ONTARIO LOBE
PRE-VALLEY HEADS ADIRONDACK ICE
SAND HILL
RECESSION
VALLEY HEADS ONTARIO LOBE
G9
G8
REFORESTATION AREA
1300
1400

39.5 (1.3) Rt. 8 loops through the Hinckley Quad. and returns to Newport Quad.

40.0 (0.5) Turn right onto Hurricane Rd. which crosses into the Middleville Quadrangle.

41.2 (1.2) Hurricane Rd. rises onto a flat topped hill. Turn left (north) staying on Hurricane Rd.

41.8 (0.6) Pull over to the right side of the road on the flat top of an ice-contact delta of Lake Miller, the Ohio Delta.

STOP 1-8 The Ohio Delta, glacial Lake Miller

The first, and most extensive, Valley Heads readvance of the Ontario Lobe, which deposited the Norway Diamicton in the lower West Canada Valley, advanced far enough to the northeast to close off the upper West Canada Valley at the west end of Dairy Hill (Fig. E5). As a result, Lake Miller was impounded at about 1410 ft in the upper West Canada Valley and had its spillway draining into Spruce Creek on the east side of Dairy Hill. West of Dairy Hill a large ice-contact delta, the Ohio Delta, was built into Lake Miller from the margin of the Ontario Lobe. The flat, distal topset surface of the Ohio Delta is seen at this stop (Fig. L6). Recession of the Ontario Lobe caused breaching of the Ohio Delta and southward drainage of Lake Miller into temporary lower lakes along the margin of the Ontario Lobe. These temporary lakes were initially at an elevation of about 1380 ft. Rt. 8 in this area runs through the drainage channel for Lake Miller. From this stop we will descend to the floor of the drainage channel and follow it south for about 1 mile until it cuts eastward along what represents a recessional position of the Ontario Lobe.

Reboard vehicles and continue north on Burt Rd.

42.0 (0.2) Turn left onto Hall Rd. which descends to the floor of a channel cut through the Ohio Delta by water draining southward out of Lake Miller. Southward drainage was facilitated by recession of the Ontario Lobe and the drainage channel appears to be graded to a temporary lake impounded along the margin of the Ontario Lobe.

42.5 (0.5) At the intersection, turn left onto Rt. 8 south. Follow Rt. 8 toward Poland.

43.5 (1.0) Rt. 8 continues to follow the Lake Miller channel and cuts across the corner of the Middleville Quad. back into the Newport Quad.

47.8 (4.3) Center of Poland. Turn left onto Rt. 28 south toward Newport.

Figure L6. Topography in the area of Stop 1-8 showing the Ohio Delta and Lake Miller drainage channel.

51.5 (3.7) At the flashing light in the center of Newport, turn right. (Leaving Rt. 28.) This is the beginning of a traverse across the top of the Deerfield Hills on our way back to Herkimer.

51.75 (0.25) After crossing West Canada Ck., make a left onto the Newport Rd. heading south.

54.2 (2.45) Follow the Newport Rd. south up a hill to a stop sign. DANGEROUS INTERSECTION!

55.1 (0.9) Cross over intersection and go up hill on what is now Hawthorne Rd. At the top of Harter Hill there is a panoramic view to the northeast of the West Canada Valley. The road is at an elevation of 1500 ft while the town of Newport is at 650 ft.

55.4 (0.3) Bear to the left at intersection.

55.8 (0.4) Near base of hill turn left onto Carey Rd.

56.3 (0.5) Turn right onto Cook Hill Rd. which will cross over the top of Schrader Hill in the distance.

57.3 (1.0) Cook Hill Rd. crosses the Newport/Ilion Quadrangle boundary. Non calcareous olive gray shale of the Lorraine Group crops out along the left (east) side of the road.

57.6 (0.3) Turn left onto Schrader Hill Rd. Hopefully your breaks work!

59.7 (2.1) Schrader Hill Rd. descends to the West Canada Valley south of Middleville and crosses from the Ilion into the Herkimer Quadrangle. Turn right onto Rt. 28.

62.6 (2.9) Arrive at parking area which was the start of today's excursion.

------ END OF DAY 1 ------

Today's objective is to make an east-to-west traverse of the western Mohawk Valley (Fig. L7) in order to gain an appreciation of the overall complexity of the glacial stratigraphy (Fig. L8) and history (Fig. L9) of the valley. We will be concerned with the history of readvances and lake impoundment at various times during Valley Heads glaciation, and how the eastward drainage of Lake Iroquois was established. In marked contrast to yesterday's trip in the West Canada Valley, Valley Heads lacustrine sequences in the Mohawk Valley have thick sand and gravel units. Subaqueous meltwater discharge along the axis of the Mohawk Valley must have been extremely active during both Mohawk and Ontario Lobe readvances and recessions. A fluvial gravel, with paleocurrent features indicating flow to the east (down valley), occurs below the Valley Heads stratigraphy, and appears to be an Erie Interstade equivalent (see Ridge, in prep., Article D). Numbered sections and stratigraphic units are shown on Figures L8 and L9.

Assembly Point: We will be passing through Herkimer around noon, and it would be advantageous to consolidate vehicles in Herkimer where they can be picked up later. After breakfast in Little Falls we will assemble and leave at 8:00 AM from a parking area on the south side of Rt. 167 North (not 169). Directions: From the center of Little Falls (Little Falls Quad.) continue east on combined Rts. 5 and 167. About 0.8 miles east of town, and after passing outcrops of gneiss, take Rt. 167 north (up hill) for 0.9 miles to a parking area on the right. The view from the parking area is southeast into the Mohawk Valley across a near vertical fault, the southeast side of which is down.

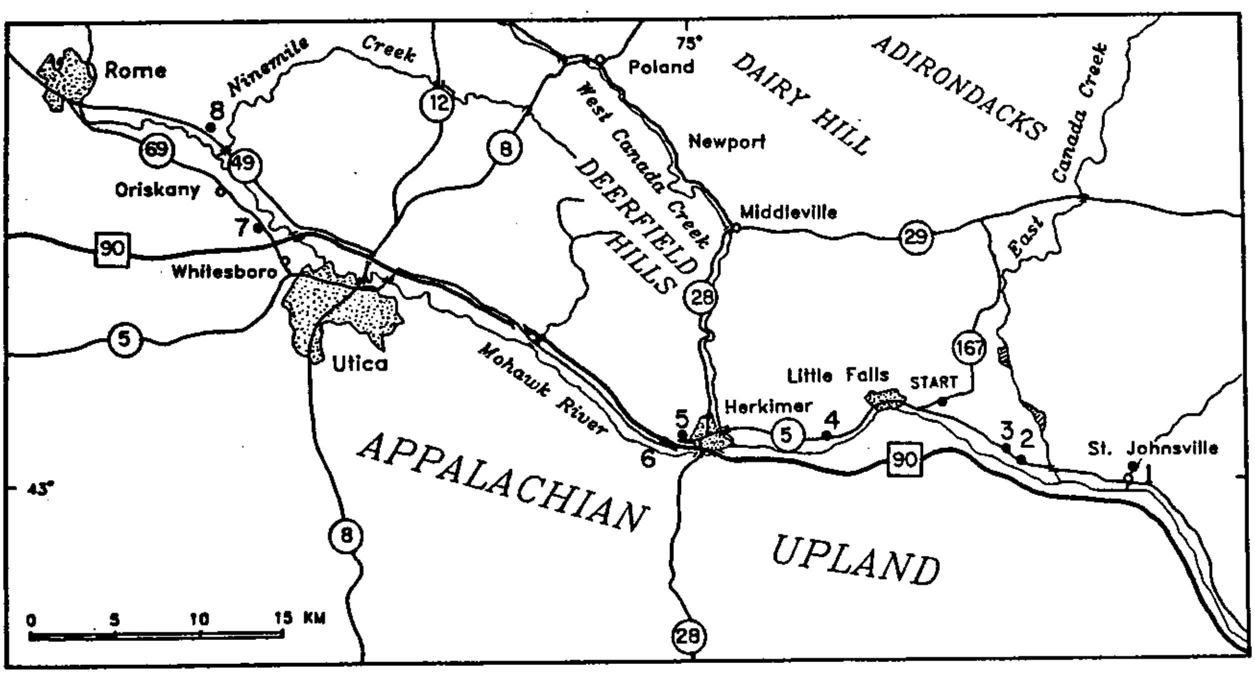


Figure L7. Location map of western Mohawk Valley showing field trip stops for Day 2.

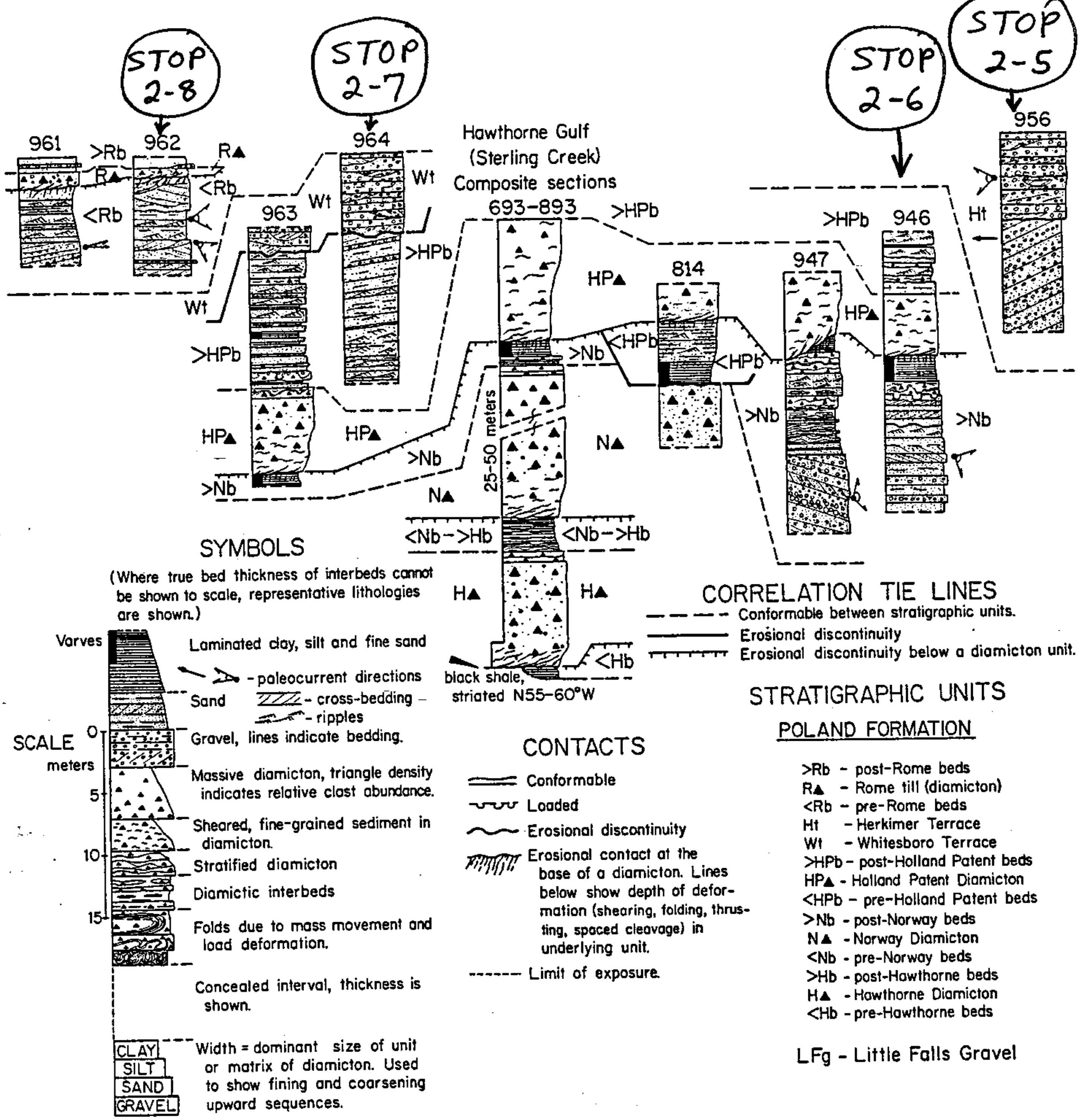
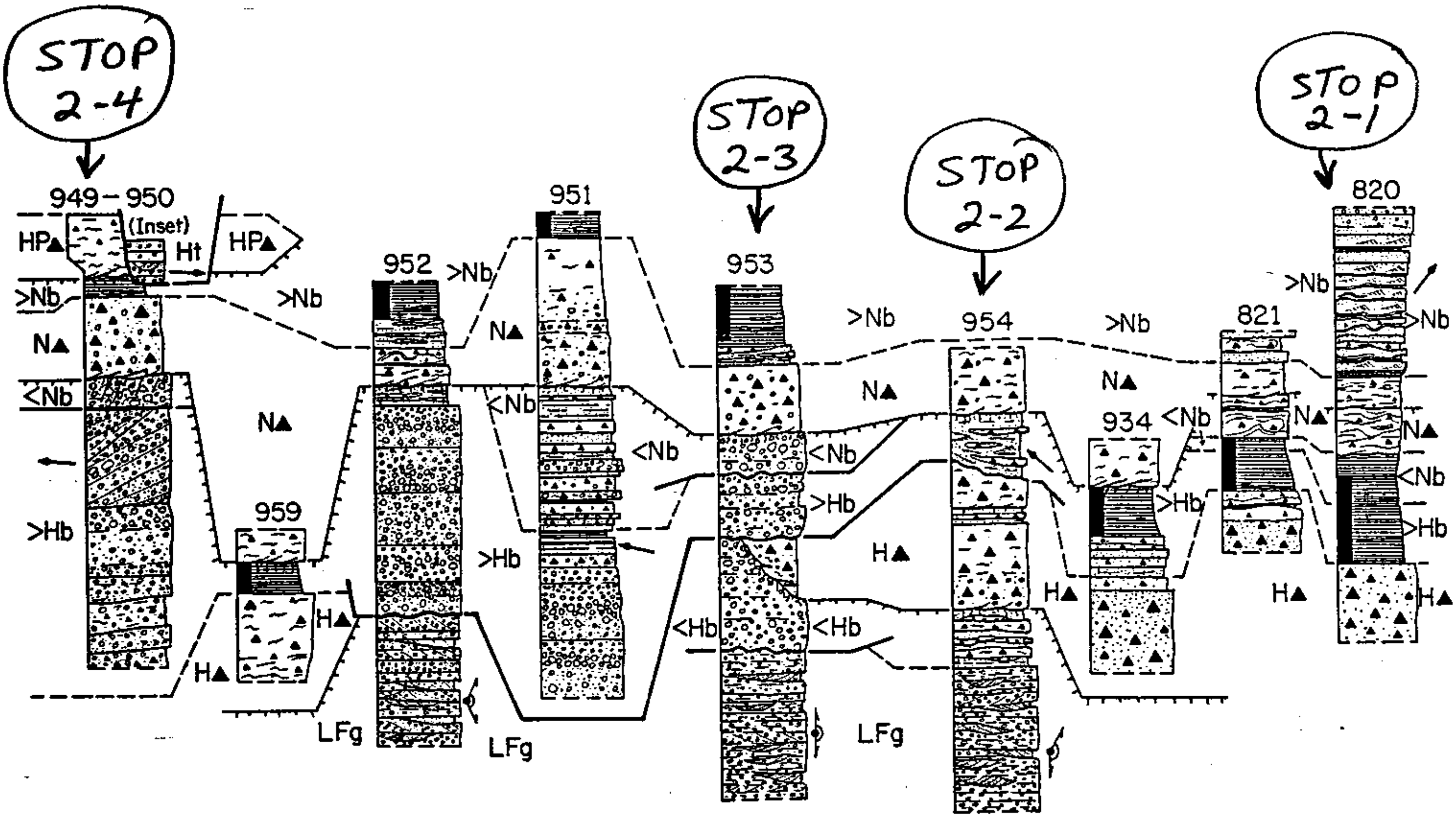


Figure L8. Late Wisconsinan stratigraphic sections in the western Mohawk Valley from St. Johnsville to Rome.


STOP 2-4
STOP 2-3
STOP 2-2
STOP 2-1
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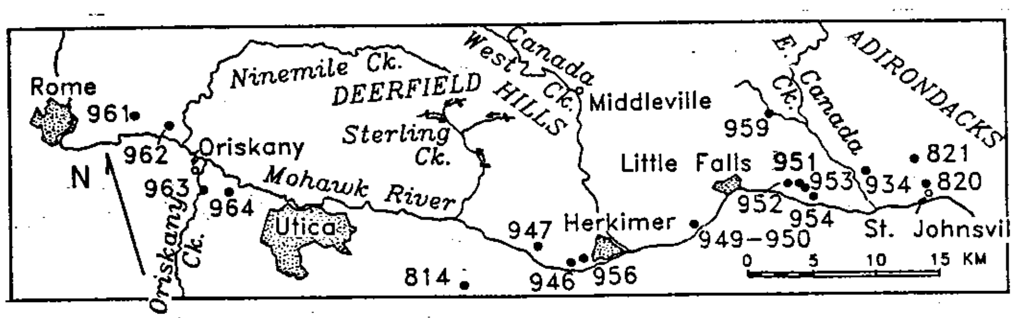
LFg

LOCATION


Rome
961
962
963
964
Oriskany
Oriskany Ck.
N
Ninemile Ck.
DEERFIELD HILLS
Sterling Ck.
West Canada Ck.
Middleville
Mohawk River
Utica
814
947
946
956
Herkimer
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Little Falls
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821
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St. Johnsville
0 5 10 15 KM

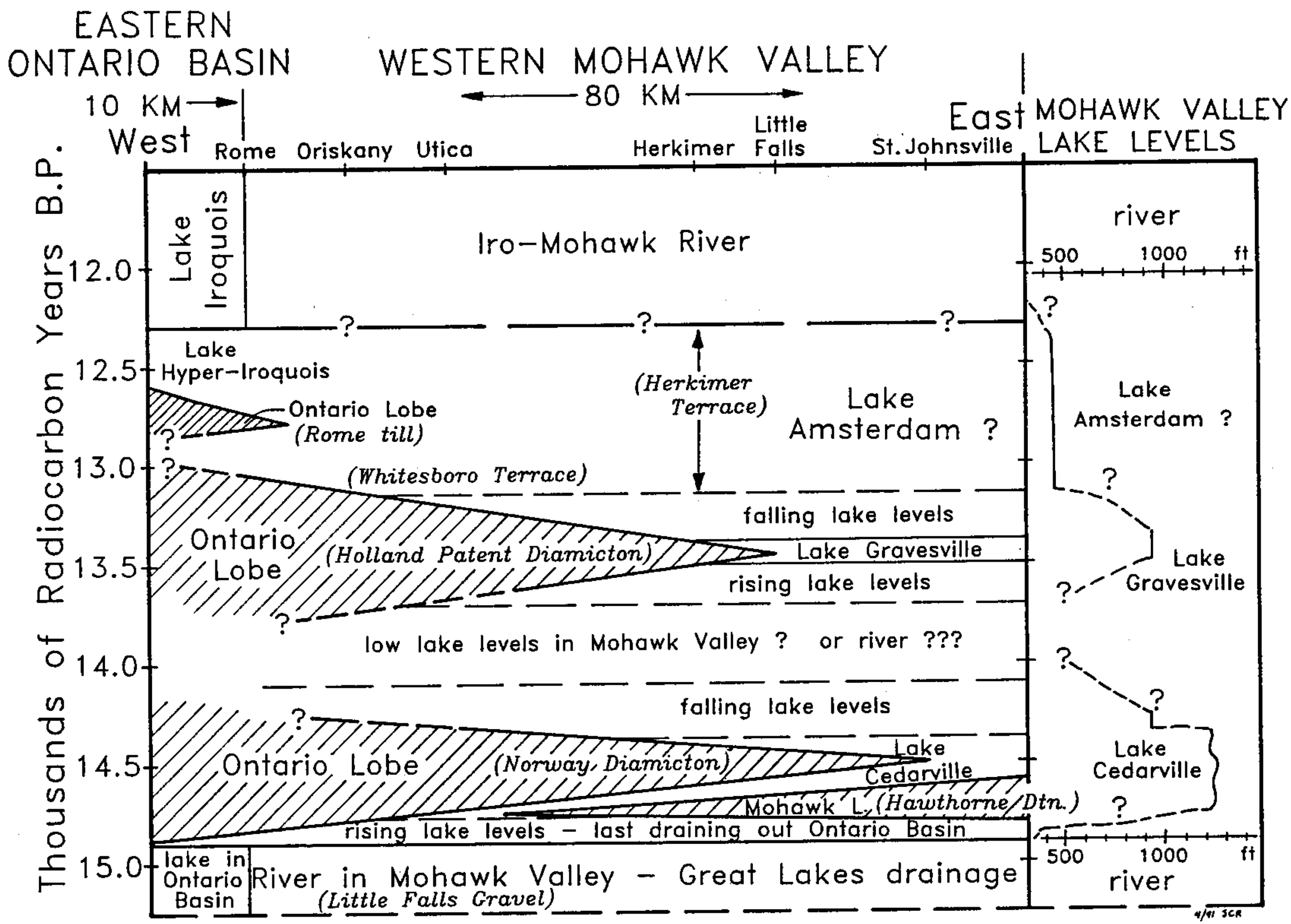


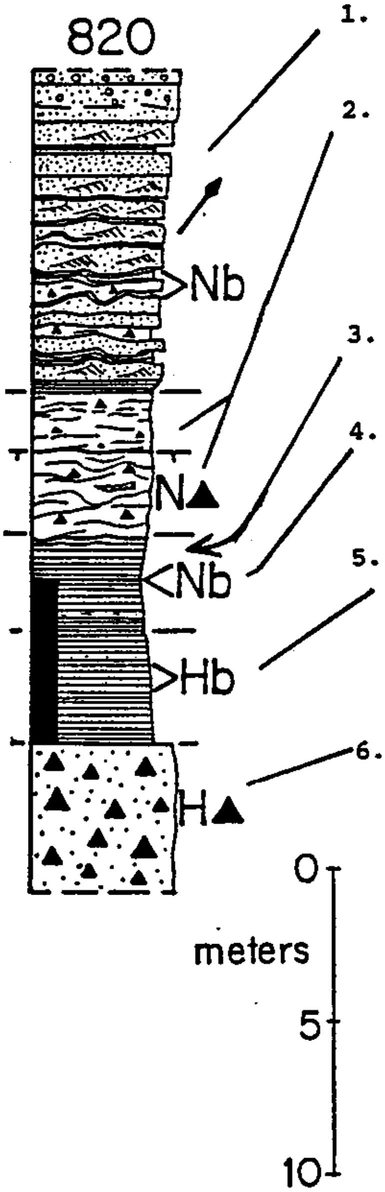
Figure L9. A time-distance plot of valley Heads glaciation in the western Mohawk Valley, including glacial readvances and impounding of glacial lakes. Lithostratigraphic and morphostratigraphic units are shown in italics.

Mileage (pt. to pt.)		Route description
0.0	(0.0)	Head southwest towards Little Falls on Rt. 167.
0.9	(0.9)	At the intersection of Rts. 167 and 5, turn left onto Rt. 5 (east) toward St. Johnsville. The first mile of Rt. 5 will be through outcrops of Precambrian gneiss.
6.3	(5.4)	Boundary of Little Falls/Oppenheim Quadrangles.
6.7	(0.4)	Bridge over East Canada Ck.
8.8	(2.1)	Boundary of Oppenheim/Fort Plain Quadrangles.
9.85	(1.05)	Enter St. Johnsville and at traffic light turn left onto Division St. which heads north along Zimmerman Brook.
9.9	(0.05)	Boundary of Fort Plain/Oppenheim Quadrangles.
10.1	(0.2)	Pull over at side of Division St. where side street merges from right. STOP 2-1 is located behind houses to west along Zimmerman Brook.

STOP 2-1 Zimmerman Brook, St. Johnsville, Section 820 (Muddy section, small stream crossing.)

The section on Zimmerman Brook is composed of Valley Heads deposits which record the advance and recession of the Mohawk Lobe (Fig. E4) and the eastern limit of the Ontario Lobe (Fig. E5). Irregular ice-contact landforms in the area composed of mostly lacustrine sand (unit at top of bank) are part of a large morainal bank and subaqueous fan complex built at the maximum extent of the Ontario Lobe. Lacustrine sand of the post-Norway beds and a continuous sequence of lake bottom clay and silt beds in the pre-Norway and post-Hawthorne beds are traceable northward to elevations of more than 1000 ft. These units provide evidence of deep lake impoundment (Lake Cedarville) between the Mohawk and Ontario Lobes. The superposition of diamicton units also demonstrates the non-synchronous pattern of Mohawk and Ontario Lobe readvances during Valley Heads glaciation. Readvance of a Mohawk Lobe west of St. Johnsville into the West Canada Creek valley and western Mohawk Valley (Fig. E4) was followed by about 75-100 years of Mohawk Lobe recession to St. Johnsville and another 100 years of varve deposition, all prior to the complete Valley Heads advance of the Ontario Lobe (Fig. E5).

STOP 2-1



Important features: (top to bottom)

1. Rippled sand, reddish clay, and thin diamicton beds, post-Norway beds. Paleocurrents: northeast.

2. Norway Diamicton, two separate facies. Top is massive pinkish gray silty clay with occasional stones and few pellets (deformation till or proglacial diamicton?) Bottom is clayey diamicton with faint contorted beds (proglacial diamicton). Ontario Lobe provenance: red and pink beds and pellets.

3. Non varved (or very thickly varved) top of pre-Norway beds. Reddish pink beds and pellets.

4. Pinkish to tannish gray varves of pre-Norway beds. Pink and red pellets. Base is 0.5-1.0 m transition zone with unit below. Varves thicken upward.

5. Post-Hawthorne beds. Dark gray silt beds and tannish, pinkish (top) to silvery (bottom) gray clay beds of mostly Mohawk Lobe provenance. Very rare red and pinkish pellets, varves thicken downward. Paleomagnetic declination: (at top) 1.0° West.

6. Very stony and sandy Hawthorne Diamicton. Mohawk Lobe provenance: 30-50% of stones are dolostone and metamorphic rock types.

Reboard vehicles and return to downtown St. Johnsville on Division St.

10.35 (0.25) Turn right (west) onto Rt. 5 at traffic light.

10.8 (0.45) Rt. 5 heads out of St. Johnsville through a series of fluvial terraces that mark the development of Lake Iroquois drainage through the Mohawk Valley. This fluvial system is known as the Iro-Mohawk River. Fluvial gravel terraces, from St. Johnsville westward to the mouth of East Canada Ck., at an elevation up to 410 ft represent this event. The Iro-Mohawk terraces may be graded to a lake in the eastern Mohawk Valley (Lake Amsterdam) or temporary nick points.

13.5 (2.7) Bridge over East Canada Ck. Near the mouth of East Canada Ck. several gravel-capped strath terraces punctuate the late Wisconsinan stratigraphy. Terrace surfaces range in elevation from 400-520 ft. Terraces near 400 ft represent the Iro-Mohawk River. Terraces that occur at about 450-520 ft are fluvial surfaces graded to lakes in the Mohawk Valley during the final recession of the Ontario Lobe from the western end of the Mohawk Valley (STOPS 2-5 thru 2-8). The controlling spillways for these lakes have not been precisely identified but the lakes may be a western extension of Lake Amsterdam in the eastern Mohawk Valley. Lakes west of Little Falls at similar elevations may have been continuous with the lakes at the mouth of East Canada Ck., in which case the lakes did not have a controlling spillway at Little Falls.

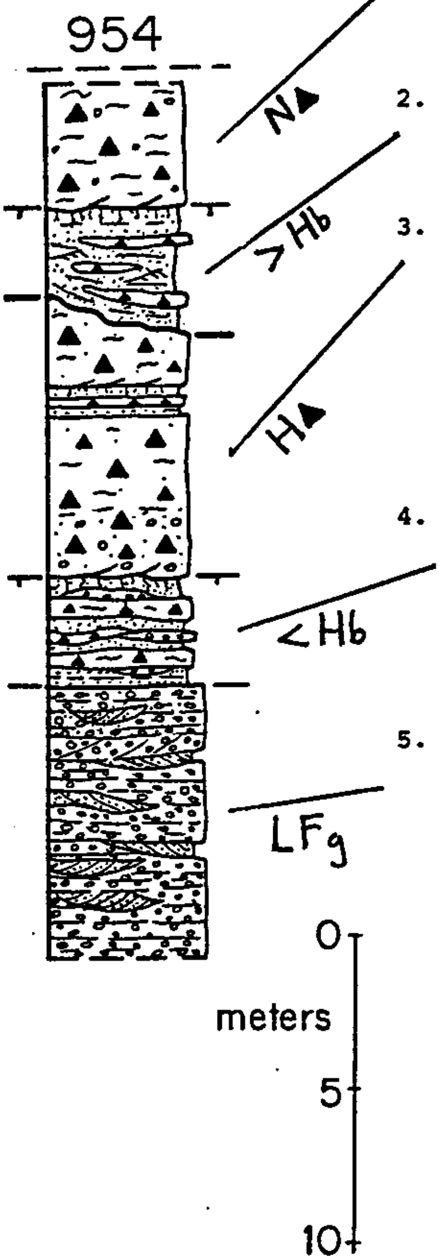
14.8 (0.9) Take a left (south) off of Rt. 5 onto Ashe Road (Old Rt. 5). Rt. 5 is on a highly dissected and fragmented terrace of the Iro-Mohawk River. The terrace has an elevation of 400-440 ft and may be graded to Lake Amsterdam to the east.

16.2 (1.4) Pull over on the right side of Ashe Rd. by gravel pit. Ashe Rd. descends to the base of the gravel-capped Iro-Mohawk terrace which sits along the modern Mohawk River flood plain.

STOP 2-2 Ashe Road (Old Rt. 5), Section 954. (Very steep bank.)

The section on Ashe Road has a basal fluvial gravel unit, the Little Falls Gravel, which appears to represent eastward drainage of the Ontario Basin during the Erie Interstade (between pre-Valley Heads and Valley Heads glaciations; see Ridge, in prep., Article D). The very top of the bluff (above exposed section) is an Iro-Mohawk River terrace.

STOP 2-2



Important features: (top to bottom)

1. Moderately to sparsely stony Norway Diamicton (above present exposure). Ontario Lobe provenance. This unit represents the most extensive Valley Heads readvance of the Ontario Lobe (Fig. E5).

2. Muddy medium sand with diamicton beds, post-Hawthorne beds. Groundwater seepage and oxidation. Lower contact sits on steeply dipping erosion surface cut into unit below.

3. Black, stony Hawthorne Diamicton, subglacial till with an intra-till lens of muddy coarse sand and pebbles (partly deformed subglacial channel?). Mohawk Lobe provenance: black color, abundant black shale. Contains many rounded pebbles from reworked gravel, deformed sand and gravel in base of unit. This unit represents the most extensive Mohawk Lobe readvance during Valley Heads glaciation (Fig. E4).

4. Pre-Hawthorne beds, initial Valley Heads lacustrine deposits, top is deformed and eroded. Interbedded gray to black diamicton layers, muddy sand and gravel, poorly sorted boulder to pebble gravel, crossbedded and rippled sand, and laminated fine to medium sand and clayey silt. Paleocurrents: west (up valley).

5. Little Falls Gravel. Flat and crossbedded cobble gravel to coarse sand. Extremely rounded and well sorted as compared to gravels in unit above. Paleocurrents: east of northeast to south (down valley!).

Reboard vehicles and continue west on Ashe Rd.

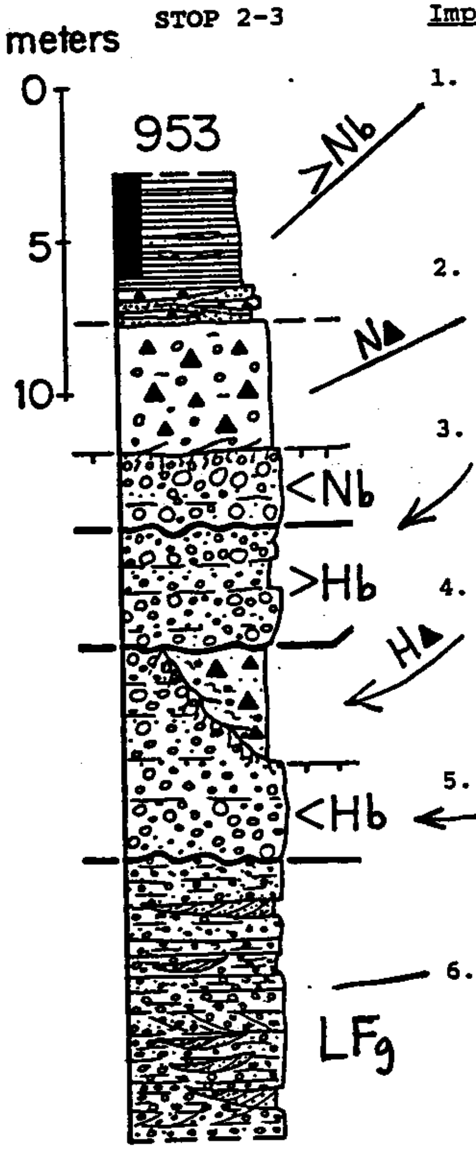
16.7 (0.5) Junction of Ashe Rd. and Rt. 5. Continue west on Rt. 5. BE CAREFUL, THIS IS A TREACHEROUS INTERSECTION!

16.85 (0.15) Pull over in front of used car dealership on the north side of Rt. 5.

STOP 2-3 Route 5 used car lot, Section 953. (Steep embankment with many boulders, watch for others below!)

This section on Rt. 5 shows the contrast in grain size and sorting between the Little Falls Gravel at the base of the section and younger Valley Heads subglacial and subaqueous gravels higher in the section. Also apparent is the pinch out of the Hawthorne Diamicton in the middle of the section and evidence for subglacial meltwater erosion. The Hawthorne Diamicton does not appear in outcrops immediately to the west along Rt. 5 (sections 951 and 952).

STOP 2-3



Important features: (top to bottom)

1. Post-Norway beds. Sand beds and varves with many beds composed of red and gray pellets, oxidized brown. Terrace-like land surface above is underlain by this unit which was not capped by a gravel or sand or overridden by ice.

2. Dark gray (oxidized in base) Norway Diamicton with many rounded stones reworked from gravel below. Ontario Lobe provenance: abundant sandstone and limestone pebbles, not as black or shaley as diamicton unit of the Mohawk Lobe.

3. Pre-Norway and post-Hawthorne beds composed of bouldery subaqueous or subglacial gravel. Top unit has very large and striated boulders. Base truncates units below along a well defined erosion surface.

4. Dark gray to black, shaley Hawthorne Diamicton, subglacial till. Mohawk Lobe provenance: abundant black shale. Unit dips to east and is pinched out to west by erosion beneath unit above. Base is 15 cm of oxidized, highly sheared muddy sand.

5. Pre-Hawthorne beds. Poorly sorted subaqueous or subglacial bouldery gravel. Top of unit dips to east, truncated to west by erosion beneath post-Hawthorne beds, truncated to the east by subglacial erosion at base of Hawthorne Diamicton.

6. Little Falls Gravel (same as STOP 2-2). Well sorted, horizontal beds of flat and crossbedded cobble to pebble gravel. Paleocurrents: east of north and south.

Reboard vehicles and continue west on Rt. 5.

17.5 (0.65) Large bluffs on the north side of Rt. 5 (section 952) expose a stratigraphy very similar to STOP 2-3 except that the Hawthorne Diamicton has been completely eroded from the section. The Little Falls Gravel forms a prominant cemented gravel bench in the base of the Rt. 5 sections.

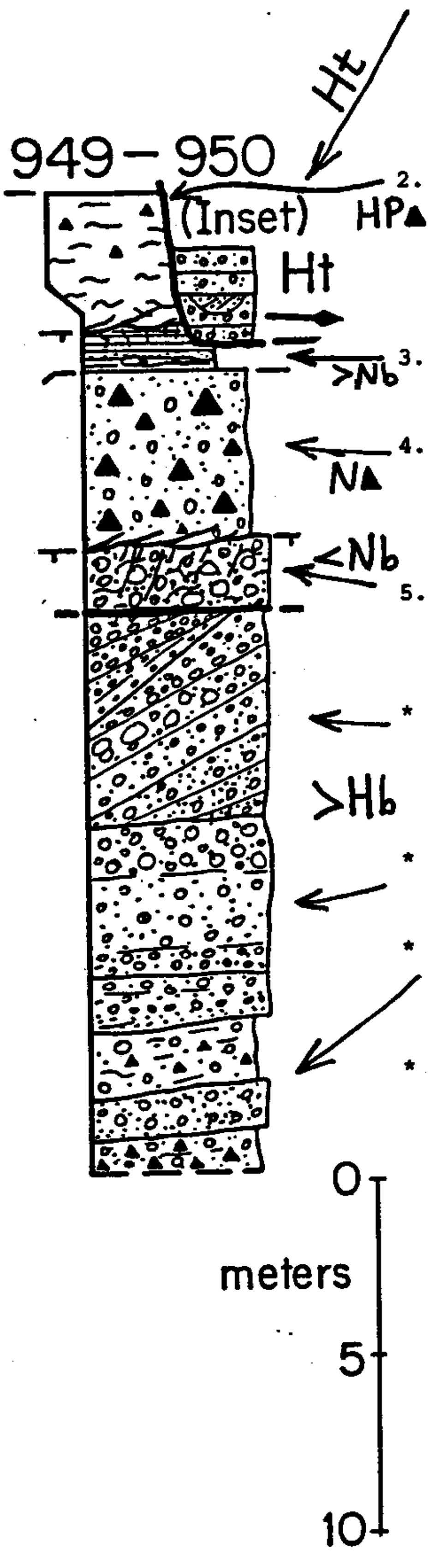
21.7 (4.2) Continue west on Rt. 5 to the west side of Little Falls. Boundary of Little Falls/ Herkimer Quads. If you need to use a bathroom, you may try MacDonald's in Little Falls. You can rejoin the caravan at STOP 2-4 which is west of Little Falls on Rt. 5.

22.9 (1.2) After continuing west of Little Falls on Rt. 5, pull over at used car lot on north side of highway.

STOP 2-4 West of Little Falls, used car dealership, Sections 949-950. (Very steep bank. You may climb to the top of the bluff by way of the large central gully.)

West of Little Falls occurs a stratigraphy similar to east of Little Falls. One big difference, however, is the appearance of a second Ontario Lobe diamicton at the top of the section, the Holland Patent Diamicton, which represents a second less extensive Ontario Lobe readvance in the Mohawk Valley (Fig. E6). Little Falls is at about the eastern limit of the Holland Patent Diamicton which is an extremely clayey unit capping high bluffs west of Little Falls.

STOP 2-4



Important features: (top to bottom)

1. Inset in the Holland Patent Diamicton and post-Norway beds at the top of the bluff is post-Holland Patent fluvial gravel at an elevation of 480-500 ft. This unit is continuous with gravel further west which is part of a fluvial terrace (Herkimer Terrace) graded to a lake in the Mohawk Valley at an elevation of about 460 ft.

2. Very clayey and sparsely to very sparsely stony Holland Patent Diamicton. The unit is subglacial till that is traceable up the slope behind the bluff to an elevation of about 800 ft. Ontario Lobe provenance: pinkish and tannish gray color.

3. Post-Norway beds, top subglacially deformed. Exposed at top of bluff face on west side.

4. Very stony dark gray Norway Diamicton, subglacial till. Unit dips to west. Ontario Lobe provenance: dark gray color and limestone clasts reflect geology immediately to the west.

5. Pre-Norway beds (?). Bouldery to pebbly muddy gravel that pinches out to the east. Chaotic structure may be due to subglacial deformation of gravel (deformation till?).

* 6. Steeply dipping gravel and coarse sand, post-Hawthorne beds. Unit pinches out to east where it is truncated beneath Norway Diamicton. Subaqueous outwash fan. Paleocurrent: west.

* 7. Flat-lying, large boulder to pebble gravel, post-Hawthorne beds.

* 8. Interbedded coarse sand, gravel and diamicton with many round stones that appear to be an ice marginal deposit of the Mohawk Lobe, post-Hawthorne beds.

* Units 6-8 together appear to represent an aggrading and prograding subaqueous fan derived from the east. Sorting improves slightly upward.

Reboard vehicles and continue west on Rt. 5 toward Herkimer.

24.6 (1.7) Rt. 5 rises onto the top of the Herkimer Terrace. The terrace top is composed of at least 12 m of fluvial gravel which sits unconformably on silt and clay varves of the post-Holland Patent beds. The heavily channeled and fluvially dissected terrace surface has an elevation of 480-510 ft. Depressions on the terrace surface are not kettles, but instead are preserved channels cut into the terrace by later fluvial drainage. The terrace top gets progressively higher to the west where it can be traced a short distance up the West Canada Ck. valley to an elevation of about 540 ft. Another part of the Herkimer Terrace on the west side of West Canada Ck. in Herkimer (STOP 2-5), gets lower to the west. This same level is recorded by terraces at the mouth of East Canada Ck. (east of Little Falls). Aggradational fluvial terraces seen on Saturday's trip in the upper West Canada Valley (STOP 1-6 and between Poland and Middleville) appear to be equivalent in age. The terrace at Herkimer represents initial dissection followed by delta progradation and fluvial aggradation at the mouth of an inwash system which was graded to a lake in the Mohawk Valley at an elevation of 450-460 ft.

26.9 (2.3) Cross bridge over West Canada Ck. Stay on Rt. 5 which is State St. in Herkimer. DO NOT get off on Rt. 5s which will take you south of the Mohawk River.

- - - - - - At this point in the trip we will break for half an hour (or some mutually agreed upon time) to allow people to visit restrooms in Herkimer and retrieve vehicles. We will convene at STOP 2-5 which is located at the west end of German St. in west Herkimer. German St. can be reached by taking any N-S street (west of Rt. 28) in Herkimer to the north side of town. **The directions to STOP 2-5 given below are a continuation on Rt. 5 without any stops in town.**

28.0 (1.1) The last traffic light in west Herkimer on Rt. 5 is the intersection of State and Caroline Streets. There will be a railroad yard across the intersection on the right. Stay on Rt. 5 west.

28.9 (0.9) Rt. 5 passes under the NY State Thruway. Under the bridge make a hard right onto West German St. Stop 2-5 is in the gravel pit immediately in front of you after the turn. The field trip route has also crossed the Herkimer/Ilion Quadrangle boundary.

STOP 2-5 Boyle's Pit, in west Herkimer on German St.

Boyle's Pit is an exposure in the 480-510 ft Herkimer Terrace west of the mouth of West Canada Creek. The landform here is an inwash delta built into a Mohawk Valley lake by drainage from the West Canada Creek valley (Fig. L10). Topset/foreset contacts in the delta vary little and were measured at four places to be 456.1, 456.3, 456.7 and 457.5 ft. Foreset beds dip to the west-northwest. The Boyle's Pit delta was deposited in a lake that pre-dates the drainage of Lake Iroquois by way of the Iro-Mohawk River (Figs. E8 and E9).

The Boyle's Pit delta cannot be an Ontario Lobe ice-contact feature because water levels were above 500 ft during the westward recession of the Ontario Lobe from Little Falls to Oriskany (Fig. E7). The delta at Boyle's Pit shows no evidence of ice-contact such as kettles or collapse features. The delta's upper topset surface falls well below the elevation of lacustrine sand (above 500 ft.) overlying the Holland Patent Diamicton on both sides of the Mohawk Valley to the west (STOP 2-6, Fig. L10). Ice-contact, deltaic foreset beds, deposited in a Mohawk Valley lake at Corrado Corners (5.5 km due west of Boyle's Pit at the mouth of Moyer Creek, Fig. L10), are as high as 526 ft. where they are truncated by Pleistocene alluvial fan deposits.

The Boyle's Pit delta also cannot be a Mohawk Lobe ice-contact deposit. Water levels below 500 ft would be impossible at the margin of a receding Mohawk Lobe which would have dammed high lake levels in the western Mohawk Valley. Farther east near little Falls, water levels in front of the last Mohawk Lobe to invade the western Mohawk Valley are recorded by lacustrine sediment above an elevation of 1000 ft., and these deposits are overlain by diamicton units of a later Ontario Lobe readvance which covered the Boyle's Pit area.

Reboard vehicles and head back to Rt. 5. Turn onto Rt. 5 west toward Utica.

29.3 (0.4) Pull over to the right (north) side of Rt. 5 as far off the shoulder as possible.

STOP 2-6 North Ilion gravel pit, Section 946. (This pit can be extremely muddy.)

The North Ilion pit (Fig. L10) provides evidence of the advance and recession of two separate Ontario Lobes (Figs. E5 and E6). The first Ontario Lobe recession in the area is marked by esker and subaqueous fan deposition, followed by varve sedimentation, at a calving deepwater ice margin. The second Ontario Lobe readvance is represented by the Holland Patent Diamicton, which is overlain by lacustrine sand at an elevation above 500 ft.

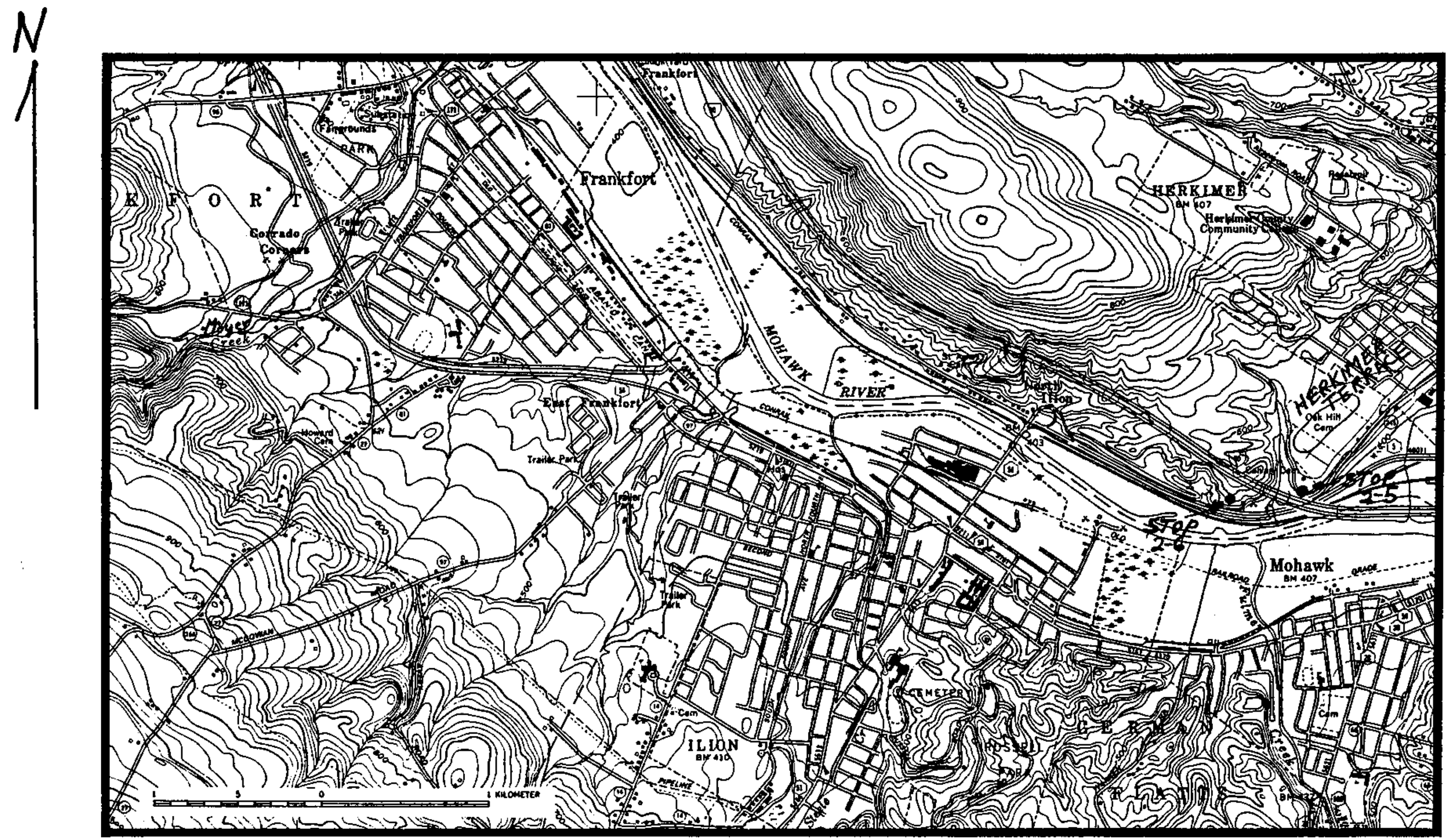
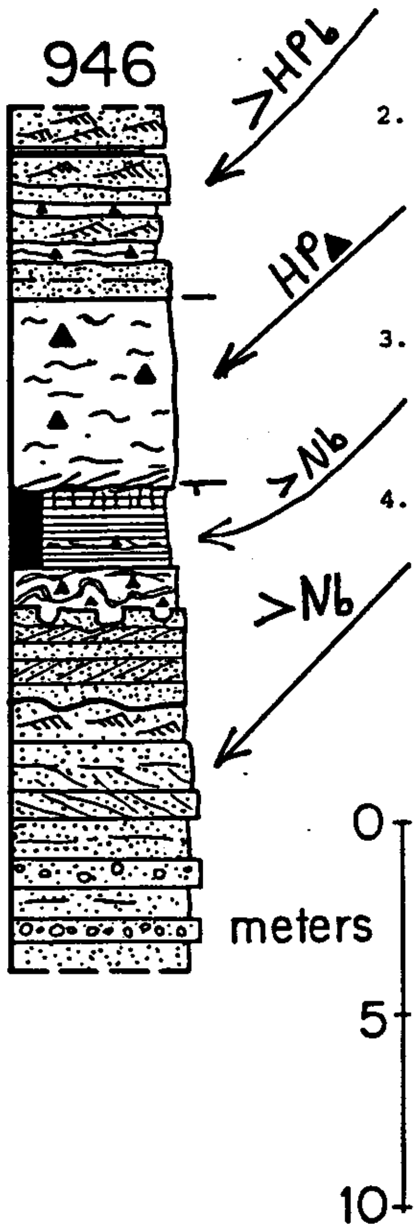


Figure L10. Topography west of Herkimer in the area of Stop 2-5, the Herkimer Terrace, and Stop 2-6.

STOP 2-6



Important features: (top to bottom)

1. Rippled and laminated lacustrine sand with clayey diamicton and laminated silt and clay beds, post-Holland Patent beds. Poorly exposed in soil and graded part of pit at top of section, but occurs at an elevation above 500 ft.

2. Very clayey and very sparsely stony, tannish to pinkish gray Holland Patent Diamicton, mostly subglacial deformation till. Grades laterally to the north (beyond pit area) to shaley black till where ice overrode the Utica Shale. Base of unit contains deformed beds of lacustrine clay and silt.

3. Post-Norway beds, top deformed by overriding ice. Contains abundant red and gray pellets and some large piles of red diamicton which are interpreted to be iceberg dump deposits. Abundant nematode worm trails.

4. Post-Norway beds. Chaotic gravel sheets grading upward to massive, crossbedded and rippled sand. Subaqueous fan sediment. Some parts of the pit have exposed a coarse gravel core to these deposits thought to be an esker.

Reboard vehicles and continue west on Rt. 5. The route to the next stop will be the longest individual drive of the trip and also the easiest on which to get lost. Just remember two things: (1) You want to get west of Utica, and (2) you want to end up on Rt. 49 West headed toward an intersection with Rt. 291 (Rome is in this direction).

29.8 (0.5) Pass by exit for Rt. 51 south. Continue west on Rt. 5. DO NOT follow signs for Rt. 5s.

32.8 (3.0) Entering town of East Schuyler (pronounced: sky-ler). At this point the valley floor opens up and Rt. 5 travels along an Iro-Mohawk River terrace. This terrace is easily traced to Rome along Rts. 5 and 49. The terrace is capped by up to 8 m (thickest known) of fluvial cobble gravel to pebbly sand which truncates a number of underlying units. The gravel cap has been found unconformably overlying silt and clay varves and lacustrine sand of the post-Holland Patent beds, the Norway and Holland Patent Diamictons, and black calcareous Utica Shale. The Iro-Mohawk terrace is inset in a prominent scarp running parallel to Rt. 5 about 0.3-0.5 miles to the north. Near the mouths of some streams heading south from the Deerfield Hills, large inwash deltas from a Mohawk Valley lake have upper topset surfaces at 500-540 ft. These deltas may represent the same lake seen at Boyles Pit (STOP 2-5). Rapid erosion in post-glacial time is evident from the many ravines and gorges which drain to the Mohawk River from both sides of the valley. During the existence of the Iro-Mohawk River, inwash delta surfaces were dissected to an elevation of 420 ft. In post-Iroquois time (very latest Wisconsinan and Holocene) large alluvial fans have been deposited on the Iro-Mohawk terrace at the mouths of small streams which are prone to flash floods from the Deerfield Hills.

36.4 (3.6) Rt. 5 crosses over the NY State Thruway. In another 0.2 miles the field trip route crosses the Ilion/Utica East Quadrangle boundary.

39.2 (2.8) Cross over Herkimer/Oneida County line. Continue west on Rt. 5 which will deliver us to Rt. 49.

41.0 (1.8) Approaching complex of exits in 0.2 miles. Continue on Rt. 5 west and watch for signs to Rt. 49 west toward Rome.

42.0 (1.0) A batch of exits in 0.2 miles. Head for Rt. 49 west toward Maynard, Marcy, and Rome.

46.5 (4.5) Hopefully you are on Rt. 49 West which turns into a split highway near our exit. Take clover leaf exit for Rt. 291 south or west to Whitesboro or Whitestown. Our trip passes from the Utica East Quad. across the South Trenton and into the Oriskany Quad. at mile 43.7.

47.5 (1.0) Rt. 291 southwest arrives at Rt. 69 after crossing the Mohawk River flood plain. Turn right (northwest) onto Rt. 69 towards Oriskany.

47.7 (0.2) Enter parking lot of Burrows Trucking Co. and head for large sand and gravel pit behind garages.

STOP 2-7 Whitesboro Terrace, Burrows Hauling Co. Pit, Section 964.

The Whitesboro Terrace is an extensive, flat-topped sand and gravel deposit which has kettles and eskers at its southwestern to western side (Fig. L11). At first glance on a map, or in the field, the Whitesboro Terrace appears to be an ice-contact, esker-fed delta produced by meltwater drainage from the Oriskany Valley. Exposures in the terrace, however, reveal a different situation. Fluvial gravel deposits which compose the top 15-25 ft of the terrace unconformably overlie what appears to be deltaic lower foreset and bottomset beds and lake-bottom sand. The contact between the fluvial and subaqueous units lies at an elevation of 533.3 ft. in the back (west end) of the Burrows Hauling Co. pit, but can be seen in the form of channels cut deeply into underlying sands in the front of the pit. The irregular fluvial gravel/subaqueous sand contact at an inconsistent elevation appears to represent fluvial trimming of lacustrine deposits followed by fluvial deposition, reflecting a drop in lake level. The Whitesboro Terrace exposure demonstrates that lakes in the Mohawk Valley remained up to an elevation of at least 533 ft. until the Ontario Lobe receded to Oriskany (Fig. E8). Lake level dropped at the time of the fluvial gravel deposition because the fluvial unit is esker-fed and it truncates lacustrine deposits below. Much lower topset/foreset contacts in deltas downvalley, at places like Herkimer (Fig. L10), represent later lake levels, possibly established at the time of, or later than, fluvial gravel deposition on the Whitesboro Terrace (Figs. E8 and E9).

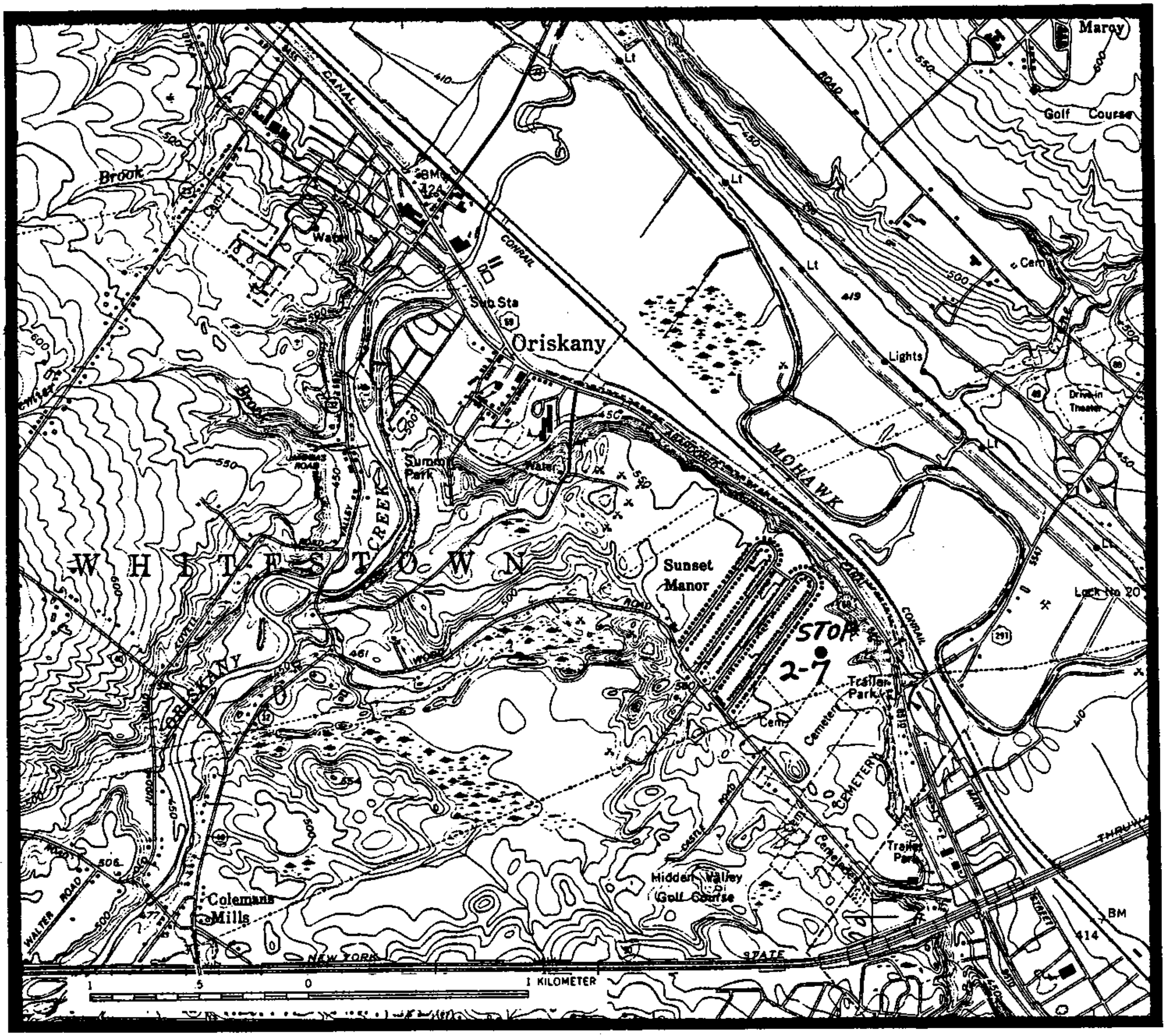


Figure L11. Topography in the area of Stop 2-7 near Oriskany, the Whitesboro Terrace.

Reboard vehicles and continue northwest on Rt. 69 toward Oriskany.

49.4 (1.7) Cross over Oriskany Creek and take the first right (northeast) onto a road which crosses to the north side of the Mohawk Valley.

49.9 (0.5) Bridge crossing over Mohawk River. Start to look for signs for River Rd.

50.8 (0.9) From the Mohawk River bridge proceed through exits and stop signs to River Rd. Turn north (left) onto River Rd.

52.0 (1.2) Follow River Rd. and pull over on right into sand pit just beyond road to Floyd.

STOP 2-8 River Road (Old Rt. 49) sand pit, Section 962.

The River Road exposure provides evidence of the third, final, and least extensive Ontario Lobe readvance into the Mohawk Valley during Valley Heads glaciation. Evidence is in the form of red till deposited over subglacially deformed lacustrine sand. The thin red till exposed near the top of the pit has been found at three other sites (see section 961, Fig. L8) encompassing an area of at least 8 km. to the north and east. On a topographic map the land surface in this area appears to have a flat, terrace-like form (Fig. L12), but in the field the surface is gently rolling with a pronounced southeast-northwest streamlining, apparently the result of overriding ice-flow. The red till has not been found on the slightly higher terraces east of Ninemile Creek. The River Road exposure is very close to the eastern limit of the red till (Rome till of Muller and others, 1986). The red till limit coincides with the beginning of a fluvial gravel terrace (530-500 ft.) that is traceable down the north side of the Mohawk Valley for 4.5 km and may be graded to a lake in the Mohawk Valley at an elevation of 480-500 ft (Fig. E9). This lake level and the fluvial terrace are below the upper elevation of lacustrine sediment in the Whitesboro Terrace (533 ft.) which is immediately to the south across the Mohawk River valley (Fig. L11). After accounting for potential tilting during postglacial isostatic rebound of the area, the fluvial surface beginning east of the red till covered area may be graded to the same lake as the Herkimer Terrace (Figs. L10 and E9). After recession of the Ontario Lobe from the surface of the red till, the till was not buried by lacustrine sediment or a continuous blanket of fluvial deposits. The red till along River Road may represent the eastern limit of a glacial readvance in the Rome area recognized by Fullerton (1971) as the Stanwix Readvance. The thin character of the red till may reflect rapid recession following a surge-like readvance.

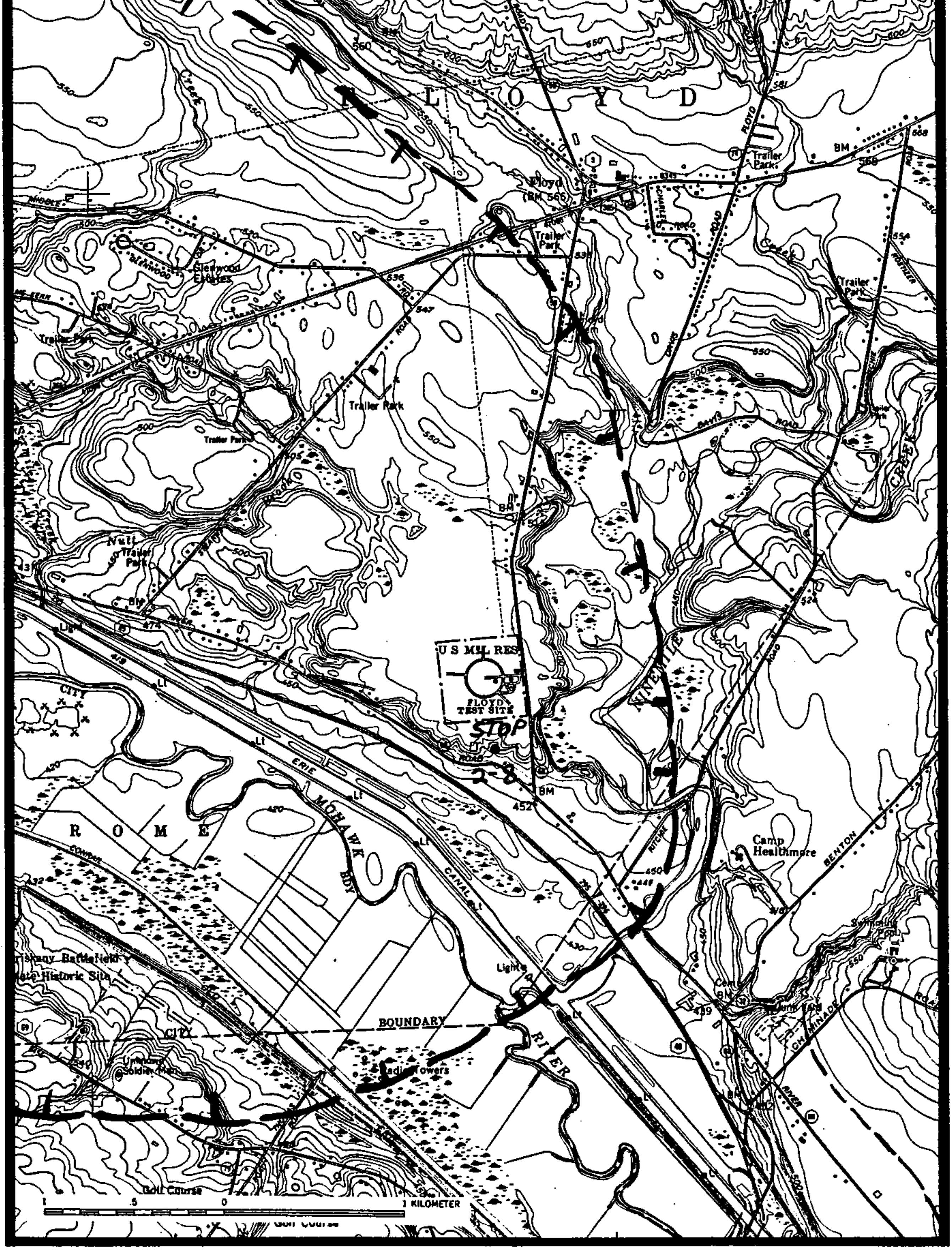
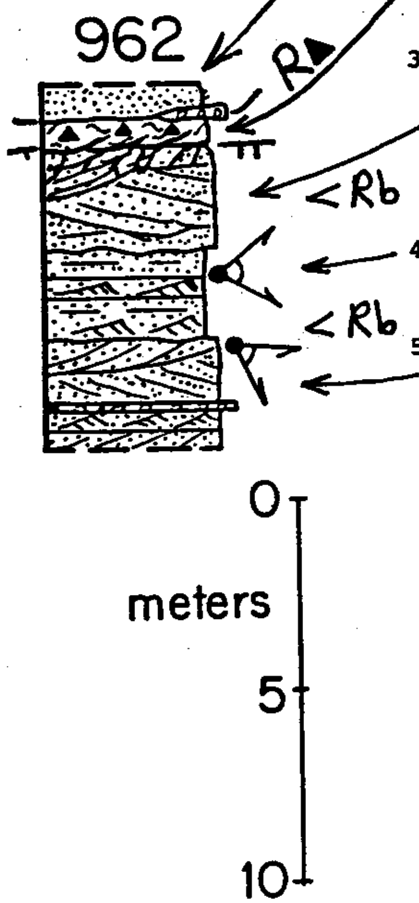


Figure L12. Topography in the area of Stop 2-8 along River Road east of Rome.

STOP 2-8



<u>Important features</u>: (top to bottom)

1. Massive, eolian fine sand in soil on thin, discontinuous gravel beds which overlie the red till.

2. Sparsely to moderately stony, sandy in places, clayey, red subglacial till.

3. Crossbedded medium to coarse sand with shale fragments, top 0.3 m is subglacially faulted, folded, and load deformed. The southwest face of the pit has in the past exposed large thrust faults. Paleocurrents: east to southeast. Eroded contacts above and below.

4. Laminated and rippled fine to medium sand. Paleocurrents: northeast to southeast. Eroded contact below.

5. Interbedded large sweeping sand crossbeds and rippled medium sand. One 15-cm thick cobble to boulder gravel bed (flood from the north due to ice-dammed lake drainage ?). Paleocurrents: northeast to southeast.

- - - - - - - - - - - -

This is the end of the field trip. If you are heading west toward Rome and Syracuse, continue west on River Rd. to Rome where it joins Rt. 365 West, which will take you to an exit on the NY State Thruway. If you are heading east, follow River Rd. east to Rt. 49, which will take you to a NY State Thruway exit north of the Mohawk River in Utica.

Have a safe trip home!

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